TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 169

AIR RESISTANCE MEASUREMENTS ON ACTUAL AIRPLANE PARTS.

By C. Wieselsberger.

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For the calculation of the parasite resistance of an airplane, a knowledge of the resistance of the individual structural and accessory parts is necessary. The most reliable basis for this is given by tests with actual airplane parts at airspeeds which occur in practice. The results of similar tests already published (experiments on wires, radiators, etc.), can render useful service in this connection. The tests will, however, be extended to other structural parts. The accompanying data relate to the following experimental objects:

1. Landing gear of a Siemens-Schuckert DI airplane;
2. Landing gear of a "Luftfahrzeug-Gesellschaft" airplane, type Roland D11a;
3. Landing gear of a "Flugzeugbau Friedrichshafen" G airplane;
4. Machine gun;
5. Exhaust manifold of a 260 HP engine.

(Items 4 and 5: Tests made for the "Deutsche Flugzeug Werke," Leipzig.)

No. 1 - The landing gear is shown in Figs. 1 and 2. In order that all parts, especially the wheels, might be well surrounded by the stream of air, only half of the landing gear was exposed to the air stream. Otherwise the results

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would have been unreliable, since the wheels would have been too near the edge of the air stream. The results (Table I and Figure 3) were, however, multiplied by 2 and hence apply to the whole landing gear. The sides of the wheels were covered with fabric in the usual way. Besides the tests with the landing gear as a whole, two other series of tests were carried out. In one, the wheels were only attached as dummies, i.e., they were not rigidly connected to the landing gear, but were held by a special device. In this way, the resistance without wheels was determined and yet the remaining parts were in a current of air influenced by the wheels. The third test was carried out entirely without the wheels. In Fig. 3 the equivalent resistance surface S_D in square meters is plotted against the pressure

$$q = \rho V^2/2g \text{ kg/m}^2 \quad (\text{Resistance } D = S_D \cdot q).$$

On this occasion a few parallel experiments were carried out, in order to throw light on the question as to whether the sum of the resistances of the individual parts of the landing gear gives the true total resistance. To this end, the resistance of the wheels by themselves was determined. It was shown in this way that such addition is not permissible. This is also comprehensible from the fact that the assembly of the individual parts sets up an essentially different disturbance of the air stream from that set up by individual parts separately. The air flow past the wheels is noticeably affected by the neighboring parts.

No. 2 - The "Luftfahrzeug-Gesellschaft" landing gear, which is somewhat larger than the Siemens-Schuckert, is shown in Figs. 4 and 5. The frontal projection of the wheels is 760 × 100 mm (29.921 x 3.937 in) against 710 × 85 mm (27.953 × 3.346 in) for the first landing gear (Figs. 1 and 2).

The sides of the wheels were covered as usual. Furthermore, the track width of the wheels was increased from 1600 mm (5.249 ft) to 1775 mm (5.823 ft). Hence, a greater surface resistance was to be expected. The results, Table II and Figure 6, confirm this supposition. In this case, too, a further test was made with the wheels removed, and the resistance of the exposed end of the axle estimated. Both curves show a drop at about 60 kg/m² (12.29 lb/ft²) pressure. This break in the curve, which subsequent tests have confirmed, is obviously due to the fact that the critical velocity for the struts is exceeded at this pressure.

No. 3 - Tests were made on the portion of a landing gear, shown in Figs. 7 to 9, with two wheels arranged alongside each other. As a corollary thereto, the effect of different wheel coverings on the resistance was investigated. In addition to the ordinary cloth covering (Fig. 10) three sheet-metal coverings were tested (Figs. 11 to 13). Lastly, tests were made on the landing gear without wheels. The estimated resistance of the axle ends was deducted from the results shown in Table III and Fig. 14. The experiments were continued up to velocities of about 50 meters per second (164.04 feet per second). The smallest resistance is obviously caused by the covering shown in Fig. 13 in which the side coverings are attached tangentially to the tires. Of course, the practical application of this method of covering presents greater difficulties than the others.

No. 4 - The machine gun shown in Figs. 15 to 17 was provided with cartridge drum and mounting. The air resistance was measured for the following positions and arrangements.

(a) Barrel perpendicular to air stream, with drum;

(b) Barrel parallel to air stream, with drum;

(c) Barrel parallel to air stream, without drum.

