TECHNICAL MEMORANDUMS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 271

BALLOON FLIGHT AND ATMOSPHERIC ELECTRICITY.

From the German translation of the original Spanish by Emilio Herrera, "Luftfahrt," April 15, 1924.

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BALLOON FLIGHT AND ATMOSPHERIC ELECTRICITY.*

The air is known to be charged with electricity (chiefly positive) with reference to the earth, so that its potential increases with the altitude and the difference in potential between two points in the same vertical line, divided by the distance between them, gives a value called the "potential gradient," which may vary greatly with the altitude, the nature of the ground and the atmospheric conditions.

In fair weather the potential gradient is normally about 60-80 volts per meter, though it may increase to over 300 volts above high mountains. At about 3000 m (10,000 ft.) above the ground the potential gradient normally sinks to 10-20 volts and at 6000 m (20,000 ft.) to less than 8 volts per meter (3.28 ft.). The lines of equal tension are practically parallel to the ground in the lowest air strata (because of the good conductivity of the earth), but gradually approach the horizontal position as the altitude increases (Fig. 1).

The condensation of water vapor into clouds greatly increases the electric charge on the surface of each particle of water, thereby creating, by induction, corresponding charges of opposite sign on the neighboring portions of the earth's surface. Hereby

* From the German translation of the original Spanish by Emilio Herrera, "Luftfahrt," April 15, 1924, pp. 59-61.

the potential gradient of the air, which acts as a dielectric between the cloud and the ground, is increased greatly in excess of the normal. This can amount to 11,000 or more volts, as shown in Fig. 2. Since, in connection with these disturbances, the conductivity of the earth is not perfectly uniform, the tension of its surface will not be uniform.

A good conductor without points could exhibit no difference in tension in air charged with such a potential, since any difference would be immediately eliminated by currents through the conductor. A good conductor thus influences the potential lines only in so far as they conform to the body of the conductor and thereby raise the potential gradient of the surrounding air (Fig. 3,a). If the conductor has a point, it constantly discharges into the air, thereby lowering the potential gradient of the latter (Fig. 3,b).

In accordance with these principles, we can consider the effects of atmospheric electricity on aircraft. These effects will differ greatly, according to whether the aircraft have good or poor conductors and points.

Heavier-than-air aircraft (airplanes) commonly consist of metal, wood and cloth. Metal parts are good conductors, while wood and cloth are poor conductors. The latter, however, have small vertical dimensions and electric capacity, so that they have but little effect on the potential lines they intersect. Hence an airplane in flight is exposed only to the same danger of being struck by lightning as any other point in the air, at any rate so long as it makes no sudden vertical motion and has no antenna hanging out. In order to avoid the danger of being struck by lightning, the antenna is usually reeled in, when flying in the vicinity of storm clouds.

Until helium is produced commercially at a low cost, lighter-than-air aircraft (balloons) will continue to be inflated with hydrogen, a gas known to be a good conductor of electricity (though helium is a still better conductor). The envelope containing the gas may likewise be a good conductor, or it may be made of insulating material.

Let us consider the case of a balloon with an envelope of conducting material, e.g., goldbeater's skin, inflated with hydrogen. This balloon will be uniformly charged with a certain potential, which (if no vertical motion sets in) is the same as the mean potential of the air strata in which it is floating (Fig. 4,a). In ascending, however, (Fig. 4,b) or in descending (Fig. 4,c), the strata of like tension will be distorted as shown in the figure, i.e., the potential gradient of the air over or under the good-conducting balloon, or the difference in tension of the electric charge of the balloon and of the surrounding air, will be increased.

If the envelope of the balloon is made of insulating material, its inner surface will everywhere have the same tension, since it is in contact with the good-conducting gas. Its outer surface, however, will have the tension of the air, whose potential lines will not be distorted in this event and there will be a great difference in tension between the gas and the outer surface of the envelope (in proportion to the rapidity of the vertical motion) and this difference may cause a sudden discharge, in the form of a spark, the instant the outlet or inlet valve is opened, or even through the envelope material, if the electric tension is great enough. A spark through the air may even be produced, if the gas is escaping from the balloon (through either the appendix or safety valve) during very swift ascent.

