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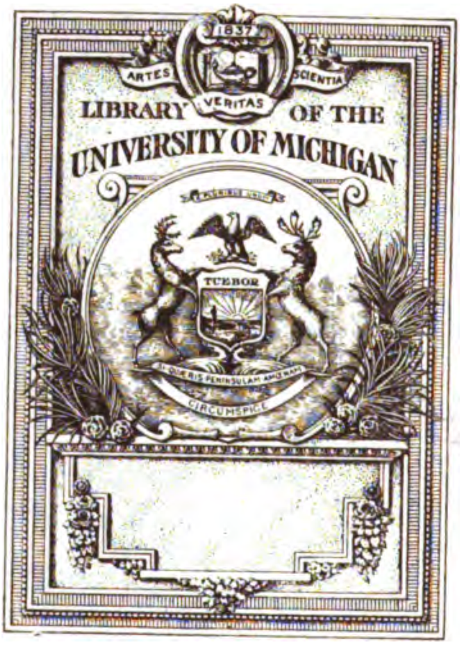

THE CONQUEST OF THE AIR

NAVIGATING THE AIR
A SCIENTIFIC STATEMENT OF
THE PROGRESS OF AERO-
NAUTICAL SCIENCE
UP TO THE
PRESENT
TIME

In One Volume, Crown 8vo. Illustrated
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PLATE I

[illegible] Commandant P. Renard

[illegible] OVER PARIS [illegible] 1885

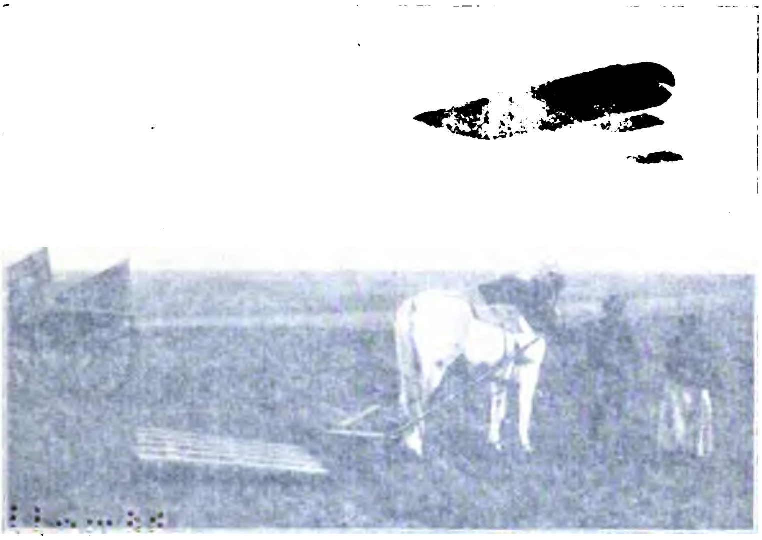

Photo. Rol

[illegible] PLANE FROM TOURY TO ARTENAY AND BACK

[illegible] (OCT. [illegible], 1908)

THE CONQUEST OF THE AIR

AERONAUTICS
AVIATION

HISTORY : THEORY : PRACTICE

BY

ALPHONSE BERGET
DOCTEUR ÈS SCIENCES. PROFESSEUR A L'INSTITUT OCÉANOGRAPHIQUE
PAST PRESIDENT LA SOCIÉTÉ FRANÇAISE DE NAVIGATION
AÉRIENNE

WITH EXPLANATORY DIAGRAMS
AND PHOTOGRAPHS

LONDON : WILLIAM HEINEMANN
NEW YORK : G. P. PUTNAM'S SONS
1909

DEDICATED TO

PROFESSOR SILVANUS P. THOMPSON, D.Sc., F.R.S.

PRINCIPAL OF THE CITY AND GUILDS TECHNICAL
COLLEGE; PAST PRESIDENT OF THE
INSTITUTION OF ELECTRICAL
ENGINEERS

At this moment no one can foresee the influence of Aviation upon the habits of mankind

PREFACE TO ENGLISH EDITION

The year 1908 was one of experiments in aerial navigation; 1909 is the year of the most brilliant achievements.

In 1908 the magnificent experiments of the Wright Brothers excited the admiration of all to a supreme degree; and in the month of October of the same year two audacious aviators, Farman and Blériot, leaving their experimenting grounds, boldly set out into the realm of practice. On October 30 Farman accomplished the first "aerial voyage," by travelling from Châlons to Rheims, passing over villages, forests, and hills; and the next day Blériot achieved the first "cross-country" journey in a closed circle between Toury and Artenay, making two descents *en route*, and restarting *under his own effort*, without any launching apparatus, finally returning to his starting-point.

The "Conquest of the Air," commenced in 1885 by the first dirigible, *La France*, built by Colonel Renard, is to-day asserted in the new development—aviation.

But now, in 1909, our human birds have excelled. By a remarkable flight, Blériot, more fortunate than his rival, Latham, who came to grief off his destination, succeeded in crossing the Channel on July 25, thus realising through the atmosphere that *entente cordiale* made between two nations; and in the month of August, on the plain of Bethany, near Rheims, in the first "aviation meeting" that has been held, all previous records were beaten. Paulhan, upon a biplane built by Voisin, covered 131 kilometres; Latham, on an *Antoinette* monoplane, traversed 154·500 kilometres without a stop; and Henri Farman, in a triumphant continuous flight, ultimately completed 180 kilometres in 3 hours 4 minutes 56 seconds. In addition to these marvellous exploits, Hubert Latham, striving to secure the victory for height, rose to 156 metres; and Curtis, the American, won the speed trophy by travelling 30 kilometres in 21 minutes 15 seconds—that is to say, flew at 75 kilometres per hour.

If one also recalls the fact that it was in the course of this same year, 1909, that the two most remarkable voyages were accomplished by dirigible balloons, which have definitely asserted the possibility of their practical application, one will understand that the highway of the atmosphere is now open, and that the "Conquest of the Air" has become an accomplished fact.

The moment is therefore opportune to explain how this conquest has been effected, to describe the principles of the construction and control of aerial vessels, dirigible balloons, or aviation apparatus; that is my reason for writing this book.

I have written it as lucidly as possible, so that it can be read by all. It has no pretensions to being an "aeronautical encyclopædia," but rather an "introduction to the study of aeronautics," that those who read and understand it may be able to follow accordingly and with advantage the whole progress of the new science

PLATE IA

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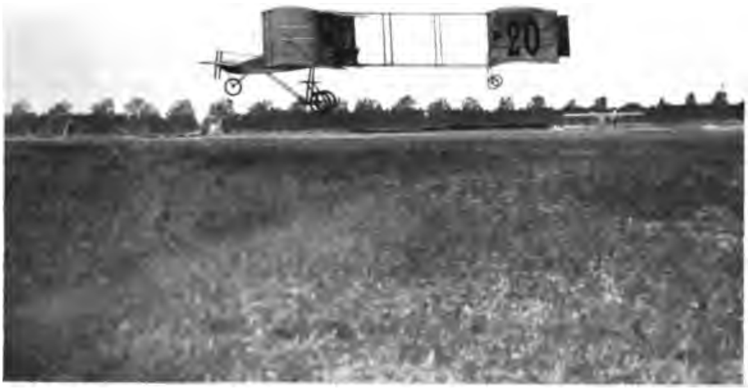
MR. FARMAN AND HIS BIPLANE ON WHICH HE FLEW 180 KILOMETRES (112½ MILES) IN 3 HOURS



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M. PAULHAN FINISHING HIS MORNING FLIGHT OF 50 KILOMETRES (31¼ MILES) IN 56 MINUTES ON HIS VOISIN BIPLANE

as it develops and is set forth in the Press and the technical treatises.

Thus I hope to have contributed to the diffusion of an interest in the science of the air in the same manner as I hope to have rendered a worthy appreciative tribute to the names of those who were, and are, the victors.

ALPHONSE BERGET
PROFESSOR DE L'INSTITUT OCÉANOGRAPHIQUE
DE PARIS
PAST PRESIDENT OF THE SOCIÉTÉ FRANÇAISE
DE NAVIGATION AÉRIENNE

PARIS, *August* 31, 1909

PREFACE

Within the last twelve months the definitive conquest of the air has been accomplished; dirigible balloons have cruised about in the atmosphere for several consecutive hours and have returned without difficulty to their starting-points; audacious aviators have ceased to manœuvre over their trial grounds, and, contemptuously abandoning pylons and launching rails, have embarked on the first aerial voyages taken in machines "heavier than the air"; Farman and Blériot have flown from town to town, passing over the open country, cities and forests, stopping, descending, and starting again at will.

This is, it seems to me, an opportune moment to describe the bases of aerial navigation in its two actual forms: the dirigible balloon and the aeroplane. I have set aside all that concerns aerostation by free balloons; that is already ancient history, it belongs to the past, and I confine myself to the present with the hope of forecasting the future.

This book is not a treatise on aeronautics; my readers must not expect to find in it an encyclopædia of aerial navigation; but, on the other hand, I have tried to make it as clear as possible. I hope that, by suppressing useless details, I have furnished a kind of

Introduction to the Study of Aeronautics, which will enable those who have read it to attack more elaborate works with profit. But though it is elementary, I have sought to make it complete, and to give my readers an accurate idea of the present state of aerial locomotion. I have left historical details to the end, for these, interesting as they are to the initiated, are merely cumbersome to the learner.

If, as I hope, this little book helps to elucidate the ideas every one must form in these days on a question which is exciting the keenest interest throughout the world, it will enable my readers to appreciate all the new essays in this field as they are made, to judge their merits and discern their weak points; it may even incline them in their turn to do something for the progress of the glorious and pre-eminently French science of aeronautics, which, created by Montgolfier, was finally emancipated by Colonel Ch. Renard.

ALPHONSE BERGET

PARIS, *June* 15, 1909

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INTRODUCTION

Aeronautics is the art of sustaining and directing oneself in the atmosphere, without coming into contact with the earth or the water on its surface.

This problem, the solution of which has been sought throughout the ages by man, ambitious to imitate the birds, only began to be resolved, and then partially, in 1783, when the Brothers Montgolfier succeeded for the first time in raising and sustaining in the air a heavy body capable of transporting passengers. This discovery, the principle of which differs from that of the flight of birds, was of the utmost importance; it had the merit, not only of showing that the atmosphere is not a realm sternly forbidden to man, but also, by giving him the means of sustaining himself in it, allowing him to hope that he might some day be able to steer his course in it.

But Montgolfier's invention did not constitute aerial navigation: the "aerostat," so admirably named from its birth, was passive in the midst of the atmosphere; it was to the airship of man's dreams what the buoy is to the ship, that is, a floating object, the toy of the fluid in which it floats. Three-quarters of a century passed in vain attempts to direct aerostats until the day when the Frenchman Giffard first showed by a conclusive experiment the possibility of steering balloons, a possibility which was triumphantly realised by Colonel Renard twenty-five years ago, in 1884.

It is now therefore possible to direct a balloon floating in the air by virtue of the principle formulated by Archimedes, because its weight is less than that of the air it displaces. This first solution of aerial navigation has the merit of complete novelty; Nature has nothing comparable to show us; it differs as much from the flight of birds as the action of a railway-train from that of the most agile of our quadrupeds.

But the example of birds was always present, inciting the human brain to seek a further solution; the problem was to rise into the air mechanically, without the cumbersome intermediary of a volume of light gas enclosed in an impermeable envelope; in a word, to navigate the air after the manner of birds with an apparatus *heavier than air.*

The first essays were made a long time ago, but it was not until 1895 that the solution already presaged began to be tangible. Now at last aerial navigation without an aerostat, mechanical sustentation, *aviation*, in short, is an accomplished fact; its practical application is merely a question of minor improvements.

There are then two quite distinct forms of aerial navigation, that of the *dirigible balloon*, and that of *aviation.* We have therefore a natural division for this book, in the first part of which we shall deal with dirigible balloons.

PART I

DIRIGIBLE BALLOONS

CHAPTER I

PRINCIPLES

How the aerial vessel floats and moves: Why dirigibility must depend on a motor and a propeller: A comparison between marine and aerial navigation

THE PRINCIPLE OF ARCHIMEDES

A DIRIGIBLE balloon is an apparatus which is supported in the air by making use of the *pressure* exercised by this on all bodies plunged into it; thanks to a *propeller* revolved by a *motor*, it can and must move in this element at the will of the aeronaut.

I may state the fundamental principle of aerostation in a very few words.

Archimedes discovered it, and formulated it as follows:

Every body plunged into a fluid is subjected by this fluid to a "pressure" from below to above, which is equal to the weight of the fluid displaced by the body.

It is in virtue of this principle that ships float on the water and fish swim in it. When a body, the exterior volume of which is a cubic metre, is plunged into water, this body also displaces a cubic metre of water, or, in other words, 1000 litres. Now 1000 litres of water weigh 1000 kilogrammes. Three possibilities may then arise: the weight of the body immersed may be less than 1000 kilogrammes, and it will then rise and float on the surface; or it may be exactly 1000 kilogrammes, in which case it will remain in equilibrium in the water at a certain level; or, finally, it may weigh more than 1000 kilogrammes, and then it will sink to the bottom.

These three factors are realised by fish, which are able at will to rise to the surface, to suspend themselves in the water, and to go down to the bottom; to carry out these operations they vary their specific gravity by the help of their natatory gland, a bag containing air which they can dilate or compress as they please; we shall find later, in dealing with dirigible balloons, a similar organ in the "air-ballonnet."

HOW DOES A DIRIGIBLE BALLOON RISE? THE ASCENDING EFFORT

The principle being laid down, we may make use of it to raise an object into the atmosphere; we have only to produce a body, the total weight of which shall be less than that of the volume of air it displaces.

Now the weight of the air is known: a cubic metre of it weighs 1·298 kilogrammes, that is to say, about 1300 grammes, when the temperature is at zero and the barometer indicates 760 millimetres. On the other hand, there are "light" gases, such as the gas used for illuminating purposes and hydrogen. A cubic metre of lighting gas, at zero, weighs about 500 grammes, and a cubic metre of hydrogen, under the same conditions, weighs only 110 grammes.

Let us take this latter, the most suitable for the object we have in view. Let us make a huge receptacle of some supple and impermeable material—a "balloon"—and let us fill this "envelope" with hydrogen gas. Let us suppose that the interior volume of this receptacle is 1000 cubic metres; when filled with hydrogen it will weigh 110 kilogrammes; but the 1000 cubic metres of air that it displaces will weigh 1293 kilogrammes.

The difference, *i.e.*, 1183 kilogrammes, will be the vertical *pressure* from below to above on the receptacle by virtue of Archimedes' principle. The envelope thus inflated with hydrogen would therefore be capable of lifting 1183 kilogrammes, that is to say, 1 kilogramme 183 grammes per cubic metre. A balloon thus constructed is called an *aerostat.* The point where the pressure which supports it is exerted is called the *centre of pressure,* and its position coincides more or less with that of the centre of gravity of the inflated envelope.

If, then, the weight of the envelope itself, plus the weight of a support affixed to it to carry the motor and propeller, and the weight of the travellers, does not exceed 1180 kilogrammes, the apparatus will rise; the difference will be its *ascensional effort.* If the total weight of the envelope and of the system it supports exceeds 1180 kilogrammes, the apparatus will remain fixed to the ground.

If, instead of inflating our envelope with hydrogen, we had used lighting gas, it would only have been able to raise 690 kilogrammes instead of 1180; obviously therefore, there is an advantage in using hydrogen.

The very existence of the ascensional effort produced by the pressure of the ambient air provides the aeronaut with the simple means of making his balloon rise or sink at will. If he wishes to rise, he has only to throw out of his car a portion of the weight it contains; *ballast,* in the form of bags of sand, is always carried for this purpose. If, on the other hand, he wishes to descend, he has only to diminish the ascensional effort of the aerostat; this is done by allowing a certain quantity of the light gas it contains to escape by means of a *valve*, which can be opened and closed at will; the difference between the weight of the air and the weight of the gas is diminished; that is to say, the pressure becomes less and the balloon descends.

THE BALLOON ENVELOPE, RIGGING, AND CAR

The essential device for sustaining the balloon in the air is therefore the *envelope*, which we shall inflate with a light gas; it must further fulfil the conditions of *lightness*, *strength*, and *impermeability*.

It must be *light*, because its weight forms part of the total weight the balloon can lift, and must be deducted from the load which the apparatus will be able to carry. It must be *strong*, for it will have to bear the interior strain of the gas that fills it, and also the stresses exercised on its various parts by the weight of the objects and passengers on the one hand, and by the motor on the other. It must be *impermeable*, that is to say, must not allow the gas it contains to escape through its pores, for it is this gas which by its lightness enables the balloon to rise into the air, and if any portion of it were to escape, the ascensional effort would be at once diminished.

The material now almost exclusively used for the construction of dirigible balloons is a composite fabric, consisting of two layers of cotton, between which is inserted a thin layer of india-rubber, the tenth of a millimetre in thickness. This material is unvarnished; it weighs 300 grammes per square metre, can withstand a strain of 1250 grammes per metre, and has an equal power of resistance in the direction of warp and woof. The manufacture of this material is carried on in France and Germany; it has become a regular off-shoot of the rubber industry.

Light as our envelope is, it has nevertheless an appreciable weight, to which we must add that of the "rigging"—*i.e.*, the suspension ropes by which the aerostat supports the *car*, that light, yet solid, receptacle which contains the motor and the passengers, and carries the *propeller*, that is to say, the mechanism which utilises the resistance of the air to drive the dirigible balloon forward.

We may note in passing that an aerostat furnished with a motor is often called an airship.

IT IS ONLY POSSIBLE TO DIRECT A BALLOON BY THE HELP OF A MOTOR

Why was it so long before it was possible to steer a balloon, when, so far back as 1783, man, applying the principle formulated by Archimedes, had been able to lift himself into the air? It was not, indeed, until 1884 that the first *circular* flight in a closed circle was accomplished by Colonel Renard with a balloon which after all deserved the title of *dirigible*. Why was this?

Because, before it is possible to "steer" a body floating in a fluid, it is absolutely essential that this body should possess an *independent speed* to permit it to move in this fluid of its own accord. I may illustrate this by a very simple and familiar comparison.

Let us take a boat which has a rudder at the stern and is propelled by a pair of oars. A rower, manipulating these, gives a certain speed to the boat; we shall see that so long as this speed is appreciable, the rudder acts efficiently, and that the steersman has only to move it to the right or to the left at will to procure the evolution of the vessel. But let the rower rest on his oars, the boat, deprived of speed, will float "like a buoy," and it will be useless for the helmsman to work the rudder, as the latter will have no effect upon the boat, which will be the sport of the water on which it floats; in order to steer it, we must propel it.

In the same way we must "propel" an aerostat if we want to "steer" it. But to propel it we must have a motor, and every motor is necessarily heavy. Let us now inquire into the respective weights of the motors it would be possible to use.

In the first place, there is the "human motor," that is to say, the muscular energy of the passengers in the car. It is hardly necessary to say that this was the first motor to be taken into account in the earliest days of aerostation, for at that period it was the only one known. But though such a dream was possible then, it is so no longer, for the more precise data concerning mechanical experiments have established the weight-conditions of each category of motors.

The practical unit of energy is steam horse-power, that is to say, a force capable of raising 75 kilogrammes one metre from the ground in one second. This power is very much greater than that of the animal horse. A man represents but a fraction of it. Now mechanicians have established by experiment, independently of all theory, that the weight of the steam horse-power translated into human muscular power, is about 1000 kilogrammes; in other words, it takes 1000 kilogrammes of men to produce an effort equal to that of the steam horse! It was therefore obviously futile to attempt to steer balloons by utilising the muscular power of the few aeronauts who controlled them.

In the early days of steam power, motors were of considerable weight. The engine of the *Sphinx*, the first steamship in the French Navy, weighed more than 1000 kilogrammes per horse-power, and even thirty years ago steam motors weighed some 100 kilogrammes per horse-power. Hence the first steam engines were no more suitable for the propulsion of aerostats than human effort, to say nothing of the danger of installing a boiler heated by coal beneath an envelope inflated with hydrogen, an eminently inflammable gas.

Nevertheless, steam was the power used in the first motor employed in a balloon. Its application was essayed in 1852 by the engineer, Henry Giffard. Instead of using the steam motors already in existence, he had one of 3 horse-power, expressly built for his experiment; he succeeded in reducing the weight per horse-power to 53 kilogrammes; this was a remarkable achievement at the time and an enterprise of extraordinary audacity, taking its dangers into account. But the steam engine was very soon abandoned, owing to the risk of fire, and aeronauts adopted the electric motor, which, from 1880, was the recognised motor of the future. Colonel Renard succeeded in obtaining an electric motor of 8 horse-power, weighing only 40 kilogrammes per horse-power, and capable of prolonged action; this made *real* aerial navigation a possibility, and he had the glory of first accomplishing it in 1886.

But about 1890 a new engine made its appearance; rude and clumsy at first, it was very soon improved and perfected; thanks to this invention, a new industry was born—the automobile—which has revolutionised all our habits. The engine was the "explosion motor."

The explosion motor is the lightest of any of equal power. To-day mechanicians have succeeded in reducing motors especially designed for aviation to the almost incredible weight of 2 kilogrammes per horse-power. Moreover, its action has been perfected; it can start in an instant without any preparation. The volume has been reduced proportionately to the weight, so the engine is not cumbersome. It is due to this invention that aeronautics have become what we see, and that aviation has been made possible in its turn. The explosion motor is the *only* one now used for aerial navigation.

WEIGHT PER HORSE-POWER, AND PER HORSE-POWER HOUR

If we consider a machine able to give 100 horse-power for a weight of 1000 kilogrammes, we shall say that the "weight per horse-power" is 10 kilogrammes. But such data is insufficient for the aeronaut in working out his plans of construction.

For we have not only to raise our machine, but to use it, to make it go, and for this we require a combustible, which in our particular case is petrol. Then we must have water to cool the motor, oil to grease its mechanism, and the accessories necessary for the working of the engine. In a word, if our 100 horse-power engine consumes 1 kilogramme of various materials per horse-power, it will use 100 kilogrammes of provisions

PLATE II

Photo, Branger

THE DIRIGIBLE BALLOON "RÉPUBLIQUE"

per hour. If we want to make it go for ten hours, it will require 1000 kilogrammes of provisions, the weight of which must be added to that of the machine itself.

Thus, in the example we have taken, we shall have 1000 kilogrammes, the net weight of the engine, and 1000 kilogrammes of provisions, to enable it to run for ten hours, making a total of 2000 kilogrammes. But for these 2000 kilogrammes we shall get 100 horse-power for ten hours—that is, 1000 horse-power hours. The weight per horse-power hour is, therefore, to be obtained by dividing 2000 by 1000; that is to say, it will be 2 kilogrammes.

It is essential that we should not confound these two terms; the weight per horse-power hour depends on a proper use of the combustible by the engine, whereas the weight per horse-power only depends solely on the construction of the engine. As Colonel Renard has already pointed out, it is possible to have the same number of kilogrammes for the weight per horse-power hour with a light engine that consumes a great deal, as with a heavy engine that consumes very little; but with too heavy an engine the balloon would not perhaps rise at all; and the first duty of a balloon, even of a dirigible, is to rise into the air: *primum vivere, deinde philosophari*, said the philosophers.

To conclude what we have been saying, we may lay down this principle: the motor should, above all things, be as light as possible; that is to say, the point of primary importance is to keep down the weight per horse-power. As to the diminution of the horse-power hour, this would merely enable us to prolong the duration of the voyage, or, to use a phrase proper to naval warfare, to extend the "radius of action" of the airship.

MARINE AND AERIAL NAVIGATION

THE DIRIGIBLE, THE STEAMSHIP, AND THE SUBMARINE

The airship has often been compared to the steamship, the aerial ocean to the marine ocean; is this a legitimate comparison? We will briefly examine this question.

We must first note the essential and absolute difference between an airship and a vessel. The latter floats upon an element of great density, the water, in which its propellers find an appreciable fulcrum, by virtue of its great resistance; only a part of its hull is immersed, and it is upon this part only that the resistance which the surrounding liquid offers to the advance of the vessel is exercised. The balloon, on the other hand, is completely immersed in the liquid which sustains it by its vertical thrust, and this, due to the weight of a gas the thermal expansion of which is very great, varies every instant in accordance with the slightest vicissitudes of temperature or of barometric pressure, whereas the "hydrostatic pressure" which causes the ship to float upon the water does not vary appreciably when the temperature changes.

But no floating vehicle, be it balloon or vessel, is ever required to float in a perfectly immobile element; the sea is agitated by marine currents, such as the Gulf Stream, which circulates across the Atlantic, or the tidal currents at certain places on our coasts; on the other hand, the atmosphere is in perpetual motion under the action of the "winds," which are aerial currents. There is, however, an essential difference between these two kinds of currents. Whereas the most rapid of the marine currents, such as the Raz de Sein and the Raz Blanchard do not exceed a speed of 9 knots (16·500 km. per hour), the aerial currents have often very considerable speeds. Directly the wind "freshens," as sailors say, its speed is very soon increased from 10 to 15 metres a second, that is, from 36 to 56 kilometres an hour. A ship, to which its engines give a speed which is very considerable in the most modern types (20, 25, and even 30 knots, or 37, 46, and 55 kilometres an hour), will very soon overcome the ocean currents, the speed of which need only be deducted from that of the ship; whereas the dirigible balloons are obliged to struggle against currents of air the violence of which condemn it to immobility—or to retreat.

In short, the ship and the dirigible balloon are not comparable. The only exact parallel of this kind which we could draw is that of the airship and the submarine, which is also completely immersed in the fluid which supports it. But the advantage is still on the side of the submarine, which never has to overcome the rapid currents with which its aerial counterpart has to contend. A juster comparison might be made between a dirigible balloon and a submarine which had to advance, not against a current, but against a torrent.

We see how difficult a problem the propulsion and steering of aerostats is, and we can readily understand why it has taken a century to discover how to guide the machine which the brothers Montgolfier launched in the air for the first time in 1783.

CHAPTER II

THE RESISTANCE OF THE AIR

THE OBSTACLES WHICH THE "SURROUNDING AIR" OPPOSES TO THE PROGRESS OF THE AEROSTAT: THE MOST ADVANTAGEOUS CONDITIONS OF SHAPE AND DIMENSIONS FOR THE ENVELOPE: INDEFORMABILITY: THE EQUILIBRIUM AND STABILITY OF AIRSHIPS

THE RESISTANCE OF THE AIR

WE are therefore going to take an aerostat, and provide it with a motor to give it an "independent speed" which will ensure its propulsion, and consequently, its direction.

But when we thus propel our aerostat, it will experience a resistance from the surrounding atmosphere to its forward movement. Whenever we attempt to displace a body of any kind in a material fluid—for instance, if we try to move a board which we hold in our hand in the water—we feel a resistance to the movement we are trying to produce. This resistance does not depend upon the volume or the total mass of the body displaced, for we feel that it varies according as to whether we try to hold the board flat or edgewise. We also note that the resistance is greater, if, all other conditions being equal, we try to move it faster.

Physicists on the one hand and engineers on the other, have attempted to establish the laws of this "air-resistance" both by calculation and experiment. They have arrived at the following conclusion, which is exact in the main, but merely approximate if we demand precision : " the resistance offered by the air to a surface element which is moving on a line perpendicular to its plane is proportional to the extent of this surface, to the square of the speed which animates it, and to a numerical *co-efficient,* the mean value of which is 0·125. The resistance is, thus, expressed in kilogrammes, if the surface of the moving element is measured in square metres, and if the speed is expressed in metres per second (Fig. 1).[1]

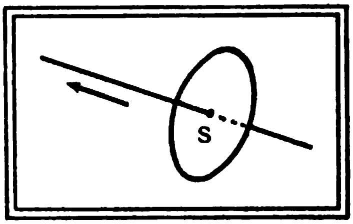

FIG. 1. Resistance of the air upon a normally moving surface

For instance, let us consider a panel, a board of 4 square metres surface, moving normally to its plane at a speed of 10 metres per second; the resistance, in kilogrammes, will be obtained by multiplying the surface, 4, by the square of the speed, that is to say by 10 × 10, or 100, and by multiplying the sum by the *co-efficient* 0·125. It will therefore be the product of 4 × 100 × 0·125, that is to say, 50 kilogrames. If the speed of movement be doubled, the resistance of the air will be quadrupled ; it would become nine times greater if the resistance were tripled—and so on.

