TECHNICAL MEMORANDUMS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 269

EXPERIMENTS ON THE RESISTANCE OF AIRPLANE WHEELS AND RADIATORS.

From "Verslagen en Verhandelingen van den Rijks-Studiedienst voor de Luchtvaart," Amsterdam, Part II, 1923, Report A64.

July, 1924.

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EXPERIMENTS ON THE RESISTANCE OF AIRPLANE WHEELS AND RADIATORS.*

Experiments were made on the resistance of four airplanes wheels of different sizes and coverings and two Lamblin radiators. The results show the important influence of the wheel coverings. The closing of a shutter, which was fitted to one of the radiators, considerably lessened the resistance.

These experiments are of importance, because there has been published but little information on the resistance of airplane wheels and radiators of the type (Lamblin) here tested.**

Drawings of these parts with their principal dimensions are given in Figs. 1-6, while Table I gives a few details regarding the wheels, with the name of the airplane on which they are used. The two radiators differ, aside from their dimensions, in that No. 2 has an adjustable shutter for regulating the degree of cooling. This shutter is attached to the front collar of the radiator and consists of four sectors capable of rotating about their respective axes of symmetry (Fig. 6). These sectors, when closed,

* From "Verslagen en Verhandelingen van den Rijks-Studiedienst voor de Luchtvaart, Amsterdam, Part II, 1923, Report A64, pp.55-63.

** On air resistance of airplane wheels.- Fuchs-Hopf, "Aeradynamik," p.234; Bairstow, "Applied Mechanics," p.179; Griffiths and Coales, "The Wind Resistance of an Aeroplane Wheel," R. and M., 207th Technical Report of the Advisory Committee for Aeronautics (British), 1915-1916, p.221.

On Lamblin radiators there is only one reference: Eiffel, "Resume des principaux travaux," 1915-1918, p.176.

completely close the aperture within the front band. When opened, they lie in the direction of the wind. The whole shutter can be removed.

The parts were suspended in the wind tunnel by steel wires, as shown in Figs. 7 and 8. The diameters of these wires were between 0.8 and 1.5 mm (0.031 and 0.059 in.), according to the weight of the objects suspended. The resistance was measured with the balance b, which was connected with the object by means of the wires c. These wires had a diameter of 0.4 mm (0.016 in.). The ratio between the force exerted on the object and the weight necessary to maintain the equilibrium of the balance was determined by calibration.

The results obtained by this method must be corrected for the resistance of the suspension and balance wires. The correction is calculated from the length and diameter of the wires, by using a known value of the drag coefficient.* The resistance or drag was expressed in two different ways with the aid of the formulas:

$$R_X = C_1 \frac{\gamma}{g} V^2$$

and

$$R_X = C_2 \frac{\gamma}{g} SV^2$$

in which R_X = drag in kg; C_1 and C_2 are drag coefficients; γ = density of air in kg per cubic meter; g = acceleration due to

* Wieselsberger, C., "Neuere Feststellungen über die Gesetze des Flussigkeits- und Luftwiderstandes," Physikalische Zeitschrift, 1921, p.321.

gravity in m/sec.^{2}; S = area in square meters; V = velocity in m/sec.

For the area of the wheels, the rectangle was taken which had for its sides the thickness and diameter of the tires; for the area of the radiators, their largest cross-sections at right angles to the direction of the wind. The coefficient C_1 has the dimensions of a surface, while the coefficient C_2 is non-dimensional. The reason for having two different coefficients is the following:

For practical use, the coefficient C_1 is more convenient either for wheels or radiators of the same size, but furnishes no comparative values for wheels of different sizes and shapes, such as are desirable for determining the best shape to give a wheel independently of its size. It can not even be used for comparing two radiators of different sizes, but both conditions are fully met by the coefficient C_2.

The values of both coefficients are given in Figs. 9-12 in terms of the wind velocity. The results demonstrate, for the wheels, the great advantage of having a suitable covering (Fig. 10). Wheels 2-4 have comparatively flat coverings, which are joined to the outside of the rims or tires, and consequently have, at high velocities, about 60% lower values of C_2 than wheel 1 without covering. Wheel 3 is less favorable, probably because the cover is attached to the middle of the rim, thereby producing a vortex region behind the uncovered portion of the latter and the strongly conical covering of one side. In the cover of wheel 2 there is a circular hole (Fig. 2), whose effect on the resistance is slight, however. Table II gives, under "2a," the drag coefficients for this wheel after the hole had been closed with a piece of paper.

Fig. 12 demonstrates that radiators 1 and 2 have the same drag coefficients C_2 and that the shutter has no effect when open. The closing of the shutter has the remarkable effect of decreasing the resistance about 40%. When the shutter is opened, the resistance due to the shape of the object is diminished, while the resistance due to the friction of the air coming in contact with a larger portion of the cooling surface is increased. The results of the experiments show that the latter effect is the stronger of the two. An experimental investigation of the dynamie and static pressure behind the radiator, both with the shutter closed and with it open, gave no positive result.

For some of the parts, the drag and the horsepower necessary for their propulsion at 50 m (164 ft.) per second or 180 km (112 mi.) per hour were calculated. The drag coefficient obtained in the test at the highest velocity was adopted and the mutual interference effects were neglected. The propeller efficiency was taken at 0.7,

Table I. - Wheels.

