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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 235

STATIC SOARING FLIGHT OVER FLAT SEA COASTS.

By W. Georgii.

From "Zeitschrift für Flugtechnik und Motorluftschiffahrt,"
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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

TECHNICAL MEMORANDUM NO. 235.

STATIC SOARING FLIGHT OVER FLAT SEA COASTS.*

By W. Georgii.

Static soaring flight has hitherto been accomplished principally by means of two sources of energy: ascending air currents in the vicinity of obstacles and those produced by unequal heating. The former source has been so thoroughly investigated that it is possible to estimate the altitudes and distances thereby attainable. The latter has not yet been practically tested in soaring flight, though we know that its energy is sufficient to enable flight. The upward acceleration of a relatively warm body of air is proportional to the temperature difference between it and the surrounding air, so that

$$\frac{d^2 z}{d t^2} = g \frac{T - T'}{T'}$$

in which T is the absolute temperature of the ascending body of air, T' that of the surrounding air and g the acceleration due to gravity. From these the vertical velocity of the ascending air at the altitude z is found to be

$$\frac{dz}{dt} = \sqrt{2g \frac{T - T'}{T'} z}$$

It is accordingly evident that, for even small temperature differences, the vertical velocity is sufficient for soaring flight

* From "Zeitschrift für Flugtechnik und Motorluftschiffahrt," July 26, 1923, pp. 114-115.

at an altitude of several hundred meters. Direct measurements have given the following vertical velocities of cumulus clouds.

June 6, 1913, 12:24 P.M.				Nov. 19, 1923.			
Altitude		Velocity		Altitude		Velocity	
m	ft	m/s	ft/sec	m	ft	m/s	ft/sec
0-242	0-794	+0.18	+0.59	0-76	0-249	0.00	0.00
242-316	794-1037	+0.63	+2.07	76-127	249-417	-0.42	-1.38
316-698	1037-2290	+1.35	+4.43	127-386	417-1266	+0.13	+0.43
				386-608	1266-1995	+1.68	+5.51

According to both these examples, the ascending wind was strong enough for soaring flight at an altitude of 300 to 600 meters (984 to 1969 ft). The flight from cloud to cloud seems quite tempting.

Aside from these two kinds of ascending motions of the air, it may be expedient to call the attention to still another source of energy for static soaring flight, which has thus far received but little consideration. These are vertical motions of the air produced by frictional variations. The continuity of the air flow demands that, at every point where the friction between the air and the ground either increases or decreases and, consequently, the horizontal wind is hindered or accelerated, an ascending or descending compensating current is formed. In meteorology there are known various phenomena indicating that the strength of these vertical motions is considerable. The decrease in friction experienced by an air current in passing over rivers and lakes produces a descending current which is often evidenced by the dissipation of the clouds. The change in friction is especially great between sea and land. In passing from the sea to the land, there is a strong retardation due to the increased friction. As a result of this, more air flows from the sea than can continue over the land, thus forming a bank of air along the coast and necessitating an upward flow. This case is illustrated diagrammatically by Fig. 1. Immediately over the coast there is a turbulent layer, over which the incoming air ascends. In many respects the phenomena are the same as in the flow of air over mountains. Here also the lines of flow must bend upward with increased velocity to a certain height, owing to the narrowing of the cross-section of the path of flow. The same thermal characteristics must also appear in this ascending current, as in passing over mountains. The ascending air is cooled adiabatically about $1^{\circ}C$ ($33.8^{\circ}F$) for every 100 m (328 ft). In the horizontally flowing air current (over the sea) the temperature decrease is generally less for the same increase in altitude. Consequently, the air over the coast must be colder up to a certain height (the same as that of the deflected lines of flow) than at the same altitude above the sea. Above this altitude, however, the air has the same temperature as over the sea. In the ascending wind, therefore, there is a temperature inversion whose upper limit is likewise the upper limit of the ascending air current. In Fig. 1, these characteristic temperature relations are indicated by numbers, while Fig. 2 gives the thermodynamic curve of the air in the region of the ascending wind. The temperature inversion enables the determination of the altitude attained by the ascending wind, the same as over mountains. During the war, W. Peppler carried out kite experiments on the coast of Flanders, which afford excellent examples of the relations shown above.*

May 15, 1916, 8-9 A.M., Cloudiness 10.

Altitude		Temperature		Direction	Velocity		
m	ft	°C	°F		m/s	ft/sec	
0	0	11.2	52.16	S.W.	11	36.1	
200	656	9.7	49.46	S.W.	22-25	72-82	Region of temperature inversion and wind increase.
500	1640	9.8	49.64	W.	26-29	85-95	
1000	3281	8.4	47.12	W.	22	72.17	

The above example shows a slight temperature increase between 200 and 500 meters (656 and 1640 feet) altitude. Hence the upper limit of the ascending wind is to be sought at 500 meters. The wind increase due to the narrowing of the path of flow is very pronounced. The wind velocity increases between the ground and 500 m, from 11 to 28 m/s (36.1 to 91.9 ft/sec), and then decreases to 22 m/s (72.2 ft/sec). Both the temperature inversion and the wind increase indicate that, in passing from the sea to the land, the effect of friction is felt up to 500 m (1640 ft) altitude, and consequently, the ascending motion of the wind reaches this altitude. If, from the kite experiments made by Peppler on the Flanders coast,

* "Aerologische und hydrographische Beobachtung der deutschen Marinestationen während der Kriegzeit 1914-1918" (Aerological and hydrographical observations by the German naval stations during the war of 1914-1918), No.4, Hamburg, 1922. German naval observatories.

we select the ones with the wind blowing toward the land, we can determine, as in the above example, from the location of the increased wind or temperature inversion, the altitude commonly attained by the ascending wind. It is found that this average 500 meters resulting exclusively from the increased friction over the land.