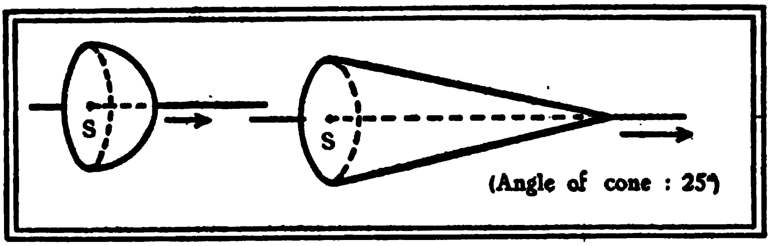

FIG. 2. Influence of front shape

When the moving body is preceded by a "prow," that

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[1] The reader who wishes to know the *formula* of the resistance of the air, is referred to the Appendix at the end of the book.

is, a surface having tapering sides, which separate the molecules of air without striking them sharply as would a flat surface confronting them, the resistance is diminished. Thus, if we take the panel of Fig. 1, but cause it to be preceded by surfaces which will divide and thrust aside the molecules of air, as would be the case if we made use of the hemisphere or the cone (Fig. 2) with a base of the same superficies as the panel, the resistance of the air to the speed of 10 metres per second, which was 50 kilogrammes for the flat panel moving orthogonally, will be but 25 kilogrammes for the hemisphere, and only 9 kilogrammes for the acute-angled cone.

Experience has shown that not only is the shape of the " bow " of the moving body important, but also that of its "stern," that is to say of the "poop," for the profile of the latter may either permit an easy reunion of the molecules of air separated by the prow, and gliding along the sides to rejoin each other, or, on the other hand, its abrupt line may cause the molecules separated by the prow to re-unite tumultuously, clashing one with another and producing eddies behind the moving body.

THE SHAPE OF DIRIGIBLE BALLOONS: SPINDLE, FISH, AND CYLINDER

The points we have just considered must be taken into account in determining the shape of dirigible balloons.

In the first place, there can be no question of attempting to propel a spherical balloon; the surface on which the resistance of the air would be exercised during the progress of the balloon would be enormous. With an equal volume of envelope, it is necessary to choose a shape that presents as small a surface as possible to the air as it advances, while preserving as great a lifting power as possible. This condition is fulfilled by giving the envelope an elongated form in the direction of travel.

But what should this elongated form be? Should it be that of a symmetrical spindle, an ovoid body, and, if so, should it advance with the larger or the smaller end foremost? or should it be a cylinder?

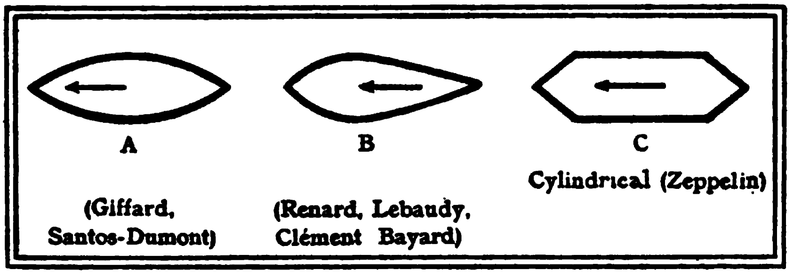


FIG. 3. Different shapes of dirigibles

The first attempts, those of Giffard in 1852, of Dupuy de Lôme in 1872, and of Tissandier in 1884, were made with "fusiform" (spindle-shaped) balloons; in other words, their shape, equally pointed at either end, was symmetrical in relation to the central plan (Fig. 3). But all this was changed when that man of genius appeared who was indisputably the real creator of aerial navigation, Colonel Charles Renard, whose premature death in 1905 was an irreparable loss to science and to France.

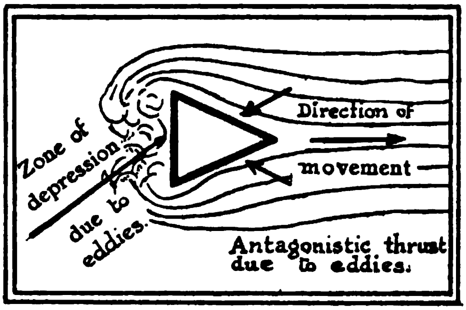


FIG. 4. Eddying action resulting from flat shape of stern

Renard demonstrated by his calculations that the most advantageous shape is that of a dissymmetrical fish (B), with the largest end at the front. So long ago as the beginning of the nineteenth century, Marey-Monge had presaged the necessity of adopting this form if an attempt should be made to propel aerostats: "They must have the head of a cod and the tail of a mackerel" was his dictum.

This, indeed, is the shape of all birds and of all swiftly moving fishes: whales, cachalots, and porpoises. At present all dirigible balloons which have proved really capable of progression are all constructed in the shape worked out by Renard.

We must now point out that if the conditions of progression and of the resistance of the air are to be normal, *the balloon must preserve its shape* during its course, either ascending or descending; we shall see later how this condition is fulfilled by the "air ballonnet."

As to the cylindrical form (C), adopted in Germany by Count Zeppelin, it seems less advantageous; the molecules of air thrust apart by the point in front exercise an exaggerated friction on the sides before they re-unite, thus retarding the progress of the airship. The other German aeronauts are therefore gradually returning to the pisciform shape.

In any case, the pointed end behind is indispensable, for without it there would be an eddy of the molecules of air, and consequently a partial vacuum which would cause antagonistic prow thrust; this pressure, exercised against the forward movement, would retard the speed of the airship (Fig. 4); it is therefore necessary at all costs to avoid it by tapering the rear end of the balloon.

RESULT OF AIR RESISTANCE: ADVANTAGE OF BALLOONS OF LARGE CAPACITY, STRENGTH AND SPEED

The resistance of the air to the movement being proportionate to the square of the speed of the moving body, will lead us to a most important conclusion. It is, that balloons of large size have an advantage over those of smaller dimensions. Let me explain.

To start with a clear idea, let us consider an airship in the shape of an oblong box with a square base, the latter being, for instance, 1 metre each side, by 5 metres long. Its volume will be 5 cubic metres, and its ascensional effort, taking this at 1 kilogramme per cubic metre, will be 5 kilogrammes. This balloon, if inflated with hydrogen, will, in round numbers, lift a motor the power of which will be limited by this weight of 5 kilogrammes; and if we suppose that a motor weighing exactly 5 kilogrammes per horse-power has been constructed, the motor this balloon can lift will be of one horse-power.

Having demonstrated this, let us construct a second airship, exactly similar to the first, and also inflated with hydrogen, but with all the dimensions doubled; that is to say, having a squared base of 2 metres, by a length of 10 metres instead of 5. The volume of this balloon will not be double that of the first, it will be 2 × 2 × 10, in other words 40 cubic metres; that is, eight times larger, while its surface of resistance to progression will be that of its base, *i.e.*, 4 square metres.

Thus, as we have doubled all the dimensions, the resistance of the air will be *four* times greater, whereas the volume, that is to say the lifting power, will be *eight* times as much. Now, with a lifting power eight times greater, it will be possible to lift a motor eight times more powerful, and even more, for the weight per horse-power diminishes in proportion as the power of the motor increases. The balloon whose dimensions have been doubled will therefore have a motor of at least 40 horse-power to meet a resistance of the air bearing upon four square metres, that is to say, 10 horse-power per one square metre of the transverse section, whereas the balloon of half this size will have only a 5 horse-power per one square metre of the section. The advantage is consequently all on the side of large balloons, and aeronauts who wish to undertake important journeys, and carry large stores of combustibles and numerous passengers, will find it profitable to construct dirigible balloons of large dimensions. The largest dirigible balloon yet constructed is the *Zeppelin*, of 12,000 cubic metres, while the smallest is the Santos Dumont, No. 1, which gauged but 180 cubic metres; it is true that its only passenger, M. Santos Dumont, weighed only 52 kilogrammes, and that the whole car weighed only 10 kilogrammes!

To sum up, we may say that the volume, on which the power of the motor that can be carried depends, varies according to the cubic dimensions of the airship, whereas its surface, on which the resistance offered by the air to its progress depends, varies only according to the square.

Finally, it is necessary to point out *that the power necessary to communicate increasing speeds to the same airship increases proportionately to the cube of the speed.* This law has been demonstrated by calculation and verified by experience. It is of vital importance, for it leads to various conclusions of the utmost moment. Thus, to double the speed of a dirigible balloon, we must give it a motor power not *twice*, but *eight* times greater (8 is the cube of 2; $8 = 2 \times 2 \times 2$). We see therefore that great care is necessary in calculating the elements of a dirigible balloon, when it is destined to undertake journeys of any length.

THE "RADIUS OF ACTION" OF AN AIRSHIP

A dirigible balloon ought not, indeed, to be a mere object of scientific curiosity, or an instrument of sport; it should have a useful application; it should be able to accomplish journeys. The longer these can be made to last, the greater will be the utility of the engine. Therefore it will be necessary, first and foremost, to ensure long-sustained flight in the ascents of this dirigible balloon.

Here the question of speed plays a very important part, as does also that of the motor power it will be necessary to apply to the airship to give it the desired speed. This power, as we have just seen, is proportional to the *cube* of the speed. And this must be taken into account if travelling velocity is not the sole desideratum, and if the *total* distance the aerial vessel can travel is also an important factor.

Let us consider a balloon of 3000 cubic metres, travelling at the rate of 60 kilometres an hour, with two engines of 60 horse-power each. These two engines would consume a total quantity of 60 kilogrammes of petrol an hour. The balloon, carrying six passengers, can take 600 kilogrammes of petrol, which will make it possible for it to travel for ten hours; if we take into consideration that it has to return to its mooring-ground, its pilot will have five hours of progress at his disposal, or, reckoning 60 kilometres to the hour, 300 kilometres. We should say under these conditions that the *radius of action of this dirigible balloon is* 300 *kilometres.*

Let us now suppose that only one of the motors is used; the propelling power then will be only 60 horsepower; the speed will be divided by the cubic root of 2, that is, in round numbers, 1·25; it will therefore be 48 kilometres an hour. But the single motor will only consume 30 kilogrammes of petrol, and there are 600 on board; the airship would therefore *have twenty hours of travel* before it, instead of ten, that is, ten to go and ten to return; it will therefore be able to travel 10 times 48 kilometres, and still have the means of returning to its starting-point. We should therefore say that *under these altered conditions, the radius of action of the dirigible is* 480 *kilometres.*

Thus, by demanding a speed of 48 kilometres only per hour instead of 60, we extend the *radius of action* of the same dirigible from 300 to 480 kilometres. We have consequently increased it very considerably.

This shows us how important this consideration of the radius of action is, especially in the application of aerial navigation to military or geographical matters. One thing should be clearly understood: *speed is costly* on an airship as on a transatlantic liner; to double it, the motor power must be multiplied by 8; the balloon must therefore carry eight times more fuel; whereas, by diminishing the motor-power by one-half, the speed is only reduced by one-fifth. When, therefore, airships attempt to perform long aerial voyages, the problem that

PLATE III

Photo, Neurdeiu, Fr.

THE SCREW-PROPELLER OF THE "VILLE DE PARIS"

Photo, Branger

THE SCREW-PROPELLER OF THE "BAYARD-CLÉMENT"

confronts them will be, how to reconcile the minimum speed which will enable them to make way effectually against the prevailing winds, with a reduction of the motor power, which, by diminishing the amount of fuel consumed, will enable the store of petrol to hold out sufficiently to reach the most distant points! The wisest solution would obviously be to furnish the dirigible balloon with two independent motors; when a "special effort" was required, the two engines could be used; but in favourable atmospheric conditions, the travellers would be content with the propulsion furnished by a single motor. Though the speed would be somewhat diminished, it would be possible to travel a good deal farther.

All we have just said of the "radius of action" of a dirigible applies of course to aeroplanes, for which this consideration is also of the greatest importance.

CONDITIONS OF EQUILIBRIUM OF DIRIGIBLES

The first condition to be fulfilled by our dirigible balloon, whether stationary or in motion, is that it should always be "in equilibrium."

When stationary, the airship should always maintain such a position that the geometrical axis of the solid body formed by its envelope is horizontal. Now when a dirigible balloon is suspended motionless in calm air, it is subjected to the action of two forces; one is its *weight*, P (Fig. 5), which is applied to the centre of gravity C of the system formed by the envelope and all it supports; the other is the *thrust* of the air, applied to a point B called the *centre of thrust.* If the envelope contained only its inflating gas, and had neither car nor cargo to carry, and even if the weight of this envelope were negligible, the centre of thrust and the centre of gravity would coincide. But the addition of the weights that the envelope has to lift into the atmosphere causes this result: these two forces are not a continuation of one another.

As they must necessarily be equal if the balloon neither ascends nor descends, it follows that they will make the balloon turn until they are a continuation of one another, and our airship will then take the position indicated by Fig. 5 (No. 2).

To avoid this position, which would be incompatible with rapid propulsion, the weight must be properly distributed along the car from M to N, in such a manner that, when the balloon is horizontal, the two forces, the pressure BQ and the weight CP, are upon the same vertical line. "Static equilibrium" will then be ensured. We see therefore that the connections between the car and the envelope must never vary, though at the same time they must be allowed a certain flexibility, indispensable in aerial navigation. We shall return to this point when we deal with longitudinal stability.

But this is not all; the balloon, as it advances under the combined action of its motor, its rudder and the resistance of the air, must preserve a general stability; it must remain perceptibly horizontal, and must not execute violent or extensive movements, either from fore to aft, or from right to left; in other words, there must be neither "pitching" nor "rolling."

Every one knows what are the classic methods of aeronauts who go up in spherical non-dirigible balloons. To ascend, they diminish the total weight of their balloon

PLATE IV

Photo, Branger

THE DIRIGIBLE "BAYARD-CLÉMENT"

by throwing out ballast, that is, part of a supplementary weight, composed of sandbags, which they take with them at starting. When, on the other hand, they want to descend, as they have no means of increasing their weight, they diminish the thrust of the air on the balloon by letting some of the light gas of the envelope (the specific lightness of which constitutes the lifting force of the balloon) escape from a valve. This ascensional effort diminishes in proportion to the amount of gas allowed to escape. The aeronaut is therefore able to ascend or descend at will by the dual means of ballast and valve.

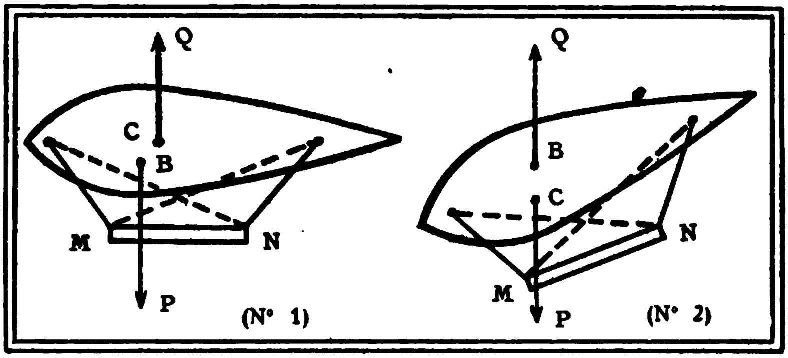


FIG. 5. Triangular connection suspension (indeformable)

But this simple method cannot be applied to the conduct of a dirigible balloon. Dynamic equilibrium, that is to say the equilibrium of the airship in motion, must take into account not only its weight and the sustaining pressure of the air, but also the resistance of the air exercised upon its envelope, which resistance depends on the dimensions and the *shape* of that envelope; in calculations, this shape is assumed to be invariable. Now what will happen if we allow a portion of the gas enclosed in the envelope to escape? When the balloon descends from the atmospheric stratum from which the aeronaut wishes to approach the earth, it will find itself in masses of air, the pressure of which will increase as he comes nearer to the ground; this will be easily understood, since these lower strata bear the weight of the upper strata. The confined gas, now insufficient to fill the balloon, as a certain portion has been allowed to escape, will contract; the balloon, no longer full, will become flaccid, and will not retain its original shape. The centre of resistance of the air will consequently have changed, as well as the centre of thrust, and the initial conditions will no longer be in force. As these conditions were used as the basis of calculations dealing with the equilibrium of the airship, that equilibrium can be no longer maintained.

THE AIR BALLONNET: RIGID BALLOONS

All these inconveniences are obviated by an ingenious contrivance, the idea of which originated with General Meusnier, who formulated it in 1784, only a year after the brilliant experiments of the Montgolfier brothers. Like all remarkable developments prematurely evolved, General Meusnier's idea was forgotten, and it was not until 1872 that the famous naval engineer, Dupuy de Lôme, the inventor of the ironclad, resuscitated it in connection with his attempts to make balloons dirigible.

We have seen above that it is absolutely essential to keep the balloon always perfectly inflated; on the other hand, in order to descend, it is necessary to let out gas, which partially empties the envelope. To maintain the volume of this, it would therefore be necessary to take a stock of hydrogen to introduce into the envelope by means of a pump worked from the car. But when we consider that it would be necessary to carry this hydrogen compressed in very strong steel cylinders, we see, as a simple calculation will sufficiently prove, that the weight of the necessary number of cylinders would be prohibitive. Consequently, the aeronaut is obliged to reject this method, which is perfect from the theoretical point of view, but impracticable in fact. He will rely, not upon a supplementary stock of hydrogen, but on air drawn from the ambient atmosphere, to restore the original volume, and he will replace the volume of hydrogen lost in the descent by an equal volume of air which he will introduce into the envelope by means of a pump.

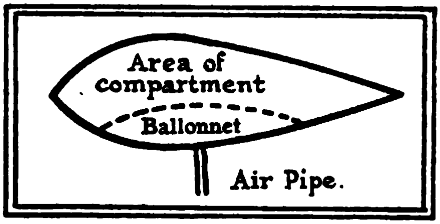


FIG. 6. Air-Ballonnet

At the same time, the danger that would be incurred by sending this air directly into the envelope of the balloon must not be overlooked ; it would mingle with the remaining hydrogen, and we should thus have a gas not only as inflammable as hydrogen, but an explosive element infinitely more dangerous. Here the ingenious artifice of the ballonnet comes into play.

Instead of making the interior of the balloon a single capacity, constituting the whole interior, it is divided in two by a fabric partition liable to deformation (Fig. 6). This partition occupies the lower part of the balloon, and there forms a space called the *air-ballonnet*, terminating in a tube that descends into the car, whence a pump can charge air into it.

When the balloon, at the beginning of its ascent, is completely inflated with hydrogen, this fabric partition lies against the lower part of the envelope, exactly like a lining. If the balloon rises, the interior gas dilates, because the outer air becomes less dense, and a portion of this gas escapes through automatic valves; the balloon therefore remains fully inflated so long as it rises. If the descent begins, the gas, diminished by the quantity which has escaped during the ascent, no longer suffices to fill the envelope, which would then become flaccid, lose its original shape, and compromise the general equilibrium.

The ballonnet now comes into play; by means of a pump installed in the car, the aeronauts force air into it, until the sum of the new volume it acquires and that of the remaining hydrogen gas, reconstitute the total original volume of the aerostat. In this way the initial conditions of equilibrium are always maintained, in conformity with the calculations of the constructors.

There is obviously another way of ensuring this permanence of form so necessary to the dirigible balloon; it is to make the balloon *rigid;* this last heroic solution has been adopted by Count Zeppelin for his gigantic balloon of 12,000 cubic metres, the *Zeppelin.*

To ensure this invariability of form, the balloon is furnished with an absolutely rigid metallic skeleton, made of aluminium tubes. This framing is divided into several compartments, and a very strong yet light fabric is stretched over the whole. This is the outer envelope, on which the resistance of the air is exercised during the progress of the balloon. In addition, there is, in the interior of each compartment, a balloon of air-tight rubber fabric, which is inflated with hydrogen. Thus the airship contains a certain number of balloons, the sum of whose lifting power constitutes the total ascensional effort. The external form is invariable, thanks to the material of the envelope and the framework on which it is stretched.

We see at a glance what colossal difficulties such an arrangement presents, the difficulty of constructing a trellised cylinder 120 metres long and 11 metres wide to say nothing of its expense; the difficulty of fixing the external envelope, and finally, the complication of inflating the elementary balloons contained in each of the compartments. Experience has shown the difficulty of managing such masses both at starting and landing: we shall return to this question later on. In any case it is difficult, and also very perilous, to give the body of an airship a rigid substructure.

ALTITUDE STABILITY: ELEVATING RUDDERS

This question of stability is therefore of the utmost importance; it is the basis of aerial navigation.

Every one knows that the aerostat, whether dirigible or not, can rise or sink at will by the double action of the ballast and the escape-valve; the skill of the aeronaut lies in economising the expenditure of these two essential elements; the ballonnet, in these conditions, ensures the permanence of the exterior form.

But this double action, expenditure of ballast and expenditure of gas, soon puts the aerostat *hors de combat*: it must therefore carefully preserve a sufficient stock of ballast to guard against the always possible dangers of a difficult or unexpected landing; it must also preserve enough gas to be able at the last moment, to let out a portion of it and descend abruptly. Thus it has been found necessary to invent something else for dirigible aerostats destined to undertake long voyages, and this new appliance is the "elevating rudder."

A dirigible balloon, indeed, requires a motive power, which, through the intermediary of a propeller (generally a screw) communicates to it the independent speed without which it is impossible to steer it. But of this motive power, employed for horizontal propulsion, a small portion may be diverted which will serve for vertical propulsion; that is to say, in the particular case we are considering, it will be used to make the aerostat rise or sink slightly, without any expenditure either of gas or ballast.

The arrangement consists in providing the dirigible balloon with planes which can be inclined at will, known as "elevating rudders." These planes move about a horizontal axis, placed transversely to the axis of the balloon (Fig. 7), and may be placed in the middle, or fore or aft of the apparatus. In our figure, we have supposed that they are placed at the back of the pisciform envelope; a glance at these two figures will convince us of their controlling action; they raise or depress the "nose" of the balloon at will, just as the ordinary rudder turns it to the right or left. The same thing happens if they are placed in front. Generally speaking, it is difficult to fix them on the envelope itself, and they are placed on the car, as in the case of the *Clément-Bayard* (Fig. 24), where we see this rudder, in the form of three parallel planes, fixed in front of the long car, immediately behind the screw propeller; the apparatus is also called a "stabilisator."

Elevating rudders may also be placed towards the middle either of the envelope or of the car; they then, by virtue of the resistance they offer to the air, no longer serve to raise or depress the stern or the bow, that is to say, to incline the balloon, but to raise or depress the whole body.

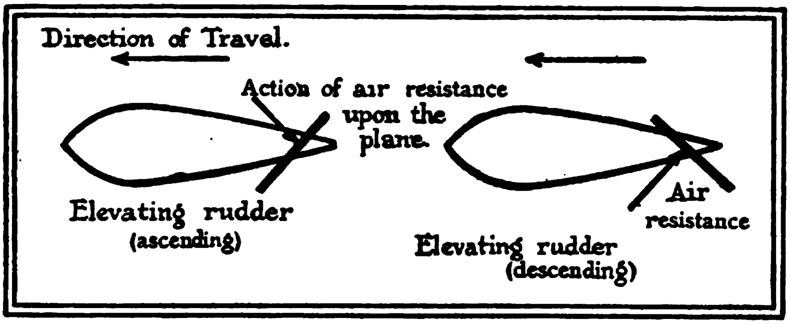


FIG. 7. Action of the elevating rudder

It has been proposed to get the same result by means of screws with vertical axes, which would, of course, turn horizontally; their action, in this case, would have the effect of raising or lowering the airship by exercising pressure on it either from above or below, according to the direction in which they were worked. A more rational proposition is to joint the shaft of the screw, so that it could be inclined either upwards or downwards. But neither of these expedients is as simple or more efficacious than the elevating rudder, which is now in general use.

STABILITY OF DIRECTION: LONGITUDINAL STABILITY

"Route Stability," or "Stability of Direction," consists of the following condition which the balloon ought to fulfil: its axis must always be at a tangent to the curve it describes if its course be curvilinear, and steered in accordance with the direction of this course itself if the latter be straight (Fig. 8). This stability is a quality which is exercised in the horizontal plane; we must therefore suppose that in Fig. 8 the dirigible balloon is seen from above and is travelling parallel with the ground.

How is this stability to be ensured? In the following manner: as soon as the balloon shows a disposition to diverge from the direction it ought to follow TT, a direction which is tangent to its trajectory, it must be brought back by the resistance of the air itself. For this purpose, constant use may be made of the "steering rudder," which, like the rudder of boats, serves to direct the airship from right to left. But this method would be fatiguing to the pilot, and not sufficiently efficacious to prevent unforeseen divergencies. Aeronauts, therefore, prefer to ensure stability of direction by the construction of the balloon itself, and this is the chief reason for constructing our modern dirigible on the lines of the fish, with the larger end in front; the centre of gravity of the balloon is thus brought to the front, and the "leverage" of the stabilisating elements formed by the stern of the envelope is very efficaciously augmented.

However, the envelope of the balloon itself would not suffice, so just astern of the latter "stabilisating surfaces," have been disposed, formed of vertical planes fixed to the envelope, the sum of which form, as it were, the keel of the dirigible analogous to the keel of a ship. By this means, stability of direction is obtained naturally, without having recourse to the ordinary rudder, which is only used to obtain change of direction.

PLATE V

Photo, Trampus

SCREW-PROPELLER AND CAR OF THE GERMAN AIRSHIP "PARSEVAL"

Photo, Branger

COL. LOWTHER, M. CAPAZZA, M. CLEMENT

CAR OF THE "BAYARD-CLÉMENT"

We have still to consider "longitudinal stability." What is this third stability? It is the property of remaining always horizontal or nearly so, which the balloon ought to retain, whatever evolutions its pilot may cause it to make. In other words, it is the property of not "pitching."

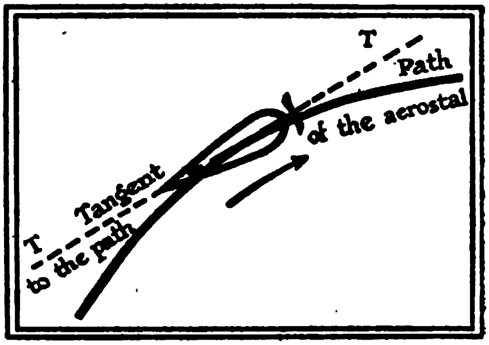


FIG. 8. Route stability

This longitudinal stability is much more important even than stability of direction. For should this latter be imperfect, the aeronaut corrects it readily by working his steering apparatus more frequently. But if longitudinal stability is defective, the balloon may incline in a dangerous manner, and here the necessity of an unvarying connection between the car and the envelope appears more important than ever.

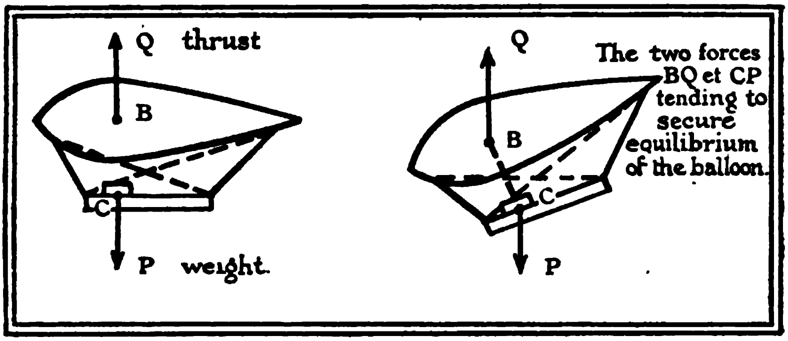


FIG. 9. Longitudinal stability

If, in fact, the balloon and the car are united by unvarying attachments, the suspension being triangular when in a state of equilibrium, the thrust and the weight are in the extension of one another; if the balloon inclines, the car retaining its relative position, the weight is no longer in the prolongation of thrust; but then the two forces tend to "trim" the airship. If, on the contrary, the suspension is liable to displacement (Fig. 10), we see that if the dirigible inclined for some reason, its equilibrium would not be restored by the action of the weight of its car and cargo.

