TECHNICAL NOTES
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 169

AIR RESISTANCE MEASUREMENTS ON ACTUAL AIRPLANE PARTS.
By C. Wieselsberger.

From Technische Berichte, Volume III, No. 7.

November, 1923.
AIR RESISTANCE MEASUREMENTS ON ACTUAL AIRPLANE PARTS*

By C. Wieselsberger.

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" C airplane;
4. Machine gun;
5. Exhaust manifold of a 260 HP engine.


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

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 rig-
idly connected to the landing gear, but were held by a special
device. In this way, the resistance without wheels was deter-
mined and yet the remaining parts were in a current of air in-
fluenced by the wheels. The third test was carried out entire-
ly without the wheels. In Fig. 3 the equivalent resistance
surface \( S_D \) in square meters is plotted against the pressure

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

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 resist-
ance 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 in-
dividual 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 × 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).
est 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>
<thead>
<tr>
<th>Pressure $q$ (kg/m²)</th>
<th>Resistance $D$ (kg)</th>
<th>Resistance $D$ (lb)</th>
<th>Res. surface $S_D$ (m²)</th>
<th>Res. surface $S_D$ (ft²)</th>
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<td>77.1</td>
<td>15.791</td>
<td>8.133</td>
<td>17.930</td>
</tr>
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</table>

With dummy wheels.

Landing gear without wheels.
Table II. Landing gear of the Luftfahrzeug-Gesellschaft

Airplane Roland D'illa.

<table>
<thead>
<tr>
<th>Pressure $q$ (kg/m²)</th>
<th>Resistance $D$ (kg)</th>
<th>Resistance $D$ (lb)</th>
<th>Res. surface $S_D$ (m²)</th>
<th>Res. surface $S_D$ (ft²)</th>
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<tbody>
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<td>3.611</td>
<td>7.961</td>
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<td>26.6</td>
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<td>13.241</td>
<td>0.226</td>
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<td>8.418</td>
<td>8.985</td>
<td>19.809</td>
<td>0.218</td>
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<tr>
<td>58.9</td>
<td>12.064</td>
<td>12.611</td>
<td>27.802</td>
<td>0.214</td>
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<td>80.5</td>
<td>16.488</td>
<td>15.838</td>
<td>34.917</td>
<td>0.197</td>
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<tr>
<td>105.1</td>
<td>19.845</td>
<td>43.751</td>
<td>0.189</td>
<td>2.034</td>
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<td>Complete landing gear.</td>
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<td>2.284</td>
<td>5.035</td>
<td>0.153</td>
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<td>5.407</td>
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<td>5.568</td>
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<tr>
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<td>12.125</td>
<td>7.752</td>
<td>17.090</td>
<td>0.131</td>
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<tr>
<td>80.5</td>
<td>16.488</td>
<td>9.869</td>
<td>21.757</td>
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<tr>
<td>105.4</td>
<td>21.588</td>
<td>12.702</td>
<td>28.003</td>
<td>0.120</td>
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<tr>
<td>Landing gear without wheels.</td>
<td></td>
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</tr>
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### Table III. Landing gear of the "Flugzeugbau Friedrichshafen"

**Airplane G type.**

<table>
<thead>
<tr>
<th>Pressure $q$ kg/m²</th>
<th>Resistance $D$ kg</th>
<th>Res. surface $S_D$ m²</th>
<th>Wheels as in Figure 10.</th>
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<tbody>
<tr>
<td>6 kg/m² 1.229 lb/ft²</td>
<td>1.820 lb 4.012 lb</td>
<td>0.303 m² 3.261 ft²</td>
<td>6 kg/m² 1.229 lb/ft²</td>
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<tr>
<td>14</td>
<td>2.867 lb 6.708 lb</td>
<td>0.282 m² 3.035 ft²</td>
<td>14 kg/m² 2.867 lb/ft²</td>
</tr>
<tr>
<td>25</td>
<td>5.120 lb 15.102 lb</td>
<td>0.274 m² 2.949 ft²</td>
<td>25 kg/m² 5.120 lb/ft²</td>
</tr>
<tr>
<td>39</td>
<td>7.988 lb 22.443 lb</td>
<td>0.261 m² 2.809 ft²</td>
<td>39 kg/m² 7.988 lb/ft²</td>
</tr>
<tr>
<td>56</td>
<td>11.470 lb 31.724 lb</td>
<td>0.256 m² 2.756 ft²</td>
<td>56 kg/m² 11.470 lb/ft²</td>
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<tr>
<td>76</td>
<td>15.566 lb 42.042 lb</td>
<td>0.251 m² 2.702 ft²</td>
<td>76 kg/m² 15.566 lb/ft²</td>
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<tr>
<td>100</td>
<td>20.482 lb 54.741 lb</td>
<td>0.248 m² 2.670 ft²</td>
<td>100 kg/m² 20.482 lb/ft²</td>
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<tr>
<td>127</td>
<td>26.012 lb 66.646 lb</td>
<td>0.238 m² 2.562 ft²</td>
<td>127 kg/m² 26.012 lb/ft²</td>
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<tr>
<td>156</td>
<td>31.951 lb 73.327 lb</td>
<td>0.213 m² 2.393 ft²</td>
<td>156 kg/m² 31.951 lb/ft²</td>
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Wheels as in Figure 11.