In these cases (Figs. 5-6) the gas forms a column which attracts and conducts the lightning, since the latter chooses the path of greatest potential gradient and least resistance or, in other words, the path of least impedance. Unfortunately, this conductive gas-column consists of a very explosive mixture of hydrogen and air which, because of its poor conductivity, is heated by the electric discharge to the ignition point. The flame, thus produced, may be transferred to the balloon. A similar effect may be produced by pulling the rip-cord at the instant of touching the ground in landing.

This was the cause, in 1904, of an accident to an Italian military balloon which, after a swift ascent during a tempest, was struck by lightning at the moment when gas was escaping through the appendix. The two aviators lost their lives. The destruction of a Spanish military captive balloon at Zaragossa in 1908 was caused in a similar manner. The mooring cable broke in a strong wind and the balloon was struck by lightning, as it shot suddenly upward.

Airships are also exposed to similar accidents, rendering it necessary to heed certain conditions in their construction, in order to prevent them or at least mitigate their results. Hence, in building Zeppelin airships, rubberized fabrics and other insulating materials are avoided and goldbeater's skins employed instead. The latter, together with the metal frame and the contained gas, forms a single, good-conducting mass, which can never become highly charged, because the pointed bow and stern and the radio antenna, connected with the metal frame, serve to reduce the tension. Due to these precautions, Zeppelin airships during the war escaped without injury on many occasions when struck by lightning, as evidenced by fused spots at the extreme ends of the metal frame and on the lead antenna-weight, i.e., at the entrance and exit points of the electric current. The same phenomenon occurs in lightning rods on houses, where only the tip is fused without harming the rest of the rod, although the current strength sometimes attains 20,000 amperes.

Precautions should therefore be adopted on airships: First, to lessen the liability of being struck by lightning; secondly, to prevent damage when an airship is struck.

Since the gases used in balloons are good conductors, it is advisable to avoid the use of non-conducting materials. If such materials have to be used, however, it is important to employ them in such manner that they will offer no resistance to the passage of the electric current nor act as a dielectric to produce the effect of a condenser. All good conductors must therefore be connected with one another by good conductors. In order to prevent the airship from becoming too highly charged with electricity, it is desirable for all conducting masses to have projecting points in considerable number throughout the entire length of the airship, except in the vicinity of valves or where gas can escape.

During flight, especially in stormy weather, the mixing of the balloon gas and air must be avoided as much as possible by keeping the appendix either tightly closed, or wide open so that the gas can escape easily.

The regulations for free balloons prescribe that they must land at the first sign of a thunder-storm.

Airships, obliged to continue their journey, should fly around the storm cloud (which is usually of small extent) and indeed, in the northern hemisphere, on the right side, thus obtaining a fair wind in most instances.

When a free balloon is obliged to remain in the air under such conditions, it should try to ascend as high as possible, in order to reach an air stratum in which the direction of the wind forms an obtuse angle with the direction followed by the storm, and thus get away from the center of the low-pressure area.

When one finds himself in the midst of a storm, he must try to avoid all vertical motion of the balloon and all escape of gas. He must not, therefore, attempt to land, since the difference in tension between the balloon and the earth might, with the escape of the gas, cause a sudden electric discharge.

If, in spite of every precaution, such a discharge should occur and the balloon be set on fire, then the only thing to do is to open the rip-panel completely, as Captain Gomez Guillamon did in the Brussels contest and thus escaped otherwise certain death. Hereby one must make sure that the appendix ropes are freed from the basket, so as not to prevent the envelope from forming a parachute.

If there is sufficient ballast at hand and the ground is favorable, a balloon can descend in this manner from any altitude without serious danger to its occupants, as happened with two balloons, one American and one Spanish, in the Berlin 1908 Gordon-Bennett contest.

When captive balloons are obliged to remain in the air during a tempest, the mooring cable must be well grounded, so that it may act as a lightning-rod in equalizing the tension between the earth and the air. On airships the antenna should be conductively connected with the hull and not entirely drawn in, so that any electric discharge will take place at some distance from the hull.

