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A Speedometer which Indicates True Airspeeds.

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Abstract.

We have constructed a differential pressure type airspeed indicator which is compensated for the variations of the density of the air perfecty in its principle, and calibrated it using the low pressure, low temperature wind tunnel in the institute. From the results of the calibration we see that the new indicator indicates very nearly the true airspeeds.

Introduction.

In ordinary differential pressure type airspeed indicators, the indicated speeds vary according as the variations of the density of the air. This is due to the fact that an airspeed pressure nozzle such as Pitot-static nozzle or Venturi nozzle by its motion through the air developes a pressure or a suction which is proportional to the density of the air.

Many attempts have been made in this country and abroad to invent an indicator, Pitot or Venturi type, which is not affected by the density of the air, but so far as I am aware no device exists which compensates perfecty the effect of variations of the air density and indicates the true airspeeds.

The principle of compensation for the air density.

We have used the ordinary aneroid diaphragm capsule, which is deflected by the variations of the density of the air, in conjunction with the capsule for an ordinary pressure type airspeed indicator. The principle of compensation in shown in Fig. 1. The two capsules are arranged perpendicular to each other. BA represents the line of motion of the

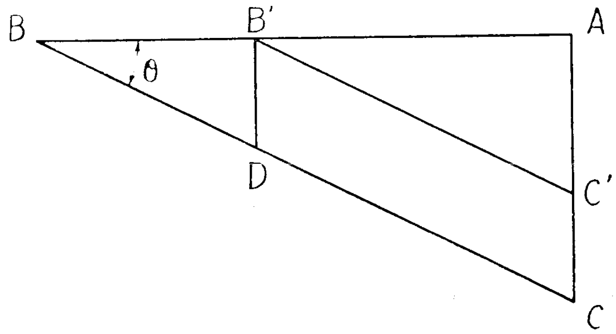


Fig. 1.

centre of the capsule for altitude, and AC represents that of the centre of the capsule for airspeed. Let B be the position of the centre of the altitude capsule at some air density ρ_0, and it is deflected toward A as the density is decreased. A represents the position of the centre of the capsule when it is put in the vacuum. Let C represent the centre of the airspeed capsule at some air density ρ_0 and at some airspeed V. The point A represents the position of it at zero airspeed.

When the density of the air is decreased to ρ, the centre of the altitude capsule is deflected to some position B'. The deflection of the centre of the airspeed capsule is proportional to the density of the air and the square of the airspeed. Hence at a density ρ and at an airspeed V it is deflected to some point C', where $B'C'$ is parallel to BA.

As $B'D$ is equal to $C'C$ we have

$$\tan\theta = \frac{B'D}{BB'} = K\frac{(\rho_0-\rho)v^2}{\rho_0-\rho} = Kv^2$$

where K is a constant depending on the properties of the altimeter and the speedometer.

From the above reasoning we see that θ serves as a measure of the airspeed not at all affected by the density of the air.

The mechanism.

Fig. 2 shows the mechanism of the new airspeed indicator constructed in accordance with the above principle.

A post B is fixed to the centre of the altitude capsule D and carries at its end a pin, the sharp end of which slides over the surface of a lever formed somewhat like a bell crank E as the diaphragm capsule D is deflected.

The deflection of the centre of the airspeed capsule C is transmitted to a frame I, to which is pivoted the axle A of the bell crank E. The upper surface of a lever of the bell crank constitutes a well polished flat surface, on which the pin attached at the end of the post B slides. Hence the point of contact of the former and the latter corresponds to the point B or B' in Fig. 1, and the point, where the extension of the locus of the point of contact and the central line of the axle A cross, corresponds to the point A in Fig. 1.

The rotating angle of the axle of the bell crank corresponds to θ in Fig. 1. The rotation is magnified by means of the other lever of the bell crank E, a chain F and an arbor G. The axle of the arbor is on the same axis as the shaft H of the pointer, and the former can slide in the latter. Hence the rotation of the arbor shaft causes the rotation of the pointer shaft, but no deflection of the capsule C causes an axial movement of the pointer. By means of a spiral spring, which is wound around the shaft of the pointer, the pin attached to the post B is always kept in contact with the upper surface of a lever of the bell crank E.

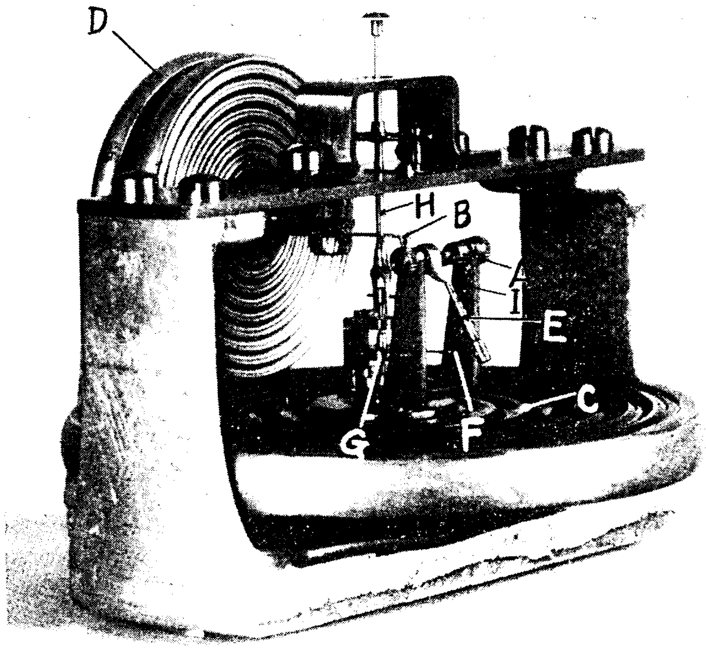


Fig. 2.