<table>
<thead>
<tr>
<th>Pressure $q$ kg/m²</th>
<th>Resistance $D$ kg</th>
<th>Res. surface $S_D$ m²</th>
<th>Wheels as in Figure 11.</th>
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</thead>
<tbody>
<tr>
<td>6 kg/m² 1.229 lb/ft²</td>
<td>1.830 lb 4.034 lb</td>
<td>0.304 m² 3.272 ft²</td>
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<tr>
<td>14</td>
<td>2.867 lb 8.929 lb</td>
<td>0.289 m² 3.111 ft²</td>
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</tr>
<tr>
<td>25</td>
<td>5.120 lb 15.476 lb</td>
<td>0.281 m² 3.025 ft²</td>
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<tr>
<td>39</td>
<td>7.988 lb 23.457 lb</td>
<td>0.273 m² 2.939 ft²</td>
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</tr>
<tr>
<td>56</td>
<td>11.470 lb 33.069 lb</td>
<td>0.268 m² 2.885 ft²</td>
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<tr>
<td>76</td>
<td>15.566 lb 44.688 lb</td>
<td>0.266 m² 2.863 ft²</td>
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</tr>
<tr>
<td>100</td>
<td>20.482 lb 53.462 lb</td>
<td>0.243 m² 2.616 ft²</td>
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<tr>
<td>127</td>
<td>26.012 lb 59.150 lb</td>
<td>0.211 m² 2.271 ft²</td>
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<tr>
<td>156</td>
<td>31.951 lb 65.632 lb</td>
<td>0.191 m² 2.056 ft²</td>
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Table III. Landing gear of the "Flugzeugbau Friedrichshafen" Airplane G type (cont.).

<table>
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<tr>
<th>Pressure $q$ kg/m²</th>
<th>Resistance $D$ kg</th>
<th>Res. surface $S_{\Delta D}$ m²</th>
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<td>14.990</td>
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<table>
<thead>
<tr>
<th>Wheels as in Figure 13.</th>
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<tr>
<td>25</td>
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<tr>
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Table III. Landing gear of the "Flugzeugbau Friedrichshafen" 

Airplane G type (Cont.).

<table>
<thead>
<tr>
<th>Pressure $q$ $\text{kg/m}^2$</th>
<th>$q$ $\text{lb/ft}^2$</th>
<th>Resistance $D$ $\text{kg}$</th>
<th>$D$ $\text{lb}$</th>
<th>Res. surface $S_D$ $\text{m}^2$</th>
<th>$S_D$ $\text{ft}^2$</th>
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<tr>
<td>Landing gear without wheels and axle.</td>
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<td>6</td>
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<td>1.539</td>
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<td>0.119</td>
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Table IV. Machine gun.

<table>
<thead>
<tr>
<th>Pressure $q$ (kg/m²)</th>
<th>Resistance $D$ (kg)</th>
<th>Res. surface $S_D$ (m²)</th>
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<tr>
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<tr>
<td><strong>Barrel perpendicular to airstream (with drum).</strong></td>
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</tr>
<tr>
<td>39.0</td>
<td>7.988</td>
<td>5.312</td>
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<td>56.5</td>
<td>11.572</td>
<td>7.610</td>
</tr>
<tr>
<td>77.0</td>
<td>15.771</td>
<td>10.216</td>
</tr>
<tr>
<td>100.0</td>
<td>20.482</td>
<td>13.372</td>
</tr>
<tr>
<td><strong>Barrel parallel to airstream (with drum).</strong></td>
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<td>39.1</td>
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<td>3.656</td>
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<td>57.0</td>
<td>11.675</td>
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<td>15.771</td>
<td>7.124</td>
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<td>101.0</td>
<td>20.687</td>
<td>9.249</td>
</tr>
<tr>
<td><strong>Barrel parallel to airstream (without drum).</strong></td>
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Table V. Exhaust manifold.