Lastly, after landing with a balloon made of insulating material, care must be taken not to establish connection with the earth by touching the valve before the balloon is entirely empty of gas, since the electric tension of the gas might cause a spark to pass between the metal portion of the valve and the person touching it, thus igniting the gas. By these precautions we consider it possible to avoid accidents from the atmospheric electricity, but it should nevertheless be strictly forbidden to announce balloon contests with the assurance that they will take place without regard to weather conditions, as was done in the last Gordon-Bennett contest at Brussels and as had previously been done in other balloon contests in Belgium and France.

Such an absurd announcement may have serious consequences, like those we now bewail, and is entirely unjustifiable, since both the management and the public know that conditions may occur, under which the inflation of balloons in open field and their ascent should not be allowed.

Translation by Dwight M. Miner,
National Advisory Committee
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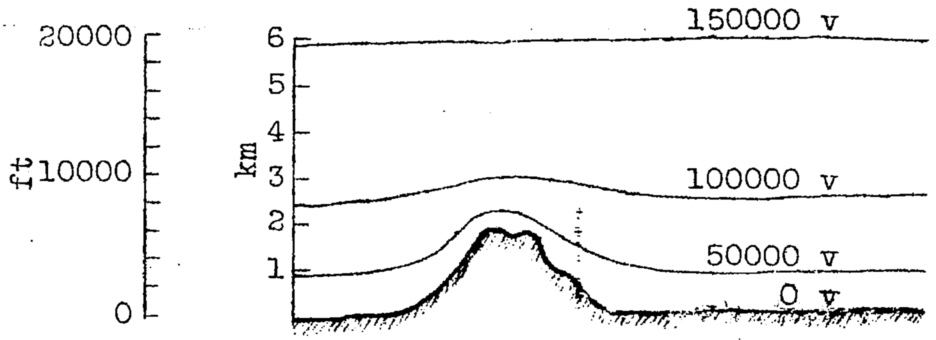

Fig. 1 Course of potential lines over land in fair weather

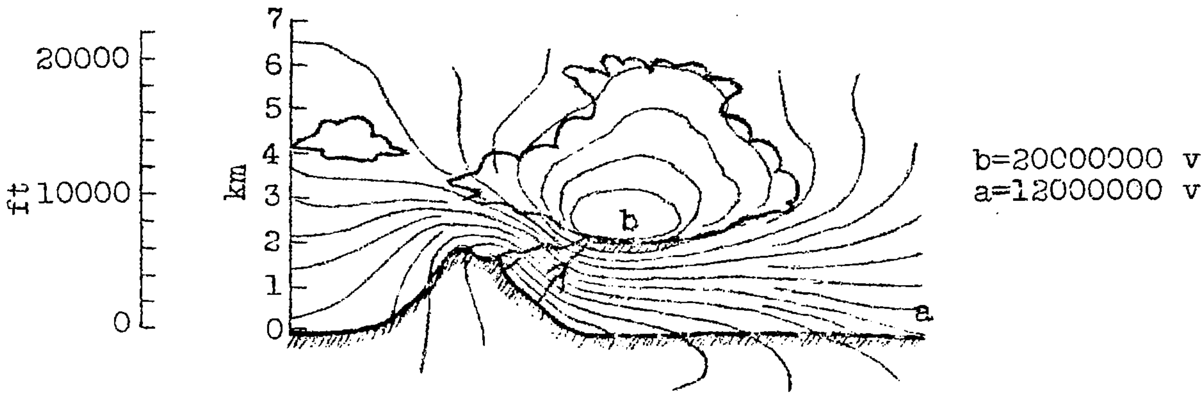

Fig. 2 Potential lines in cloud formation (tempest)