The suspension must, therefore, be incapable of displacement, and for this reason the idea of making the balloon rigid, and of uniting it to its car by rigid attachments has often presented itself (*Zeppelin*, *Pax*, for instance). But absolute rigidity involves terrible drawbacks; all rigid balloons have hitherto ended by accidents. Aeronauts in general have decided in favour of triangular suspension (Fig. 9); these are sufficiently unvarying, as long experience has shown.

One of the most serious causes of longitudinal instability lies in the gas which fills the balloon; its tendency is to augment any inclination accidentally produced. This gas, by the very fact of its gaseous nature, is compressible, and on the other hand, the envelope of supple material, is essentially deformable. A transverse section of an inflated balloon would not therefore be a circle, but an ovoid figure (Fig. 11), the larger end of which would be uppermost. There are two causes for this: in the first place, the traction of the suspensory ropes of the car compresses the envelope laterally from A to B and from A′ to B′, making it almost flat; in the second place, the interior gas, being lighter than air, tends to accumulate in the upper part, and this force obviously acts in the same manner as the preceding one, deforming the transverse section of the balloon.

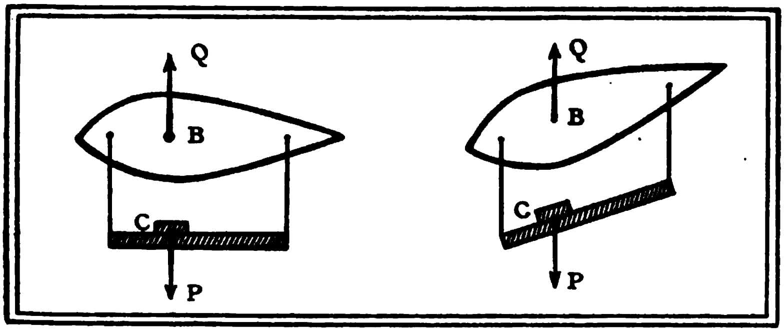


FIG. 10. Instability produced by parallel connections

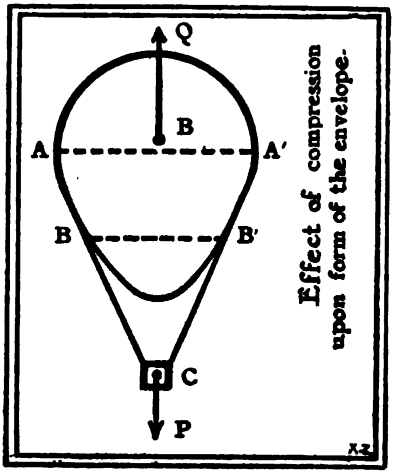


FIG. 11. Deformation of shape of transverse section

At a first glance, this deformation would not appear to have any injurious influence on longitudinal stability; nevertheless, the last cause we have put forward may be adverse to this stability. Let us suppose, for example, that the balloon is inclined, as in Fig. 12; the interior gas, which is lighter than air, will immediately rush to the upper part, leaving the lowered end. The latter will be insufficiently inflated, whereas the former will be inflated to excess. The centre of thrust B will be displaced towards the right and as the two forces which would tend to restore the equilibrium of the balloon, BP and CP will be less and less distant one from another, this restoration will not take place. Such a contingency would be especially serious if the balloon were imperfectly inflated, for with a perfectly full balloon, this accident is less redoubtable. Thus the function of the ballonnet is doubly important, because it ensures permanent inflation, and consequently persistent stability,

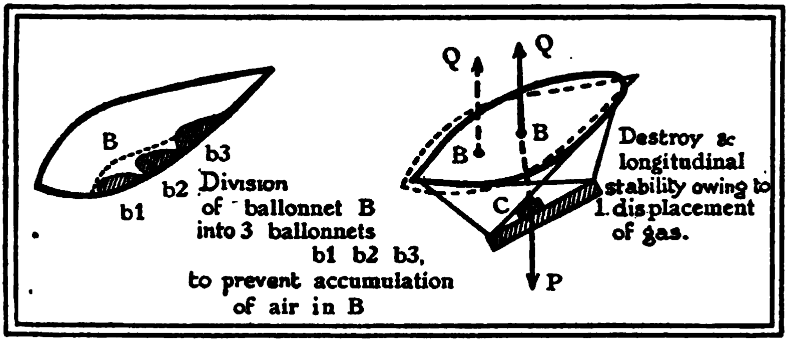
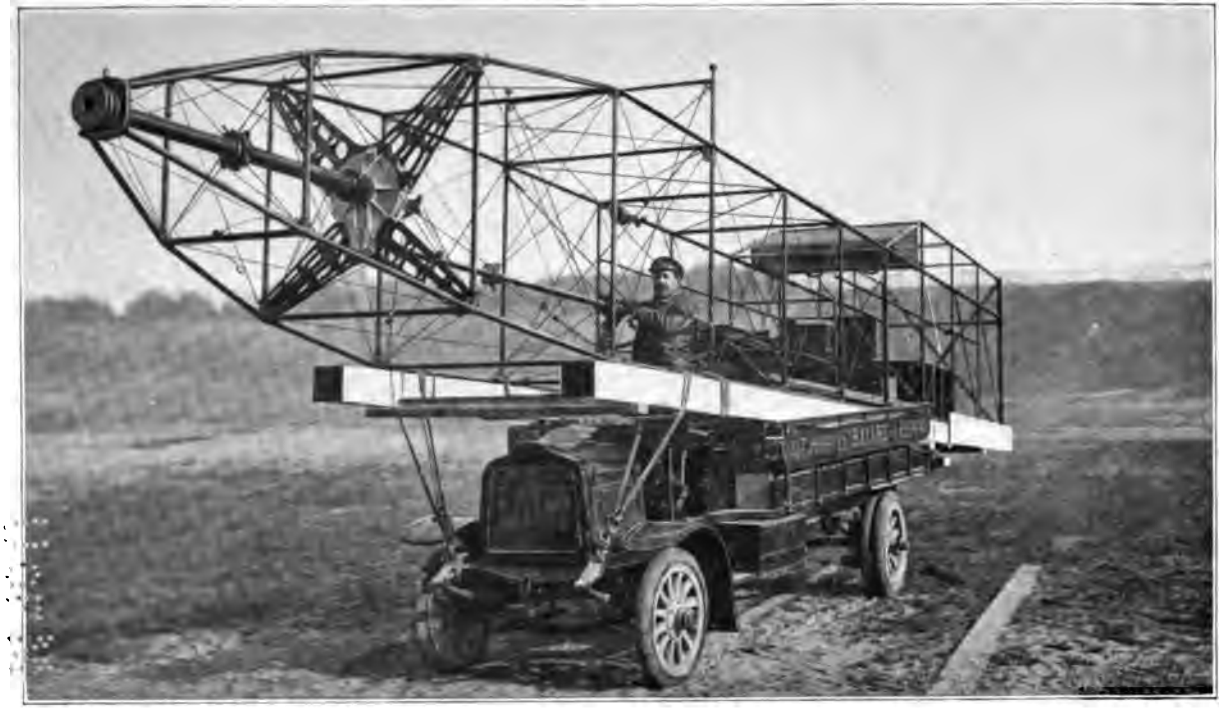


FIG. 12. Action of the ballonnet

for the gas of the ballonnet, imprisoned in its special envelope, cannot accumulate in the lower part of the dirigible's envelope. Colonel Renard even divided the ballonnet into several flexible compartments without any intercommunication in such a manner that the air contained in it could in no possible case accumulate by its own weight or inclination at either end of it (Fig. 12 B).

Aeronauts have every reason to dread the inclination of airships, and to avoid them by every possible device. For the resistance of the material and of the suspension, &c., is calculated on the assumption that the airship will be horizontal, or very nearly so, in which case the strain is equally distributed throughout the suspension and on all the material. If, on the contrary, the airship should incline in an exaggerated and unforeseen fashion, there would be elements which take no strain at all, and others

PLATE VI



Photo, Branger

FRONT PART OF THE "BAYARD-CLÉMENT" CAR SHOWING PROPELLER SHAFT

which would be loaded to excess; grave accidents have resulted from such a cause.

The operation of filling the ballonnet is consequently a most important manœuvre in aeronautics. Many constructors now make it automatic: a pump is continually sending air into the ballonnet, and a valve in the latter opens as soon as the pressure of the air exceeds a given value; the air it contains then escapes into the atmosphere, and the pressure resumes its normal value, ensuring the preservation of the form automatically.

REALISATION OF DYNAMIC EQUILIBRIUM: THE CRITICAL SPEED: THE "EMPENNAGE"

It was in 1904 that Colonel Charles Renard first formulated the exact laws concerning the dynamic equilibrium of dirigible balloons, discovered the causes which render this equilibrium precarious, and at the same time indicated by what means it might be completely obtained. Let us now briefly summarise the results achieved by this distinguished officer.

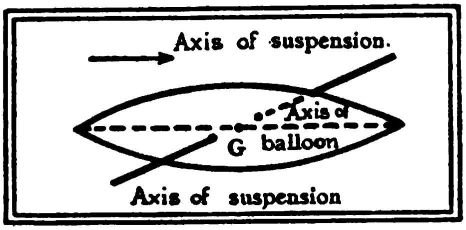


FIG. 13. Imperfect equilibrium

We will begin by noting that if we took a symmetrical fusiform balloon, tapering equally at each end and suspended in a horizontal axis passing through its centre of gravity, this balloon would be in a state of "indifferent" longitudinal equilibrium (Fig. 13). If the axis of the balloon is horizontal, and if a horizontal current of air bears upon it, the balloon will be in equilibrium, but an equilibrium essentially "unstable," for calculation shows, and experience has proved, that so soon as the envelope thus suspended inclines ever so slightly, this inclination will increase until the axis of the balloon is perpendicular to the current of air; in other words, till it assumes a vertical position; this position is inadmissible, for it would amount in an airship to absolute instability.

If, instead of a symmetrical fusiform balloon, we take a pisciform balloon, with the larger end in front, the instability would still persist, though it would be considerably diminished, and here we are not in the domain of theory but of experience, for it was by dint of innumerable experiments, instituted with admirable method, that Colonel Renard obtained all the results we are now discussing. In the case of a pisciform balloon the disturbing effect is due, in unequal degrees, to the diameter of the balloon, its inclination and speed, whereas the stabilisating effect depends on the inclination and diameter of the balloon, but not upon the speed. The disturbing effect in the equilibrium therefore depends solely on the speed, and augments very swiftly as the speed itself increases.

It will, therefore, be easily understood that there is a certain speed for which the two effects are equal, and beyond which the disturbing effect, depending on speed will overpower the the stabilisating effect. To this speed Colonel Renard gave the name "critical speed"; if this is exceeded, the equilibrium of the balloon becomes unstable. The most remarkable feature of Colonel Renard's brilliant labours in this field is, that they are the expression, no doubt, of learned calculations, but, above all, of *experiments* built up and conducted on a highly scientific method, experiments in which the gifted aeronaut submitted *keels* of various shapes and dimensions to the action of a current of air which he could modify at will.

We shall naturally ask if this "critical speed" is very considerable. We shall find that it is relatively slight, as the following numbers will show. Let us take, for instance, a dirigible pisciform balloon of the type *La France;* its critical speed is 10 metres a second, or 36 kilometres an hour, and a 24 horse-power motor suffices to supply this speed. Now the lightness of contemporary motors is such, that a balloon of this type could easily lift a motor of from 80 to 100 horse-power. With this motor it might theoretically have a speed of 15 metres a second, or 55 kilometres per hour, but it could not accomplish this in practice; for, its critical speed being 36 kilometres, its equilibrium would become unstable if this were exceeded; long before this speed was attained, in fact, the stability of an airship would become precarious and totally inadequate.

It would therefore be useless to essay the lightening of the motor, that is to say the augmentation of the speed of balloons, unless we had a means of ensuring its stability, for, as Colonel Renard wittily observed in the case we have quoted: "If the balloon were provided with a motor of 100 horse-power, the first 24 would make it go, and the other 76 break our necks."

This means of stabilisating is the "empennage," that is to say, the systematic use of rigid planes, both vertical and horizontal, passing through the axis of the balloon, and placed very much behind the centre of gravity; the resemblance of a balloon thus armed to a feathered arrow is obvious, hence the name of the apparatus.

With a balloon of the size of *La France* (60 metres long and 10 metres in diameter), the surface necessary to achieve strict *empennation*, *i.e.*, to annul the disturbing effect, is 40 square metres, lying 25 metres behind the centre of gravity. By slightly augmenting the surface and the distance, a degree of security higher still is secured.

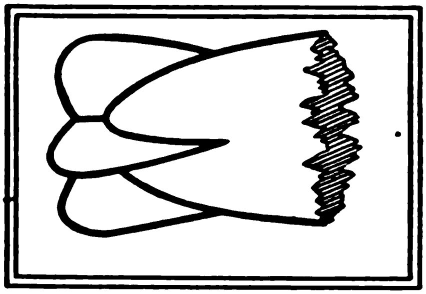


FIG. 14. Cruciform empennage of the *Patrie* and *République*

But how is this "empennation" to be carried out? In the *Lebaudy* balloon it was fulfilled by means of surfaces affixed to the framework between the balloon and the car; in *La Patrie*, a still better plan was adopted; the feathered arrow has been literally realised by fitting four surfaces in the form of a cross to the stern of the envelope, as shown in Fig. 14. Colonel Renard pointed out another method of obtaining the effect of the empennage without the use of rigid planes, difficult to fix to the envelope of the airship and tending to overload

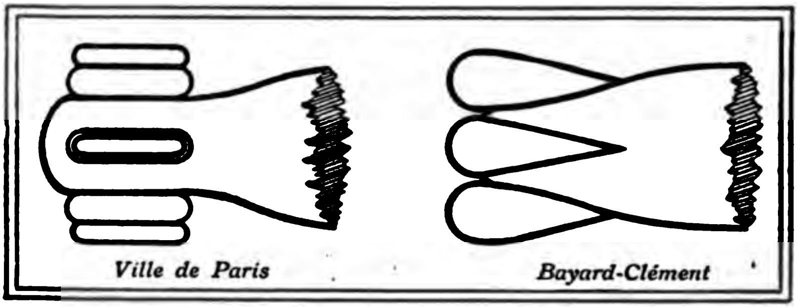


FIG. 15. Pneumatic empennages

PLATE VII

THE "BAYARD-CLÉMENT" RETURNING TO ITS GARAGE
(SHOWING THE DETAILS OF THE PNEUMATIC EMPENNAGE)

the prow; this was to affix to the extremity of the envelope elongated ballonnets projecting from the body of the balloon. This method was adopted by M. Surcouf in two different forms: cylindrical ballonnets for M. Deutsch's *Ville de Paris* (Fig. 15), and conical ballonnets for M. Clément's *Bayard*. Inflated with hydrogen, these ballonnets exercise a pressure which compensates for their weight, and they no longer constitute a useless and unsymmetrical supplementary load to the airship.

There are obviously other means by which instability in motion may be counteracted; the use, for instance, of a very elongated car, which allows a considerable weight to be displaced from stem to stern; this method was adopted in the *Zeppelin;* but such an arrangement is difficult to work, and the "empennage" is at once simpler and very much safer.

POINT OF APPLICATION OF THE PROPULSIVE FORCE: "DEVIATION"

Where should the motive power which is to propel the dirigible balloon be applied? At what point of the complex system formed by the envelope and its accessories should the propulsive force act? We have still to examine this question.

As the essential sustaining part of the airship is the envelope, it is this which offers the maximum resistance to the air. Theoretically, therefore, the propulsive effort should be applied to the axis of the balloon itself, and so many inventors have thought; several have attempted to materialise this theory, notably the unfortunate Brazilian Severo d'Albuquerque in his balloon *Pax*, which ended in a catastrophe, and the constructor Rose, who produced a twin airship, the axis of the screw being between the two balloons which constituted his system.

This conception would be a perfectly just one if the car and the rigging offered no resistance to the air; but their resistance is far from negligible. The car has a transverse section of several square metres, and the sum of the surfaces presented by the suspensory ropes is enormous. To give an idea of this, let us take these to be steel cords of three strands, each of three threads, that is, nine threads to the cord; their diameter is about three millimetres, their length between the car and the balloon about ten metres. One of these ropes would therefore offer a resisting surface of about 300 square centimetres or three square decimetres; ten of these cords would thus represent a surface resistance of about one-third of a square metre, and sixty cords would equal two square metres. Add to this the sum of the sections of the knots, splices, pulleys, ropes used in the working of the vessel, transverse members which serve to send compressed air into the ballonnet by the special pump, the surfaces of the rigging, guide-ropes, &c., and finally the surfaces of the passengers, and you will soon arrive at a sum of resisting surfaces, exterior to the sustaining envelope, and equal to a quarter, a third, and even more of a transverse section thereof. If, therefore, we represent the resistance offered by the envelope as BR (Fig. 16), and that offered by the car and its accessories as CR′, the motor-power AF must be applied at the point A, between B and C, and nearer to B than to C, to ensure the permanently horizontal position of the system under the combined action of motor and resisting effort. But, on the other hand, it is difficult, at least in the present state of aeronautic construction, to fix the shaft of the screw to the envelope itself, without using rigid envelopes like those of the *Zeppelin* or the *Pax*. Perforce, therefore, the aeronaut has to be content with an application of the motor power to the car itself. Hence a tendency in the dirigible balloon to tip up at the nose, because the force F is not exercised directly at the point of application A, the resultant of the two forces R and R′. The constant use of the elevating rudder becomes necessary, and we find that this tilting is the more pronounced the farther the car is from the envelope. The term "deviation" is used to describe this tilting effect produced by the action of the propeller.

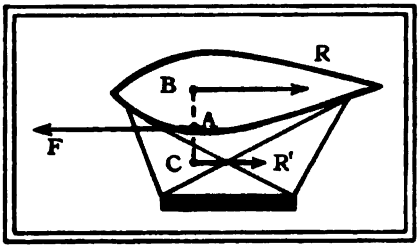


FIG. 16. Application point of the propelling force

It will be readily understood that this "deviation" will be modified in proportion as the car is brought closer to the balloon; but this approximation is limited by the danger of installing a combustion engine too close to an envelope containing an inflammable gas. The golden mean must therefore be observed. If the car were too far from the balloon, the tilting effect would be very great, and the balloon would incline without advancing.

The Comte de la Vaulx has found a very ingenious solution of this difficulty. It consists in fixing the screw H (Fig. 17) to a shaft HK placed at a height between the envelope and the car. The latter contains the motor which works the shaft HK through a transmission system. This is a very rational solution, and it is probable that it will be widely followed in airship construction.

As to the position of the screw, this may vary considerably: Colonel Renard and M. Surcouf, the constructor of the balloons *Bayard-Clément* and *Ville de Paris*, place it at the prow of the car; under these conditions it *draws* the balloon. Other constructors place it at the stern; this was the plan adopted by Giffard, Dupuy de Lôme, and the brothers Tissandier. M. Julliot, the engineer, to whom we owe the *Lebaudy* and the *Patrie*, introduced two screws, which he fixed outside the car, on either side and almost at its centre. We see then that various arrangements are in use. But on the whole there seems to be a preference for the screw at the prow of the car.

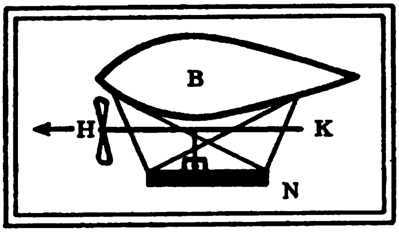


FIG. 17. Rational arrangement of the screw

CHAPTER III

THE WIND AND DIRIGIBLE BALLOONS

THE CHIEF ENEMY OF THE AERONAUT: HOW THE WIND INTERVENES IN THE PROBLEM OF AERIAL NAVIGATION: RELATION BETWEEN THE SPEED OF THE WIND AND THAT OF THE AIRSHIP: THE "APPROACHABLE ANGLE": ACCESSIBLE AND INACCESSIBLE REGIONS

WHAT IS THE WIND?

THE wind is easy to define: it is the movement of atmospheric masses in a horizontal direction, the displacement of air parallel to the surface of the earth. The study of the winds is one of the principal objects of that branch of physics called meteorology.

Meteorology, or at least the study of atmospheric phenomena over continents, otherwise called "Continental meteorology," is relatively backward, compared with nautical meteorology. The reason is that above oceans the immense and uniform surface of the waters allows molecules of air to obey the laws of equilibrium and the movement of fluids freely, whereas the surface of the land, bristling with an infinite variety of obstacles, offers much greater difficulty to the establishment of clearly defined rules. Moreover, the waters of the sea cover nearly three-quarters of the surface of the terrestrial globe; it is above them, therefore, that the great laws of the movements of the atmosphere are demonstrated; finally, all sailors are meteorologists, whereas keen observers are rare on land; this fact has given rise to the sarcastic definition of meteorology as a science which consists in knowing what kind of weather it was yesterday.

Yet it is with the winds that blow over continents that aeronauts will have to reckon, at least, in their early days, for the moment has not yet come (though, indeed, it may not be far distant) when, launching themselves audaciously over the waters, they will have to struggle with oceanic winds, and consequently to experience personally the laws of nautical meteorology.

The wind is differentiated by its *direction* and its *velocity*, or its *force*. Its *direction* is indicated by naming the point of the horizon whence it blows: a north-east wind is a wind which blows from the point of the horizon situated in the north-east, &c.; the so-called "compass-card" of the mariner gives all directions of wind by their initials (Fig. 18).

The velocity of the wind is reckoned by metres per second. We should say, for instance, a wind of 7·50 m. per second. By multiplying the speed in metres per second by the factor 3600, the number of seconds in an hour, we get the speed of the wind in kilometres per hour. A wind of 10 metres a second is, therefore, 36 kilometres an hour; the wind of 7·50 m. corresponds to 26 kilometres an hour.

The force of the wind may be measured by the pressure it exercises upon a motionless obstacle normally opposed to it. Sailors have deduced from centuries of navigation in sailing-vessels that the pressure of a wind making a metre per second upon a surface of one square metre perpendicular to its direction is 0·125 m., or, in correct language, 125 grammes to the square metre. This pressure

PLATE VIII

THE "BAYARD-CLÉMENT" OVER THE MADELEINE

THE PLACE VENDÔME

THE MADELEINE

(AS SEEN FROM THE "BAYARD-CLÉMENT)

increases in proportion to the surface of resistance, and in proportion to the square of the wind's speed. For a wind of 2 metres per second, it would therefore amount to 4 × 0·125 kg., or 500 grammes per square metre; for a wind travelling at a speed of 4 metres, it would be 16 × 0·125, or 2 kilogrammes per square metre, and so on.

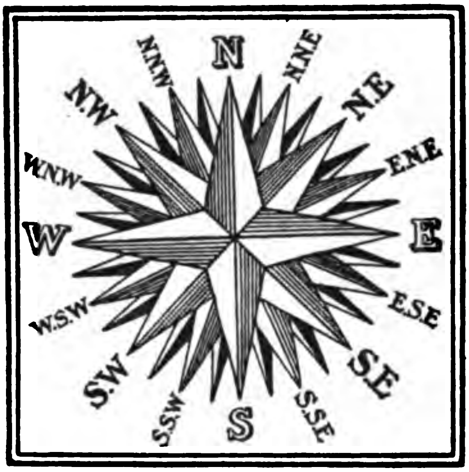


FIG. 18. Compass-card

When the speed of the wind becomes considerable, the pressure it excrcises upon fixed obstacles becomes in its turn enormous; a wind of 25 metres per second, or 90 kilometres an hour, would exercise a pressure of 25 × 25 × 0·125, or nearly 80 kilogrammes per square metre. The accident which resulted in the loss of the dirigible balloon *La Patrie* was due to this formidable pressure.

THE WIND AND THE AERONAUT

Let us now define this idea of the wind rather more precisely, for, in the special case we are studying, an inaccurate idea of it is often formed, and it must not be forgotten that it is in the very bosom of the atmosphere that we encounter it with our dirigible balloons. Let us therefore study the wind, not in its relation to the ground, but in its relation to the airship.

If we were in a spherical balloon, it would be susceptible to this pressure so long as, in process of inflation, it were held to the ground by mooring ropes; this "force of the wind" would tend to beat it down upon the ground or to tear it from the hands of those who were holding and keeping it stationary. But so soon as its moorings are cast off, so soon as the balloon rises into the air without any propelling mechanism, the aeronaut is conscious of absolute calm: the wind, in fact, is imperceptible to him, because the *wind* is a *relative* movement of the molecules of air in respect of an observer stationed upon the ground. Once in the air, a spherical balloon forms part of the atmosphere. It is carried along by the wind itself, and moves *with it;* is not displaced *in relation to it.* So long as the balloon neither rises nor sinks, a little banderole fastened to the rigging hangs vertically, without fluttering as it would do under the action of the wind if it were fixed to the ground.

Thus, *for the aeronaut who belongs, not to the earth, but to the atmosphere, wind does not exist;* these are the very words used by Colonel Renard the first time he described in public his definitive experiments upon the steering of balloons. If then we were to take an airship, dirigible or otherwise, everything in connection with it would happen as if the air were motionless. If the balloon is dirigible, that is to say, if it is furnished with a motor and a propeller, and if these forms have been duly studied, the aeronaut could move in this atmosphere in every direction, as if the wind did not exist; as his balloon advanced, he would have the same sensations as if he were passing through an absolutely calm atmosphere. He would have an impression of *wind,* but this wind would have no relation to that which blows over the surface of the earth; it would be a current of air from the stem to the stern of the balloon, *and this wind would be created by the aeronaut himself in his progress;* it would be the result of the displacement of the balloon under the action of its screw. Should he stop this, calm would be at once established, and the aerial navigator would no longer feel the slightest current of air.

To sum up, then, we may say with Colonel Renard that "the balloon belongs to the air and has nothing to fear from it. If it is furnished with a propeller and a motor, in a word, if it is dirigible, the wind changes nothing, either in the nature of the efforts it has to undergo during the voyage or in the speed of its displacement in relation to the aerial ocean in which it floats: and everything goes on as if, the air being perfectly motionless, the earth were flying beneath it with a speed equal and contrary to that of the wind."[1]

In the case of the aerostat, as of the airship, the wind therefore means, from the point of view of a final result, *a relative displacement of the ground*, exactly as if the aerial swimmer being motionless, the earth were carried along by the current of air. From this we shall note interesting results, which will show us the limitations of the efficacious action of dirigible balloons.

INDEPENDENT SPEED AND WIND VELOCITY: THE APPROACHABLE ANGLE

Let us imagine an "aerial fleet"[2] (Fig. 19) hovering over Paris, composed of a central balloon, playing the

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[1] Colonel Ch. Renard: *La Navigation aérienne*, a lecture delivered at a meeting of the Société des Amis de la Science, April 8, 1886.

[2] *Ibid.*

part of flagship, and six "aerial cruisers"; the admiral's balloon occupies the centre of the circle formed by the six cruisers; all the engines have stopped, and the flotilla is for the moment motionless in relation to the air. The wind is west, blowing at a speed of 8 metres per second, that is to say, 29 kilometres an hour.