Experiment.

We have carried out a calibration of the new airspeed indicator using the low pressure, low temperature wind tunnel in this institute. The results are shown in Figs. 3–8, and in Tables 1–6. In Fig. 9 we have put these results together to make clear how little the variations of the air density affect the indications of the now indicator.

In Figs. 10, 11 and 12 are shown the results of calibration of the ordinary airspeed indicators without any compensating mechanism for the variations of the air density.

Comparing these results we see how good our new indicator indicates the true airspeeds.

(The altitudes written in the figures are measured by an altimeter and so there are some differences between these altitudes and those computed from the pressures in the wind tunnel.)

In the following tables the true airspeeds of the wind tunnel are measured by means of a standard Pitot-static nozzle whose coefficient is 0·9995.

If p is the pressure difference developed by the Pitot-static nozzle, which is measured by an alcohol manometer, and K is the Pitot constant, which is 0·9995 in our case, the true airspeed v is calculated by

$$v = \sqrt{\frac{2p}{K\rho}} \cdot \qquad \text{(1)}$$

Let ρ_a = Density of alcohol

h = Height of the alcohol [illegible]

g = Acceleration of gravity

π = Pressure in the wind tunnel

T = Absolute temperature of the air in the wind tunnel

R = Gas constant for air,

then we have

$$p = \rho_a h g,$$

$$\rho = \frac{\pi}{TR} \cdot$$

Substituting these relations in (1) we get

$$v = \sqrt{\frac{2\rho_a hgTR}{K\pi}} \cdot$$

The airspeeds of the wind tunnel are computed from this formula.

At the Ground Level.

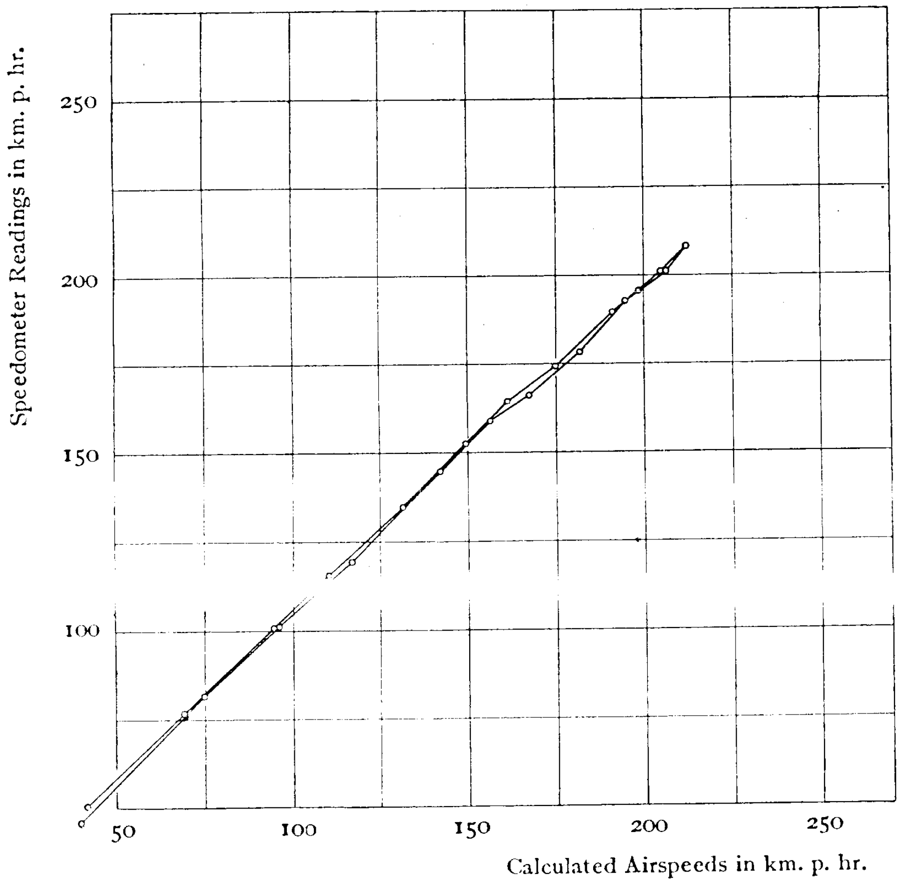


Fig. 3.

At the Altitude 1000 m.