The circumference of the drum was covered with sheet metal making it very similar to the real drum filled with cartridges. The results (Table IV and Figure 18) show that, in this case, the resistance is approximately proportional to the square of the speed which might be expected on account of the many edges on the model.

No. 5 - The exhaust manifold is represented in Figs. 19 and 20. The experimental results (Table V and Fig. 21) show that, in this case also, the air resistance is proportional to the square of the speed.

Table I. Siemens-Schuckert D1 Landing gear complete.

Pressure q		Resistance D		Res. surface S_D	
kg/m²	lb/ft²	kg	lb	m²	ft²
6.1	1.249	1.360	2.998	0.224	2.411
14.6	2.990	2.922	6.442	0.200	2.153
25.3	5.182	4.890	10.781	0.194	2.088
39.3	8.049	7.176	15.820	0.182	1.959
56.9	11.654	10.084	22.231	0.178	1.916
		With dummy wheels.			
6.6	1.352	1.184	2.610	0.180	1.937
14.2	2.908	1.966	4.334	0.138	1.485
25.2	5.161	3.388	7.469	0.134	1.442
39.3	8.049	4.976	10.970	0.126	1.356
56.6	11,593	6.344	13.986	0.112	1.206
77.1	15.791	8.372	18.457	0.108	1.162
		Landing gear without wheels.			
6.4	1.311	0.918	2.024	0.144	1.550
14.4	2.949	1.918	4.228	0.134	1.442
25.3	5.182	3.292	7.258	0.130	1.400
39.4	8.070	4.662	10.278	0.118	1.270
56.6	11.593	6.336	13.968	0.112	1.206
77.1	15.791	8.133	17.930	0.106	1.141

Table II. Landing gear of the Luftfahrzeug-Gesellschaft

Airplane Roland DIIIa.

Pressure q kg/m²	Pressure q lb/ft²	Resistance D kg	Resistance D lb	Res. surface S_D m²	Res. surface S_D ft²
		Complete landing gear.			
15.2	3.113	3.611	7.961	0.238	2.562
26.6	5.448	6.006	13.241	0.226	2.433
41.1	8.418	8.985	19.809	0.218	2.347
58.9	12.064	12.611	27.802	0.214	2.303
80.5	16.488	15.838	34.917	0.197	2.120
105.1		19.845	43.751	0.189	2.034
		Landing gear without wheels.			
15.0	3.072	2.284	5.035	0.153	1.647
26.4	5.407	3.733	8.230	0.141	1.518
41.2	8.438	5.568	12.275	0.135	1.453
59.2	12.125	7.752	17.090	0.131	1.410
80.5	16.488	9.869	21.757	0.123	1.324
105.4	21.588	12.702	28.003	0.120	1.292

Table III. Landing gear of the "Flugzeugbau Friedrichshafen" Airplane G type.

Pressure q kg/m²	lb/ft²	Resistance D kg	lb	Res. surface S_D m²	ft²
		Wheels as in Figure 10.			
6	1.229	1.820	4.012	0.303	3.261
14	2.867	3.950	8.708	0.282	3.035
25	5.120	6.850	15.102	0.274	2.949
39	7.988	10.180	22.443	0.261	2.809
56	11.470	14.390	31.724	0.256	2.756
76	15.566	19.070	42.042	0.251	2.702
100	20.482	24.830	54.741	0.248	2.670
127	26.012	30.230	66.646	0.238	2.562
156	31.951	33.220	73.237	0.213	2.293
		Wheels as in Figure 11.			
6	1.229	1.830	4.034	0.304	3.272
14	2.867	4.050	8.929	0.289	3.111
25	5.120	7.020	15.476	0.281	3.025
39	7.988	10.640	23.457	0.273	2.939
56	11.470	15.000	33.069	0.268	2.885
76	15.566	20.270	44.688	0.266	2.863
100	20.482	24.250	53.462	0.243	2.616
127	26.012	26.830	59.150	0.211	2.271
156	31.951	29.770	65.632	0.191	2.056

Table III. Landing gear of the "Flugzeugbau Friedrichshafen" Airplane G type (Cont.).