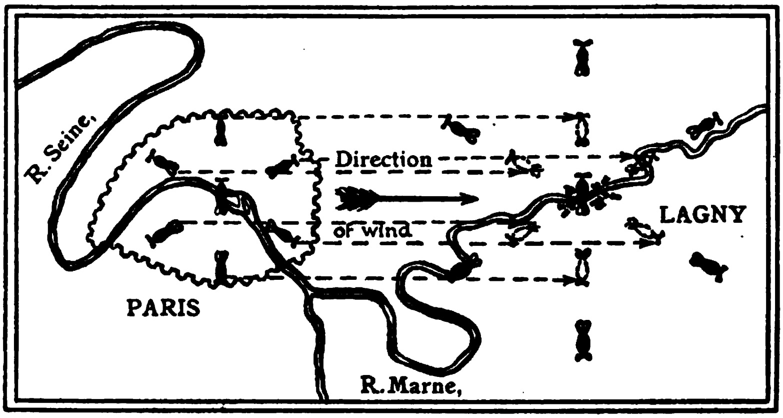


FIG. 19. Example of relative wind

At this moment the admiral's balloon issues an order: the six cruisers are to effect a reconnaissance, each going off in a different direction, while the balloon in command will remain motionless to await their return. Let us imagine all these cruisers travelling at the same speed of 6·50 metres a second, for instance, or 22 kilometres an hour: this is the independent speed of each in calm air. At the end of an hour they would all be 22 kilometres from the admiral's balloon; in other words, they would be distributed on the circumference of a circle with a radius of 22 kilometres, the geometrical centre of which would be occupied by the balloon in command. This is what would be happening *in the air*. Now let us see how our seven balloons have been disposed *above the ground*, taking into account the wind, which is blowing at the rate of 7 metres a second, or 29 kilometres an hour.

The earth will appear to have fled towards the west precisely at the speed of the wind, that is, 29 kilometres an hour. Thus Paris, which was just now immediately under the admiral's balloon, will be removed 29 kilometres west of the airship, which, having stopped its engine, has remained motionless in the air. Below this balloon will stretch a new region, that of the Marne, and Lagny is now the centre of the circle with a radius of 22 kilometres, on the circumference of which the six aerial cruisers are symmetrically distributed. Consequently the west wind has really had no effect but that of displacing the whole aerial fleet *en bloc* towards the west by a distance of 29 kilometres under the wind. It has therefore made no change in the relative positions of the airships.

Armed with this result, we may now determine the points which the dirigible balloon could attempt to reach, taking into account its independent speed and the velocity of the wind.

Let us imagine our balloon furnished, by means of its motor and its screw, with an independent speed of 6·50 metres per second; this, as we have already explained, amounts to saying that in absolutely calm air this balloon would travel 22 kilometres to the hour. Let us suppose that this independent speed differs from that of the wind, which we will take to be 8 metres a second (29 kilometres an hour). The balloon starts from the point P (Fig. 20), in the direction PA, at an independent speed represented by the length, PB: this would mean that, if there were no wind, at the end of an hour it would have arrived at B. But the wind is blowing in the direction PS at a speed represented by PV: the balloon will therefore travel along the route indicated in length and in direction by the diagonal PR of the parallelogram BPVR, and at the end of an hour, under the combined action of its own speed BP and that of the wind, PV, it will have arrived at the point R, having throughout preserved the direction represented by the silhouettes (1) and (2). Consequently, should the speed of the wind be greater than its own, and should it be directly opposed to this, there would be regions in the atmosphere access to which would be impossible to the balloon, which could only by using its motor deviate from the direction of the wind, as is shown in Fig. 20. We will now inquire more closely into this question. Three cases might present themselves:

1. *The independent speed of the balloon is less than that of the wind.* (Fig. 21.) Let P be the starting-point of the balloon, and let us take the line PA to represent its actual speed. This means that if the air were calm, at the end of an hour it would find itself somewhere on the circumference of the circle C, the centre of which is P, and the radius of which corresponds to this speed PA. But the wind is blowing with a speed V, greater than *v*: accordingly, all the circle, C, finds itself at the end of an hour transported to C′, and the balloon will find itself somewhere on this new circle C′, which is, from this very fact, the circle of points approachable in the space of an hour, the distance, PP′, being equal to the speed of the

wind. *The only points of the space which the balloon could reach would therefore be those which would be comprised within the angle formed by the tangents leading from the point* P *to the circle* C′, that is to say, comprised in the region which is shaded in the figure. All the rest would be space inaccessible to the balloon. The accessible angle will consequently be greater, the less difference there is between the speed of the wind and that of the balloon. This space would be *nil* if the speed of the balloon were itself *nil;* this is the case with free balloons, which can only move along the line PP′.

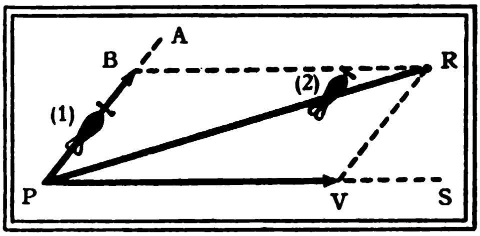


FIG. 20. Combined effects of wind and independent speed

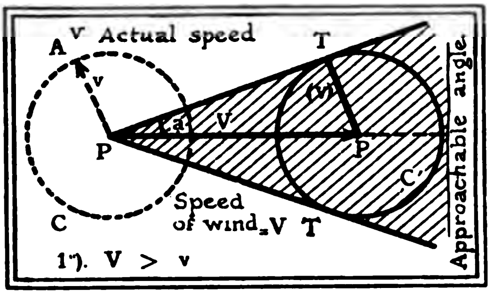


FIG. 21. Instance where the independent speed is less than the wind

2. *The independent speed of the balloon is equal to that of the wind* (Fig. 22).—The balloon is at the point P, its actual speed is PA, equal to the speed of the wind; if the wind were not blowing, at the end of an hour the balloon would be somewhere on the circumference of the circle C; but the wind is blowing with the speed PP′, exactly equal to that of the airship itself; the circle C is therefore transported to C′, and it is on the circumference of C′ that the balloon finds itself at the end of an hour.

The shaded angle of the former example, which has become more and more obtuse as the values of the two speeds approximated, becomes equal to two right angles, and the accessible region comprises the entire half of the space, that which is to the right of the tangent leads from the point P to the circle C′.

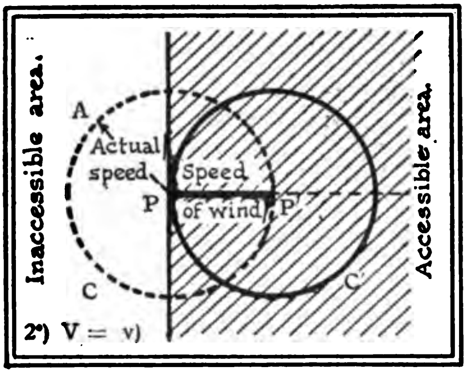


Fig. 22. Case where the independent speed equals the wind

3. *The independent speed of the balloon is greater than that of the wind* (Fig. 23).—In this case there is no special angle which limits the accessible regions; the whole space is accessible to the airship, even in the direction contrary to that of the wind, and if the balloon goes straight against the current of air, it will advance *in respect to the ground* with a speed equal to the difference between its own speed and that of the wind: *all space is therefore accessible to a dirigible balloon whose independent speed is greater than that of the wind.* This last condition is the essential and sufficient condition of perfect dirigibility.

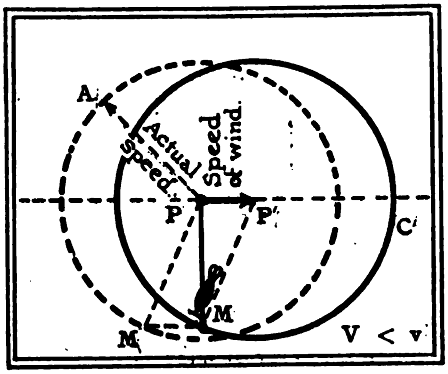


Fig. 23. The balloon speed is greater than the wind, so it can go anywhere

PLATE IX

Photo, Branger

THE CAR OF THE DIRIGIBLE "RÉPUBLIQUE"

PRESENT CONDITIONS OF DIRIGIBILITY IN RELATION TO THE WIND

We know now under what conditions an aeronaut could hope to reach any given point. Are these conditions compatible with the average state of the atmosphere, in other words, with the average speed of the winds that prevail in our regions? Here we must rely on observation alone for a satisfactory answer.

Our official meteorologists are silent on this point in their treatises, as on many others; so it has been requisite for our aeronauts to make the experiments necessary to obtain the results indispensable to them. Such experiments have been carried out for many years at the military establishment of Chalais-Meudon. The very interesting results are summarised in the following Table. In this Table, the first column gives the speed of the wind in metres per second; the second, the corresponding speed in kilometres per hour; the third, in fractions of a thousand, the possibilities of encountering a wind of the velocity denoted. Thus, for instance, if we take a wind of 5 metres a second, or 18 kilometres an hour, the possibility of having a lighter wind will be 323 thousandths, in other words, there will be 323 chances to 1000 that the wind will be blowing at a rate of less than 18 kilometres an hour. The fourth column indicates the number of days in the year when, on an average, a wind of less velocity than those indicated in the first two columns will be prevailing. These final figures are therefore those which will throw most light on the present conditions of dirigibility for the aeronaut.

We must remember that these figures apply *to the* *vicinity of Paris*, where the observations on which they are based were carried out.

Speed of the wind in metres per second.	Speed of the wind in kilometres per hour.	Possibilities (in parts of a thousand) that the wind velocity will be less than that of the first two columns.	Number of days in the year when there would be a possibility of wind velocity being less than that of the first two columns.
Metres.	Kilometres.	Thousandths.	Days.
2·50	9	109	39
5·00	18	323	117
7·50	27	543	197
10·00	36	708	258
12·50	45	815	297
15·00	54	886	323
17·50	63	937	342
20·00	72	963	350
22·50	81	978	354
25·00	90	986	358
27·50	99	991	361
30·00	108	995	363
32·50	117	996	364
35·00	126	998	364
37·50	135	999	364
40·00	144	1000	365
42·50	153	1000	365
45·00	162	1000	365

The importance of these results is at once apparent, especially if we translate the average chances of the wind into "numbers of days per year," as I have done here.

Thus, let us take the speed of 10 metres a second, or 36 kilometres an hour; according to the probabilities arrived at by these long series of observations, there are 258 days in the year when the speed of the wind in the neighbourhood of Paris is, generally speaking, less than 36 kilometres an hour. Therefore a dirigible balloon with a speed of 10 metres a second could make way against the wind, on an average, 258 days out of 365; if the balloon has a speed of 12·50 per second at least, that is to say 45 kilometres an hour (which is the speed of the *Bayard-Clément*, the *République* and the *Ville de Paris*), we see that it would be dirigible on an average 297 days out of 365, that is to say, about ten months out of the twelve. Now, as I have already stated, this is the speed actually maintained by all modern airships.

We may therefore affirm, figures in hand, *that the problem of aerial navigation by dirigible balloons is completely solved.*

Of course there are exceptional cases: thus, the average probability of winds travelling faster than 35 metres a second, that is to say, hurricanes blowing at a rate of 125 kilometres an hour and even more, is *nil*, or almost *nil;* in other words, 999 times out of a thousand the chances would be in favour of a less violent wind. Such winds, however, do occur occasionally, but they are accidents; they devastate gardens, and damage buildings, and are, I repeat, exceptional eventualities.

There is, nevertheless, one important remark still to make on the velocity of the wind; this is that the speed of atmospheric currents augments very rapidly as we rise in the air. In Paris, for instance, owing to the Eiffel Tower making it possible to observe these effects, whereas the *average* speed of the wind in the course of the year is about 2 metres per second on the level of the houses (7·200 km. per hour), it is over 8 metres at the top of the tower (about 29 kilometres an hour). Aeronauts must therefore take this circumstance very carefully into account, if they wish to form an accurate idea of the power of the wind against which their balloons will have to struggle when the voyage is to take place, not just above the earth, but at a certain height in the atmosphere.

We see, too, that if constructors accomplish the short stage connoted by the next advance in aeronautics, that is to say, if they achieve a speed of 20 metres per second or 72 kilometres an hour for the "independent" speed of airships, these will be able in our regions to travel 350 days a year; this would be absolute solution, for the days when the speed of the wind is higher than 20 metres a second are days of clearly defined bad weather, and are fortunately not very frequent.

Progress will therefore consist in augmenting the power and the output of the motor and in improving the quality of envelopes, which must be made capable of resisting the increased pressures of the air caused by the greater speed of flight in the future.

CHAPTER IV

CONSTRUCTION AND MANAGEMENT OF A DIRIGIBLE BALLOON

APPLICATION OF THE PRECEDING PRINCIPLES: HOW TO CONSTRUCT AN AIRSHIP: HOW TO ARRANGE THE MOTOR AND PROPELLER: THE TWO RUDDERS: WHAT ARE THE TRAVELLING SENSATIONS IN A DIRIGIBLE?

THE ENVELOPE AND ITS OUTLINE

WE have just shown what are the fundamental principles of aerial navigation by dirigible balloons. We must now see how these principles are applied in the construction of those airships from which practical results may be expected.

The construction of the envelope is the first thing to be done. We have already said that it must be light, strong, and impervious to hydrogen. All, or practically all, modern dirigible balloons have envelopes of rubbered material, consisting of two layers of fabric with a layer of rubber between them. This material weighs 300 grammes per square metre, and will bear a strain of 1800 grammes per metre. Very often, after the envelope is constructed, it is coated with a layer of chromate of lead, to arrest those solar rays which, by their actinic action, might affect the rubber; it was this colouring matter which gave M. Lebaudy's balloon the "yellow" tint, and suggested its popular nickname.

The outline of the envelope is important, for the exterior form of the airship ought to correspond to the minimum of effort required for propulsion in the air, while ensuring longitudinal stability. Thus the curved outlines of modern airships have been studied with the utmost mathematical precision.

The modern balloon should, following the indications given by Renard, be *pisciform*, with the larger end forward, after the manner of fishes and birds, otherwise there will be a risk of low efficiency (examples of which will be given in the following chapter). But the profile and the elongation have still to be considered.

The envelopes constitute what is known in geometry as "surfaces of revolution," in the sense that they may be considered as engendered by the rotation round their longitudinal axes, of the curve which defines their profile. The constructor begins by fixing the length of the balloon, its maximum diameter, and the position of the latter in the length of the envelope; after this he calculates the profile, generally formed since Renard's time, of two parabolas united; these parabolas are either simple or of the superior degree; but these are mathematical details which I need only indicate. When the envelope is calculated, it is drawn, and the diagrams necessary for cutting out the pieces of material are made; these pieces, sewn together, constitute the body of the balloon.

We will take as our type of a dirigible balloon the *Clément-Bayard*, which Parisians have so often seen floating above their city, and which is familiar to me from the fact that I have made various ascents and voyages therein; the perfection of its construction and the accuracy of its evolutions give it a right to be cited as a sample of French aeronautics.

THE CONSTRUCTION OF THE ENVELOPE: THE GAS

The silhouette of the envelope (Fig. 24) is formed by two parabolas of the third degree. The envelope is made of panels sewn together; its total volume is 3500 cubic metres.

Its surface is 2250 square metres. It is 56·25 metres in length and the maximum diameter at its largest section is 10·58 metres. This envelope is inflated with pure hydrogen gas; in spite of the high price of this gas, which costs 1 franc and sometimes more per cubic metre, it is preferred to illuminating gas, no matter how cheap this may be, on account of its great lifting power; and balloon-material has become so perfect that it reduces the loss of gas by exudation through the rubbered fabric to an insignificant percentage.

In the middle of the envelope there is a *ripping valve*, this is an aperture in the upper part of the envelope covered by a band of fabric which can be torn off in an instant by pulling a cord, should a rapid descent become necessary; this manœuvre can be carried out from the car. At the end is the pneumatic *empennage*, consisting of four spherico-conical ballonnets, tangent to the back part of the envelope and communicating therewith through holes. The air-ballonnet proper is divided into two parts; it is 23 metres long, and has a volume of 1100 cubic metres.

The balloon is furnished with four automatic valves; two for the hydrogen gas, which automatically open as soon as the pressure equals 40 millimetres of water, and two for the air, opening when the pressure equals 30 millimetres. These two pressures are indicated by two manometers fixed under the eyes of the pilot, on the front of the bridge. If a valve were not working automatically, he would therefore be warned, and could work it himself by pulling a cord. The air is continually pumped into the ballonnet by a fan which can pump 1800 litres per minute, and this is actuated through transmission from the motor. When this stops, the fan can be worked by hand.

The suspensions are thin steel cables of three strands, each of three threads. Some of them are 3, others 4 millimetres in diameter, and they can bear respectively a strain of 400 and 600 kilogrammes. They terminate in "goose's-feet" of hemp fastened to boxwood stakes, and the latter are encased in a "girth" sewn into the fabric, which forms the envelope of the balloon; the net is thus rendered unnecessary, and this facilitates the passage of the molecules of air along the envelope, by dispensing with the resistance offered by the asperities of loops and knots.

Beneath the "suspension girth" is placed the lifting girth, also sewn to the fabric. The "lifts" are steel ropes, which are oblique in relation to the length of the balloon, and ensure the indispensable triangular suspension that secures the solidity of the car and the envelope, both in longitudinal and lateral directions. These lifts connect together by four "knots," which also constitute the fixed points of the suspension. These knots may be distinctly seen in the diagram.

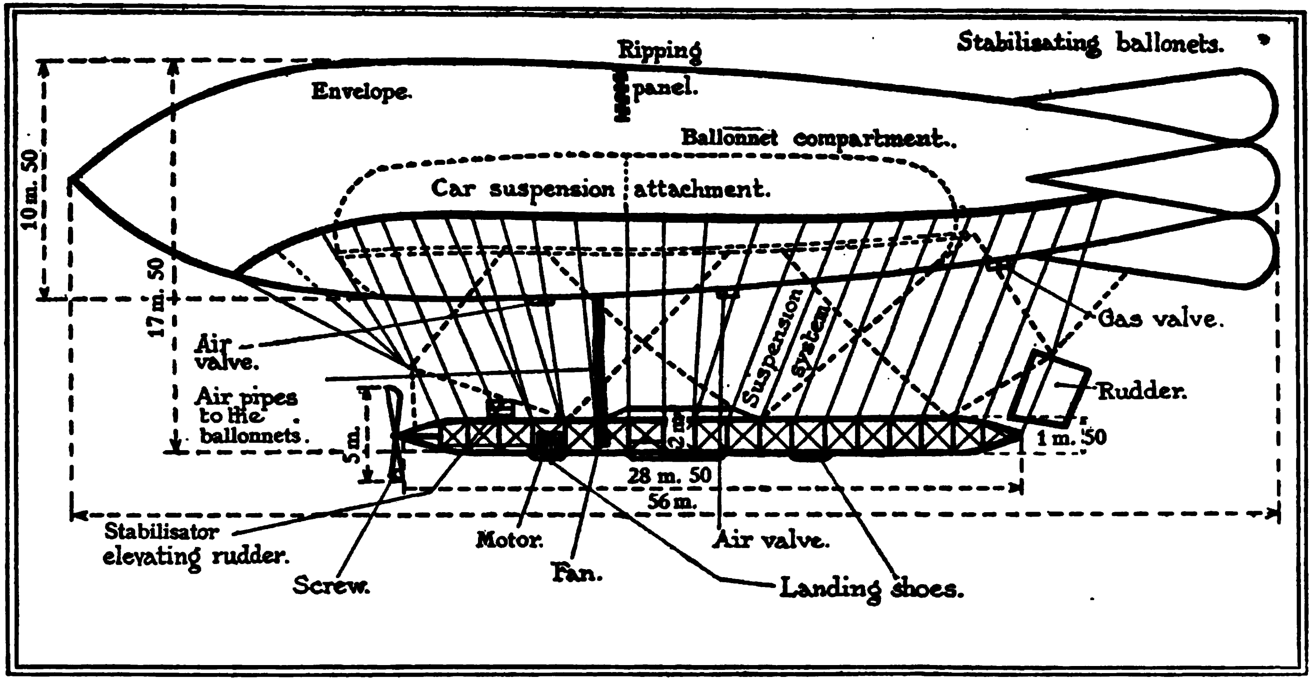


FIG. 24. The dirigible balloon "Bayard-Clément"

THE CAR, RUDDER, AND MOTOR

The car is built up of a series of cubes of steel tubes of 30 and 40 millimetres diameter. The sides of the cubes measure 1·50 metres, and their contiguity forms the car. The sides of these cubes are made rigid by steel wire diagonals fitted with stretchers. The central part of the car has a height of 2 metres; its total length is 28 metres.

The steering rudder is carried at the stern; it is double, and its surface is about 15 square metres. It is composed of rubber fabric stretched upon a steel tube framework having its axis connected to the car by means of a cardan joint. The fourth knot of the lifting ropes (that of the stern) and two stretchers serve to hold it.

The "stabilisator," or elevating rudder, fitted to the front of the car, is in reality a "triplane" turning about a horizontal axis and able to be inclined from 16 to 17 degrees above or below the horizontal. Its efficiency is considerable, inasmuch as in accordance with specific calculations, when the machine is at full speed, the effect of the stabilisator is more or less equivalent to 100 kilogrammes of ballast, according to the degree of upward or downward inclination. This rudder, and that at the stern, are controlled through steel wires and chains, by two wheels placed upon the bridge on the right and left respectively; like those of motor-cars these wheels are "irreversible."

In the centre of the car is the passengers' accommodation as well as the pilot's position. The latter, by raising the floor of the car, is elevated about 50 centimetres. The pilot, standing on the left, has the steering wheel under his hand; on his right is his assistant holding the elevating rudder-wheel. In front is the motor room, and the pilot can communicate direct with the engineer. A vertical panel on the front of the bridge carries the whole of the controlling instruments. These are the manometer of the balloon and air-ballonnet; the barometer to indicate continuously the altitude, as well as a barograph; the dynamometer which permanently records the tractive effort of the screw; and lastly, the speedometer registering the number of revolutions per minute made by the motor. In addition to this is a shelf carrying the chart and a compass, well compensated owing to the masses of iron and steel in the balloon, to set forth the course to be followed. Through the passengers' space extends a large suspended table carrying the road maps, indispensable to the voyage and for guidance by comparison with the country spread immediately below. Lastly under the car are the "skates" which enable the airship to alight without the car being injured by rubbing against the ground.

The engine is an explosion motor, such as are used in automobiles. It is multicylindrical, works with a mixture of air and petrol gas, and is of 105 horse-power. The special materials of which it is constructed ensures at one and the same time great solidity and a remarkable regularity in running, without forfeiting that lightness indispensable to an aeronautical motor. It weighs 352 kilogrammes all told. The weight of the petrol tanks is 64 kilogrammes, that of the oil reservoirs 10 kilogrammes; the motor is water-cooled; 65 litres of water being carried in a radiator and a circulating system which complete weighs 83 kilogrammes. In "working order" the total weight, everything included, represents 5 kilogrammes per horse-power.

The engine runs at 1050 revolutions per minute, but by means of a reducing-system of two gear wheels, the propeller shaft does not turn at more than a third of this speed—350 revolutions. The fuel consumption is from 38 to 40 litres per hour; of oil about 5 litres. The whole of the motor is mounted upon a chassis, fixed to the car by springs in such a manner that vibration is reduced to the minimum, being no greater than in a well-built motor-car standing still with the motor running. The connection by circular segments is fitted with springs which can be easily regulated by means of a worm wheel so as to obtain a constant and absolutely certain tightening. Lastly, we may add that the motor is fitted with two ignitions, magneto and accumulators, and that by means of decompression cocks it can be started up with the greatest ease.

THE SCREW, "SLIP," DIMENSIONS, AND POSITION

The screw is the propeller exclusively used to-day in aerial navigation, both upon dirigibles and aeroplanes. As a matter of fact, the screw essentially presents to the fullest degree the first and most important acquisition; simple, and when its design, dimensions, and its operation are well thought out, its performance is excellent.

It is scarcely necessary to explain what a propeller is: it is a *screw*, or rather, there are two elements of the threads of this screw which we call the *wings* or *blades* which screw into the air. If the screw penetrates wood or a metal nut, with each revolution it will advance a certain distance, which is always the same, known as the "pitch," and which is no more than the distance separating two consecutive threads, this distance being computed parallel to the axis. But the screw of an airship screws into the air, and the latter is, for a screw, an essentially unsteady nut, so that at each revolution the aerial vessel, instead of advancing a distance equal to the "pitch," only moves forward a part thereof. The difference between the "pitch" of the screw and the advance of the airship itself for each of these revolutions, is defined as the *slip* of the screw, that is the proportion of this difference and the "pitch" itself. Thus a screw may have a slip of $\frac{3}{10}$ if, when it makes a revolution, the airship which it drives does not move forward more than $\frac{7}{10}$ of its pitch.

This knowledge of slip enables us to consider the controversial question of large screws turning slowly, or of small screws revolving very rapidly, and we may easily understand that it is necessary, *a priori*, to reject the screws which are too small: turning very rapidly they would begin to drive away the air from around them without forcing the airship forward; their enormous slip would not enable it to advance. It is what Colonel Renard expressed in a picturesque manner by saying "We cannot propel an Atlantic liner by rowing, even very rapidly, with a penholder." Let us therefore take screws of large diameter. However, one is limited in their dimensions by their weight. As they turn powerfully but slowly, it is necessary to add to their weight that of the speed-reducing gear, which transmits the always very rapid revolutions of the light motors used in aerostation. There will be consequently an absolute limit to bear in mind, because it is necessary to choose between the efficiency of the propeller, that is to say the portion of motor effort which is transformed into useful tractive effort, and the engine-power. By augmenting the weight of the screws the efficiency of the propeller may be improved; but then it becomes necessary to increase the weight of the motor, and it must not be forgotten that in aeronautics the question of weight is always vital, and that in an airship only a total given weight is available for the whole of its mechanical equipment, motor and propeller.

One other question now remains—the position of the propeller; should it be placed at the prow, at the stern, or in the centre? We have already discussed this question (p. 43) as well as that of determining the level at which it must be driven between the axes of the balloon and the car respectively.

These principles being disposed of we will consider the propeller of the *Clément-Bayard.*

Hitherto the screws of dirigibles have been made of sheets of light metal, or bent upon metal frames; sometimes they were even made of fabric stretched over a clumsy skeleton. The screw of the *Clément-Bayard* is of wood, and is a striking piece of work by Chauvière the engineer.

It has only two blades; as a matter of fact if the number of the latter were increased too greatly, each would move upon the air already displaced by its neighbour, and efficiency would be decreased. M. Chauvière thought it possible, by special arrangements, to balance the efforts of propulsion and the effects of centrifugal force arising from the rotary movement, efforts and effects which increase in a general manner pretty well in accordance with the same laws.

The *Clément-Bayard* screw is 5 metres in diameter. The pitch is variable and increases from the axis to the extremity of the blades. It is built up of countersunk ribs assembled and superposed in the form of a fan, similar to the steps of a " winding staircase." Revolving at 350 revolutions per minute, each of the tips of the blades describes, in a circular path, 100 metres per second. This enormous "peripheral speed" is the maximum that has as yet been attained with screws of this design. At this speed it produces stabilisating effects, called *gyroscopic*, recalling to mind those of the small device used as a toy known as the *gyroscope*, the stability of which, occasionally, is disconcerting; it seems to defy the laws of balance by simultaneously maintaining its rotating speed and the mass disposed around its circumference. In the case of the actual screw its gyroscopic effects strongly oppose the pitching of the balloon, and produce a stabilisating effect. This was the reason why the constructor did not strive too much after lightness in the screw, which weighs 90 kilogrammes.

At speeds of 350 revolutions per minute the *Clément-Bayard* propeller sustains with its blades a centrifugal effort exceeding 19,000 kilogrammes, and yet so perfect is its construction that it is not submitted to more than one-twentieth of its breaking strain.

The independent speed of the balloon, driven by its motor and propeller, is 50 kilometres per hour; *i.e.*, 14 metres per second. To complete our description let us add that the dirigible is always berthed in a "hangar," which enables it to await, sheltered from heavy weather, favourable conditions for the pending journeys. This shed is at Sartrouville, but a new shelter is being built on the manœuvring ground at Issy-les-Moulineaux.