No.	Airplane	Tire dimensions	Covering: Shape	Covering: Attached to	Area
1	Fokker DX	760×100 mm (29.92×3.94 in.)	None		.076 m² (.818 ft.²)
2	" DVII	700×100 mm (27.56×3.94 in.)	Both sides slightly conical.	Both sides of rim	.070 m² (.753 ft.²)
3	" CIV	950×150 mm (37.4×4.53 in.)	One side strongly, other side slightly conical.	Middle of rim	.143 m² (1.54 ft.²)
4	" Amphibian	900×200 mm (35.43×7.87 in.)	One side slightly conical, other side flat.	Both sides of tire	.180 m² (1.94 ft.²)

Radiators.

No.	Maker	Type	Engine	Area in
1	Lamblin	AN 12	H-S, 300 HP	0.072 m² (.775 ft.²)
2	"	DF 3	N L, 450 HP	0.109 m² (1.173 ft.²)

Table II. - Drag Coefficients of the Wheels.

Number of wheel.

1			2			2a		
V	C_1	C_2	V	C_1	C_2	V	C_1	C_2
13.1	0.0310	0.410	13.0	0.0083	0.118	12.9	0.0082	0.118
18.5	0.0300	0.395	18.4	0.0084	0.120	18.2	0.0082	0.118
22.7	0.0288	0.380	22.6	0.0087	0.124	22.4	0.0084	0.120
26.2	0.0262	0.345	26.0	0.0090	0.128	25.8	0.0087	0.124
29.2	0.0258	0.339	29.1	0.0091	0.130	28.8	0.0088	0.126
32.0	0.0259	0.341	31.9	0.0093	0.132	31.6	0.0090	0.129

Table II (Cont.)

3			4		
V	C_1	C_2	V	C_1	C_2
12.9	0.0380	0.267	12.9	0.0227	0.127
18.2	0.0344	0.241	18.2	0.0246	0.137
22.4	0.0336	0.236	22.4	0.0241	0.134
25.8	0.0338	0.237	25.8	0.0241	0.134
28.8	0.0343	0.240	28.8	0.0244	0.135
31.6	0.0344	0.241	31.6	0.0246	0.137

Table III. - Drag Coefficients of the Radiators.

Number of radiator

1			2 Without shutter		
V	C_1	C_2	V	C_1	C_2
12.9	0.0292	0.408	12.8	0.0418	0.385
18.3	0.0292	0.408	18.2	0.0445	0.408
22.4	0.0292	0.406	22.2	0.0438	0.403
25.9	0.0292	0.408	25.7	0.0446	0.410
28.9	0.0292	0.407	28.7	0.0445	0.409
31.7	0.0292	0.408	31.4	0.0444	0.408

Table III (Cont.)

2 Shutter open			2 Shutter closed		
V	C_1	C_2	V	C_1	C_2
12.9	0.0420	0.387	12.9	0.0255	0.234
18.3	0.0444	0.408	18.3	0.0263	0.242
22.4	0.0443	0.407	22.4	0.0265	0.244
25.9	0.0445	0.408	25.9	0.0268	0.247
28.9	0.0443	0.408	28.9	0.0268	0.247
31.7	0.0442	0.406	31.7	0.0270	0.248

V = wind velocity in m/sec.

C_1 and C_2 = drag coefficients calculated with the formulas:

$$R_x = C_1 \frac{\gamma}{g} V^2$$

$$R_x = C_2 \frac{\gamma}{g} S V^2$$

in which R_x = resistance or drag in kg; γ = density of air in kg/m^3; g = acceleration due to gravity in $m/sec.^2$; S = area of largest cross-section of radiator in m^2. For wheels, S = width x diameter of tire in m^2.

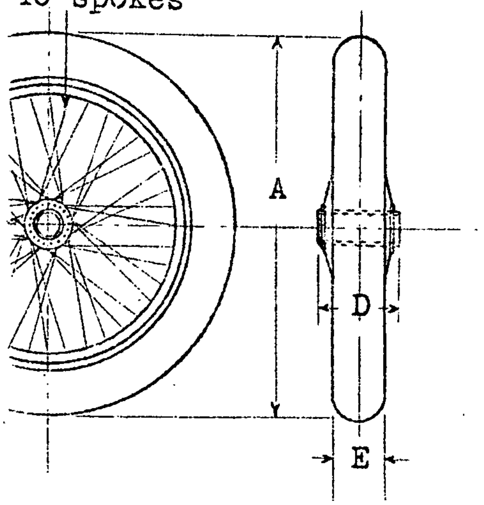
Table IV. - Drag and Requisite HP
at 50 m (164 ft.) per sec. 112 mph

	Drag in kg	Drag in lb.	Requisite HP
Wheel No. 1	8.1	17.86	7.7
" " 2	2.9	6.39	2.8
" " 4	7.7	16.98	7.3
Radiator No. 2	13.8	30.42	13.2

Translation by Dwight M. Miner
National Advisory Committee
for Aeronautics.

A = 760 mm (29.92 in.)
B = 580 mm (22.83 in.)
C = 520 mm (20.47 in.)
D = 160 mm (6.30 in.)
E = 100 mm (3.94 in.)
F = 80 mm (3.15 in.)
G = 4 mm (0.16 in.)

Wheel No.1.