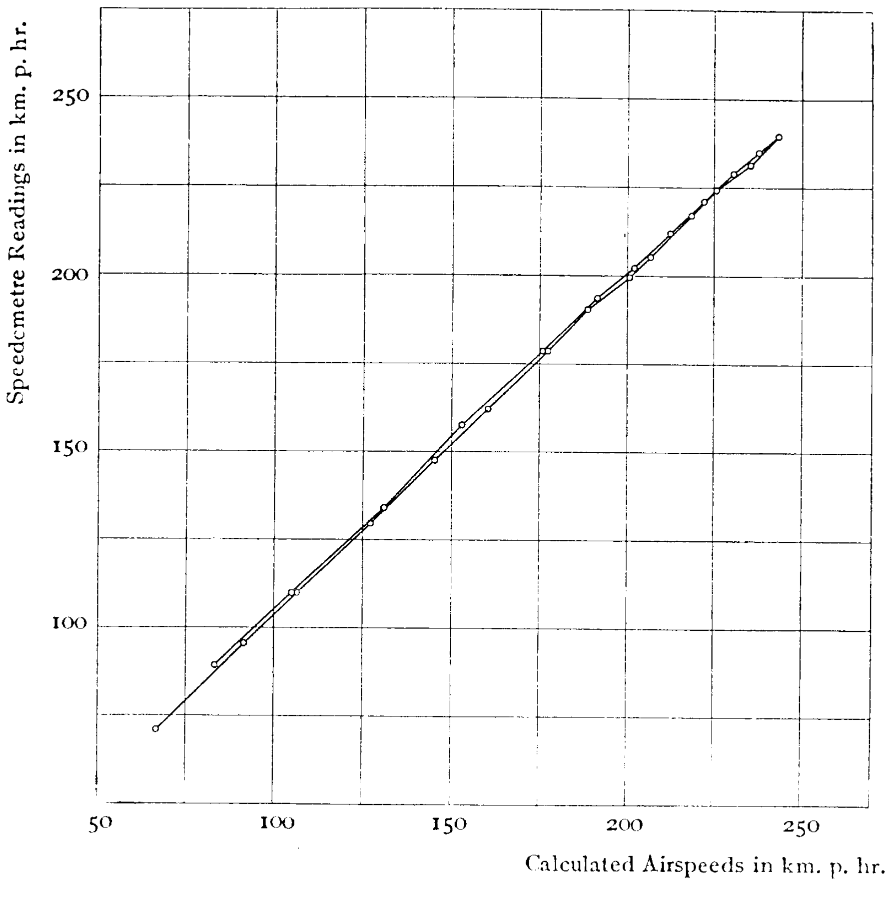


Fig. 4.

At the Altitude 2000 m.

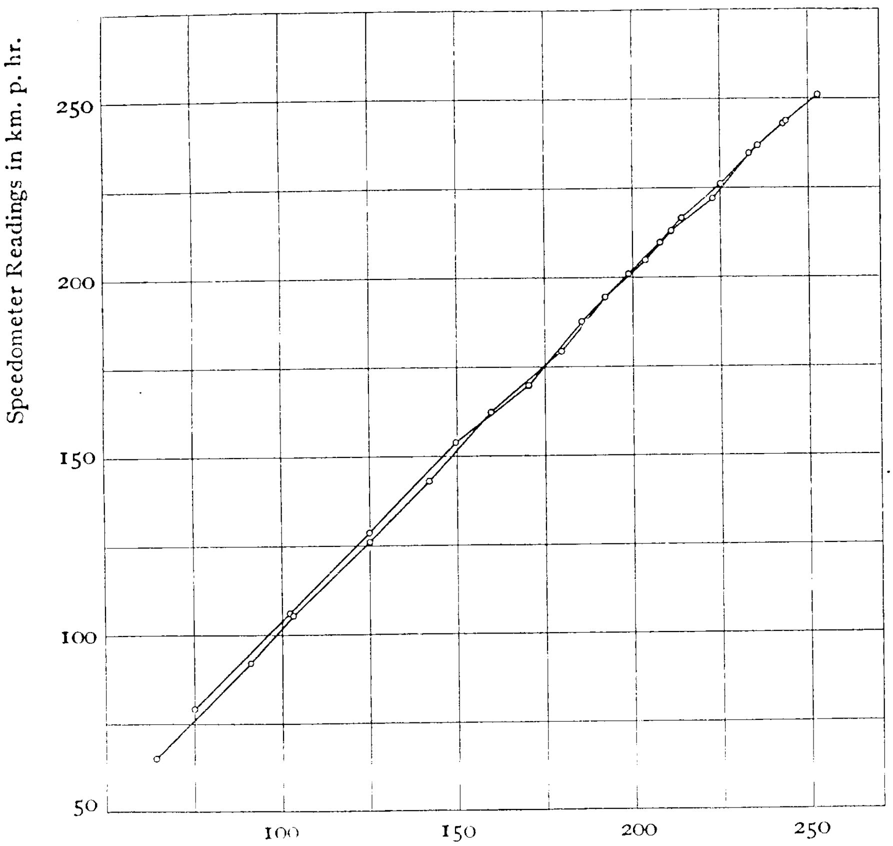


Fig. 5.

At the Altitude 3000 m.