Starting with the fourth hydrodynamic motion formula, the continuity equation, we can establish a ratio, which enables us to calculate the vertical component from the horizontal velocity of the air flow. The vertical velocity w_h at the altitude h is represented by the equation:

$$w_h = - \frac{p_o - p_h}{p_h} R \, T_h \frac{\partial c}{\partial s} \text{*}$$

in which p_o designates the air pressure on the ground, p_h the pressure at the altitude h, R the gas constant, T_h the absolute temperature at the altitude h and $\partial c/\partial s$ the increase in the horizontal wind velocity c per unit distance. For the present purpose, this formula may be simplified to

$$p_o - p_h = - \rho_m h,$$

in which ρ_m denotes the mean air density at the altitude h. We can also write $p_h = \rho_h R T_h$. The equation then becomes

$$w_h = \frac{\rho_m}{\rho_h} h \frac{\partial c}{\partial s}$$

If we also consider that ρ_m and ρ_h differ but little from each other and, for rough calculations, may be regarded as equal

* F. M. Exner: Dynamische Meteorologie, Leipzig and Berlin, 1917, p.71.

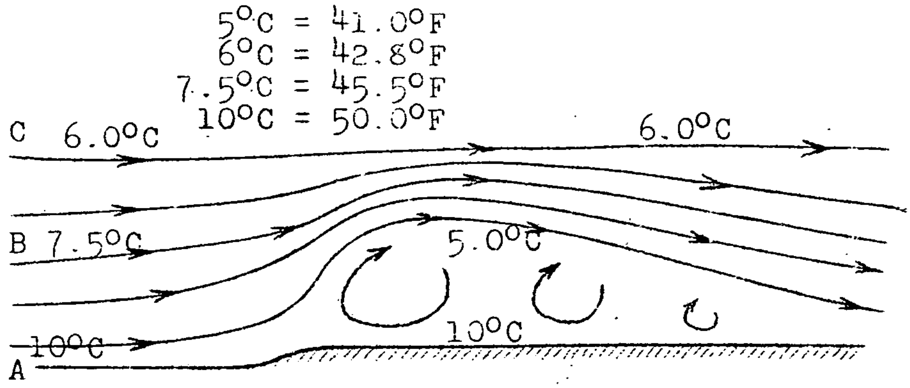
(the error is not greater than 10%), the equation assumes the simple form:

$$w_h = h \frac{\partial c}{\partial s}$$

By measuring the decrease in the horizontal wind velocity in the transition from sea to land, we can therefore readily calculate the vertical component at different altitudes. If we assume that the wind velocity is diminished 2 m/sec (6.56 ft/sec), in a distance of 1 km (3280.8 ft), (a value which is surely attained and, in the case of greater wind velocitites, often exceeded), we obtain a vertical velocity of w_h = 1 m/s (3.28 ft/sec) at 500 m (1640.4 ft) altitude. Therefore, the strength of the ascending wind on the coast is sufficient to be utilized for soaring flight. These experiments, however, require the aid of a small engine or starting kite, in order to raise the aircraft at first to the altitude where the vertical component of the wind is strong enough for soaring flight. Such experiments may be tried on any low flat coast. I am of the opinion that the Courland peninsula on the eastern shore of the Baltic Sea is especially suitable for this purpose, since strong west winds are prevalent there. It will constitute one of the finest tasks of future soaring-flight clubs in Rossitten to solve this problem of static soaring flight.

Translated by
National Advisory Committee
for Aeronautics.

Fig.1,2.



Sea — Land

$\frac{\Delta t}{\Delta z} = \begin{cases} 0.5°C \text{ at } 100m \\ 32.9°F \text{ at } 328 \text{ ft} \end{cases}$ $\frac{\Delta t'}{\Delta z'} = \begin{cases} 1.0°C \text{ at } 100m \\ 33.8°F \text{ at } 328ft \end{cases}$

Fig.1

A = H 0m , (0ft).

B = " 500m , (1640ft)

C = " 800m , (2625ft)

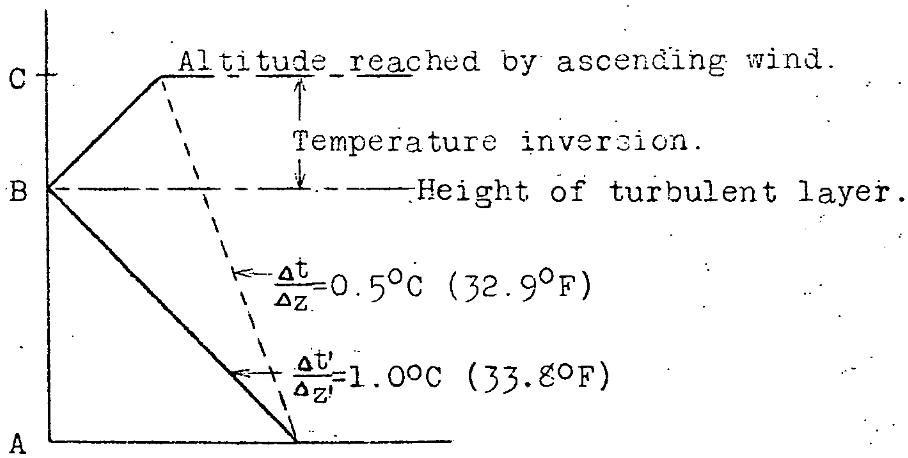


Fig.2