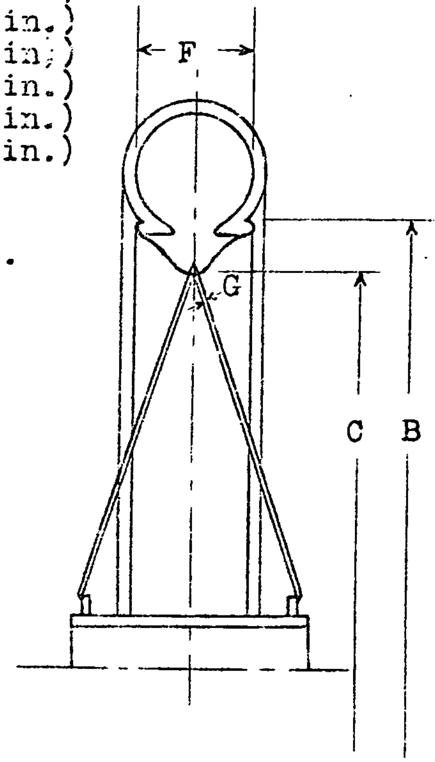
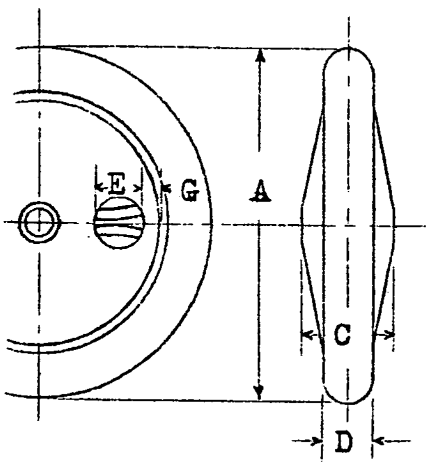


Fig.1.

A = 700 mm (27.56 in.)
B = 520 mm (20.47 in.)
C = 185 mm (7.28 in.)
D = 100 mm (3.94 in.)
E = 85 mm (3.35 in.)
F = 80 mm (3.15 in.)
G = 40 mm (1.57 in.)

Wheel No.2.



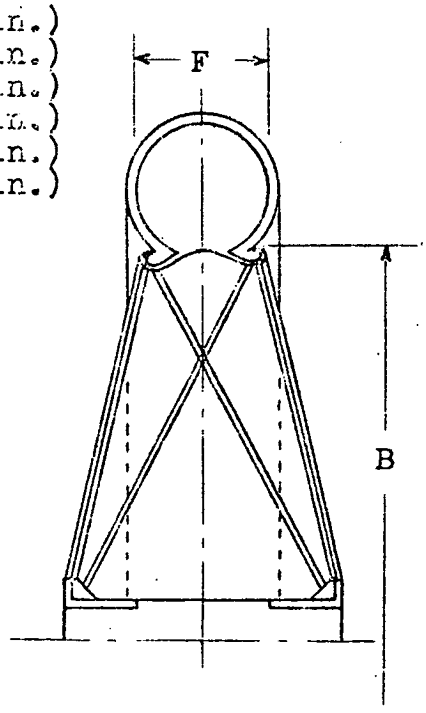
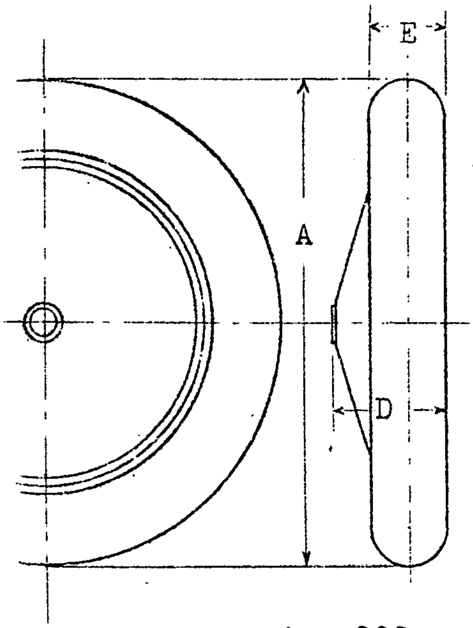
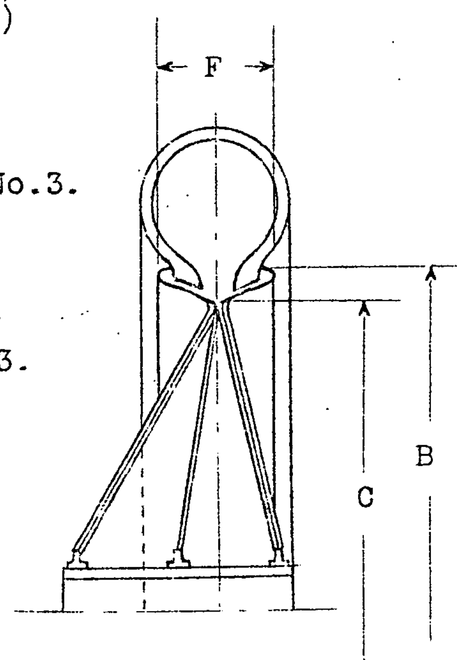


Fig.2.

A = 950 mm (37.40 in.)
B = 680 mm (26.77 in.)
C = 600 mm (23.62 in.)
D = 230 mm (9.06 in.)
E = 150 mm (5.91 in.)
F = 115 mm (4.53 in.)