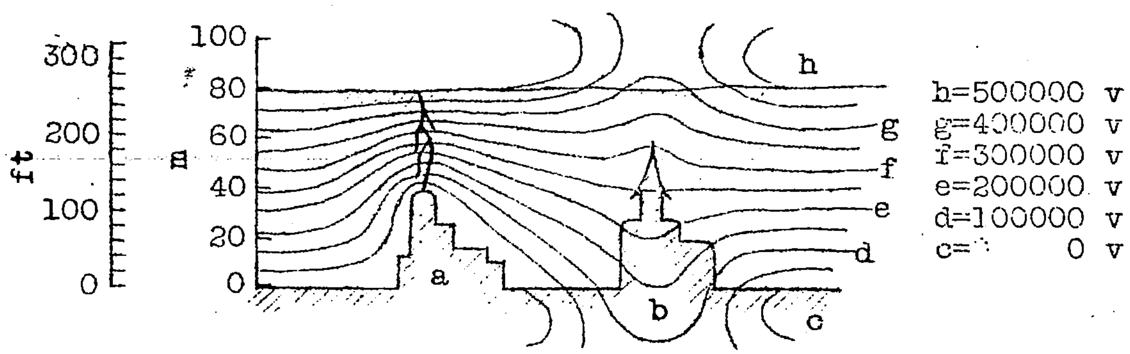

Fig. 3 Effect of points on the potential lines

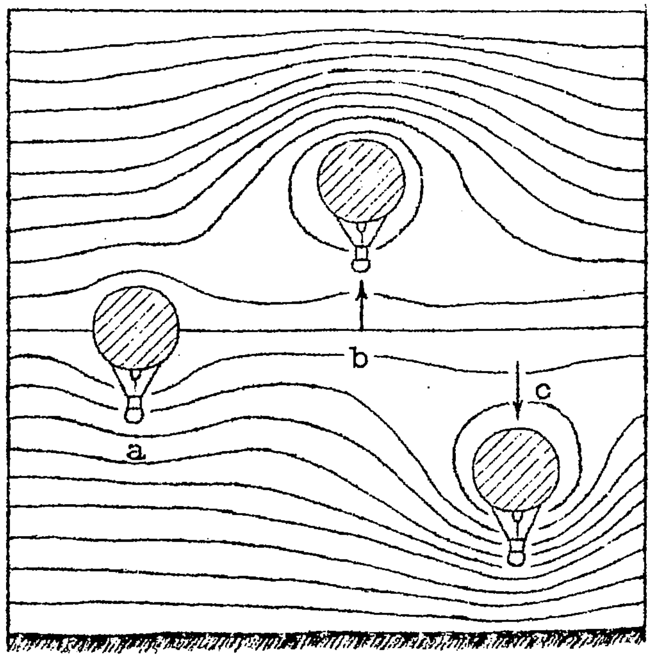

Fig. 4 Effect of vertical motions of balloons on the potential lines.

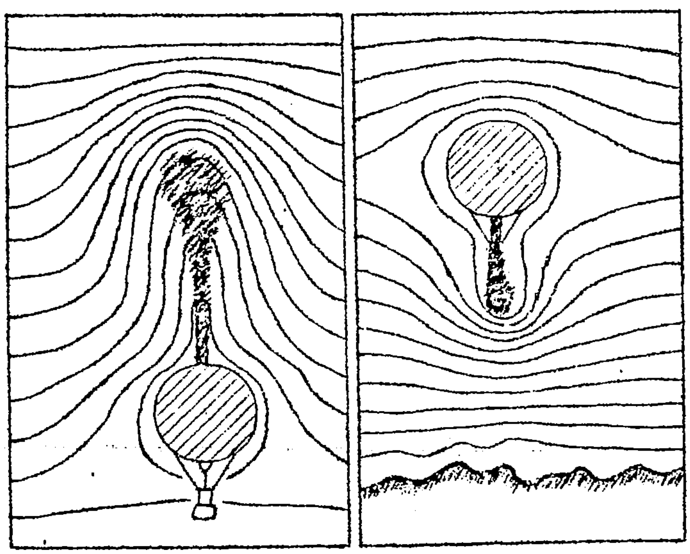

Fig. 5 Fig. 6

Endangering of balloon (rubber or silk) by opening valve or by assending.