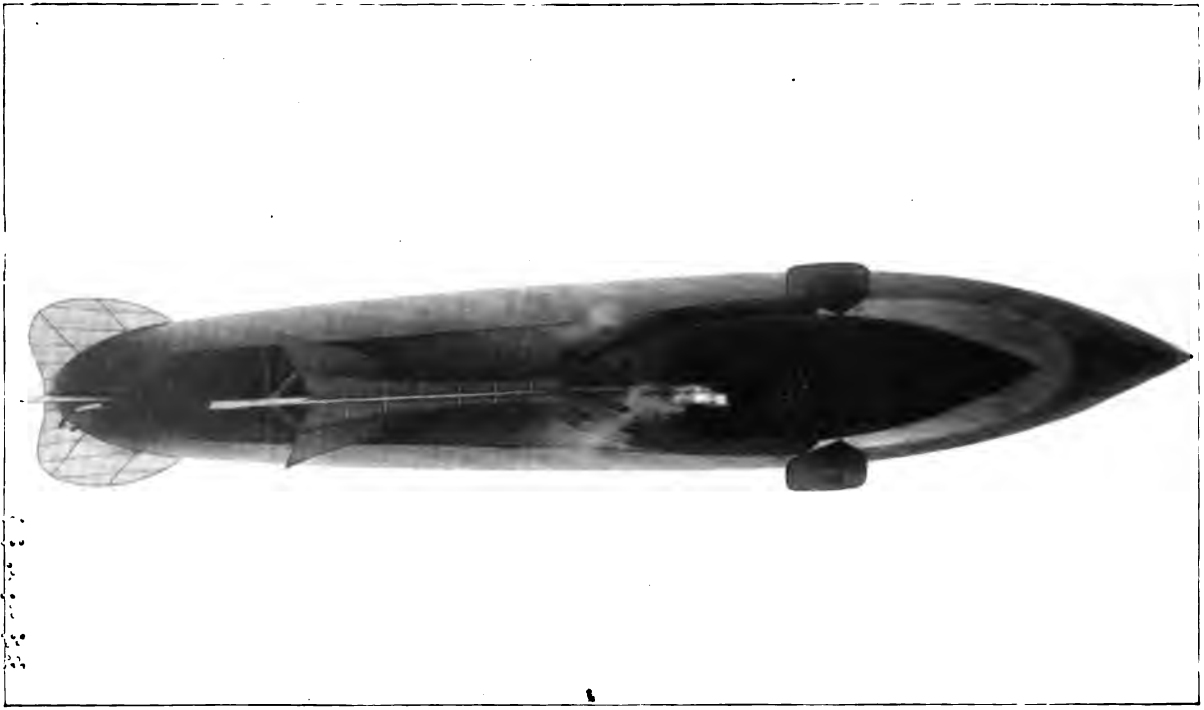
HANDLING THE AIRSHIP: STARTING OUT: *EN ROUTE:* THE DESCENT

The handling of a dirigible balloon is not so simple as that of a spherical balloon owing to the elongated form of the envelope containing the gas, and upon which depends the ascensional effort.

The dirigible must at first be brought out of its "hangar," wherein it is held upon the ground by a considerable, imposed weight, comprising bags of ballast. A number of men draw up in two lines on each side of the balloon, in which the pilot and his assistant take their places. The men detach the ballast-bags carefully until the balloon evinces a very slight tendency to lift itself; hauling with all their might they bring it out of its dock, so holding it that it almost touches the ground. Arriving in the open air it is hauled to as level an area of ground as possible, and then again surcharged with the bags of ballast, so that it rests naturally upon the earth.

The pilot assures himself that all is in good order; that the valves work, that the cords which control them are to hand, are not twisted or swollen; that the recording instruments work properly; that the wheels of the steering rudder and stabilisator efficiently govern those two mechanisms; that his compass, his charts, his ballast are all to hand, as well as the cord which operates the ripping valve. Meantime the engineer has passed as minutely over his motor, seeing to the lubrica-

PLATE X



Photo, Raffaële

THE DIRIGIBLE "PATRIE" SEEN FROM BELOW. THE HORIZONTAL STABILISATING EMPENNAGE CAN BE DISTINGUISHED AS WELL AS THE ELEVATING RUDDER IN FRONT

tion of all parts, the propeller shaft and screw bearings; tests his indicators and recording instruments, and when all is ready informs the pilot.

The latter now instructs the men to swing the balloon round in such a way that it starts out "to leeward." The passengers are embarked, and the ballast little by little discharged, until the balloon slightly rises; this operation is called "weighing" the balloon. The pilot commands the engineer to start up the motor, but without coupling the propeller. When the engine is under way and all is ready he throws out the last bags of ballast so as to give the balloon the requisite lifting effort. "Hands off," he shouts. At this word the workmen let go the sides of the car to which they have been clinging, and the balloon is now held by two ropes only, attached to the under side of the car by a "goose-foot" at front and rear. These cords are then "paid out" equally, in such a manner as to keep the airship horizontal, and when at last the pilot cries "let go," the men drop these ropes and the vessel rises. The pilot orders the engineer to let in the propeller; the balloon obtains its independent speed, and with a turn to make sure the steering mechanism is working properly, sets the course it is proposed to take.

En route, if the weather is clear, the pilot always keeps his eye upon the chart, so as to assure himself that he is following the right course by comparison with the actual topography of the country unrolled beneath the feet of the travellers. If he ventures out at night or in a fog he will fix his attention upon the compass, while his assistant at the wheel of the elevating rudder will not let his eye leave the barometer, so as to preserve by the manipulation of the rudder, the desired altitude of the balloon, without throwing out ballast or letting out gas.

With regard to the sensation of "wind" felt by travellers, this is only that due to the independent speed of the balloon, 45 to 50 kilometres per hour; whether it be a following or a head wind it will always be the same, neither more nor less intense, because the "surrounding" wind does nothing but carry the whole of the atmosphere, of which the balloon is a part, from one point of the earth to another, and travellers in the car are under the same condition as if they ran very quickly to and fro through the interior of a large ship. The speed of their movement would cause them to feel an impression of wind which would be the same, irrespective of the direction and force of the wind, which blowing over the surface of the sea transports, in a combined movement, both them and the vessel in which they were sheltered.

So far as concerns ascent and descent, this is effected within a small limit of about 100 metres by the manipulation of the stabilisator. It must be pointed out that, unlike the free balloon, the ascensional effort of an airship is constantly increasing. Unballasting is continuously taking place by the consumption of the petrol by the motor, and in this manner it loses about 40 kilogrammes per hour. This is where the charging of the air ballonnet fortunately intervenes to secure the constancy of the external shape and consequently also the constancy of the air pressure.

It is hardly necessary to urge passengers in a dirigible to exercise the greatest prudence. *Nothing must be* *thrown overboard*, be it a bottle, an empty box, or even a chicken bone, without the pilot's permission: the static sensibility of these airships is extreme, and it is necessary to avoid any action which might vary it accidentally.

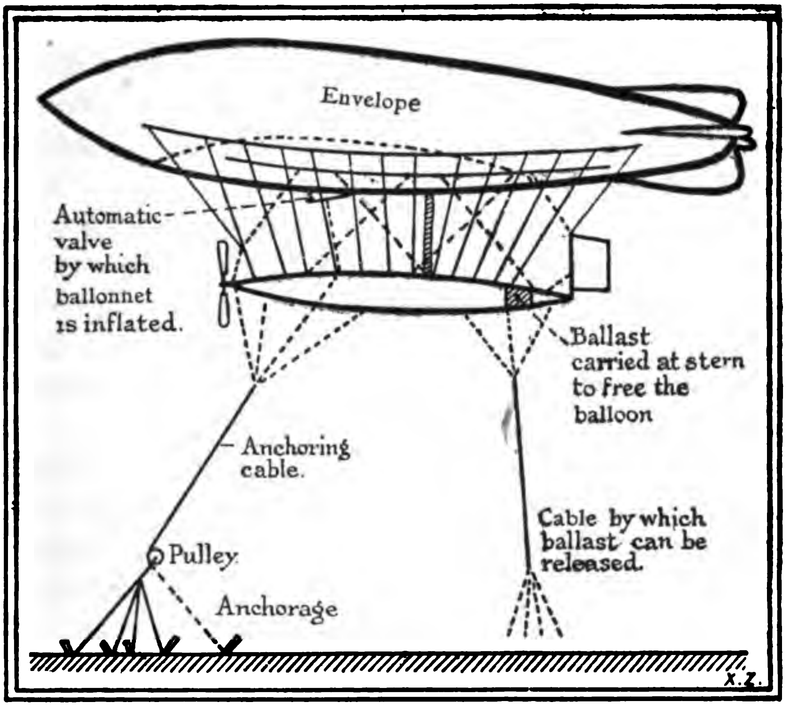


FIG. 25. Constructor Surcouf's method of "mooring" a dirigible

As to the descent of an airship, at least in the majority of cases, it must take place only in a locality where a docking "hangar" can be obtained, descent in open country being always hazardous. This was only too well shown in the accidents to the *Patrie* and the *Zeppelin.* Landing is made in a manner just opposite to that of ascent. But care must be observed that the men who seize the two guide-ropes to bring the balloon gently to earth, at first grasp the "windward" rope so as to hold the balloon with its nose to the wind; negligence of this precaution, the balloon, held only by the stern rope, would rear up, owing to the wind driving against the prow, and thus imperil it. Once the balloon has landed the workmen seize it by the car, keep it down by attaching numerous bags of ballast, and then bear it gently into its *hangar*.

It might however reach, and be compelled to descend, in open country, and to "moor" by fixing the airship with its anchors. In this case there is an arrangement conceived by M. Surcouf which appears to offer the greatest security to the airship forced to make a "halt" at a place unprovided with a special shelter.

Beneath the body, and towards the front of the balloon leading to the ballonnet, is an automatic valve (Fig. 25) which can open itself like a purse. During the journey a spring keeps it closed, and the ballonnet works as usual by means of its charging fan. But if the vessel is compelled to stop, it is fixed to the ground by anchors, or by stakes, with the cable, which by means of a "goose foot" is attached to the prow of the car, the balloon thus being held stationary, with its motor stopped, swinging in the wind. But under the influence of temperature changes the gas will contract or expand, and with the motor no longer running, the ballonnet will not be able to maintain the invariable form of the envelope.

Then, under the pulling action of the same restraining cords, the "mooring" valve opens, always to the wind, since it is to the front of the balloon, the latter adapting itself like a weather vane, nose to the wind. Under these conditions the air so caught in the pocket blows it open, and keeps the ballonnet inflated to assure the permanency of its shape. One can, for greater security, attach bags of ballast to the stern rope. If the stern of the balloon should descend this ballast would strike the ground, and the envelope, released of a considerable weight, would rise again before it could come into contact with the earth and thereby be damaged.

VOYAGES OF THE "CLÉMENT-BAYARD"

The dirigible balloon which we will describe in detail has completed more than thirty trips, with uniform success. During the Aeronautical Show held at the Grand Palais in the month of December 1908, it repeatedly came and hovered above the Champs-Élysees. Its evolutions above Paris have rendered it popular, acquainting the whole population with the appearance and travel of an airship. It has made numerous cruises around the capital, some very long, all brilliant, first under the direction of M. Kapférer, collaborator of M. Surcouf; later of M. Capazza, the eminent Corsican aeronaut, who so far has been the only one to accomplish the crossing of the Mediterranean in a balloon.

The most remarkable of these excursions was that when M. Clément resolved to set out from the airship "hangar" to visit his seat at Pierrefonds (Fig. 26). The vessel left Sartrouville on November 1 at 11.15 A.M. in a east-south-east wind blowing at a velocity of 20 kilometres per hour. M. Clément, the owner of the balloon, was accompanied by a passenger; MM. Capazza and Kapférer were on the bridge; Sabatier the engineer, and a mechanician, were at the motor. The balloon passed successively over Maisons-Lafitte, Pierrelaye, l'isle-Adam, Beaumont, Creil (at 12.30), Pont Sainte-Maxence, Compiègne (at 1.30). It then wore round to the east and arrived at Pierrefonds at two o'clock; then it resumed its journey to Paris, by Rocquemont, Ermenonville, Chennevières, Bourget (passed at 3.30), Pantin; then described a large circular sweep over Paris, and regained Sartrouville at eight minutes past four. The total distance was 200 kilometres, and it was

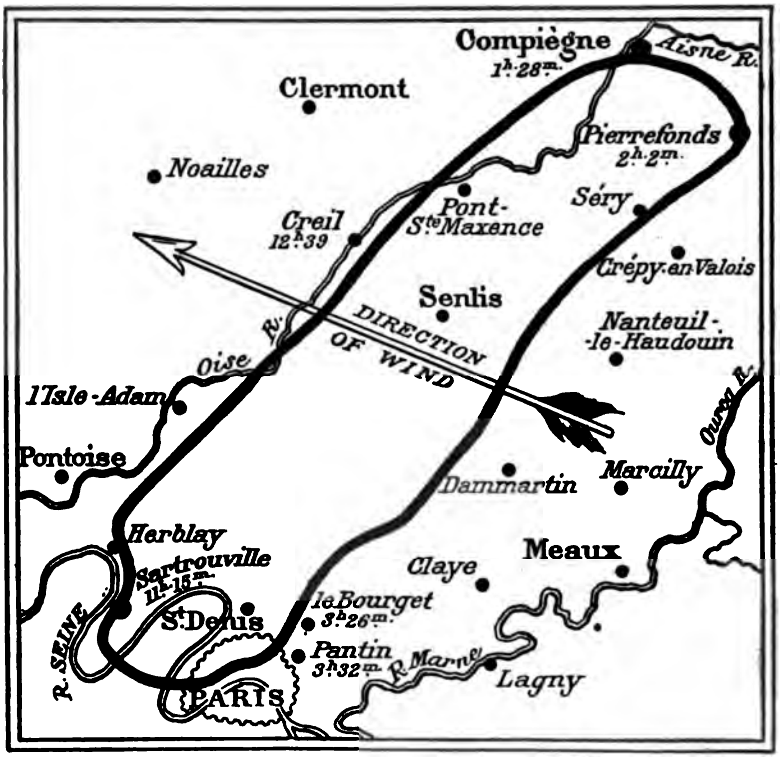


FIG. 26. Voyage of the "Clément-Bayard" (November 1908). (250 kilometres in a closed circle in five hours without descent)

covered in 4 hours 50 minutes. It was the "world's record" for *a round trip* accomplished by a dirigible without descent during its journey, and returning to its starting-point. The great journey of the *Zeppelin*, of which we shall speak in the following chapter, was not completed by return to the point of departure, inasmuch as the airship was unfortunately destroyed in the course of its homeward journey.

Here is the airship's official "bill off lading": 6 passengers, 300 litres of fuel, 20 litres of oil, 65 litres of water, 250 kilogrammes of ballast (sand in bags), and 59 kilogrammes of manœuvring ropes.

"AERIAL YACHTS"

A dirigible such as we have described is, in the field of aerial navigation, the equivalent of a warship, or of a large mercantile steamship; it is the "ocean liner." But its great cost (about £12,000) the absolute necessity of maintaining an immense and expensive *hangar* in which to dock it, renders it a vessel of pleasure inaccessible to many amateurs for aerial trips. There had to be devised the "little dirigible," the "aerial yacht" at a more popular price, and more simple to control. This very convenient type of small balloon is available to-day, and is known under the generic name of the "Zodiac."

This, to hazard a comparison borrowed from automobilism, is the "aerial voiturette." It is designed to enable one or two passengers to make easy trips into the air, and without the necessity of maintaining a sheltering *hangar*.

For this purpose the gas bag, of 700 cubic metres, is inflated not with pure hydrogen, which is expensive and not always obtainable, but with coal gas which is available at all towns and can be purchased cheaply. Inflated therewith it will lift one person, but by combining about 100 cubic metres of hydrogen, it will lift two. It is pisciform in shape, with stabilisating planes, and has two rudders.

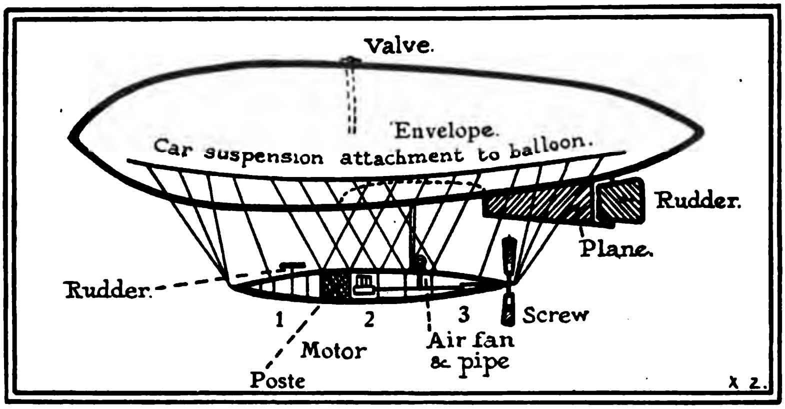


FIG. 27. A little "Zodiac" dirigible

The car is detachable into three pieces; each of them is formed of wooden trellis, light, flexible, and yet at the same time solid, being fixed together by bronze sockets, nuts, and bolts. A water-cooled, four-cylinder, 16 horsepower motor drives through cardan shafting a stern screw, which runs at about 600 revolutions per minute; the latter is of 2·30 metres diameter. The motor actuates also a fan which may be seen in the photograph; this keeps, through the medium of an air-ballonnet, the permanent external form of the envelope.

The whole balloon dismantled, car and envelope, packed in canvas cloth, can be transported by horse and cart. One inflates the balloon at the spot where the

PLATE XI

THE LITTLE DETACHABLE "ZODIAC" DIRIGIBLE

TRANSPORTING A "ZODIAC"

ASSEMBLING A "ZODIAC"

Photos, Schelcher

DIS-SEMBLING A "ZODIAC" CAR

gas is obtainable, and it can be prepared for an ascent in an hour and a half. The little airship can travel at a speed ranging from 25 to 28 kilometres per hour; can remain aloft for three hours with 75 kilogrammes of ballast, and costs ready for use £1000. Truly therefore it is the aerial "auto," enabling trips to be made in the air without being compelled to return to a stationary *hangar*, because the balloon coming to earth at the end of its journey can be deflated like a simple "spherical" and loaded upon a cart for conveyance to the nearest station.

This handy type of little dirigible certainly fulfils in every respect the "airship for all." On Easter Sunday, April 11, 1909, it made a remarkable journey. With MM. Henry de la Vaulx and Clerget on board, it manœuvred above the Bois de Boulogne for three hours with the greatest ease, before the eyes of crowds of Parisians, which the beautiful weather had caused to flock upon their favourite promenade.

IMPRESSIONS IN A DIRIGIBLE: DIZZINESS: SAFETY

And now, a question which will naturally arise in the mind of the reader, a question which is prompted to all those who have travelled in a dirigible. What are one's sensations? Does one suffer from giddiness? Has one sea-sickness? Has one fear?

I will endeavour to reply to these interrogations.

On board one has a feeling of complete security. Before entering the car there is time to take a walk round the balloon, for it is still berthed in its dock; to examine with care every part, feel the lifting and suspension system. The whole is so solid; is made of material of such perfect quality; the total resistance is so well calculated and tested to twenty times what the whole will have to withstand, that in an instant every qualm of disquietude slips from the mind: the only hesitation one has is that of actually embarking. But the catastrophes of the Pax and the Bradsky balloon have been instructive. To-day the general utilisation of the air ballonnet secures stability; the motor is placed well away from the balloon; the suspension system is indeformable and distributes the weight equally over the envelope; all parts of the motor capable of giving off either sparks or leakages of gas are boxed in or covered with metallic sheathing: lastly, trained and experienced aeronauts always conduct the ascents, for no owner of an airship would be mad enough to attempt a trip without the indispensable assistance of one of those "captains of the air" such as, for example, the Count de la Vaulx, Capazza, or Kapférer.

Mal-de-mer is unknown aboard these airships, for the simple reason that the longitudinal stability being so very great there is neither pitching nor rolling. Many are the ladies who have already received the baptism of the air; not one of them has suffered from this terrible malady of which ocean vessels preserve, alas! the unenviable monopoly.

With regard to dizziness this is unknown in a balloon when the latter is not held to the earth by a rope. Dizziness, when looking from the height of a tower or from the edge of a precipice, is produced by the view of the vertical wall which drops below one's self, and which "conducting the eye" right down to the bottom, enables one to calculate the depth of the chasm. In the captive balloon the sight of the cable may sometimes produce the same effect; but in a dirigible, there being no material connection, one cannot estimate one's altitude: one believes, and one actually is, above a magnificent plan in relief, with the feeling of beatitude which is grand, with the impression of indeed being independent of all, to have broken away from one's bonds and to be the master of space.

One can now consequently accomplish by dirigible and with absolute safety, voyages in the strictest sense of the word. I have made many myself, which I will never forget, on board the *Clément-Bayard.* The time is not far distant when airships, in addition to their military utilisation, of which we will speak after we have described aviation apparatuses, will have applications to everyday life, without speaking of their employment, which will arise, for those geographical explorations which yet remain to be made.

CHAPTER V

HISTORY AND DESCRIPTION OF THE PRINCIPAL DIRIGIBLES

EARLY DAYS OF AERONAUTICS: FROM GENERAL MEUSNIER TO COLONEL RENARD, GIFFARD, DUPUY DE LÔME, TISSANDIER: M. HENRY DEUTSCH, COUNT ZEPPELIN, M. SANTOS-DUMONT AND M. LEBAUDY

THE PIONEER: GENERAL MEUSNIER, INVENTOR OF THE AERIAL SCREW

THE history of dirigible balloons, up to recent times, has been somewhat devoid of results. If the importance of what has been done is unquestionable, it can at least be asserted that the quality in this case substitutes quantity, since it was no farther back than 1852 that the first serious attempt in this direction was made by Henry Giffard. Before him there may have been some ideas more or less vague, but nothing tangible.

However, it is one of these projects which it is necessary to describe, and that with some detail, because of its importance, its far-reaching value, and the date of its conception. It is that made in 1784, scarcely one year after the discovery of the brothers Montgolfier, by an engineering officer—Lieutenant, subsequently, General Meusnier.

Meusnier was an extraordinary intellect. He astonished his masters by his precocity, by the confidence of his reasoning, by the perspicacity of his views. He was a member of the Académie des Sciences at twenty-nine, after his work in aerostation, which however was only one of his accomplishments, and he was the collaborator of Lavoisier in several experiments. He was killed at the siege of Mayence in 1793; he was then General.

Meusnier was the true inventor of aerial navigation, and was a "scientific" initiator. Through not following the lines which he laid down, aerial navigation lost a century in futile groping about; in experiments absolutely without method. In fact, at a time when relatively nothing was known concerning the science of the atmosphere, Meusnier had the distinction of finding in one stroke all the laws governing the stability of an airship, and calculating the conditions of equilibrium for an elongated balloon, after having strikingly demonstrated the necessity of this elongation. Meusnier's designs and calculations are preserved in the technical engineering section at the French War Office in the form of drawings and numerical tables.

His airship designs relate to two balloons, one very large, the other much smaller, and it is in these projects that one finds distinctly described two absolutely new arrangements which are in universal use to-day: the *air-ballonnet* to secure stability and the *screw* for aerial propulsion. With regard to the motive power, owing to the absence of suitable motors in his day, he contented himself with the use of the muscular power of the men carried on board.

The dimensions of his largest balloon (which however was never constructed) were 260 feet in length, and 130 feet in diameter; that is to say 85 and 42·50 metres respectively. The shape was that of an ellipse, and as one may see, the elongation was equal to twice the diameter. The cubical contents were to be 60,000 cubic metres.

The balloon (Fig. 28) would thus have followed the form of a perfect ellipsoid, which was the paramount development to be realised as compared with the spherical form. It was to be a double envelope, comprising two skins, each of which was to fulfil a different purpose. The first, the "envelope of strength," very resistant, was consolidated by bands. The second, placed within the former, was to be impermeable to the light gas which was to sustain it. This inner balloon was never to be completely inflated and the space between the two envelopes was to receive, in varying quantities, the air to be forced therein through pipes by two pumps carried in the car. This was in very truth the *air-ballonnet*, and its use was certainly to maintain invariability of the exterior form.

The car was attached to the envelopes by a triangular suspension system. This was the "indeformable suspension" which is to-day considered imperative, and which is universally adopted. The lifting system was to be attached not to a net, but to a *girth* sewn to the fabric. Moreover, at three points where the lifting rope members met, forming "suspension knots," were fitted the axes of the three propellers, that Meusnier described as "revolving oars" (*rames tournantes*) and which were no other than screw propellers. Consequently this remarkable system, which is universally used to-day for driving steamships, was invented in 1784 for aerial navigation and by a Frenchman at that. But that was not all. Meusnier not only recommended the elongated form; not only conceived the girth fastening; the triangular suspension; the air ballonnet; and screw propeller; but moreover indicated the point the latter should be installed. It may be observed in the diagram that the motor shaft is not connected to the car, but is placed between this latter and the balloon. In this way the illustrious and accomplished officer set forth in one stroke everything requisite for aerial navigation. For this reason he justly deserves the distinction of being the forerunner, the initiator, of aeronautics.

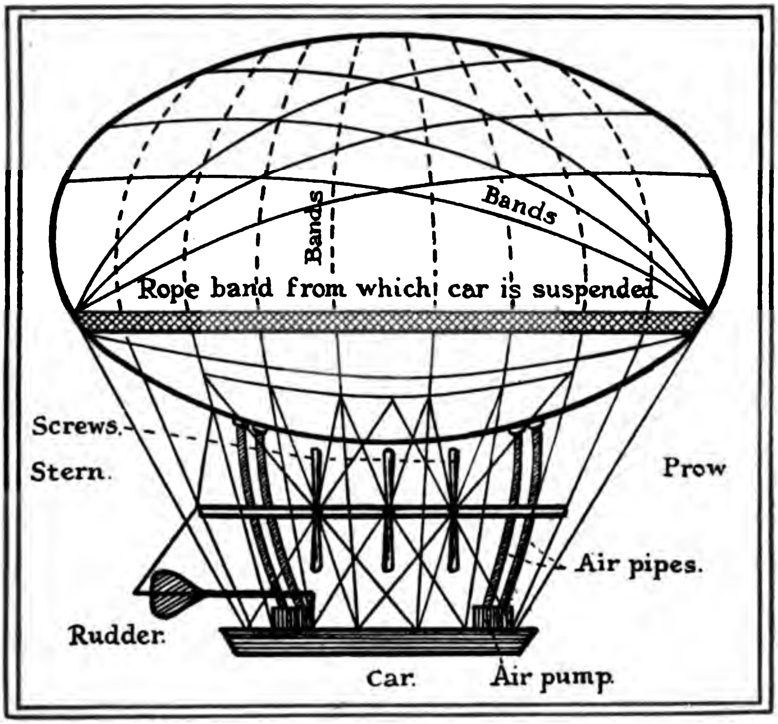


FIG. 28. Design for the first dirigible by General Meusnier (1784)

We are indebted for this information to a remarkable memoir of the engineering lieutenant Létourné, which was presented to the Académie des Sciences by General Perrier in 1886, wherein these details are set forth in a very scientific manner.

THE FIRST MOTOR BALLOON: GIFFARD'S AIRSHIP (1852)

It was some sixty years later that the solution was first practically resolved, by an eminent engineer whose name is justly celebrated—Henry Giffard, the inventor of the "Giffard injector," used throughout the world in connection with the boilers of locomotives. Giffard was convinced of the impotency of the "human motor," and its excessive weight, and he conceived the audacious project of carrying under an elongated balloon, a steam-engine complete with boiler and propeller. One shudders in thinking of the courage of this man in venturing to carry an incandescent fire immediately beneath his balloon inflated with hydrogen. But the many precautions which he adopted ensured him of safety.

The shape of his balloon was of a symmetrical cigar, pointed at both ends (Fig. 29). Its length was 44 metres, diameter 12 metres, the elongation thus being in the proportion of 3·5. Its volume was 2500 cubic metres, and it was inflated with coal-gas which gave him a lifting power of 1200 kilogrammes. The steam-engine, including boiler, weighed 159 kilogrammes, and developed 3 horse-power, giving a weight of 53 kilogrammes per horse-power. It was at that time a noteworthy achievement. The engine was inverted, to reduce the risks from fire, and was mounted on a platform attached by six ropes to a "strengthened beam" supported by slings connected to a net which covered the whole of the balloon except on its under side. This suspension, one can see, had the drawback of being possible of displacement. Moreover, the absence of the ballonnet did not secure permanence of the envelope's exterior form. On the other hand, the use of the long pole had the advantage of distributing, in a pretty uniform manner, the strain upon the whole of the aerostatic envelope. At the stern a triangular sail, manœuvred from the car, formed the rudder.