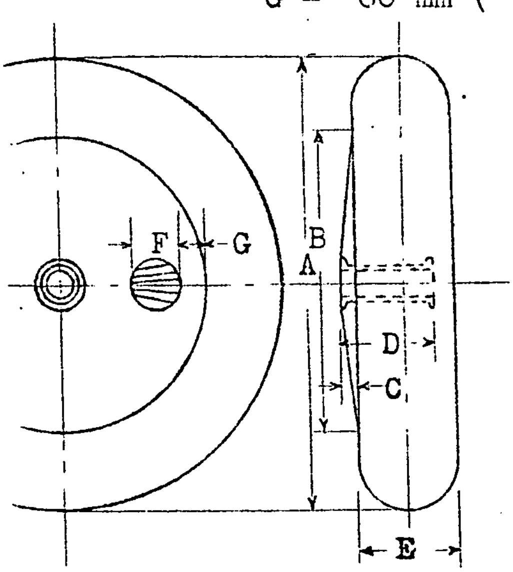


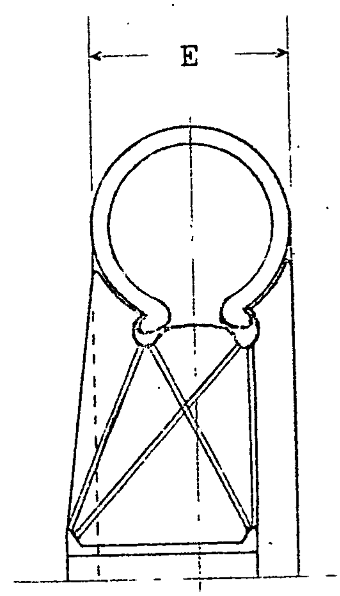


Wheel No.3.

Fig. 3.

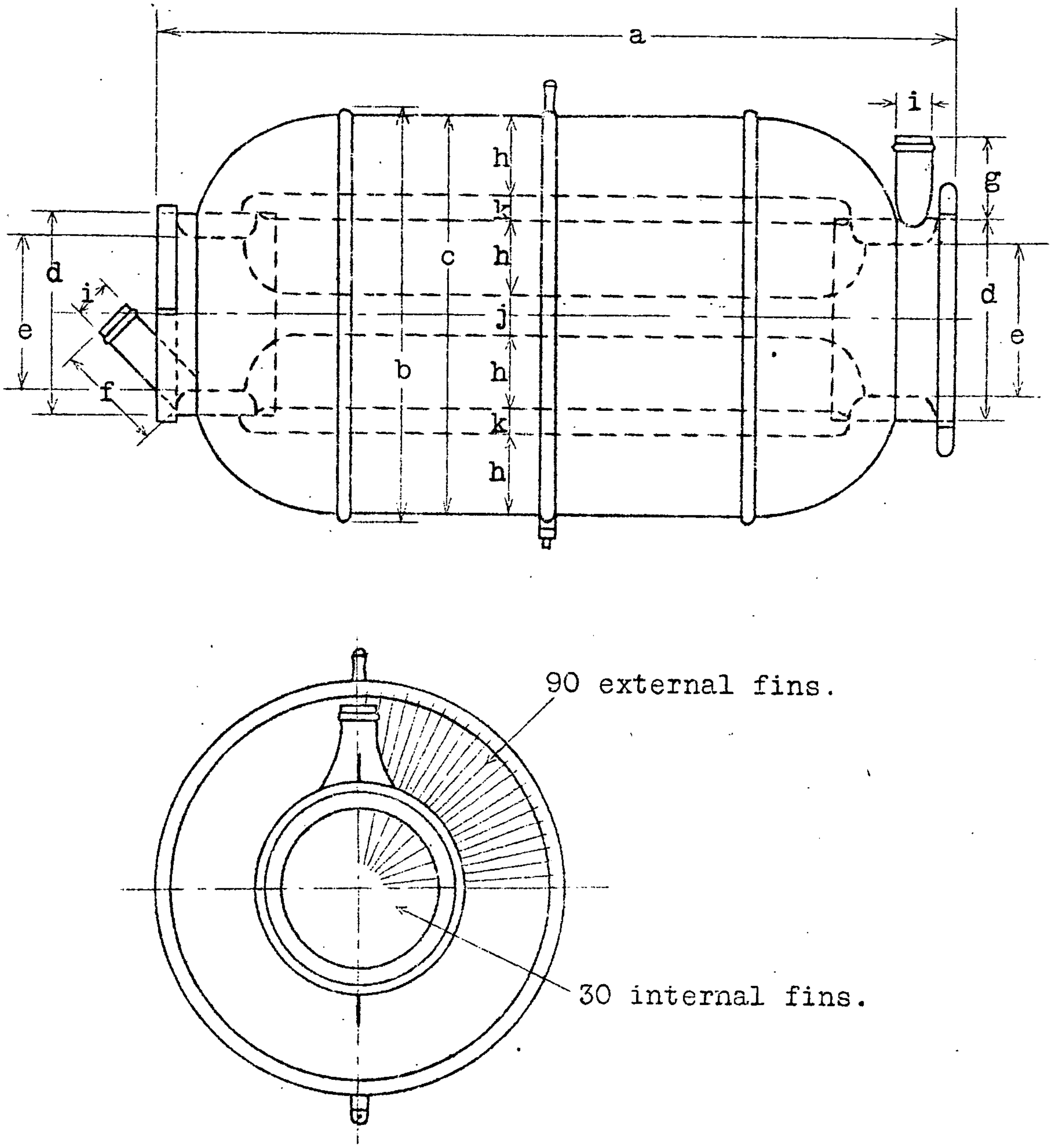
A = 900 mm (35.43 in.)
B = 590 mm (23.23 in.)
C = 30 mm (1.18 in.)
D = 185 mm (7.28 in.)
E = 200 mm (7.87 in.)
F = 85 mm (3.35 in.)
G = 60 mm (2.36 in.)