Pressure q kg/m²	lb/ft²	Resistance D kg	lb	Res. surface S_D m²	ft²
		Wheels as in Figure 12.			
6	1.229	1.870	4.123	0.311	3.348
14	2.867	4.030	8.885	0.288	3.100
25	5.120	7.010	15.454	0.280	3.014
39	7.988	10.720	23.634	0.275	2.960
56	11.470	14.990	33.047	0.268	2.885
76	15.566	20.230	44.599	0.266	2.863
100	20.482	26.170	57.695	0.262	2.820
127	26.012	31.530	69.512	0.248	2.670
156	31.951	34.420	75.883	0.221	2.379
		Wheels as in Figure 13.			
6	1.229	1.770	3.902	0.295	3.175
14	2.867	3.890	8.576	0.277	2.982
25	5.120	6.690	14.749	0.267	2.874
39	7.988	10.260	22.619	0.263	2.831
56	11.470	14.490	31.945	0.258	2.777
76	15.566	19.520	43.034	0.256	2.756
100	20.482	22.260	49.075	0.223	2.400
127	26.012	25.180	55.512	0.198	2.131
156	31.951	28.070	61.884	0.180	1.938

Table III. Landing gear of the "Flugzeugbau Friedrichshafen"

Airplane G type (Cont.).

Pressure q kg/m²	lb/ft²	Resistance D kg	lb	Res. surface S_D m²	ft²
	Landing gear without wheels and axle.				
6	1.229	0.860	1.896	0.143	1.539
14	2.867	1.830	4.034	0.131	1.410
25	5.120	2.990	6.592	0.119	1.281
39	7.988	4.550	10.031	0.116	1.249
56	11.470	6.360	14.021	0.113	1.216
76	15.566	8.510	18.761	0.112	1.206
100	20.482	10.890	24.008	0.108	1.162
127	26.012	12.530	27.624	0.106	1.141
156	31.951	16.230	35.781	0.104	1.119

Table IV. Machine gun.

Pressure q kg/m²	lb/ft²	Resistance D kg	lb	Res. surface S_D m²	ft²
Barrel perpendicular to airstream (with drum).					
39.0	7.988	5.312	11.711	0.1360	1.464
56.5	11.572	7.610	16.777	0.1350	1.453
77.0	15.771	10.216	22.522	0.1330	1.432
100.0	20.482	13.372	29.480	0.1337	1.439
Barrel parallel to airstream (with drum).					
39.1	8.008	3.656	8.060	0.0935	1.006
57.0	11.675	5.279	11.639	0.0925	0.996
77.0	15.771	7.124	15.706	0.0925	0.996
101.0	20.687	9.249	20.391	0.0915	0.985
Barrel parallel to airstream (without drum).					
39.1	8.008	0.342	0.754	0.00873	0.0940
56.8	11.634	0.496	1.093	0.00873	0.0940
77.3	15.832	0.674	1.486	0.00872	0.0939
101.6	20.809	0.886	1.953	0.00872	0.0939
128.0	26.217	1.110	2.447	0.00868	0.0934
158.0	32.361	1.387	3.058	0.00878	0.0945

Table V. Exhaust manifold.

Pressure q		Resistance D		Res. surface S_D	
kg/m²	lb/ft²	kg	lb	m²	ft²
26.3	5.387	2.415	5.324	0.0918	0.988
40.5	8.295	3.746	8.259	0.0925	0.996
57.6	11.797	5.219	11.506	0.0905	0.974
77.8	15.935	7.288	16.067	0.0936	1.007
101.5	20.789	9.278	20.454	0.0915	0.985
128.0	26.217	11.814	26.045	0.0925	0.996
157.5	32.259	14.599	32.185	0.0927	0.998