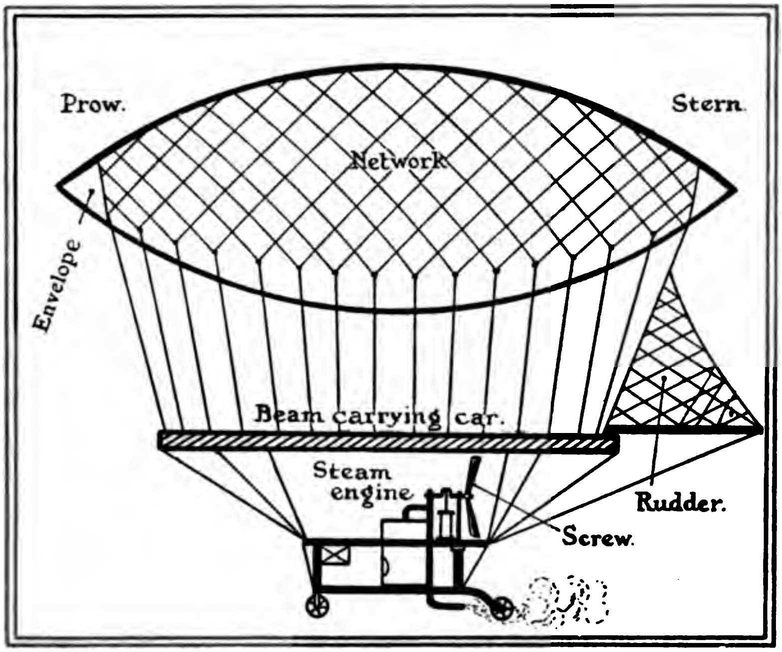


FIG. 29. Henry Giffard's steam-driven balloon (1852)

With this balloon Giffard carried out some experiments of the greatest value. True, the low independent speed (3 metres per second) which he obtained, in conformity with his calculations, did not permit him to navigate in the air in a circle: that is to fulfil an "aerial voyage";

but he was able to make some very neat evolutions, deviating at his desire from the direction of the wind, thereby testifying to the efficiency of his rudder. In a word, he succeeded in demonstrating, in an experimental and unquestionable manner, the possibility of aerial navigation by the aid of an airship furnished with a motor and a screw. His efforts justly belong, consequently, to the history of aeronautics.

DUPUY DE LÔME'S DIRIGIBLE (1872)

It is necessary to wait another twenty years to see a second rational effort in aerial navigation. This was that made by the illustrious marine engineer, Dupuy de Lôme, the inventor of the ironclad. Struck with the value of balloons during the siege of Paris, Dupuy de Lôme thought that this usefulness could be doubled if one were able, not only to leave the besieged capital as did the free balloons, but to return again at will! So he set to work to perfect a dirigible free from the disadvantages of Giffard's.

Notwithstanding the excessive weight of the human motor, he decided to rely upon the muscular energy of the passengers to move his screw, so as to avoid the dangers of the steam-engine. The balloon was fusiform, symmetrical, and pointed at both ends. Its length was 36·50 metres, diameter 14·84 metres, giving an elongation equivalent to 2·5. The volume of the envelope was 3450 cubic metres.

In the interior of the latter was placed an *air-ballonnet*; this, in short, was the first time that Meusnier's conception was realised. The volume of this ballonnet was a tenth of that of the balloon. Dupuy de Lôme did not pin his faith, in the use of the ballonnet, to the lines set forth by General Meusnier: he adopted the indeformable triangular network suspension. The screw weighed 75 kilogrammes, was 9 metres in diameter, and was driven by eight men. Under these conditions the stability was perfect, and in still air the balloon was able to travel at a speed of 2·25 metres per second—very nearly 8 kilometres per hour.

Conceived and calculated during the siege of Paris, the balloon was not built until 1872. It did no more than start at Vincennes, on February 2, 1872. Notwithstanding a violent wind, the stability was perfect, owing to the triangular suspension, and the airship was able to deviate 12 degrees from the wind's direction. This test had the merit of defining the essential points for the construction of dirigibles, and to show the possibility of obtaining, while travelling, an absolutely perfect stability.

DIRIGIBLE BALLOON OF THE BROTHERS TISSANDIER (1883)

Impressed by the qualities and regular working of the electric motor, and the absence of danger which attended its use, MM. Albert and Gaston Tissandier built, in 1883, a dirigible airship driven by an electric motor, for which the energy was supplied from a bichromate of potash pile battery.

The balloon, properly so-called, was fusiform, symmetrical, with the two ends pointed, and having an elongation equal to 3; its length was 28 metres, greatest diameter 9·2 metres, and its volume 1060 cubic metres. The netting, the cords and the knots of which, by their projection, offered such resistance to movement, was replaced by a suspension " cover." The very light screw weighed no more than 7 kilogrammes, and was set 10 metres from the balloon.

The motor (a Siemens dynamo) weighed 55 kilogrammes for a motive effort of 1½ horse-power ; the electricity was furnished by four batteries, of which each comprised six compartments, each forming a pile element. The reservoirs, raised or lowered at will by a system of pulleys, connected or disconnected the liquid exciter, which was an acid solution of bichromate of potash.

After a preliminary trip in October 1883, the balloon, in September 1884, sailed for so long as two hours at an independent speed of 4 metres per second: it was not able to go against the wind, but was able to complete numerous evolutions to the right or left of the direction of the latter. Stability was defective, owing to the absence of the ballonnet.

Be that as it may, the Tissandier balloon was the first dirigible driven by electricity; it opened a way which could be followed, and which might lead towards the definite solution of the problem of aerial navigation.

CAPTAINS RENARD AND KREBS' BALLOON "LA FRANCE" (1884 AND 1885)

It was at this time that Captain Renard, director of the military aeronautical establishment at Chalais-Meudon, in collaboration with Captain Krebs, and his brother, Captain Paul Renard, built a vessel which combined in its unprecedented type all indispensable features, and which realised all necessary requirements as much in the aerostatical as in the mechanical parts. This balloon is indisputably the starting-point of practical aerial navigation, and it has served as a model to all that have followed. Moreover, those who have digressed from the lessons furnished thereby have counted nothing else but failure.

This pisciform balloon (Fig. 30), with its larger end in front, was 51 metres long and 8·40 metres in maximum diameter, which represents an elongation equal to 6. Its volume was 1864 cubic metres. The envelope, of varnished Chinese silk, was built up of longitudinal gores converging towards the two points. The network was replaced by a "cover" formed of bands of transversal widths of silk sewn together at their edges, and so cut out as to follow the "geodesical lines" of the surface. The triangular suspension advocated by Dupuy de Lôme was discarded in favour of two oblique "cross-pieces" connecting with the front and rear of the car, and with the balloon cover suspension; those in the centre were parallel with them, and directly carried the car.

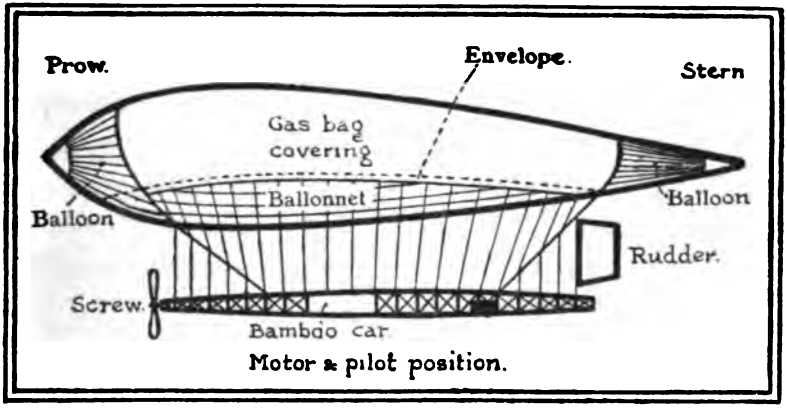


FIG. 30. Captains Renard and Krebs' balloon *La France* (1884)

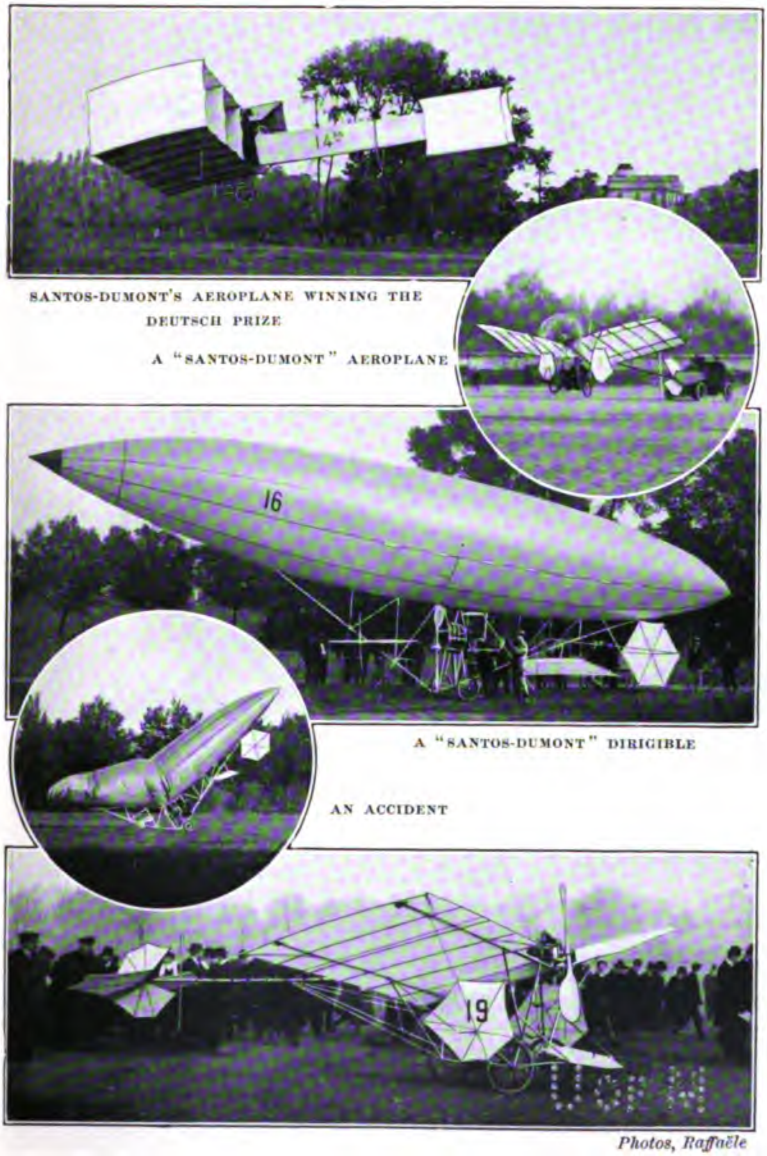
The vertical steering rudder was placed at the stern. It was a lath framework strengthened by two diagonals, and covered with a double sheathing of silk stretched to form its surface. At the rear of the car, moving about a horizontal axis, was an "elevating rudder" which inclined to the front or to the rear, enabling the balloon to be given an ascending or descending movement.

The design of the car was a completely new idea; its great length recalled the oar-propelled yawls used in regattas. It was built up of bamboo trellis, had a length of 32 metres by 1·30 metres broad, and a maximum depth of 1·80 metres. Its great length is copied to-day in the most successful dirigibles, such as the *Ville de Paris* and the *Clément-Bayard.* A "cabin," containing the motor and all necessary control, was placed forward.

The motor, built by M. Gramme, weighed 96 kilogrammes, and developed 9 horse-power. The energy was transmitted through a hollow shaft, the bearings of which were fixed to two flexible suspensions, to a screw placed at the *prow* of the vessel. This arrangement is likewise copied to-day in our most modern dirigibles. The screw was 7 metres in diameter, with a pitch of 8·50 metres, and weighed 40 kilogrammes: it made 50 revolutions per minute.

The electrical generator comprised a "chromium chloride" battery invented by Colonel Renard and was of extreme lightness. Each element was formed of a glass tube in which was a very thin platinum-silver electrode, in the centre of which was a zinc rod. The total weight of this accumulator was 400 kilogrammes, which represented 44 kilogrammes per horse-power.

PLATE XII



SANTOS-DUMONT'S AEROPLANE WINNING THE DEUTSCH PRIZE

A "SANTOS-DUMONT" AEROPLANE

A "SANTOS-DUMONT" DIRIGIBLE

AN ACCIDENT

Photos, Raffaële

THE LITTLE "SANTOS-DUMONT" AEROPLANE

The independent speed of the airship with this motive system was 6·50 metres per second.

The first ascent took place at Chalais on September 12, 1884. The balloon manœuvred with the greatest ease and returned under its own power to the starting-point.

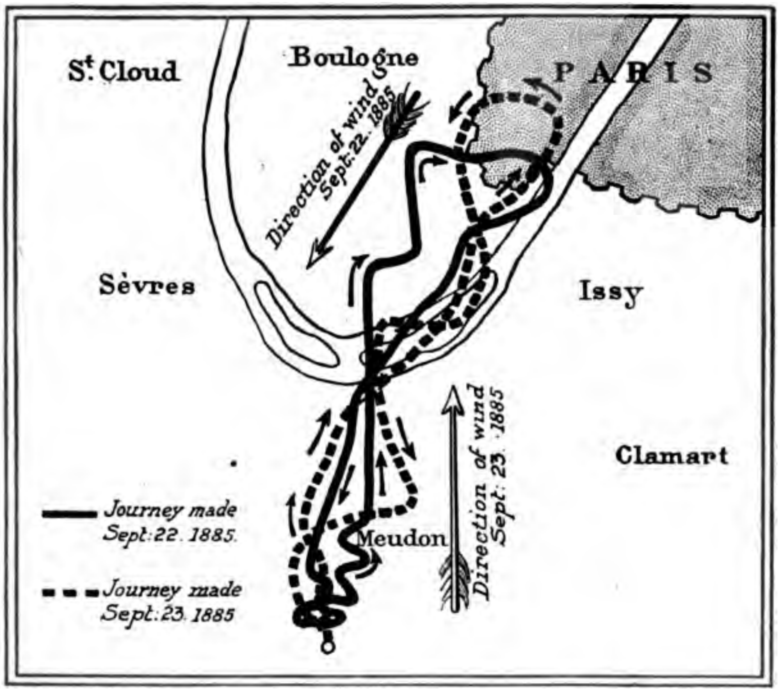


FIG. 31. The first two aerial voyages in a closed circle made by *La France*, over Paris, in 1885

This was a decided triumph, which echoed throughout the world. Three further ascents were made in the same year to tune up the apparatus. Then in September 1885 two historical ascents were held in the presence of General Campenon, Minister of War. *La France* left Chalais, described several evolutions *over Paris*, and returned to its *hangar* under its own power: *the first round* "*aerial voyage" there and back was accomplished* (Fig. 31): aerial navigation became an accomplished fact, the "highway of the air" was opened and aeronauts had only to fly.

THE ERA OF THE "EXPLOSION" MOTOR: M. HENRY DEUTSCH: M. SANTOS-DUMONT'S EXPERIMENTS

The Chalais-Meudon balloon was consequently the marvel of its day and undoubtedly with electric motors it was difficult to go farther in this direction; but a new mechanical engine had appeared creating a new industry and revolutionising the art of transportation: this was the "petrol motor." One man contributed as much by his efforts and his personal action as by his generous encouragements to popularising its exclusive use for aerial navigation. This was M. Henry Deutsch de la Meurthe.

So soon as it appeared he undertook the important task of showing the part the explosion motor was destined to fulfil; it comprised that marvellous accumulator of energy—petroleum spirit. From his youth he had been consumed by one obsession—the solution of aerial navigation. When he saw what Colonel Renard had done by the use of the electrical motor, he conceived the idea of using the petrol engine for aeronautical purposes, and as far back as 1887 demonstrated to the officers of Meudon the possibilities there were in extending their efforts towards this end. At the same time he ordered the constructors Mignon and Rouart to build an explosion motor upon the new lines, and in 1889, showed President Carnot the first petrol motor-driven carriage. Always reverting to his idea of steering balloons, he accordingly undertook to furnish the financial and material means to demonstrate its possibilities, in connection with his first idea: after expending considerable sums in actual research, he unhesitatingly offered numerous prizes to encourage the efforts of aeronauts and aviators. The "Deutsch prize" of £4000 certainly contributed much to stimulate their enthusiasm, and it is only an act of justice and acknowledgment to place the name of M. Henry Deutsch at the forefront of contemporary aeronautical history, the many conquests in which are undoubtedly due to the exclusive use of explosion motors.

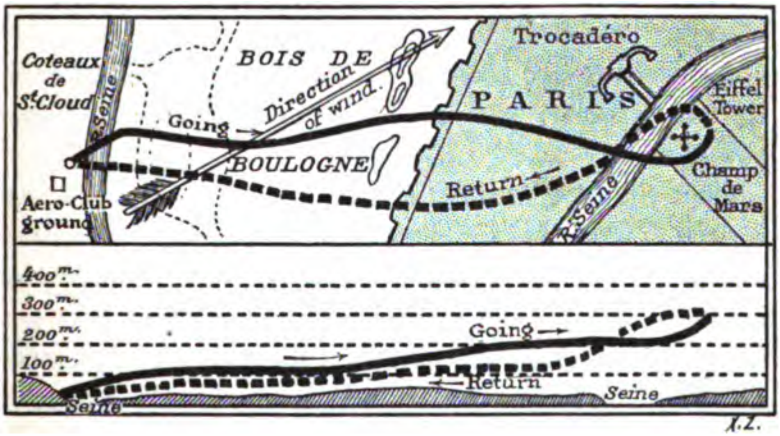


Fig. 32. Route and altitude map of Santos-Dumont's journey (the Deutsch Prize, October 1901)

It was M. Santos-Dumont who, on October 19, 1901, won the Deutsch prize, the conditions of which consisted in setting out from St. Cloud, doubling the Eiffel Tower, and returning to the starting-point within half an hour (Fig. 32). With an indomitable perseverance, an unheard-of audacity carried to intrepidity, the young Brazilian aeronaut built dirigible upon dirigible, some large, some small, some medium, and at last, after ten times escaping death, he succeeded in carrying off the much-coveted prize. His name became deservedly well known, more especially as a little later he lifted the first "Deutsch prize" for aviation. The airship with which he carried off these trophies, the Santos-Dumont No. 6, had an elliptical envelope of 33 metres length by 6 metres in diameter, and a volume of 622 cubic metres; there was an air-ballonnet of 60 cubic metres capacity, and his motor developed 16 horsepower.

Once the movement in favour of aerial navigation was started, it extended rapidly; on all sides surged inventors, not always alas! sufficiently proficient in theory or practice; not always prudent enough; not always profiting by the lessons given by their illustrious predecessors. The Brazilian Severo d'Albuquerque met his death in 1902 through his balloon exploding owing to the lack of foresight in the installation of his motor; in the course of the same year 1902, the engineer Bradsky was killed, together with his companion Paul Morin, owing to the defective character of the suspension of his dirigible, which, notwithstanding Colonel Renard's recommendations, did not include the ballonnet.

THE "LEBAUDY" BALLOON. "LA PATRIE"

These catastrophes did not damp the ardour of the aeronauts. But they made them more careful, and led them to realise the necessity there was for them to be thoroughly grounded in all questions touching aeronautics, if they desired to venture to build and test a dirigible. So in 1902, when MM. Lebaudy decided upon the construction of a huge airship, they secured the collaboration of a distinguished engineer, M. Juillot, and entrusted its erection to one of the most skilful "builders" M. Surcouf.

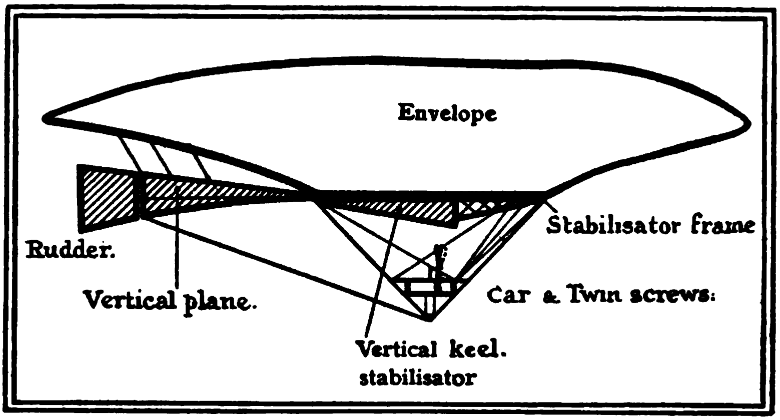


FIG. 33. The dirigible balloon *Lebaudy* (side elevation)

The *Lebaudy* balloon (Figs. 33 and 34), which the Parisians promptly christened the "Jaune" (yellow)

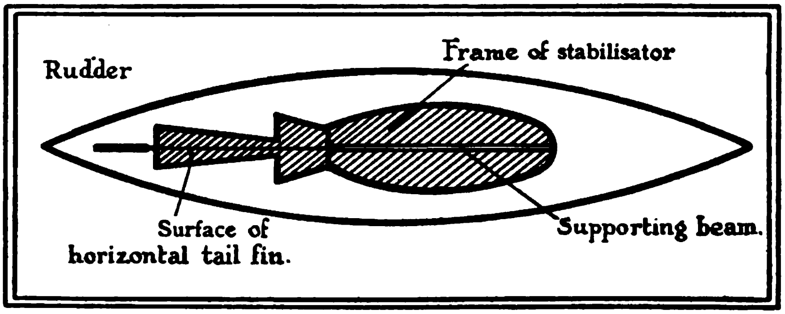


FIG. 34. The dirigible balloon *Lebaudy* (under-side plan)

owing to the colour produced by the varnish upon the external surface of its envelope, measured 58 metres long by 9.80 metres greater diameter : its elongation is consequently 5.6, and its total volume was 2300 cubic metres. It is dissymmetrical, the greatest diameter being forwards and is pointed at both ends. The body of the balloon is not completely "round," the lower part being cut by a section thereby forming a flat plane resting upon a *frame* serving as the suspension medium for the envelope and the car. At the same time, the flat form of this framing acts as a "stabilisating plane," which is efficient in use. Under this frame is a "strengthened girder," which, covered with fabric, forms a vertical stabilisating plane extended into a veritable bird's tail, a stabilisator in itself, and which is terminated by the steering rudder properly called.

The car is short, and the motor which is fitted therein transmits its power to two screws of 2·44 metres diameter, one being three, the other two, bladed. The propelling force is exerted therefore not at the extreme front, as in the *La France*, or at the rear as in the *Santos Dumont*, but about amidships. The short length of this car renders difficult the uniform distribution of its weight upon the envelope: also the latter has a peculiar "saddle form;" it is hollowed towards its centre in the manner of a saddle, due to the weight of the car imposed upon the central part of the envelope. This arrangement has its disadvantage in this sense, that the general form of the balloon is altered, and does not in practice conform to the principles which have served in determining the theoretical conditions of equilibrium and of propulsion. It is just to add that the efficiency of this balloon is remarkable. The air-ballonnet is divided into three compartments, to prevent the air surging towards the base in case the airship becomes tilted, and has a capacity of 500 cubic metres. The motor is of the Mercedes pattern, and develops 40 horse-power when running at 1200 revolutions per minute. An acetylene searchlight of 100,000 candle-power, mounted with a projector, facilitates landing at night.

PLATE XIII

Photo, Branger

THE "VILLE-DE-PARIS" IN ITS GARAGE

After a magnificent series of triumphant flights made in 1904, MM. Lebaudy in 1905 offered this magnificent dirigible to the Minister of War, who sent it to Toul. The State then decided to order a dirigible of the same "semi-rigid" type; this was *La Patrie.*

Save in some details, *La Patrie* was identical with the *Lebaudy:* its volume was increased by 200 cubic metres through extending the length by 2 metres; the ballonnet was 650 cubic metres instead of 500, and the motor built by Panhard and Levassor developed 70 as against 40 horse-power. Lastly, instead of ending in a point the stern was rounded and fitted with a cruciform "empennage" for the purpose of securing still greater stability. An elevating governor of two projecting planes was fixed to the front of the horizontal stabilisating framework. Otherwise it was a sister airship to the *Lebaudy.*

The life of the *Patrie* was brilliant but short. After it had proved its exceptional qualities such as no other airship had shown up to that time, after it had travelled under its own power from Paris to Verdun in seven hours without any incident on November 23, 1907, this magnificent dirigible some days after was caught in a gale which forced a descent. Despite the efforts of 200 soldiers the wind catching its enormous broadside surface tore the balloon from their hands, and bore it away in the storm. It passed over France and England, dropping pieces of its motor at different points on English territory, and disappeared into the North Sea, where it was perceived, still inflated, some days after the accident.

A new balloon of the same type, the *République* was ordered by the Government from MM. Lebaudy for the national defence. The *République* presents some remarkable features: the impermeability of its envelope permits it to remain inflated 110 days with one charge of gas. Its first flight, made in September 1908, lasted six and a half hours, and it covered over 200 kilometres in a closed circle. After the *Clément-Bayard* this is the most striking record of a complete trip without descent, and with return to the starting-point. The characteristics of the *République* are the same as those of *La Patrie* as well as the arrangement of the motor and "empennage." The *République* has been "militarised," and without a doubt will be employed for the defence of the eastern frontier. Lastly, a new military balloon, the *Liberté*, more powerful still, is under construction: it will be 67 metres long, of 2400 cubic metres capacity, and will be fitted with a 100 horse-power motor.