Wheel No.4.

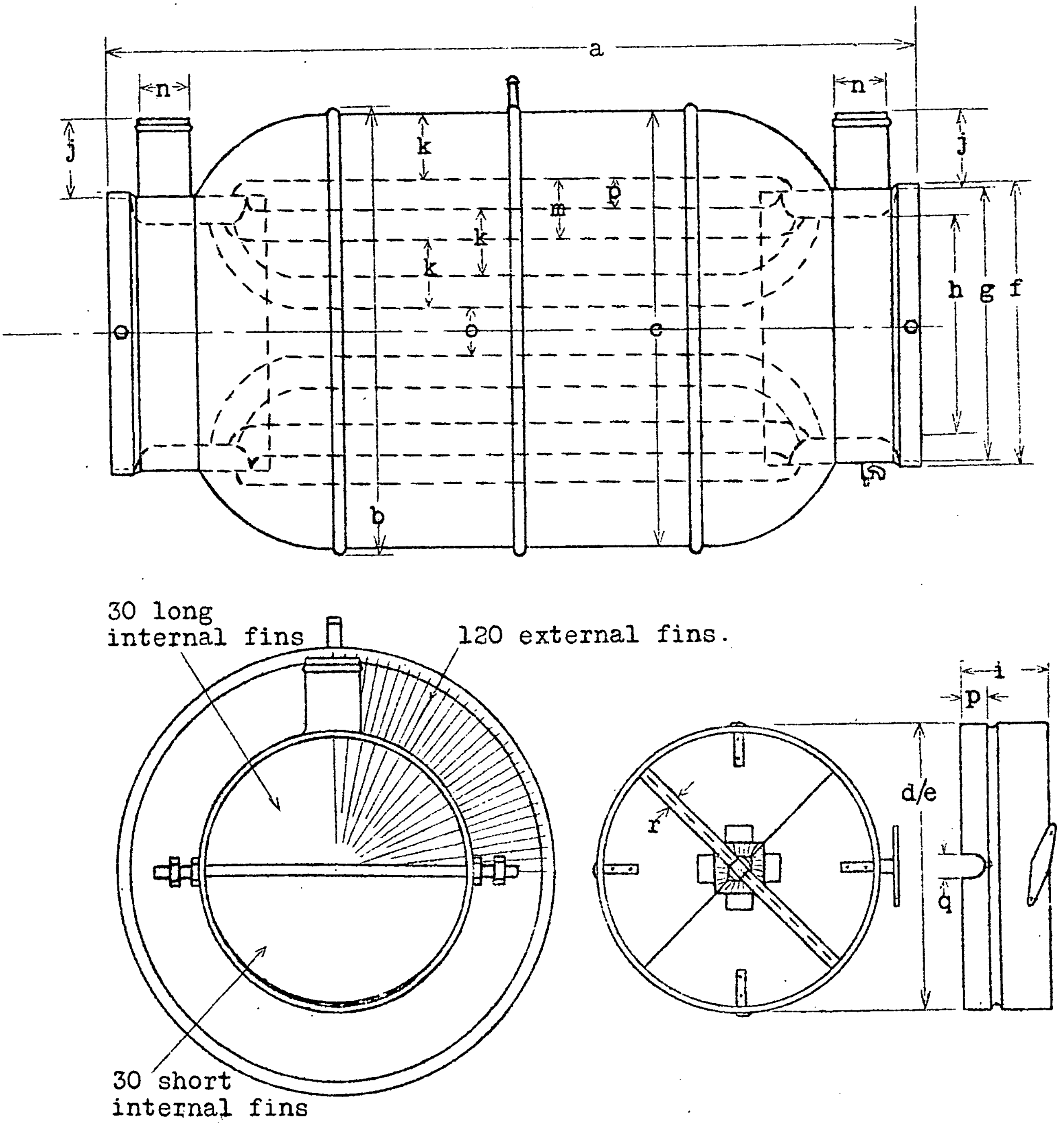
Fig.4.



a = 600 mm (23.62 in.)
b = 302 " (11.89 ")
c = 290 " (11.42 ")
d = 150 " (5.91 ")
e = 120 " (4.72 ")
f = 75 " (2.95 ")

g = 60 mm (2.36 in.)
h = 55 " (2.17 ")
i = 32 " (1.26 ")
j = 30 " (1.18 ")
k = 20 " (.79 ")

Fig.5 Radiator NO.1



a = 680 mm	(26.77 in.)	
b = 372 "	(14.65 ")	
c = 360 "	(14.17 ")	
d = 234 "	(9.21 ")	
e = 232 "	(9.13 ")	
f = 230 "	(9.06 ")	
g = 220 "	(8.66 ")	
h = 180 "	(7.09 ")	
i = 75 "	(2.95 ")	

j = 65 mm	(2.56 in.)
k = 55 "	(2.17 ")
m = 50 "	(1.97 ")
n = 45 "	(1.77 ")
o = 40 "	(1.57 ")
p = 25 "	(.98 ")
q = 20 "	(.79 ")
r = 8 "	(.31 ")