Figs. 1, 2, & 3

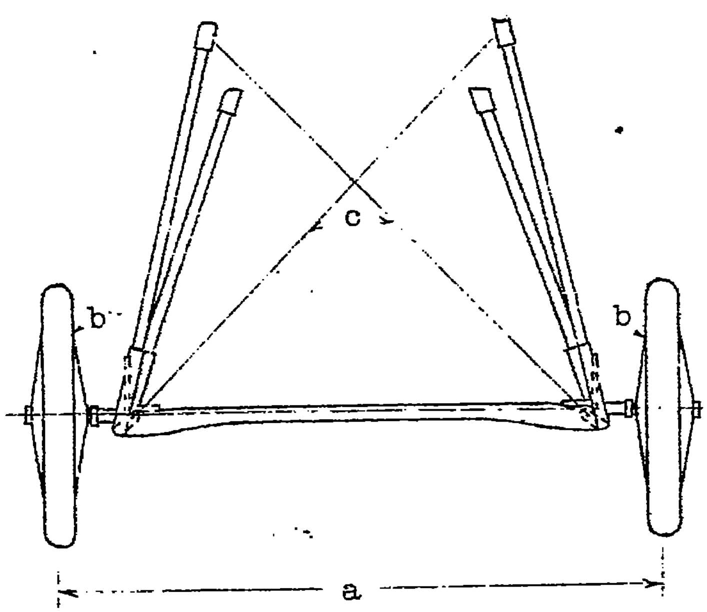


Fig. 1

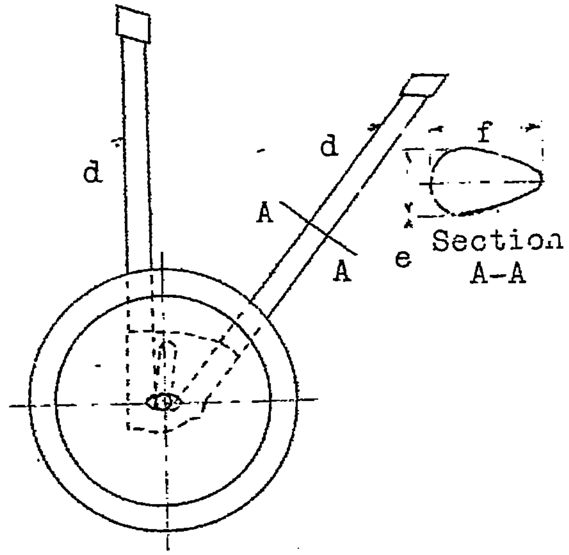


Fig. 2

a=1600 mm (5.249 ft)
b=710/85 mm (27.953/3.346 in)
c= 5 mm (0.197 in)
d=60/34 mm (2.362/1.339 in)
e= 34 mm (1.339 in)
f= 60 " (2.362 ")

Landing gear of the Siemens-Schuckert Dl airplane

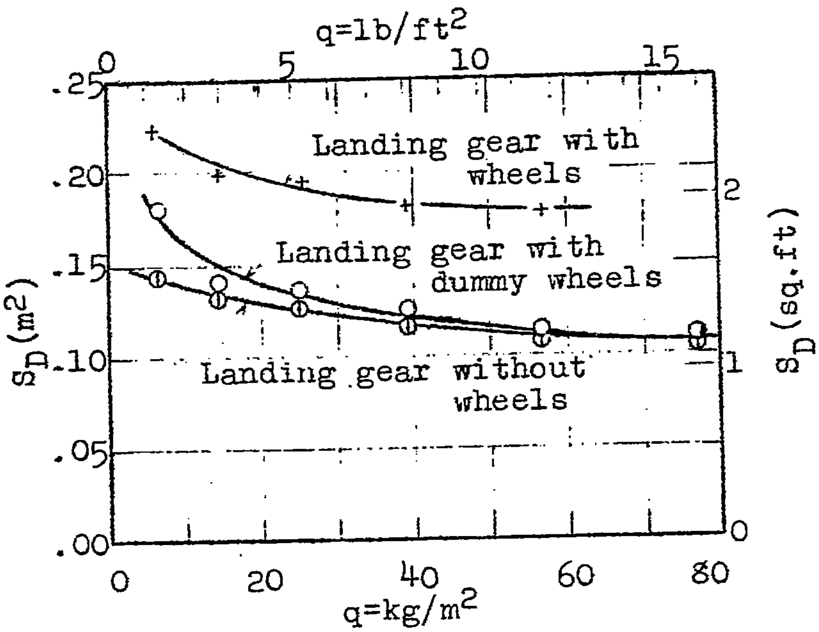


Fig. 3 Siemens-Schuckert Dl landing gear.