BALLOONS WITH HOLLOW STABILISATORS: M. DEUTSCH'S "VILLE DE PARIS": M. CLÉMENT'S "BAYARD"

All this time M. H. Deutsch de la Meurthe had not remained idle. Not content with merely having encouraged aeronautics, he wished to become a militant himself: he therefore had an airship constructed after the designs of M. Tatin. This vessel, not giving the expected results, he ordered a second in 1906, and for this secured M. Surcouf, who had become instilled with the ideas of Colonel Renard. For the first time he conceived an "empennage" of inflated ballonnets, which we have already described in discussing longitudinal stability. The body of the balloon (Fig. 35) is pisciform, with the master-diameter towards the front. The stern is connected to a cylinder carrying the stabilisating

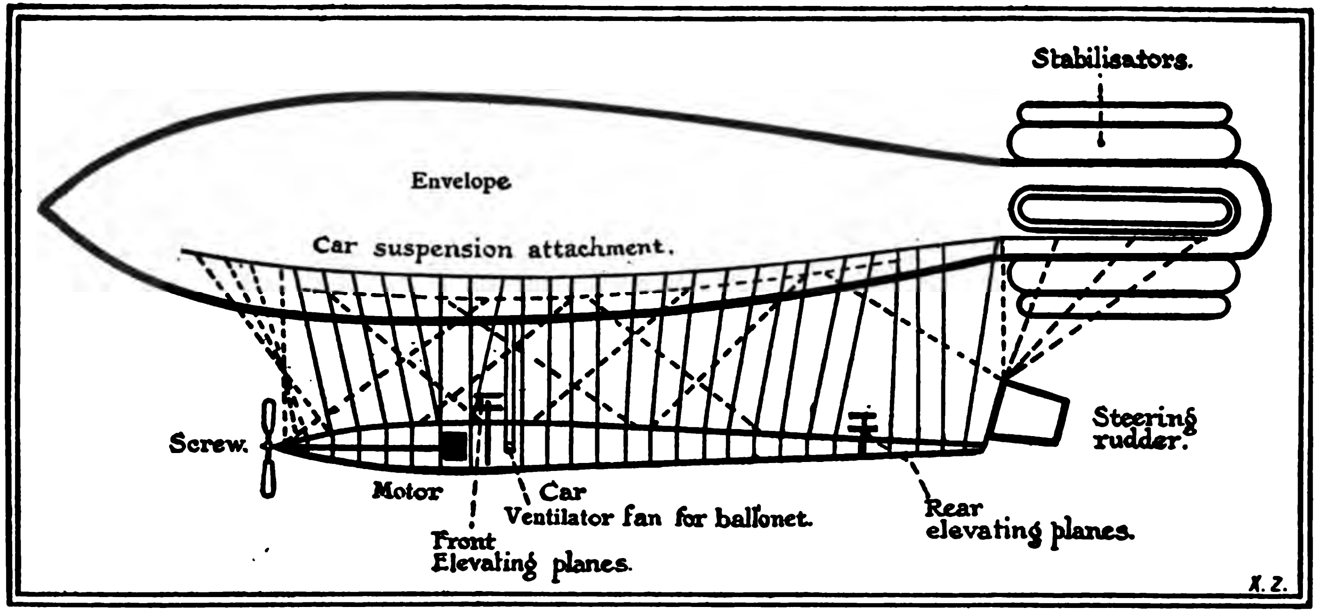


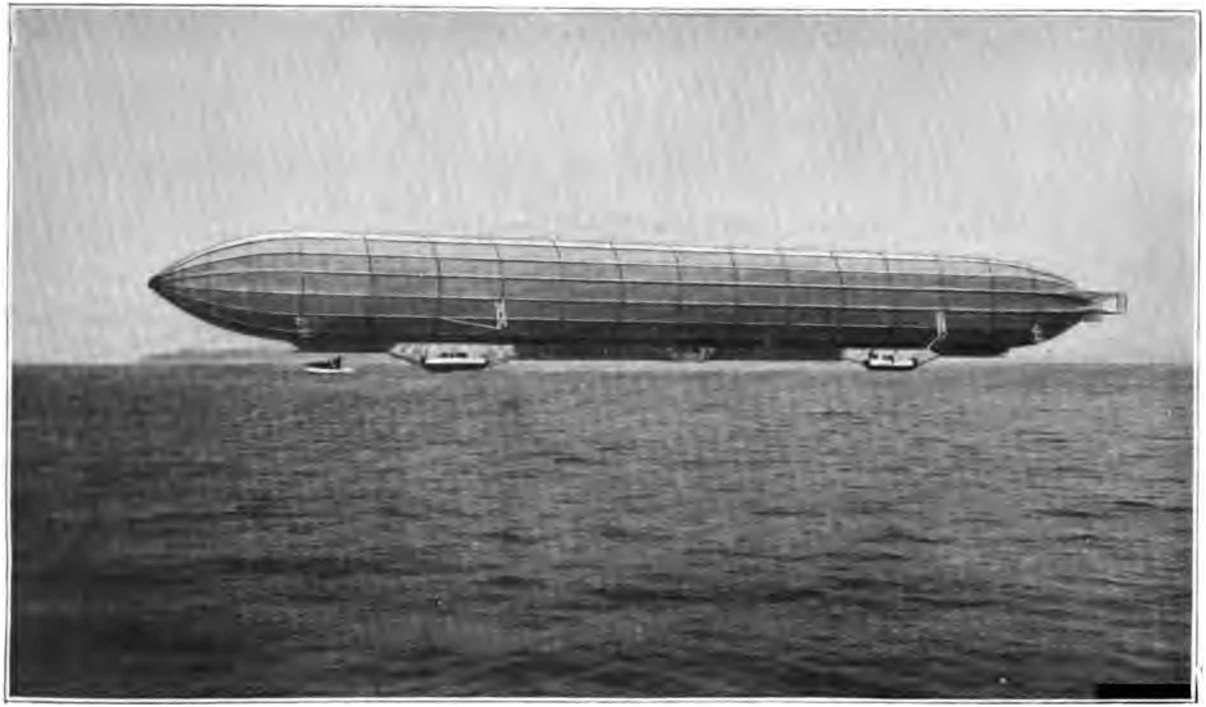
FIG. 85. The dirigible, *La Ville-de-Paris*, offered by M. Henry Deutsch to the French Minister of War

ballonnets. Its length is 60·50 metres; maximum diameter, 10·50 metres; volume, 3200 cubic metres. The car, lattice-work of metal tubing, is 30 metres long, and of the "strengthened girder" form. The ballonnet, divided into three compartments, has a volume of 500 cubic metres, and two rudders are attached to the car, one for steering laterally, and the other for ascent and descent. The 70 horse-power motor drives a two-bladed propeller 6 metres in diameter, running at 900 revolutions. The screw, placed at the prow in conformity with the ideas of Colonel Renard, makes, through a reducing gear, 180 revolutions per minute. This huge airship has accomplished successful flights, and it was on board this vessel that the Prince of Monaco, the eminent and learned navigator, who has surveyed and sounded the ocean, received the "baptism of the air," the highest altitudes of which he had previously scientifically explored in mid-Atlantic by means of "sounding balloons."

After the catastrophe which destroyed the *Patrie*, M. Henry Deutsch made a patriotic, generous offer; his balloon was ready; he submitted it to the Minister of War to take the place of the lost airship, and the *Ville-de-Paris* set out from Paris to Verdun, under its own power, to replace the wrecked dirigible. This voyage was made on January 15, 1908 (Fig. 36).

During the exploits of M. Deutsch's balloon, M. Clément, one of our best known automobile builders, ordered from M. Surcouf a dirigible of the same type, but a little larger—the *Bayard*. We have already described it in detail, so there is no need to do so again. Let us simply say that a new airship, the *Ville-de-Bordeaux*, has recently issued from the Surcouf works,

PLATE XIV



Photo, Rol

THE GERMAN DIRIGIBLE "ZEPPELIN" MANŒUVRING OVER LAKE CONSTANCE

and that its features appear to be in no way inferior to its contemporaries. Finally, another airship of the same type, the *Colonel Renard*, has been ordered by the Government for the national defence.

Count H. de la Vaulx has built some excellent small dirigibles of less cubical capacity with a very ingenious arrangement, consisting as we have already explained (page 43) in placing the screw between the balloon and the car, on a level with an intermediate beam. His dirigible, of small volume (720 cubic metres), is very manageable and has given excellent results.

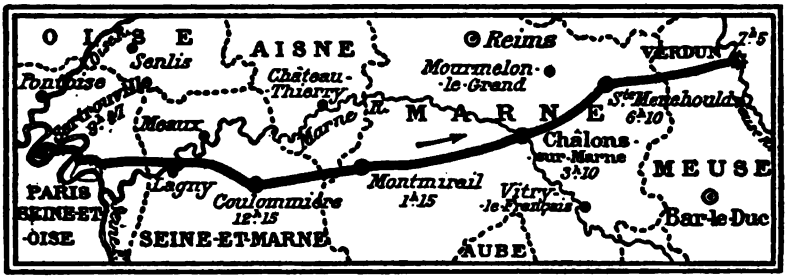


FIG. 36. Journey of the *Ville-de-Paris* from Sartrouville to Verdun (January 15, 1908)

FOREIGN DIRIGIBLES: COUNT ZEPPELIN'S AIRSHIPS

The attention of our neighbours across the Rhine was quickly drawn to the gigantic progress effected in France in aeronautical travel. They at once foresaw its military applications, and desirous of not being left behind, resolved to excel the French constructors in the building of a gigantic airship—" colossal " as it is colloquially called in Germany. It was Count Zeppelin who, with a dogged perseverance, an ardent patriotism, which one cannot but admire, concentrated his knowledge, his life, and his fortune, to the fulfilment of this idea. Moreover, it was shared and sustained not only by H.I.M. Emperor William II. and by H.I.M. the King of Wurtemberg, but also by national enthusiasm. He was advised by those admirable meteorological aeronauts who grace German science, and among whom figure Hergesell, Assmann, Berson, &c.

Conceiving an immense dirigible, he sought to secure indeformability or rigidity by *construction:* he designed a gigantic airship 130 metres in length by 11·70 metres in diameter, and with a capacity of about 12,000 cubic metres. Its form was of a cylinder having coned ends, the elongation being equal to 11 (Fig. 37).

Rigidity was secured by means of a metallic framework, in aluminium, which not only gave to the system the rigidity much sought after by its inventor, but he also divided the huge cigar into numerous compartments: 17 in all. Each of these is 8 metres long, except those 5 and 13, which corresponded to the two cars, and which are not more than 4 metres in length. The rigidity of the skeleton is secured by transverse partitions formed of cross-bracing covered with fabric. It may be seen that this balloon is not provided with a ballonnet.

Each compartment contains a balloon of india-rubber fabric partially inflated (nine-tenths only); the inflation of these 17 balloons is a lengthy and difficult operation.

The whole of the skeleton is covered with stretched fabric. The two cars are attached to the balloon in a rigid manner, and connected by a bridge, along which slides a counterweight. The two motors are of 170 horse-power, and drive four propellers of 1·30 metres diameter, running at 800 revolutions.

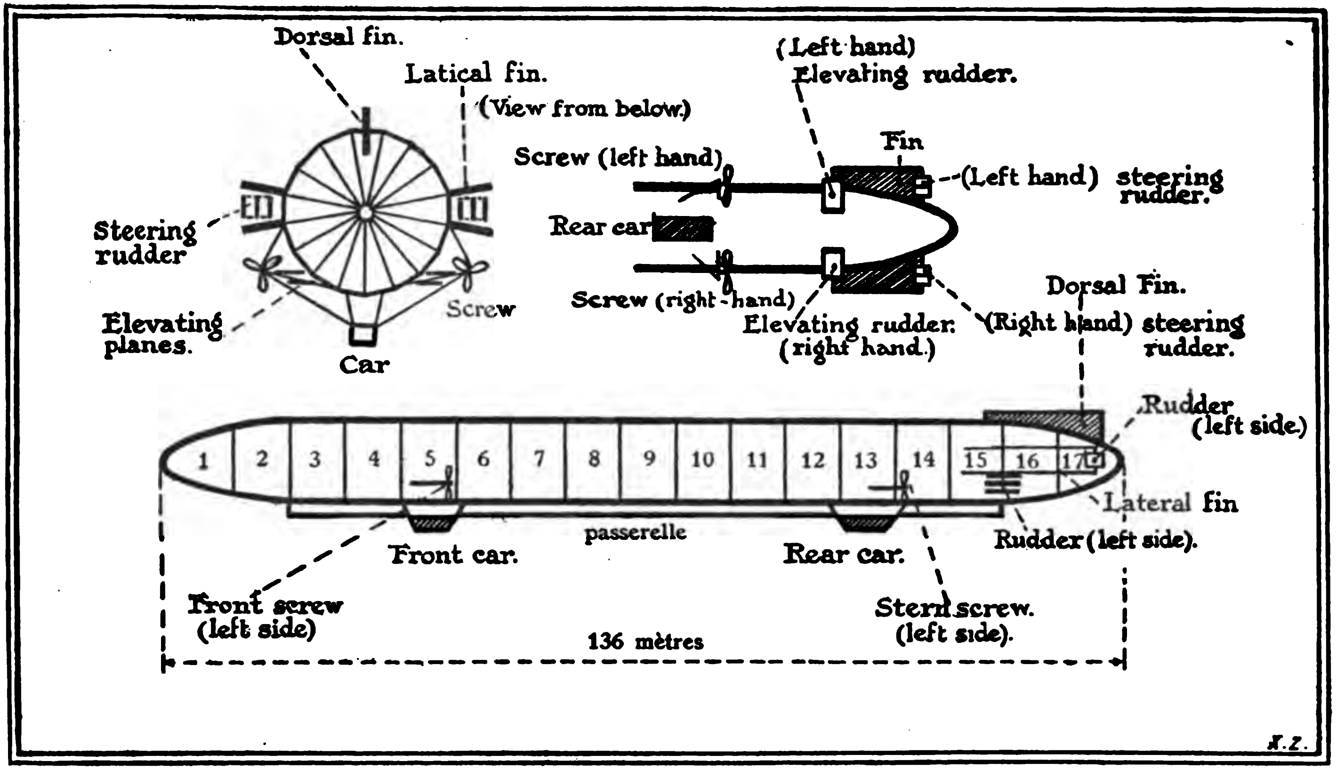


FIG. 37. The German dirigible *Zeppelin*

Such a mass is difficult, if not impossible, to handle upon the ground; so its sheltering *hangar* is a floating shed, anchored upon Lake Constance. This "dock," held only at one end by a powerful hawser, swings itself round under the action of the wind, so that the entrance is always to "leeward" for the emergence of the balloon.

Such is—or rather such *was*—the aeronautical leviathan. The German military authorities, as a condition of its definite acceptance, demanded the accomplishment of a *raid* of twenty-four hours "without descent or revictualling." It was during the summer of 1908 that this balloon, the fourth built by its learned author, attempted this official trip. After several short flights, carrying successively the King of Wurtemburg, the Queen, and some royal princes, the *Zeppelin* set out on August 4, 1908, from its *hangar* at Friederichshafen. There were twelve passengers on board. At 6.45 in the morning it rose above the lake and set a course to the East; it passed over Basle, where it veered round to the north; over Mulhouse and Strasburg, where the clanging of church bells and the salvoes of artillery heralded its passage; at 2.45 P.M. it was over Mannheim, when, before reaching Mayence, there was a slight "mishap." The fault repaired, the balloon resumed its journey, passing over Mayence during the night, and the return journey was commenced; at 6.30 A.M. it was south of Stuttgart. Some miles south of this town another accident necessitated descent. A squall struck the balloon, and from a cause still but little explained the immense airship was completely destroyed by fire in a few moments! This was a national loss for Germany, and in a magnificent outbreak of patriotism a public subscription raised in a few days the millions of marks necessary to replace the aerial vessel. Such is a beautiful example to be followed. During the erection of the new airship Count Zeppelin re-commissioned *Zeppelin No. III.*

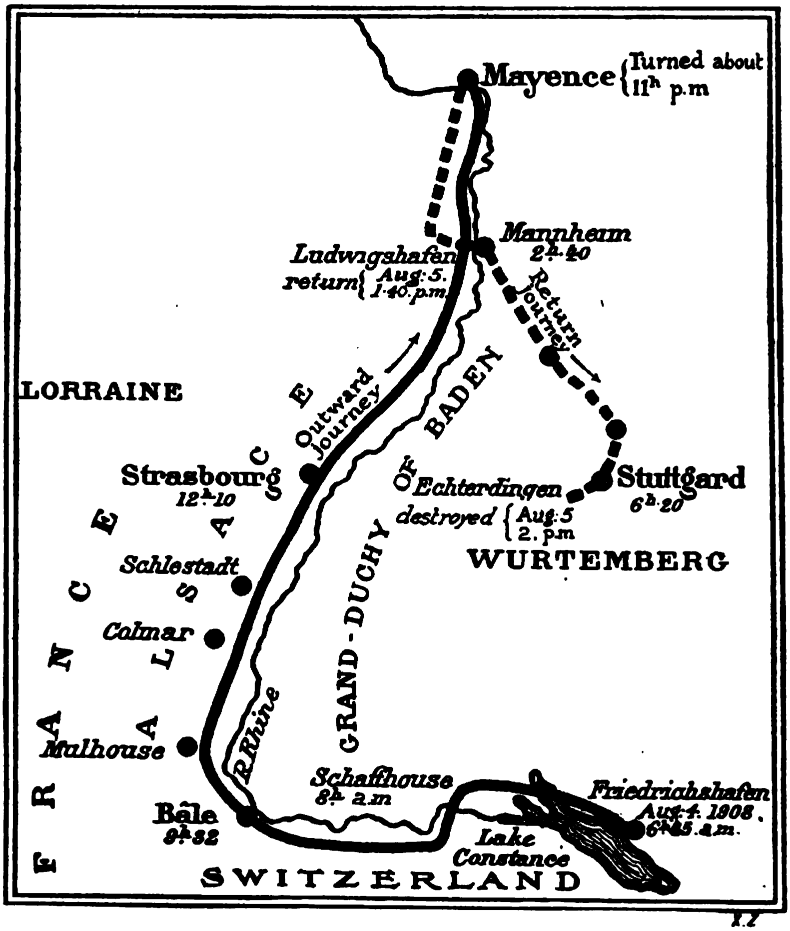


FIG. 38. Voyage of the *Zeppelin*, August 4 and 5, 1908 (606 kilometres, ending in the destruction of the airship)

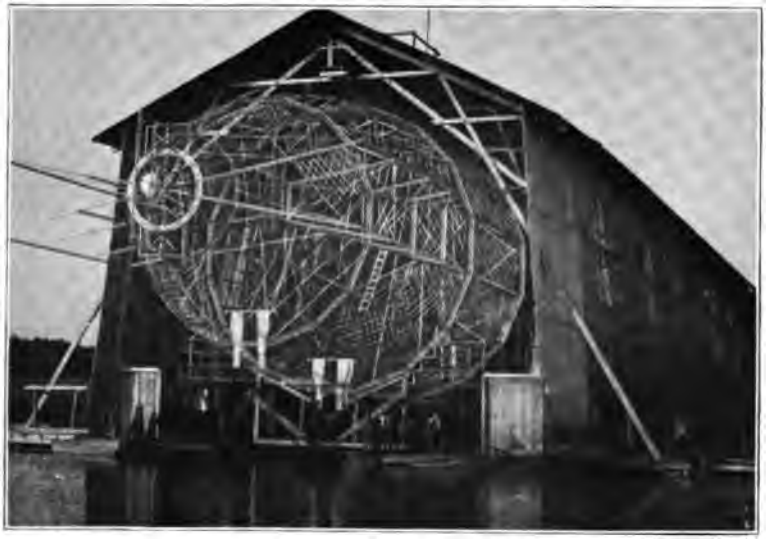
Yet *Zeppelin No. IV.* accomplished a magnificent performance: its voyage of August 4 and 5, 1908, covered as a matter of fact 606 kilometres, with two descents, and an actually travelling stay in the air of twenty hours forty-five minutes. With the new *Zeppelin* the record for duration and distance was excelled on May 31, 1909—1100 kilometres in *thirty-eight hours!* Unfortunately the difficulty of handling such a mass as this again proved disastrous, for the airship came to grief against a tree. Despite its injury it was able to return to its *hangar* after completing this magnificent journey.

Two other balloons, less bulky but more manageable, have been built by two German officers: MM. von Gross and von Parseval. These airships are non-rigid. The first made a beautiful flight *without descent*—thirteen hours. After having for a long time persisted in the adoption of airships of sausage form—*i.e.*, cylindrical with hemispherical ends—the German aeronauts have decided to revert to the tapering ends indicated by Renard. The *Gross* has even adopted the stabilisators of the *Lebaudy* and the *Patrie.*

In England military aerostation was represented by the construction of a vessel, the *Nulli Secundus*, trials with which, at first satisfactory, had an unfortunate termination. The career of this dirigible was short; but no doubt we are only staying further progress to produce at one stroke something striking.

In Italy Captain Ricaldoni has constructed a remarkable dirigible after the principles of Renard, which is one of the most perfect that has been realised up to the present. A Belgian sportsman, M. Goldschmidt, has built an airship bearing the name *Belgique;* it has two separate motors of 50 horse-power each, two screws, and capacity of 2700 metres; its length is 54·80 metres,

PLATE XV



Photo, Weyer

THE METAL SKELETON OF THE DIRIGIBLE "ZEPPELIN"

Photo, Branger

SEVERO D'ALBUQUERQUE'S RIGID DIRIGIBLE "PAX" DESTROYED BY FIRE IN PARIS (1902)

and master-diameter 9·75 metres; it can lift four persons, remain ten hours in the air, and travel at 40 kilometres per hour. Its radius of action is therefore 200 kilometres. Stability is assured by a cruciform stabilisator. This airship was constructed at the ateliers of L. Godard.

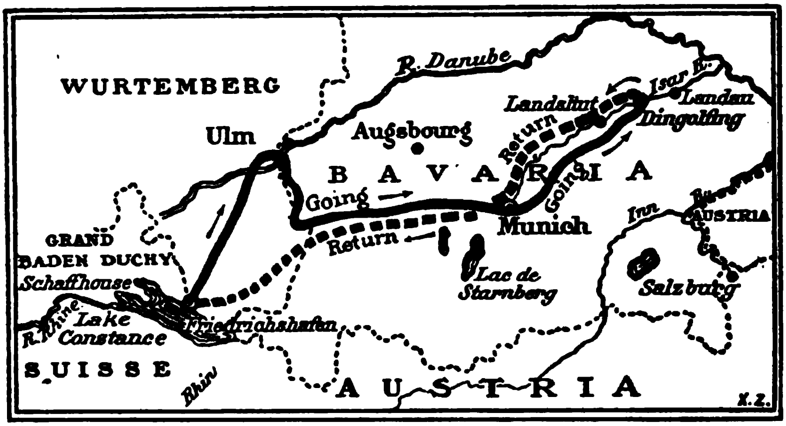


FIG. 39. Voyage of *Zeppelin III.* in a closed circle (April 1909)

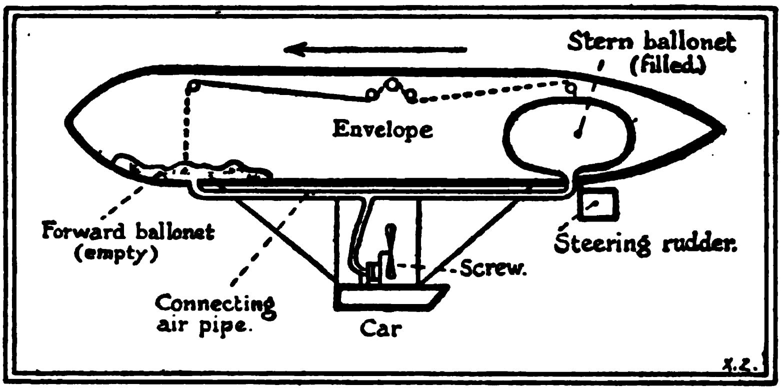


FIG. 40. The German dirigible *Parseval*

Moreover, an aeronautical construction society has been established in Belgium. Strongly supported, it has under way a powerful airship, *La Flandre*, of 6000 cubic metres.

COMPARISON OF DIFFERENT TYPES OF DIRIGIBLES: THE "CO-EFFICIENT"

We see many types of dirigible balloons, widely different from one another. Each corresponds, in short, to a new idea; each, one may say, indicates a development. But what is the net result? In short, which is the best airship?

The problem is complex, more complex even than in the case of vessels where there is something to go upon. I have accordingly attempted to resolve it, and I hope, even if it is not complete, at least to have introduced a new factor in aeronautics—the "*co-efficient of advantage*" of dirigible balloons.

To discover a mathematical formula combining speed with the shape of the aerial vessel, motive power, and dimensions of the propeller, is still somewhat impossible, there being many factors to take into consideration to formulate such a calculation. But, inspired with the example of Dupuy de Lôme in connection with steamships, I have sought to find an "empirical" formula. On the basis of results of experiments spread over a period of fifty years, the clever engineer evolved a formula called the "French marine formula," which has the advantage of simplicity.

By a slight modification I have applied it to aerial navigation. This is how: the power of the machine, expressed in horse-power, is taken, and divided by the number of square metres contained in the maximum section of the envelope. This gives a quotient, of which the

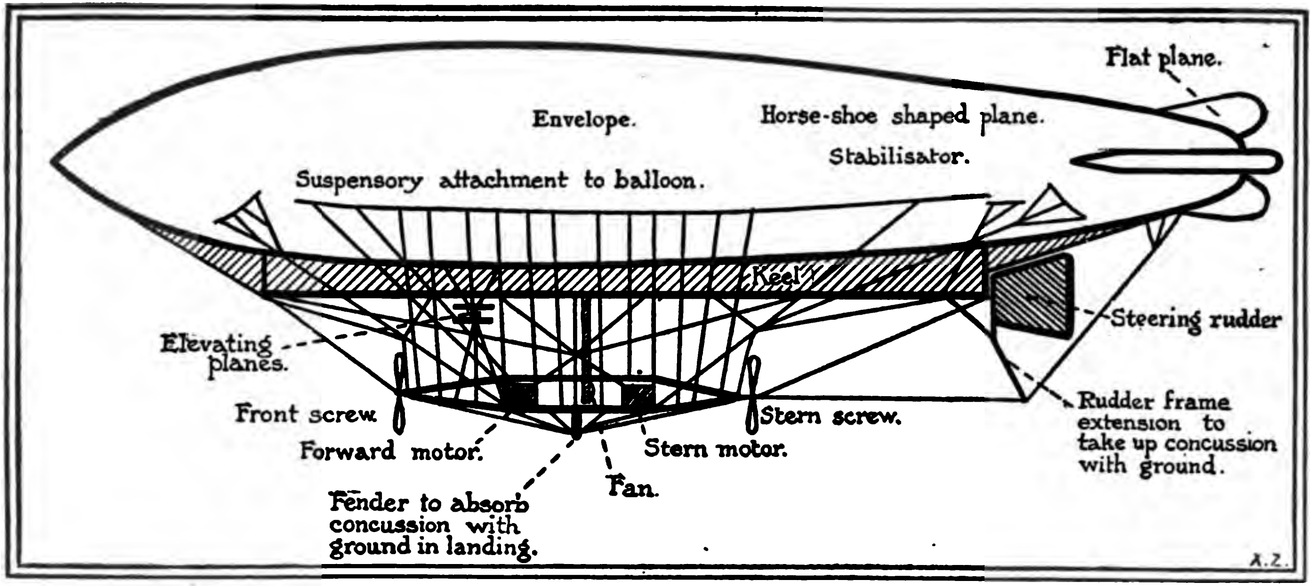


FIG. 41. The dirigible *Belgique*, with two propellers and twin screws

cube root is then extracted. The independent speed of the airship, expressed in myriametres per hour, is now divided by the above cube root: the result is a number, *always between 3 and 5*, which qualifies the airship—this is *its co-efficient of advantage*. The value of this number takes into consideration all characteristics which theory is still powerless to calculate correctly—shape of longitudinal section, resistance to air, efficiency of motor; as well as pitch, slip, and efficiency of propeller, &c.

In working with a number of dirigibles of which I have been able to obtain definite data, I have in every case been able to deduct an individual co-efficient, which is given in the following Table.

Therefore, by means of such a method of "classification," "rating" the balloons in their order of merit absolutely the same as if by trial, it is possible by means of the *indication of form* attached to each unit to compare one type with another. The more the co-efficient is in the neighbourhood of 5 the more advantageous is the airship, whereas its efficiency is inferior if the co-efficient drops below 4.

This simple method shows the superiority of Colonel Renard's ideas. The form of all dirigibles which does not follow that of the fish, which he maintained to be indispensable, have an inferior co-efficient. The *Zeppelin*, notwithstanding its huge elongation, reaps but slight advantage from its motor. On the other hand, *La France*, built twenty-five years ago, has an excellent co-efficient. The best are the *Patrie*, the *République*, and the *Italian* dirigible. Furthermore, the co-efficient 4 and 6 of our military balloons of the *République* type is additionally remarkable, inasmuch as these balloons

PLATE XVI

Photo, Rol

THE ITALIAN MILITARY DIRIGIBLE MANŒUVRING OVER BRACCIANO

Photo, Gesellschaft

THE GERMAN DIRIGIBLE "GROSS"

only have 60 horse-power motors, and always carry a large amount of disposable ballast—from 700 to 800 kilogrammes.

If it is pointed out that the co-efficients inferior to 4 affect all fusiform or cylindrical balloons, one may go further and say that *in all pisciform balloons having the greatest diameter at the prow, the co-efficient of advantage will always be between 4 and 5.*

DIRIGIBLE BALLOONS.