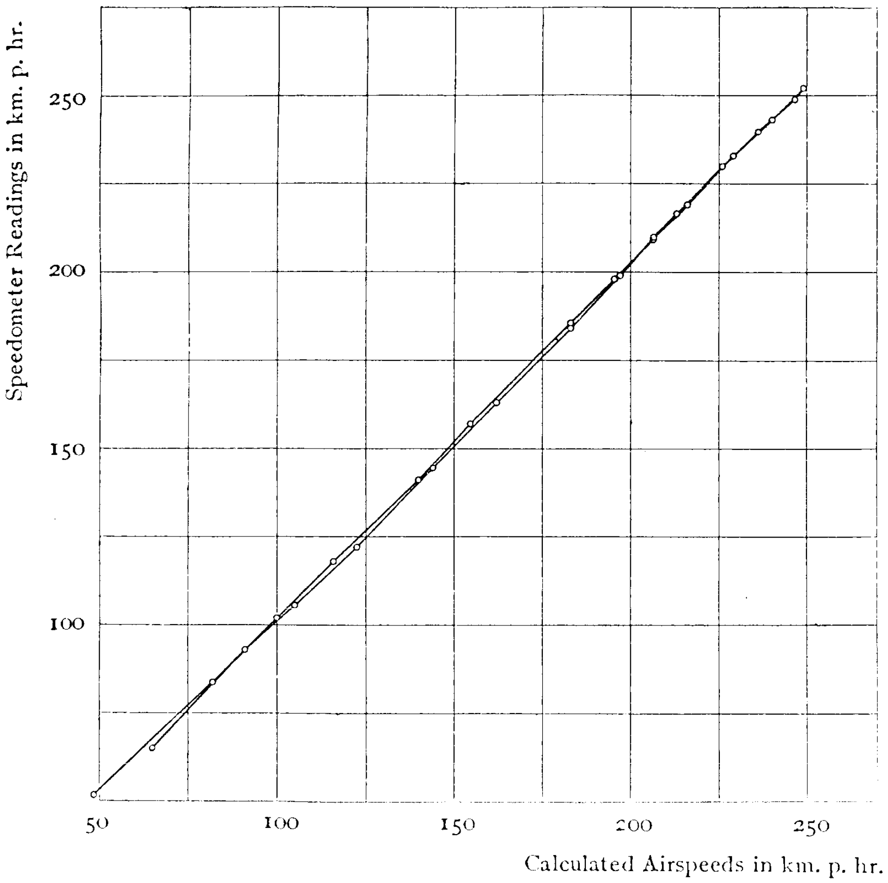


Fig. 6.

At the Altitude 4000 m.

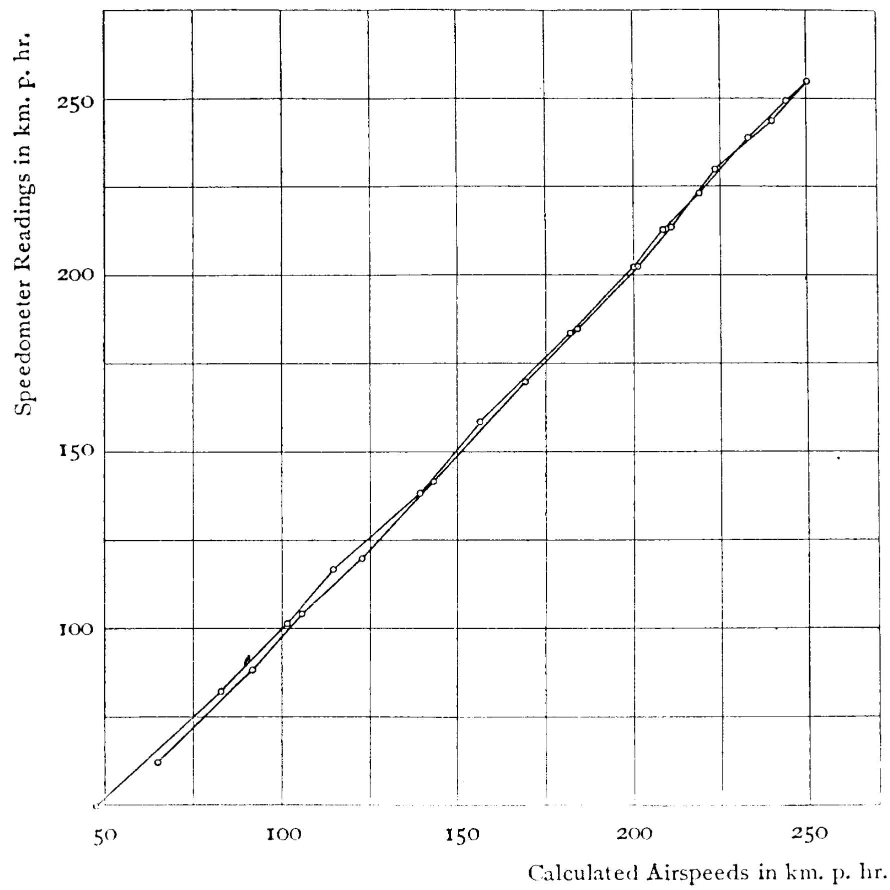


Fig. 7.

At the Altitude 5000 m.