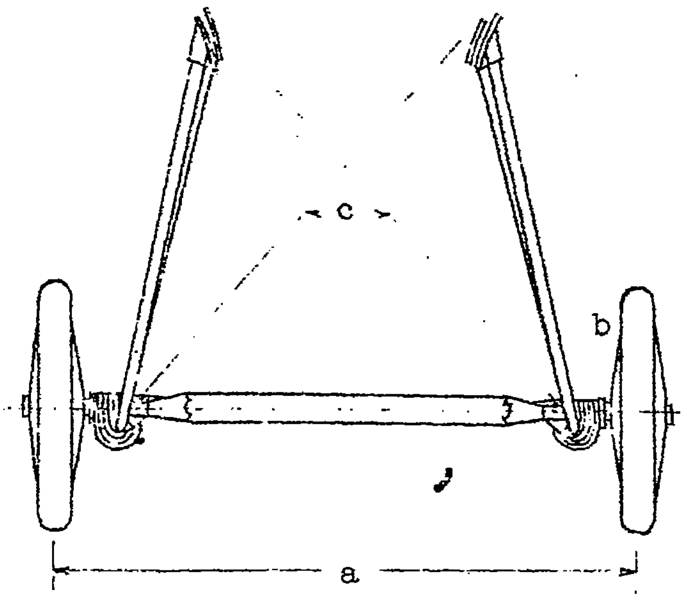


Fig. 4

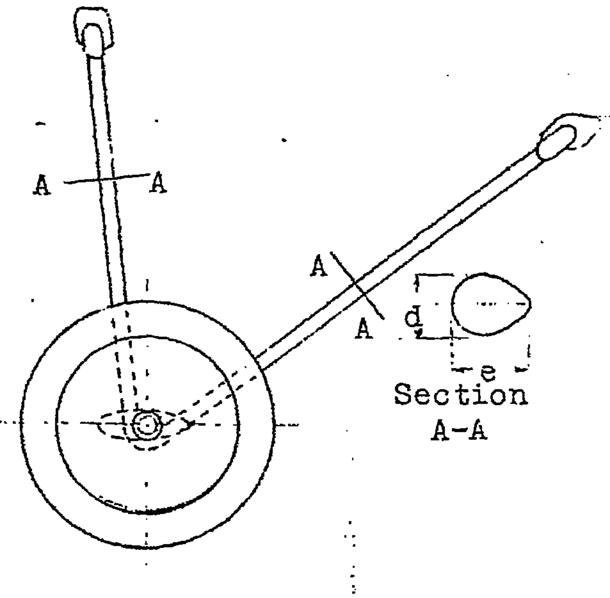


Fig. 5

a=1775 mm (5.823 ft)
b=760/100 mm (29.921/3.937 in)
c=5 mm (0.197 in)
d=38 mm (1.496 in)
e=48 " (1.890 ")

Landing gear of the Luftfahrzeug-Gesellschaft airplane.
Type Roland D11a

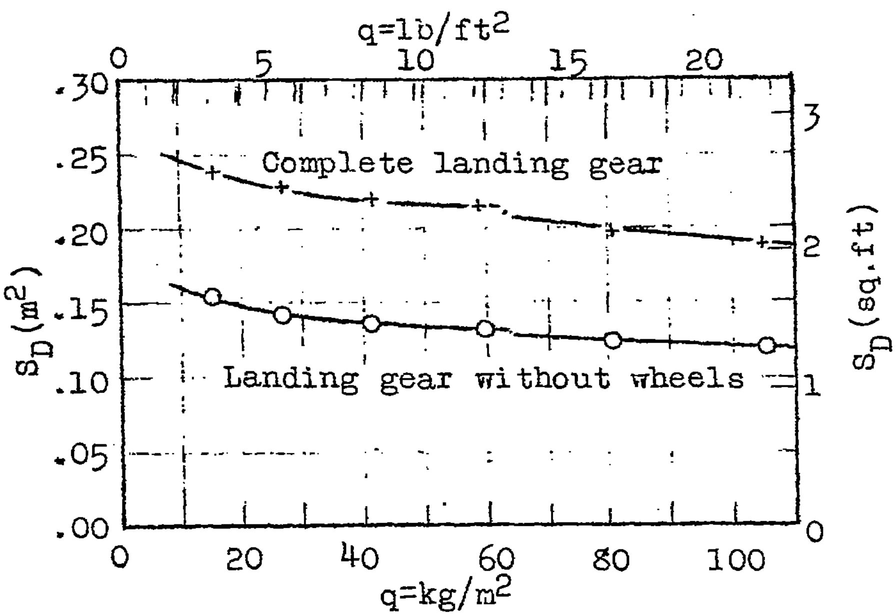


Fig. 6. Landing gear of the Luftfahrzeug-Gesellschaft airplane. Type Roland D11a.