<table>
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<th>Pressure $q$ kg/m²</th>
<th>Resistance $D$ kg</th>
<th>Res. surface $S_D$ m²</th>
<th>Res. surface $S_D$ ft²</th>
</tr>
</thead>
<tbody>
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<td>26.3</td>
<td>5.387</td>
<td>2.415</td>
<td>5.324</td>
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<td>40.5</td>
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<td>57.6</td>
<td>11.797</td>
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<td>11.506</td>
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<td>101.5</td>
<td>20.789</td>
<td>9.278</td>
<td>20.454</td>
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<tr>
<td>128.0</td>
<td>26.217</td>
<td>11.814</td>
<td>26.045</td>
</tr>
<tr>
<td>157.5</td>
<td>32.259</td>
<td>14.599</td>
<td>32.135</td>
</tr>
</tbody>
</table>
Figs. 1, 2, & 3

Landing gear of the Siemens-Schuckert DL airplane

\[
\begin{align*}
    a &= 1600 \text{ mm (5.249 ft)} \\
    b &= 710/85 \text{ mm (27.953/3.346 in)} \\
    c &= 5 \text{ mm (0.197 in)} \\
    d &= 60/34 \text{ mm (2.362/1.339 in)} \\
    e &= 34 \text{ mm (1.339 in)} \\
    f &= 60 \text{ " (2.362 ")}
\end{align*}
\]

Fig. 1

Fig. 2

Fig. 3: Siemens-Schuckert DL landing gear.
Figs. 4, 5, & 6

Fig. 4

Fig. 5

a = 1775 mm (5.623 ft)
b = 760/100 mm (29.921/3.937 in)
c = 5 mm (0.197 in)
d = 38 mm (1.496 in)
e = 48 in (1.890 in)

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

Fig. 6. Landing gear of the Luftfahrzeug-Gesellschaft airplane. Type Roland Dllla.
Landing gear of the Flugzeugbau Friedrichshafen airplane

\[ \begin{align*}
    a &= 960 \text{ mm} \quad (37.795 \text{ in}) \\
    b &= 620 \text{ in} \quad (24.409 \text{ in}) \\
    c &= 610 \text{ in} \quad (24.016 \text{ in}) \\
    d &= 540 \text{ in} \quad (21.260 \text{ in}) \\
    e &= 380 \text{ in} \quad (14.961 \text{ in}) \\
    f &= 150 \text{ in} \quad (5.905 \text{ in}) \\
    g &= 75 \text{ in} \quad (2.953 \text{ in}) \\
    h &= 6 \text{ in} \quad (0.236 \text{ in}) \\
    i &= 5.6 \text{ in} \quad (0.221 \text{ in}) \\
    j &= 70/34 \text{ mm} \quad (2.756/1.339 \text{ in}) \\
    k &= 53/18 \text{ in} \quad (2.037/0.709 \text{ in}) 
\end{align*} \]
Fig. 10, 11, 12, 13, & 14

Fig. 10

Fig. 11

Fig. 12

Fig. 13

Fig. 14 Landing gear of the Flugzeugbau Friedrichshafen airplane

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
Figs. 15, 16, & 17

Machine gun with mounting

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
Fig. 18, 19, 20, & 21

Fig. 18

Machine gun

Fig. 19 Exhaust manifold

Fig. 20

a = 670 mm (26.378 in)  
g = 113 mm (4.449 in)

b = 140 " (5.512 ")  
h = 1150 " (45.275 in)

c = 80 " (3.150 ")  
i = 96 " (3.780 ")

d = 133 " (5.236 ")  
j = 115 " (4.528 ")

e = 600 " (23.622 ")  
k = 266 " (10.472 ")

f = 105 " (4.134 ")  
l = 86 " (3.386 ")

Fig. 21 Exhaust head

q = lb/ft²

SD (sq. ft)

0 5 10 15 20 25 30 35

a = Barrel perpendicular to air stream - with drum  
b = Barrel parallel to air stream - with drum  
c = Barrel parallel to air stream - without drum

q = kg/m²

SD (sq. m²)

0 5 10 15 20 25 30 35

0.15

0.10

0.05

0.00