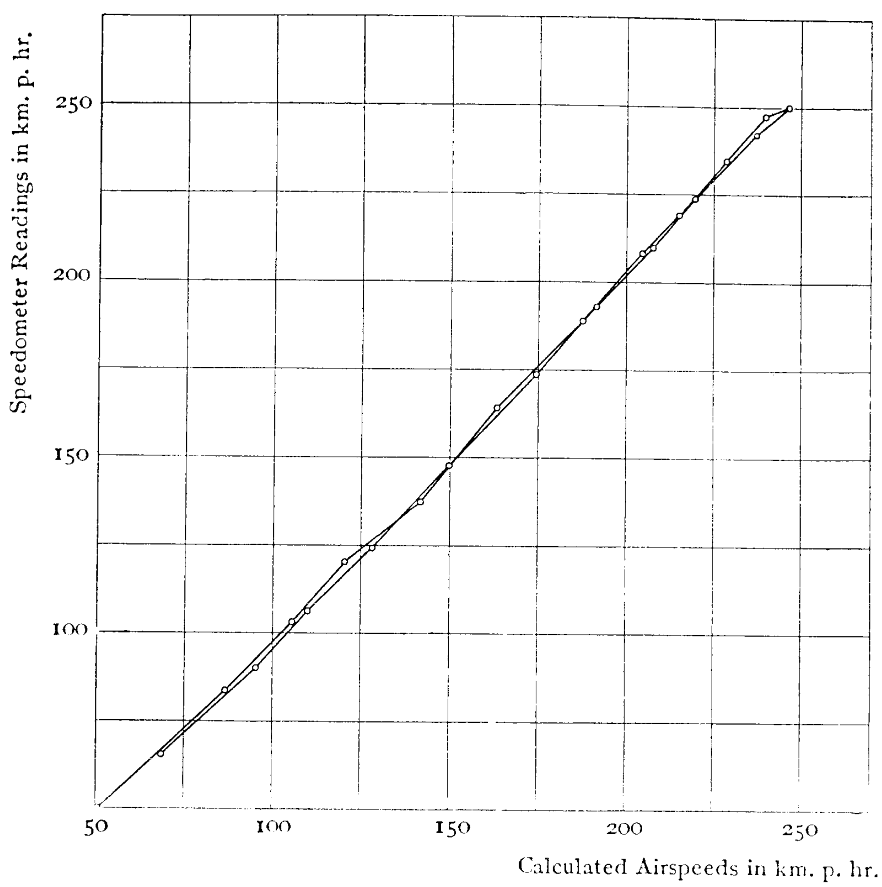


Fig. 8.