Figs. 7, 8, & 9

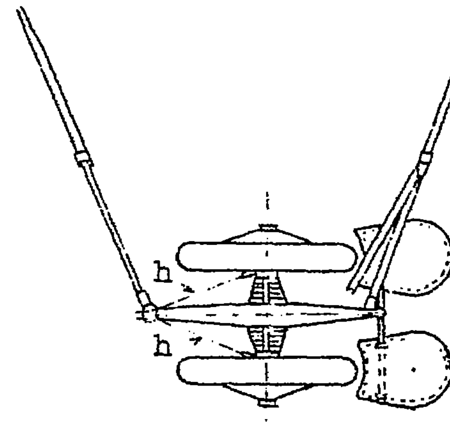


Fig. 7

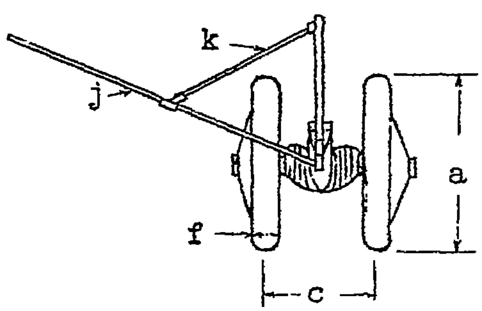


Fig. 8

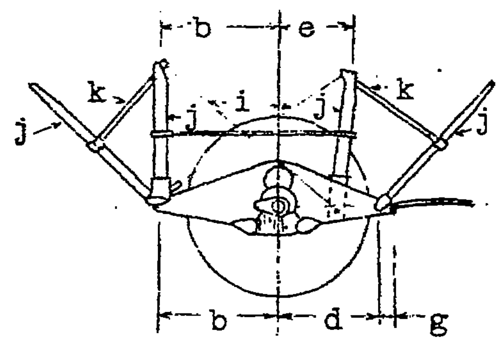


Fig. 9

a=960 mm (37.795 in)
b=620 " (24.409 ")
c=610 " (24.016 ")
d=540 " (21.260 ")
e=380 " (14.961 ")
f=150 " (5.905 ")
g= 75 " (2.953 ")
h= 6 " (0.236 ")
i=5.6 " (0.221 ")
j=70/34 mm (2.756/1.339 in)
k=53/18 " (2.087/0.709 ")