Fig.6 Radiator No.2

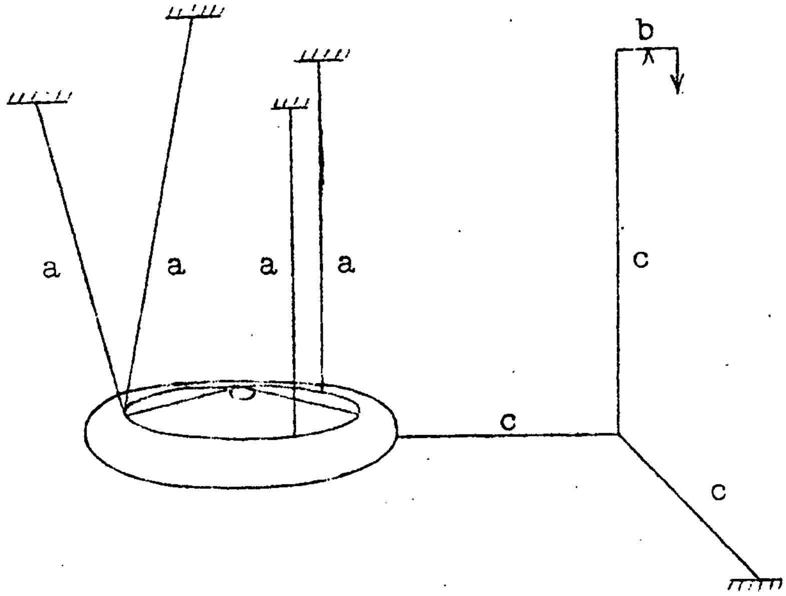


Fig. 7 Suspension of wheel in wind tunnel

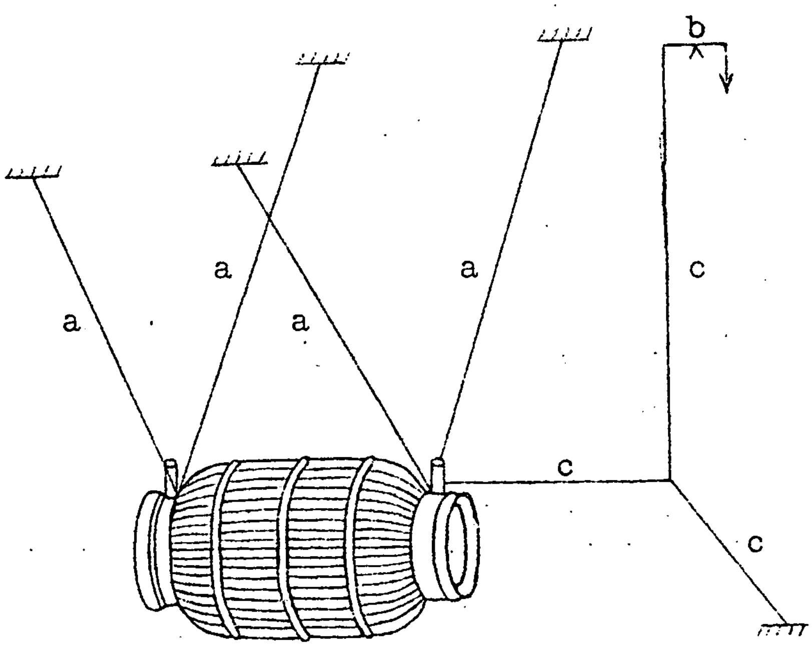


Fig. 8 Suspension of radiator in wind tunnel