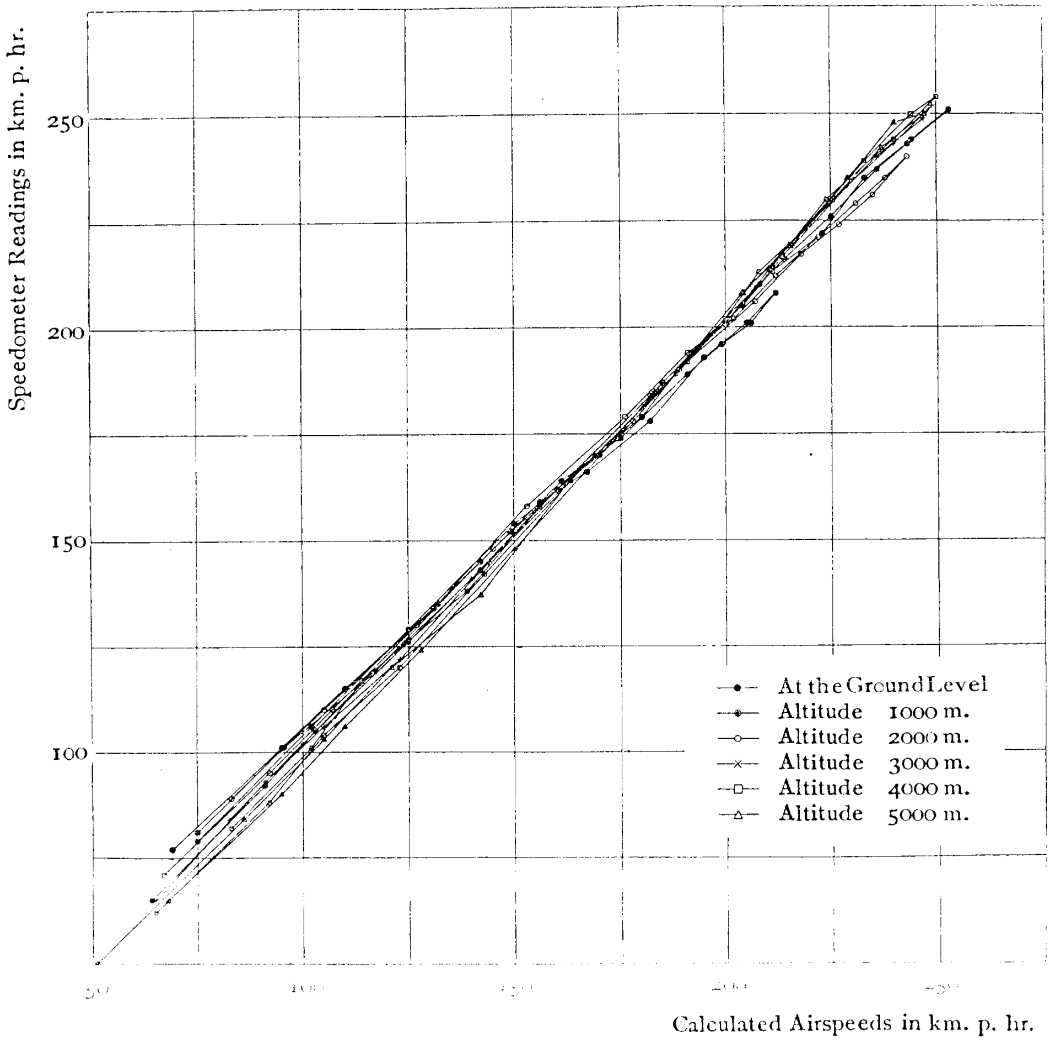
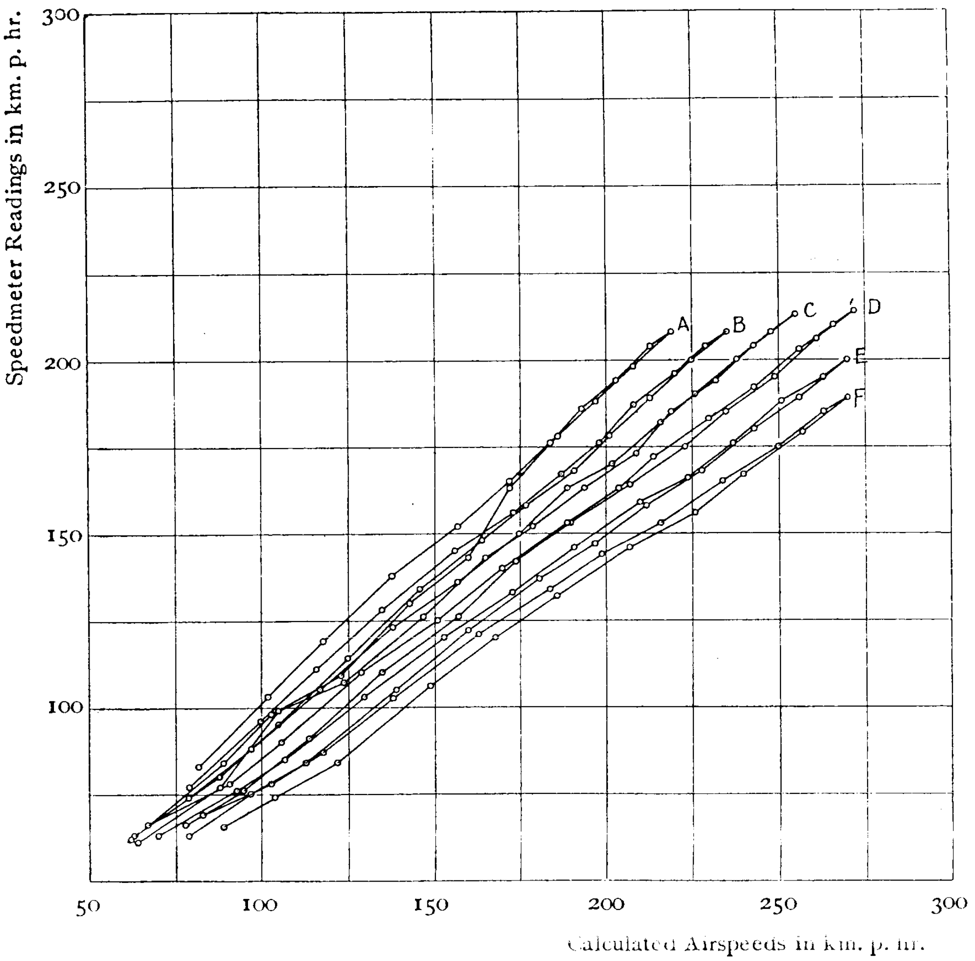

Speedometer Readings in km. p. hr.
250
200
150
100
At the Ground Level
Altitude 1000 m.
Altitude 2000 m.
Altitude 3000 m.
Altitude 4000 m.
Altitude 5000 m.
Calculated Airspeeds in km. p. hr.

Fig. 9.