Landing gear of the Flugzeugbau Friedrichshafen airplane

Figs. 10, 11, 12, 13, & 14

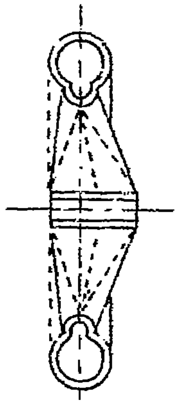


Fig. 10

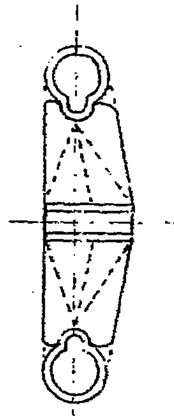


Fig. 11

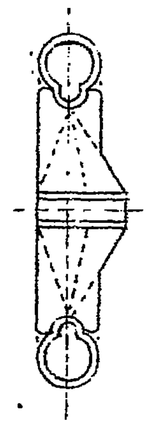


Fig. 12

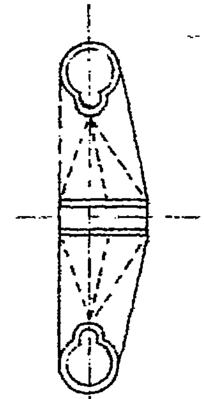
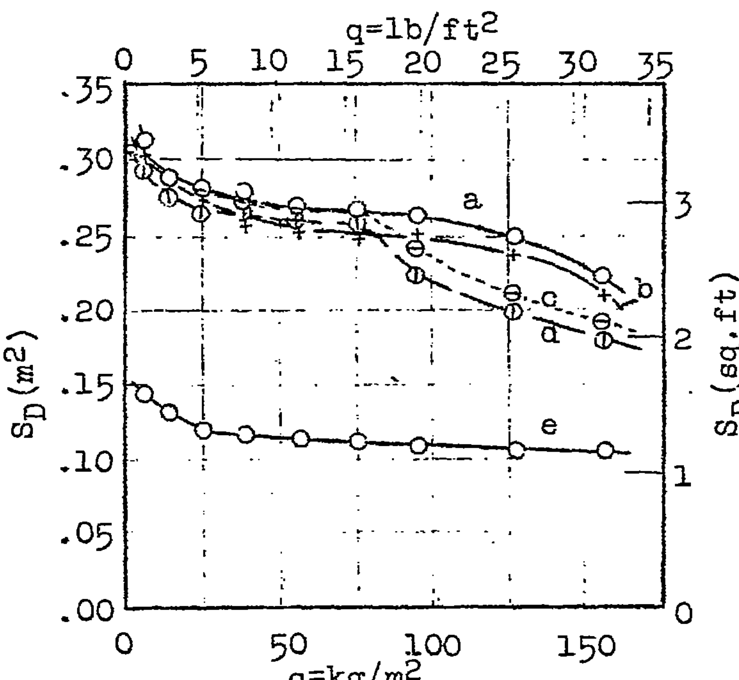


Fig. 13



a=Wheel covering as in Fig. 12
b=Wheel covering as in Fig. 10
c=Wheel covering as in Fig. 11
d=Wheel covering as in Fig. 13
e=Landing gear without wheels & axle

Fig. 14 Landing gear of the Flugzeugbau Friedrichshafen airplane

Figs. 15, 16, & 17

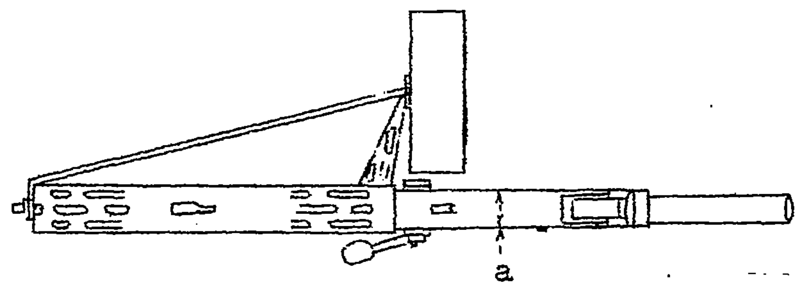


Fig. 16

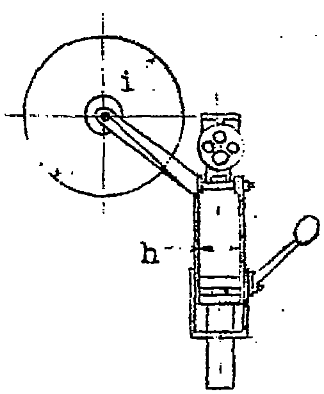


Fig. 15

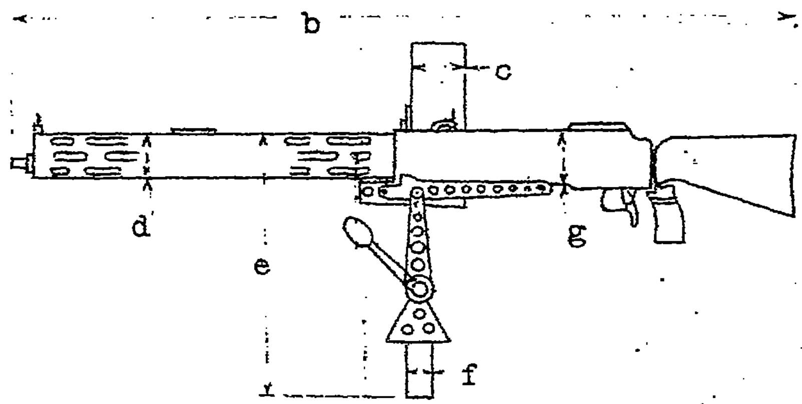


Fig. 17

a=	55 mm	(2.165 in)
b=	1224 "	(48.189 ")
c=	84 "	(3.307 ")
d=	72 "	(2.835 ")
e=	420 "	(16.535 ")
f=	42 "	(1.654 ")
g=	85 "	(3.346 ")
h=	68 "	(2.677 ")
i=	260 "	(10.236 ")