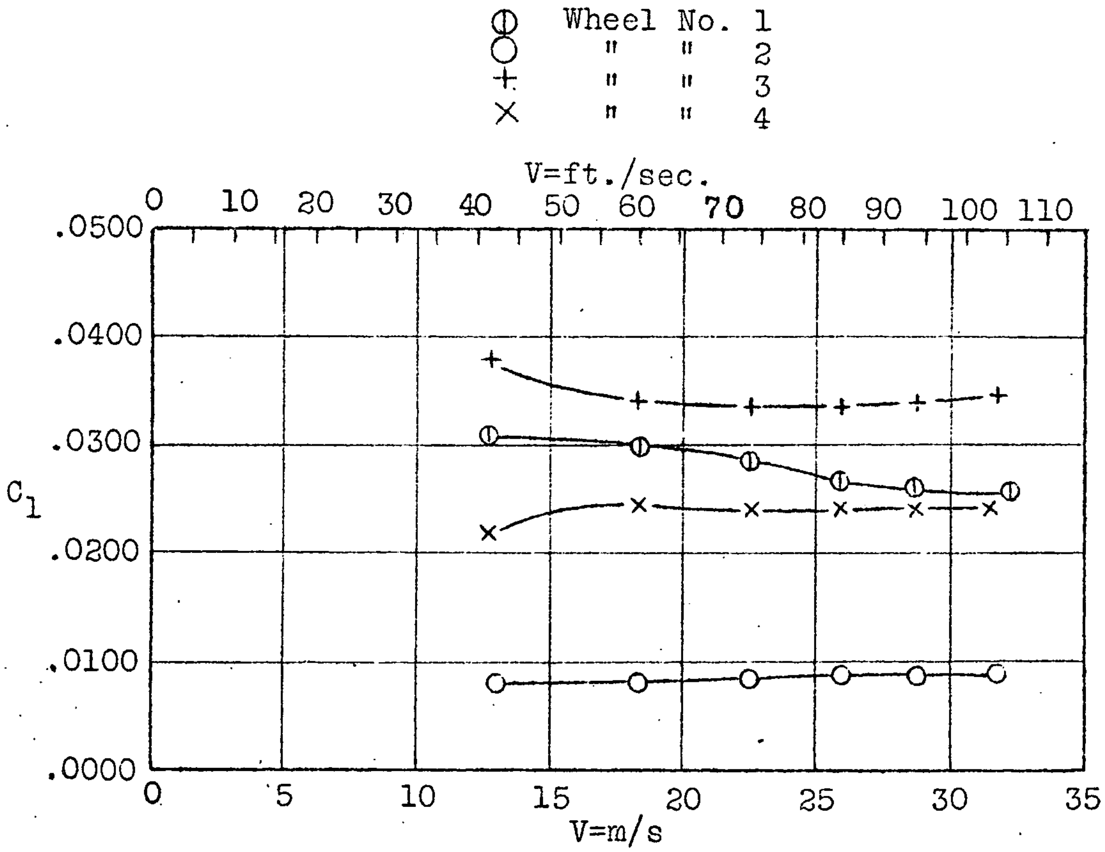


Fig. 9 Drag coefficient C_1 of the wheels

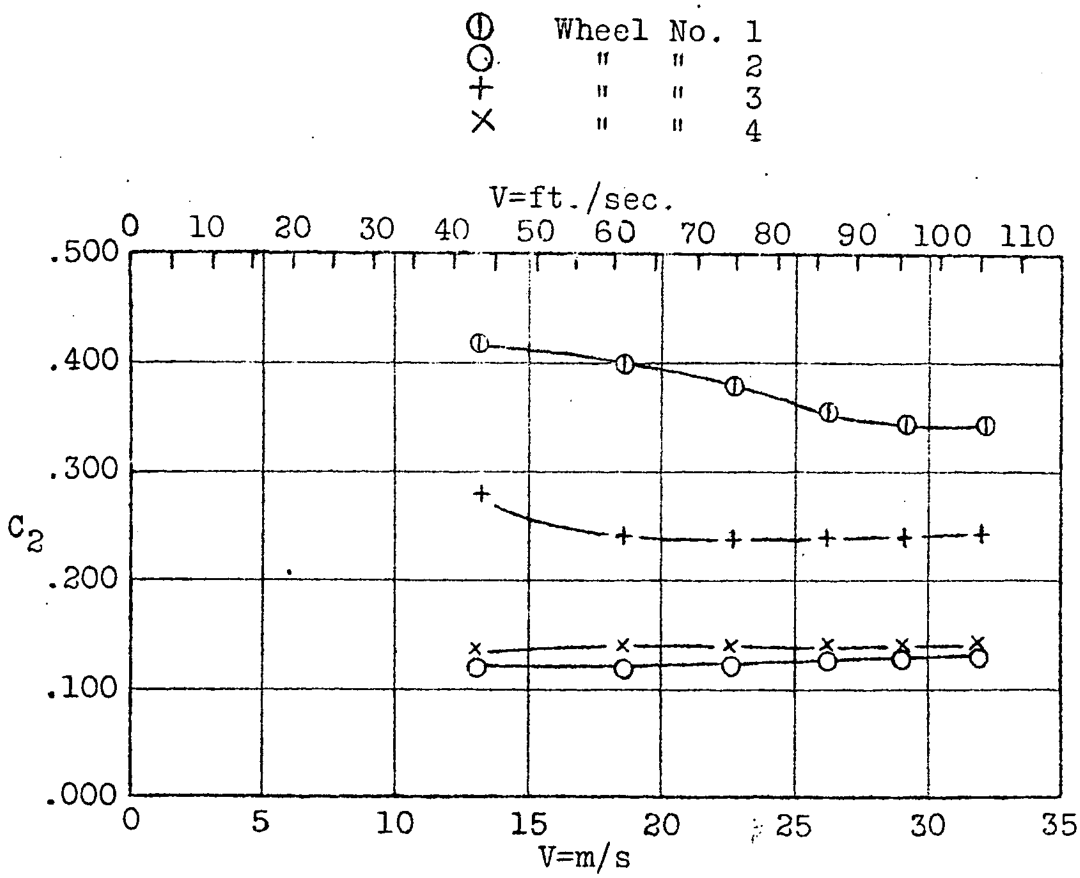


Fig. 10 Drag coefficient C_2 of the wheels