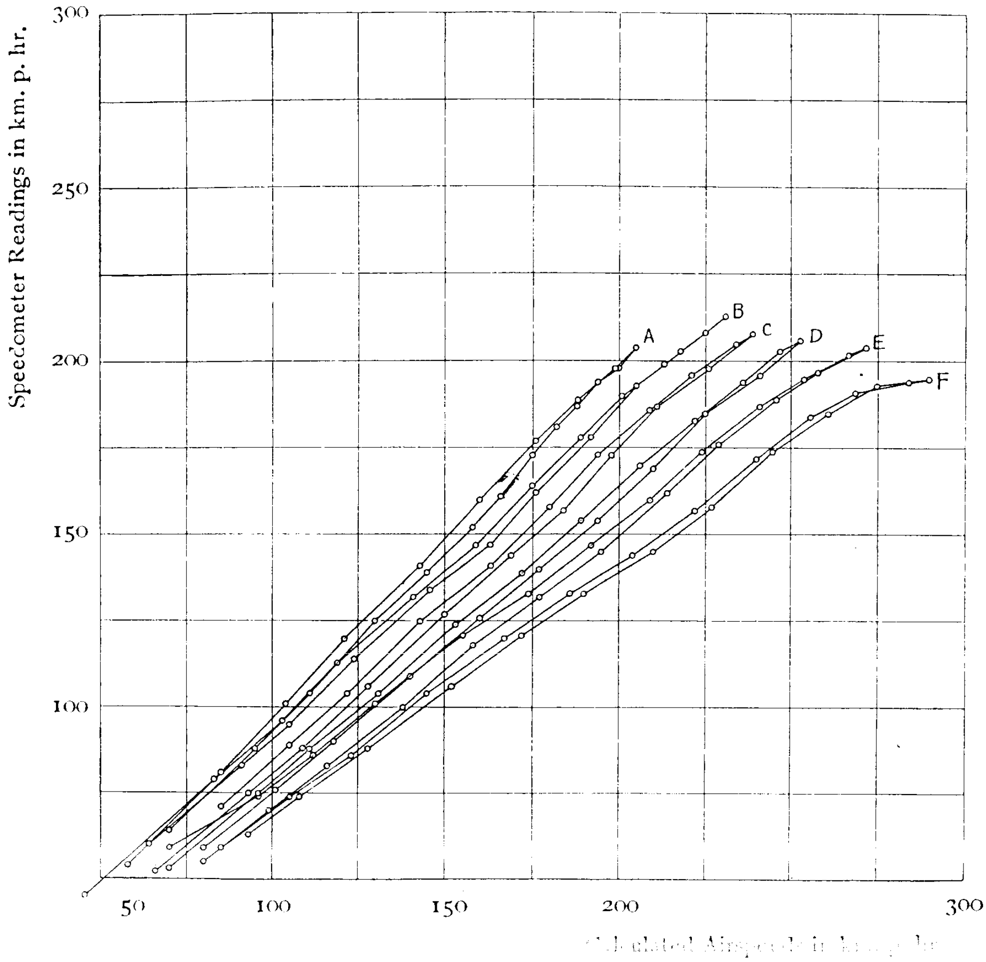
No. 1 Speedometer without Compensating Mechanism.



A At the Ground Level.		B At the Altitude	1000 m.
C At the Altitude	2000 m.	D ,,	3000 m.
E ,,	4000 m.	F ,,	5000 m.

Fig. 10.

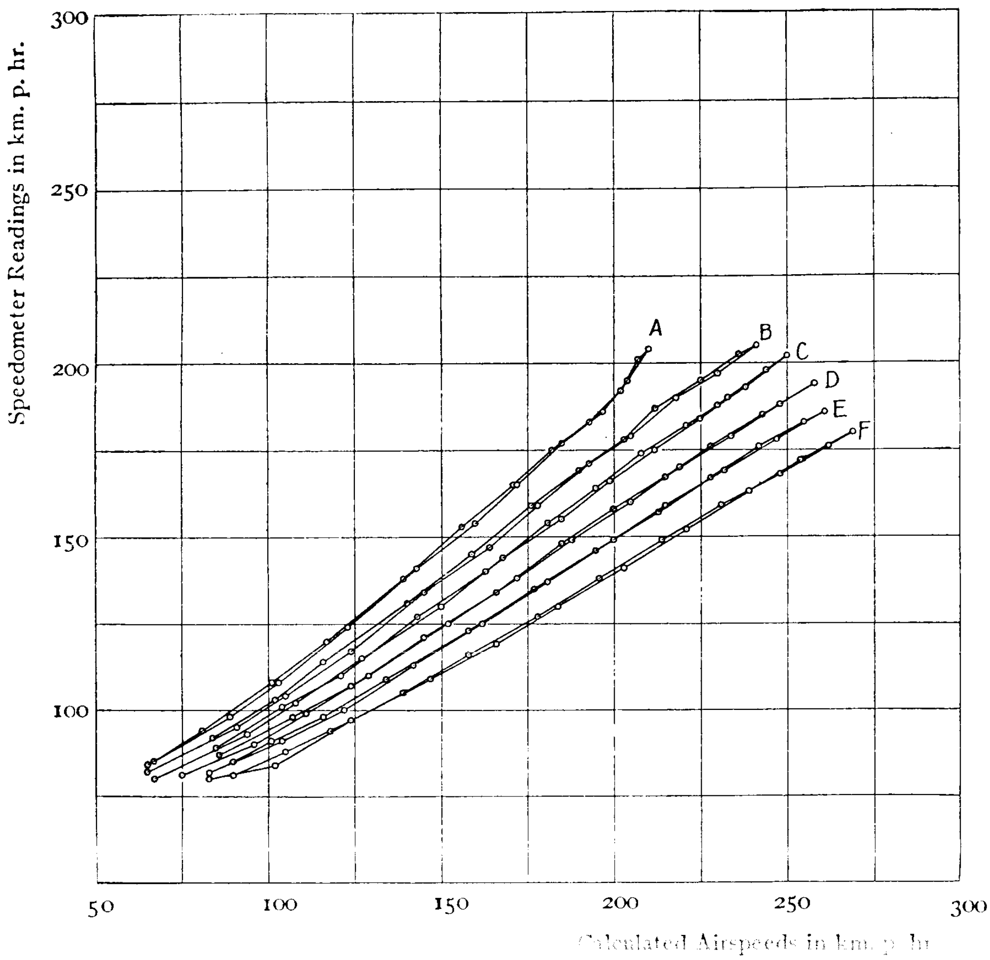
No. 2 Speedometer without Compensating Mechanism.



A	At the Ground Level.	B	At the Altitude 1000 m.
C	At the Altitude 2000 m.	D	„ 3000 m.
E	„ 4000 m.	F	„ 5000 m.