Machine gun with mounting

Figs. 18, 19, 20, & 21

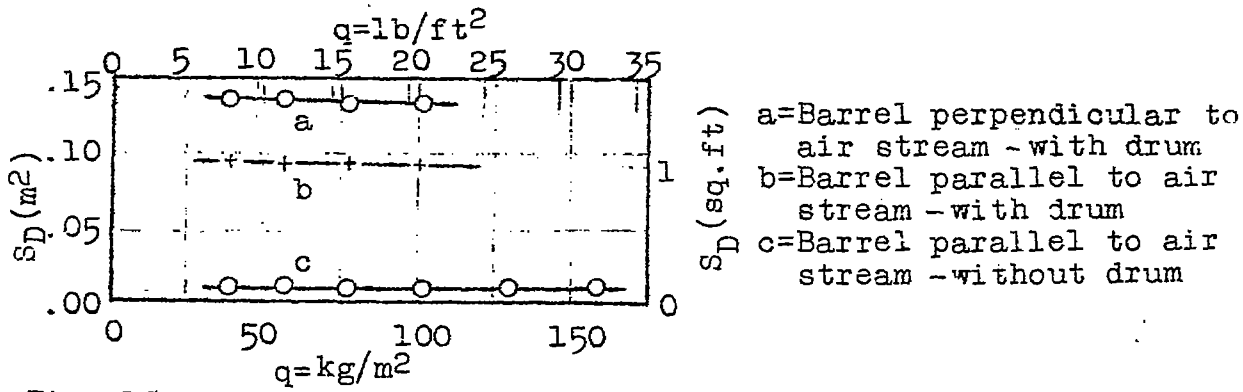
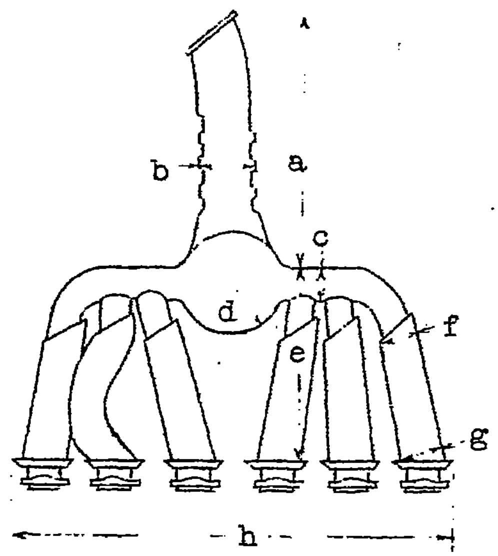


Fig. 18 Machine gun



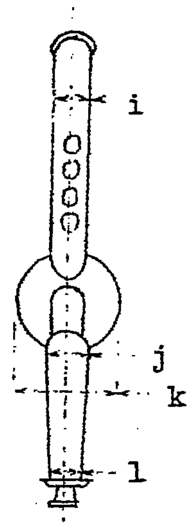


Fig. 19 Exhaust nanifold Fig. 20

a= 670 mm (26.378 in)
b= 140 " (5.512 ")
c= 80 " (3.150 ")
d= 133 " (5.236 ")
e= 600 " (23.622 ")
f= 105 " (4.134 ")

g= 113 mm (4.449 in)
h=1150 " (45.275 in)
i= 96 " (3.780 ")
j= 115 " (4.528 ")
k= 266 " (10.472 ")
l= 86 " (3.386 ")

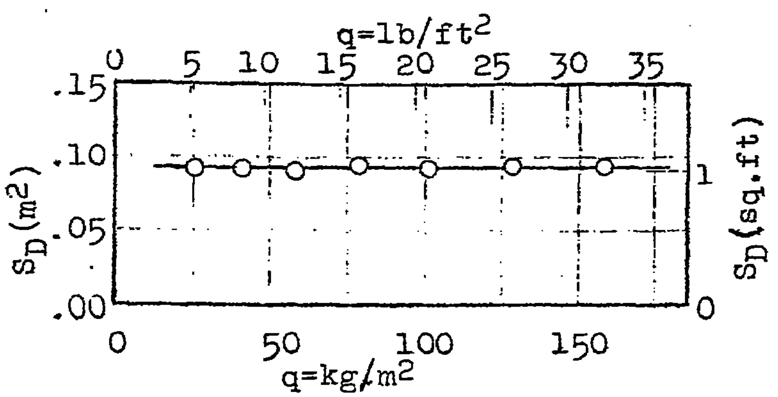


Fig. 21 Exhaust head