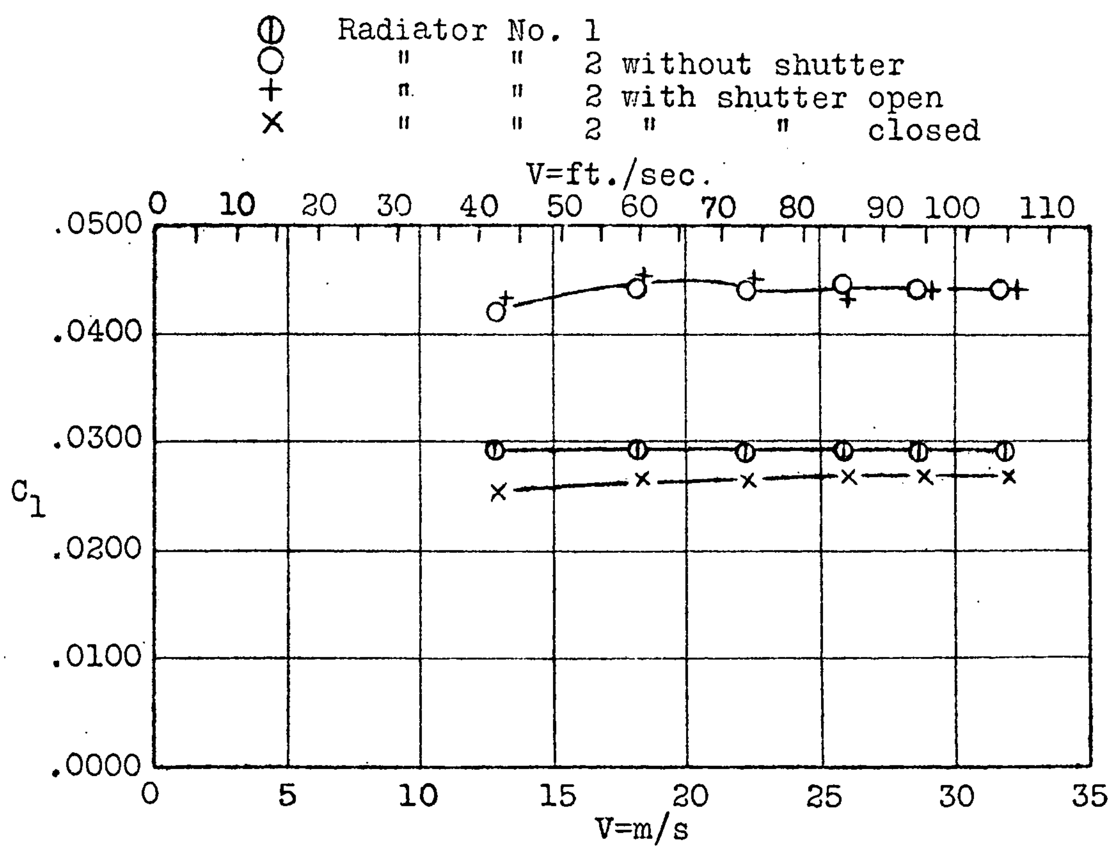


Fig. 11 Drag coefficient C_1 of the radiators

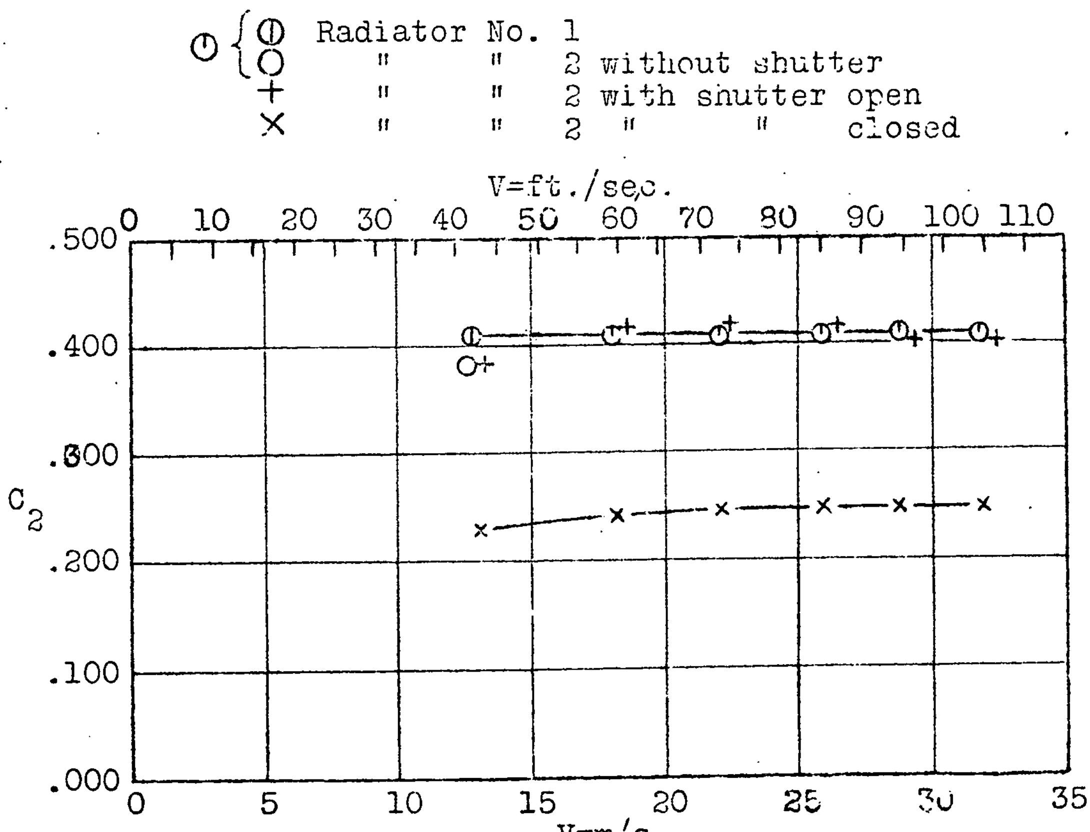


Fig. 12 Drag coefficient C_2 of the radiators