Fig. 11.

No. 3 Speedometer without Compensating Mechanism.



A	At the Ground Level.		B	At the Altitude	1000 m.
C	At the Altitude	2000 m.	D	,,	3000 m.
E	,,	4000 m.	F	,,	5000 m.

Fig. 12.

TABLE I.

Pressure in the wind tunnel	754·2 mm. Hg.
Temperature of the air in the wind tunnel	10·0°C.
Corresponding altitude	65 m.
Density of alcohol (at 7·8°C)	0·843

Height of the alcohol column in mm.	Wind speed in km. per hr.	Speedometer reading in km. per hr.
8·9	40	46
31·4	75	81
52·2	96	101
77·2	117	119
114·4	142	145
138·2	156	159
158·2	167	166
187·0	182	175
214·8	195	193
237·5	205	201
254·3	212	208
240·4	206	201
223·5	199	196
206·6	191	189
[illegible]	175	174
147·1	161	164
126·1	149	152
98·3	132	135
68·8	110	115
50·6	95	101
26·9	69	77
9·8	42	50

TABLE II.

Pressure in the wind tunnel	663·4 mm. Hg.
Temperature of the air in the wind tunnel	8·9C.
Corresponding altitude	1132 m.
Density of alcohol (at 7·9°C)	0·842

Height of the alcohol column in mm.	Wind speed in km. per hr.	Speedometer reading in km. per hr.
22·0	67	71
42·0	92	95
56·8	107	110
80·9	127	130
105·7	145	148
128·8	160	162
157·7	178	179
178·3	189	190
213·7	207	206
238·4	218	217
254·9	226	224
277·0	235	232
295·8	243	240
282·9	238	235
266·1	231	229
246·9	222	222
225·6	212	212
204·0	202	202
183·2	191	194
155·1	176	179
117·5	153	158
85·8	131	134
55·4	105	110
34·8	83	89

Table III.

Pressure in the wind tunnel	583·6 mm. Hg.
Temperature of the air in the wind tunnel	7·8°C.
Corresponding altitude	2173 m.
Density of alcohol (at 7·4°C)	0·842

Height of the alcohol column in mm.	Wind speed in km. per hr.	Speedometer reading in km. per hr.
18·1	64	65
36·6	91	91
47·2	103	105
69·2	125	126
88·9	142	143
112·5	160	162
142·6	180	179
165·8	192	194
183·8	204	205
197·2	211	213
219·8	223	222
240·1	233	235
262·6	244	244
282 2	253	251
260·2	243	243
245·2	236	237
223·9	225	226
202·6	214	216
190·0	208	210
175·0	199	201
151·8	185	188
127·8	170	170
98·9	150	154
69·1	125	129
46·1	102	106
25·0	75	79

TABLE IV.

Pressure in the wind tunnel	516·9 mm. Hg.
Temperature of the air in the wind tunnel	6·9C.
Corresponding altitude	3136 m.
Density of alcohol (at 6·9°C)	0·843

Height of the alcohol column in mm.	Wind speed in km. per hr.	Speedometer reading in km. per hr.
16·7	65	65
32·3	91	93
43·4	105	106
59·0	123	122
80·9	144	145
102·5	162	163
130 6	183	184
152·4	197	199
167·3	206	210
205·4	216	219
225·3	240	243
243·1	249	252
238·7	247	249
218·5	236	240
200·6	226	230
178·1	213	217
[illegible]	[illegible]	[illegible]
149·8	196	198
131·2	183	185
93·9	155	157
77·1	140	141
52·9	116	118
39·5	100	102
26·8	83	84

Table V.

Pressure in the wind tunnel	451·7 mm. Hg.
Temperature of the air in the wind tunnel	6·0C.
Corresponding altitude	4179 m.
Density of alcohol (at 6·5°C)	0·843

Height of the alcohol column in mm.	Wind speed in km. per hr.	Speedometer reading in km. per hr.
14·7	65	62
29·0	92	88
38·5	106	104
51·8	123	120
70·5	143	142
98·7	169	170
116·5	184	185
139·4	201	202
152·8	211	214
171·9	224	230
197·9	240	244
215·3	250	255
204·8	244	250
186·9	233	239
165·1	219	223
149·2	208	213
[illegible]	[illegible]	[illegible]
113·7	182	184
84·1	156	158
66·7	139	138
47·9	114	117
35·5	102	101
23·7	83	82
7·7	47	50

TABLE VI.

Pressure in the wind tunnel	396·3 mm. Hg.
Temperature of the air in the wind tunnel	6·0C.
Corresponding altitude	5165 m.
Density of alcohol (at 6·5°C)	0·843

Height of the alcohol column in mm.	Wind speed in km. per hr.	Speedometer reading in km. per hr.
14·1	68	65
27·3	95	90
36·5	110	106
49·5	128	124
67·6	150	148
91·7	174	174
110·8	191	193
129·8	208	210
145·5	220	224
169·5	237	242
183·1	247	250
173·1	240	248
157·4	229	235
139·7	215	219
[illegible]	[illegible]	[illegible]
106·1	188	189
79·7	163	164
60·5	142	137
44·6	121	120
33·5	105	103
22·5	86	84
7·7	51	50