Name of Dirigibles.[1]	Section.	Proportion of length to diameter.	Horse-power.	Speed.	Value of coefficient C.
Giffard (F.) . . .	113	3·66	3	0·90	3·20
Dupuy-de-Lôme (F.) .	173	2·45	3	0·80	3·08
Tissandier (F.) . .	66	3·00	1·5	1·08	3·80
La France (Renard et Krebs) (P.) . . .	55·4	6·00	9	2·33	4·24
Santos-Dumont (F.) . .	27·9	5·50	16	2·70	3·26
Lebaudy (P.) . . .	84	5·60	40	3·25	4·20
Patrie (P.) . . .	93	5·50	60	4·00	4·60
Clément-Bayard (P.) .	90	5·00	100	4·50	4·31
République (P.) . .	93	5·50	60	4·00	4·60
Zeppelin (Cyl.) . .	106	11·00	170	4·00	3·47
Parseval II. (P.) . .	68	5·00	100	4·20	4·04
Militaire Italien (P.) .	90	5·00	70	4·50	4·90

WHAT ARE THE IMPROVEMENTS TO BE EFFECTED IN AIRSHIPS?

An independent speed of 45 kilometres per hour may therefore be considered fulfilled by airships commercially constructed to-day. This speed enables them to set out

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[1] (F.): fusiform; (P.): pisciform; (Cyl.): cylindrical.

in the vicinity of Paris with the certainty of being able to cope with the wind, and to steer in all directions for, on an average, about 300 days during the year. Such is a remarkable achievement without a doubt, but it is not sufficient.

A speed of 70 kilometres per hour, that is 20 metres per second, must be attained to enable them to go out on the average 350 days during the year; the impossible days would thus only number fifteen per annum, and these would be wildly tempestuous days. Will it be possible to attain these speeds, and to increase the velocity from 13 or 14 to 20 metres per second? Such will probably be reached, but it will be difficult, since it will be necessary to employ more powerful motors. Calculations show that if 13 metres per second are obtained upon a certain airship with 100 horse-power, it will be necessary to use about 450 horse-power to give the same vessel a velocity of 20 metres per second; undoubtedly the motive power must be divided between two engines and two propellers. Thus a much more powerful motor, that is to say heavier, would have to be used, consuming four times as much fuel, and the aerial vessel's radius of action would be decreased. The balloon itself would have to be provided with a stronger and heavier envelope, to be able better to resist the greater thrusts that the increased speed would bring to bear upon its surface. Perhaps it would even be necessary to resort to compartments, which would increase the weight still more.

The solution of high speed demands consequently that airships shall be far larger and carry far more powerful engines. But then another point arises, that of the resistance of the air, which is proportional to the square of the speed. Again, the balloon will assume an inclination, and will lift its nose slightly, the action of the air will tend to lift the envelope as it lifts a kite, and one consequently reflects whether, in the case of an airship of large dimensions, the naturally rising balloon, travelling at a certain speed, would not be able to sustain itself in the atmosphere without aerostatic intervention by the Archimedean thrust, solely by the effect of the velocity of the air upon its suitably inclined surface; in other words, whether it would not be advantageous under these conditions to dispense with the "aerial float."

Colonel Renard calculated that, with an airship of the dimensions of *La France*, this result would ensue when the speed attained 72 kilometres per hour. In that case there would be no more need for the encumbering, expensive, and dangerous hydrogen, and we would rise into the air under a purely mechanical effort by an apparatus *heavier than the air*.

This brings us to the study of this second form of aerial navigation which has so brilliantly commenced in the form of the *aeroplane*.

PART II

AVIATION APPARATUS

CHAPTER I

THE PRINCIPLES OF AVIATION

THE "HEAVIER THAN AIR" PROBLEM: BIRDS AND KITES: THE PROBLEM OF EQUILIBRIUM: HOW IT CAN BE OBTAINED: DIFFERENT FORMS OF AVIATION: THE AEROPLANE

WHAT IS AVIATION?

AVIATION is the art of lifting and propelling through the atmosphere a body "heavier than the air," by utilising the resistance offered by the gaseous element to the movement of the bodies which are plunged therein.

If the first successes of mankind in aerial navigation were due to the invention and use of aerostats, undoubtedly his first ambition was to emulate the birds, which themselves are "heavier than the air." As a result it required centuries of intellectual struggle to conceive the physical principles upon which are based the action of the aerostat, whilst Nature placed under our eyes the birds, those marvellous travellers of the air. Consequently it may be affirmed that it was aviation which from the first haunted the minds of those ambitious to travel through the atmosphere.

To-day the solution has been found, and although bearing in mind that mankind has not yet realised in a satisfactory manner the solution presented by the birds, yet the problem has been resolved by three quite distinct types of flying apparatus. These are—

The *Ornithoptères* (sometimes called orthoptères), apparatus having flapping wings to imitate the birds' method of propulsion and sustentation;

Hélicoptères, apparatus which simply uses the action of screws, as much for sustaining as for moving and steering in the air; and finally,

Aeroplanes, utilising by large oblique surfaces the resistance of the air for their sustentation under a horizontal speed imparted by a screw-propeller.

Ornithoptères have only been rarely tried. Hélicoptères, very fascinating at first, are now relegated to a second position. Only aeroplanes, the study of which has only been pursued really rationally during the past two years, have developed with such rapidity, and furnished such convincing proofs of their practical value during the past twenty-four months, as to enable it to be affirmed that they have at last solved the problem of aviation. Consequently we shall devote the following pages almost exclusively to their study.

HOW BIRDS FLY

Before commencing to discuss aviation, such as it has been to-day fulfilled by man, it is indispensable to examine somewhat, aviation as practised by birds, those inimitable natural aviators, the Latin name of which (*avis*, bird) has moreover provided the appellation of the new trans-atmospherical locomotion.

Being heavier than air, birds sustain themselves therein by utilising the resistance of this element to their movement, which resistance, as we have seen in speaking about "dirigibles," is proportionate to the moving surface, and increases as the square of its speed. Birds oppose to the air very large "sustaining" surfaces, called wings; they have an organ, the tail, for balancing and guiding, and the complex movements of their wings which, striking the air, secure therein a fulcrum which enables them to propel themselves forward.

The flight of birds, which for a long time appeared mysterious, but as Marey's works completely elucidated, is effected in three distinct forms.

There is, first of all, the *oary* flight, wherein the birds flap their wings both to keep themselves up and to move about as desired.

Then, there is the *soaring* flight, which the bird practises when, hurled on at a great speed, it ceases flapping its wings, only spreading them out, and, by virtue of their large surface, gliding on the resisting molecules of the air, having only to steer while moving forward; it is this phase of the bird's flight which the aeroplane imitates.

Lastly, certain large birds, such as the albatross and the frigate-bird, practise the *sail* flight, in which, without muscular effort, they depend upon the varying wind velocities, the "squalls" which occur in the atmosphere. When the bird feels the speed of the wind increasing, it faces the latter, and with wings outspread allows the wind to bear it along, both in ascension and progression. When it feels that the squall has reached its maximum speed, and is about to decrease, it turns round and glides, owing to the velocity and altitude it has acquired with the wind behind; during this gliding it can attain and maintain high velocities, therein bringing into practice the soaring plane; when it feels a new squall coming, it turns round again, head to the wind, and the same cycle of operations is repeated. In this manner it utilises the wind velocity variations without any muscular efforts other than those necessary for reversing from time to time, and with that marvellous animal instinct, cleverly profiting by the fluctuating inequalities of the intensity of the successive squalls, will even manage to "gain upon the wind."

Whence come these squalls? So long as one is near the surface of the ground, it may be admitted that they originate from the varying reflections of the horizontal wind by the projections promiscuously scattered about constituting the terrestrial surface; but it has often been proved that such squalls exist at great atmospheric altitudes. What, then, is the cause? Would they be due to fluctuations in the intensity of solar radiance, according as to whether more or less opaque clouds interrupt the passage of the sun's rays, and thus produce unequal heating of the atmospherical masses?

Until careful observations are made, by aerostatic means, concerning this phenomena, vital to aerial navigation, one cannot but be satisfied with the fine conception of the dynamical state of the atmosphere, set forth by a clever French engineer, M. R. Soreau, an old pupil of the Ecole Polytechnique, President of the French Aerial Navigation Society, and a man whose excellent theoretical studies have perhaps most contributed to the "unravelling" of so complex a question as aviation.

M. Soreau compares the centre of the atmosphere with that of the free surface of the ocean, always traversed by "wave" systems obeying rhythmical well-determined laws, and the "swell" of which is the most commonplace and simplest manifestation. According to this clever engineer, the atmosphere would be the seat of analogous aerial waves, communicating to the gaseous masses, isochronous vibratory movements, the progress of which would be so much the more regular because they would be, at such an altitude, too distant from the ground and its projections for their regular propagation to be susceptible to confusion. It is from these "atmospherical waves" that the bird would profit in most cases of sailing flight.

Will this sailing flight ever be accessible to man? Taking into consideration the more and more powerful, and at the same time lighter and lighter, motors, which he constructs, will man ever be in a position to obtain its realisation? For my part, I do not think so. But it is interesting to bear in mind this variety of flight, which we see practised by birds having a large spread, the "great sailers" as they are called, which cut the air above the ocean, the fury of which is let loose by the tempest. Even then, they will utilise those "ascending currents of air," caused by the reflection of the prevalent wind upon the oblique slopes of the immense waves of the Atlantic and of the Southern seas, where the height of these liquid hills reaches 16 to 18 metres: this would explain why, by resorting to this sailing flight, these "birds of the tempest" always keep quite close to the disturbed surface of the ocean.

As to the "circular" flight practised by birds of prey, this is a soaring flight; and sometimes when these birds are seen rising, gaining height whilst describing their majestic rings—as does, for instance, the buzzard—it is because in so doing they utilise an ascending current of air, which is often produced in summer above ground particularly heated.

Thus, when soaring, the bird moves without effort. But a deep study of its movements shows that its wings fulfil two distinct functions: propelling and sustaining surfaces respectively; and it is especially the extremities of the wings which propel the animal, the middle part serving principally for sustentation.

Why has man not sought for the solution of the problem of aviation merely by the imitation of the flight of birds? It is because human thought has conceived, has realised, a more general and more efficacious mechanical movement than those which exist in Nature; this is *rotary motion*, of which Nature does not offer us any example, except in regard to celestial bodies. But there is a reason for this; it is because all living beings being liable to growth as time progresses, their propelling organs must lengthen freely, in proportion to this growth; this would not always be possible in combination with rotary organs.

Man has therefore sought—and success has shown that he did so with reason—to accomplish high travelling speeds on land and sea by means of revolving apparatus: wheels, screws, turbines, &c.; he has thus been able to attain and to exceed the speed of the fleetest of animals. Now, why should not what is good on land and sea also suffice for the air? We do not construct motor-cars with jointed feet nor transatlantic boats with fish fins. We can therefore seek for propulsion in the atmosphere otherwise than by flapping of wings, and if we use these *wings* for sustentation we must at least direct ourselves to machines and revolving propellers to move in the Aerial Ocean.

THE ANCESTOR OF THE AEROPLANE: THE "KITE"

The excessive weight of the "human motor," a weight which approximates as we have seen (page 8) about 1000 kilogrammes per horse-power, appears to forbid man the realisation of flight, by the use of his muscular power; the failure of all those who have tried to solve the problem of aviation in this manner may therefore be easily explained.

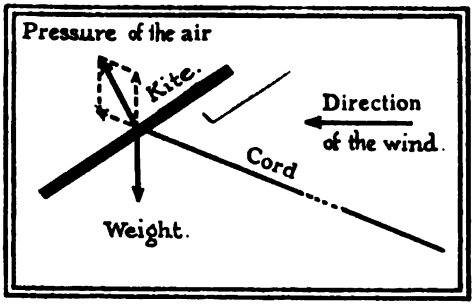


FIG. 42. Equilibrium of the kite

But from time immemorial man has found a means of raising in the air bodies "heavier than air," and the "kite," this toy which in the course of a few years has become one of the most valuable instruments of scientific investigation, has been known in China and Japan from the most remote times.

It is scarcely necessary to define the kite, which we have all handled, more or less; it is a rigid frame of wood and strings, on which is stretched a surface of cloth or paper; a string holds the apparatus to the ground, and when the wind reaches a sufficient speed, the contrivance lifts itself into the air; if the surface of the kite is large enough, it may even lift objects—meteorological instruments or photographic apparatus.

The equilibrium of the kite is easily explained by the combination of the forces which bear upon it (Fig. 42). The surface exposed to the wind is, in fact, kept "oblique" in relation to the direction of the latter.

The molecules of air, in striking against this slanting surface, exert a pressure upon it which, as is proved by calculation and verified by experiment, is perpendicular to this surface, and tends to lift it. This is one force to which the apparatus is submitted. There is a second, which tends to cause it to fall towards the earth; this is its *weight*, which acts vertically from top to bottom. There is, finally, another; this is the *tension of the cord*, the resistance of which acts as a check against the thrust of the wind. The pressure, resulting from the action of the current of air upon the surface of the kite, divides itself into two elementary actions: one is directed from bottom to top, and combats directly the thrust of the weight; the direction of the other is opposed to that of the cords, and is therefore always destroyed by the latter, which one takes to be sufficiently resistant, and not to break under the effort to which it is subjected.

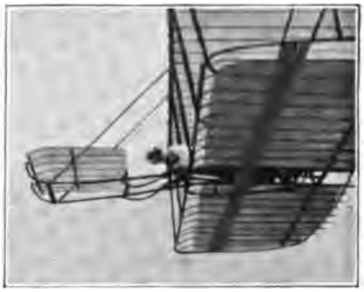
Under these conditions, the contrivance is in equilibrium. Let one of the above forces be varied, and equilibrium will be disturbed immediately. If it is the wind that increases, its pressure becomes stronger, the vertical force increases, and the kite rises. If, on the contrary, the wind did not change, and the weight of the apparatus should unexpectedly be augmented as, for instance, if it should rain, the kite falls. Lastly, if the third force is annulled, that is, if the cord breaks, the kite is borne away by "the wind."

Such is a very simple case of an apparatus, which lifts itself by utilising two forces: (1) the resistance of the air; (2) the tension of a cord, which may maintain the surface exposed to the wind. There must, of course, be a wind to lift the contrivance. Now there are some

Photo, Malcuit

M. ADER'S "AVION"

THE "AVION" WITH WINGS FOLDED



WRIGHT MAKING AN AERIAL GLIDE

OTTO LILIENTHAL GLIDING

days when there is no wind. What is to be done then? Children, the traditional operators of the kite, do not allow such a small trifle to stand in their way. There is no wind? Well, "they make some," by running as quickly as their legs will carry them, for it must not be forgotten that wind is not an absolute thing! It is the *relative* movement of the air in comparison with a body, and this movement may take place, either if the air is in motion and the body motionless, or if the air is still and the body moves rapidly in it. It is for this reason that in a motor car one has a sensation of "wind" even when there is none. And children, by following these instinctive actions, in one stroke invented and realised the *aeroplane*.

DEFINITION AND ELEMENTARY EQUILIBRIUM OF THE AEROPLANE

An aeroplane, in fact, is nothing but a kite which "creates its own wind," to accomplish which, the string is replaced by a motor, and a screw which gives it a speed equal to what the wind would have to be to support it like a kite, were it retained by a cord. The *tension* of the cord is replaced by the *power of propulsion* (Fig. 43), and the conditions of equilibrium are, at least fundamentally, quite as simple as those of the kite. An aeroplane will therefore be composed of a *supporting surface* divided into one or two parts, which are often called the *wings*, cutting the air in an oblique manner by means of a *propeller* and *motor;* it will be connected to a *skiff* or *car*, in which will be the aviator, the motor, and the mechanism for steering, comprising at least two "rudders"; one a "steering rudder," to go right or left, and the other an "elevating rudder," for ascending or descending.

The motive power propelling the apparatus, the surface of which cuts the air in an oblique manner, compels the gaseous molecules to glide under this surface; they therefore exercise a *resistance* upon it, the effect of which is a perpendicular *pressure* upon the movable plane. This pressure may be replaced by two other forces; one vertical, which tends to lift the contrivance, by annulling the effect of its *weight*, which would tend to make it fall; the other, horizontal, directed towards the stern, and tending to retard the speed of the apparatus. Therefore equilibrium is realised when the speed due to the motive power is sufficient for the thrust to be able to lift the weight of the apparatus. This speed is thus called the "critical speed," and the aerial vehicle will continue its travel in a straight line so long as the forces which act upon it retain their relative values.

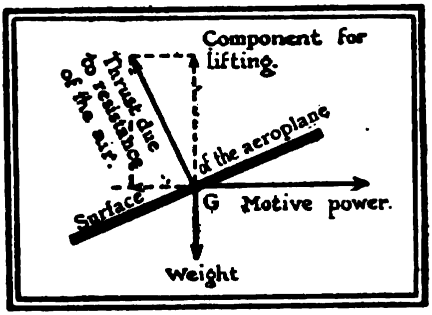


FIG. 43. Equilibrium of the theoretical aeroplane

But if any one of the considered forces should change, the equilibrium will be immediately destroyed. For instance, if the speed of propulsion increases, the pressure also increases, and therefore also the resultant vertical lifting component. The weight not changing the equilibrium is destroyed and the apparatus will rise; it will, on the contrary, descend if the speed of propulsion decreases; it will also descend should the "supporting surface" for some reason or other be diminished, in the same manner as it will rise, if the weight of the apparatus becomes less, which occurs during a journey, on account of the consumption of the fuel feeding the motor.

The very simple conditions of equilibrium which we have examined are, therefore, precarious, and the problem must be investigated a little more closely to seek the conditions answering the requirements of current practice.

RESISTANCE OF THE AIR: ANGLE OF ATTACK: CENTRE OF THRUST

To learn exactly what will happen when the regulating speed becomes varied, we must hearken back for a moment to the laws of the resistance of the air, which are fundamental in the matter of aviation.

Let us consider (Fig. 44) a movable surface, inclined in the direction of its advancing movement. The resistance of the air increases proportionately to the spread of this surface, in proportion with the square of the speed at which it is driven, and increases at the same time as the angle at which it is inclined to its trajectory, and which is called the angle of attack. Consequently, if this angle is very small, the resistance will be very slight; but on the other hand, the lifting effort will be a more considerable proportion of the thrust (Fig. 45, No. 1), whereas the resistance to advance will be a fraction less. If the angle of attack increases (Fig. 45, No. 2), immediately the thrust becomes stronger, but the proportion of this thrust, which constitutes the lifting power, decreases if more inclined on the vertical, whilst increasing that opposed to advance.

It will, therefore, be necessary to seek the *optima* value of the angle of attack. Calculation and experience agree that it must always be very small.

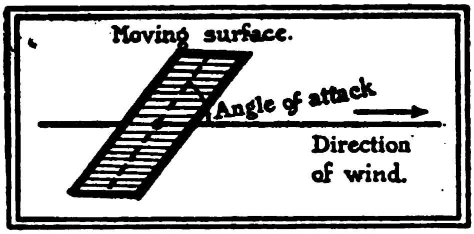


FIG. 44. Resistance of the air upon a slanting surface

But a more uninterrupted study of the resistance of the air upon a surface inclined in motion, shows us something even more important. We have supposed, in the elementary explanation which we have given of the conditions of equilibrium of an aeroplane, that this was absolutely symmetrical, and that all the forces which act upon it were applied to a common point G, which would be its *centre of gravity.* In practice, things do not happen so simply.

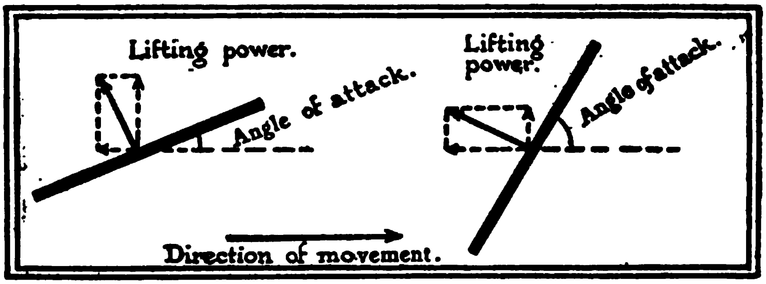


FIG. 45. Influence of the angle of attack

In reality the point of the moving surface where the pressure is applied, a point which is called the "centre of thrust," does not coincide with the centre of gravity; it is the nearer to the front edge of the moving surface, as the angle of attack is weaker. This is what experiment demonstrates: if one moves forward perpendicularly through the air a flat surface, which squarely cuts the molecules (Fig. 46), the phenomena are symmetrical, and the thrust will be exercised at the centre of gravity itself; but if the moving plane is inclined (Fig. 47), the gaseous molecules have much more difficulty to rise up under the cutting edge than to go downwards to gain the other side. The thrust will therefore be greater on the front extremity up which they are forced to travel, and the centre of thrust will be nearer the front edge.

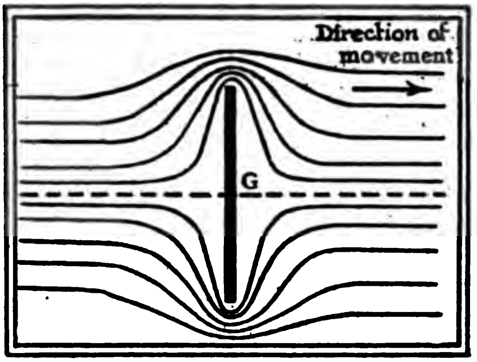


FIG. 46. Flat surface advancing normally through the air. The air molecules gliding symmetrically around the ends

This position away from the centre of thrust alters the conditions of equilibrium of the aeroplane, and affords us some data concerning construction.

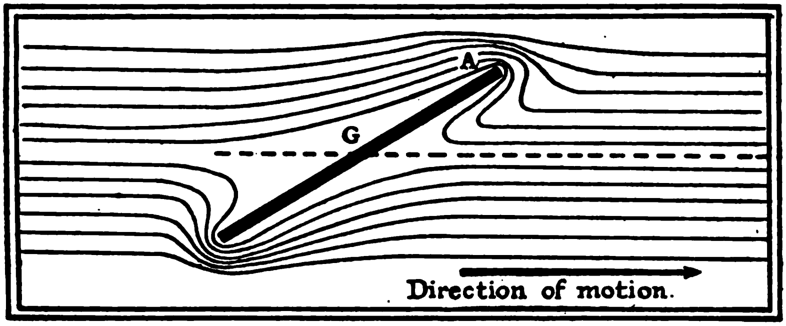


FIG. 47. The surface advancing obliquely through the air. The gaseous molecules gliding past in a dissymmetrical manner

Let us consider an aeroplane (Fig. 48) progressing with a very small angle of attack. The centre of thrust will, as we have just seen, be brought forward to a point near the front edge. The lifting effort applied to this centre will therefore no longer be directly opposed to the weight, the latter being always applied to the centre of gravity. The disposition of the two forces will therefore tend to cause the surface of the aeroplane to turn in the direction indicated by the curved arrows shown in the figure.

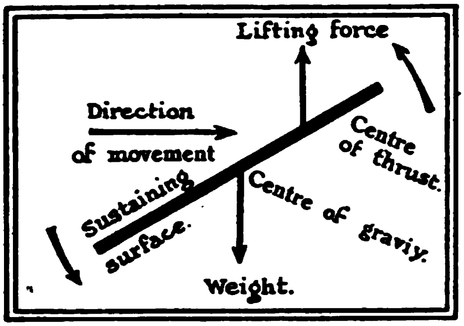


FIG. 48. Equilibrium of the actual aeroplane

Moreover it is necessary to observe that the position of the centre of thrust is not fixed, it varies for each value of the inclination of the aeroplane, and advances more towards the front as the angle of attack is made sharper. This is not all; let us suppose that, through an accident or even an incident on the way, the moving surface should incline towards the bottom; the air would then strike from above, and this would mean a certain rapid and fatal fall. A means must therefore be found for readjusting the aeroplane when it inclines in the direction of its length; this means is the "feathering" or empennage.

The empennage will comprise a surface placed well to the rear of the sustaining surface (Fig. 49) to which it will be joined by a "connection" which, being light, rigid and latticed, offers only a minimum of resistance to the air. Under these conditions, under the influence of the thrust applied forward of the centre of gravity, where the weight acts, the aeroplane would tend to turn as shown in Fig. 48, in such a manner that it would have its stern lowered towards the ground; but the thrust which is exercised upon the empennage, a thrust acting with the aid of the long "lever arm" represented by the rigid connection, lifts and brings the apparatus back to its lawful incline, in accordance with the calculation concerning its dimensions and motive power.

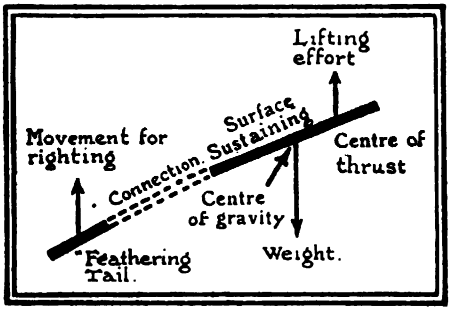


FIG. 49. Action of the empennage

In the same manner a "fringe" (Fig. 50) not very high projecting towards the stern of the sustaining surface would become "effaced" behind the front during the journey with a normal incline; but if the apparatus were to become inclined towards the bow, the air striking this fringe which would find itself unmasked by the accidental lowering of the bow, would act upon it, and this action, bearing on the stern, would lower it, and would restore the aeroplane to its normal incline. It may therefore be seen from these two examples that it is possible to give an aviation apparatus an automatic longitudinal stability.

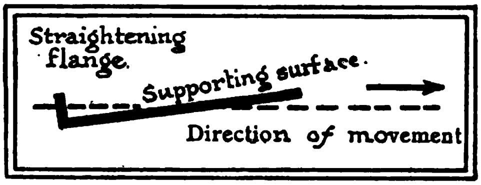


FIG. 50. Action of a vertical "fringe" at the stern

Let us remark that kites for a long time past have been fitted with this very simple means of longitudinal stabilisation; they are, in fact, provided with a *tail.* This does not only serve as a counterweight to the stern; a piece of lead at the bottom of the framework would answer this purpose without ensuring stability. The tail acts as a true stabilisator, and kites *must* be provided with it; we shall, however, return to this subject in the course of the next chapter. There is one other question, also vital for balancing the aeroplane; it is transversal stability. But in this question, the shape of the wings, dimensions, even the construction of the apparatus, are inferred as being known. Therefore we will here conclude this explanation of the general principles, to see, now, how they are applied to the conception of a projected flying machine.

CHAPTER II

APPLICATION OF THE GENERAL PRINCIPLES

From theory to practice: The wings: Monoplane or biplane: Stability, and the means for realising it

SHAPE AND DISPOSITION OF THE WINGS

We have seen, by what effects of the resistance of the air, a flying machine may be sustained in the atmosphere. We must now see in what manner we can most advantageously utilise these effects.

First of all, must flat or concave wings be used? This is the first question one asks. If we take as example the wings of birds, which are their sustaining surfaces for soaring, we notice that they are always concave underneath. Since the first attempts at aviation, constructors, therefore, have always sought to build wings distinctly concave, the concavity being turned towards the earth. Experience has shown, moreover, that a slightly concave surface towards the bottom gives to the aeroplane, for the same speed, a lifting power much superior to that obtainable where the flat surface was carried right to the extremities. Further, M. R. Soreau, in a very fine calculation, has shown that for any concave wing a flat surface may also be determined, which would act as if it were connected with the concave surface in a rigid manner, and the bearing power of which would be the same as that of the concave surface, but that, at the same time, the concavity introduces a "counter-resistance" to advance, in other words, a force of reaction which slightly increases the propelling force by acting in the same way.

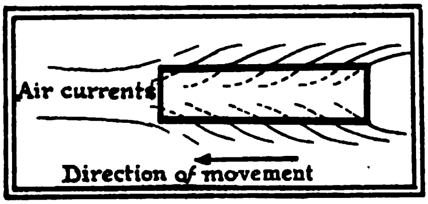


FIG. 51. A long and narrow surface

Calculation and experience being, therefore, in agreement in the recommendation of concave surfaces, these are what we shall employ in the construction of aeroplanes.

Moreover, the wings will be elongated and disposed at right angles to the length of the flying body.

For this purpose imagine a wing, a rectangular shape, measuring 2 metres by 4 metres, viz., 8 square metres (Fig. 51). If we cause this surface to move in the direction of its length, the currents of confined air struck by its front edge, after having barely crept beneath the wing, will escape under the edges to which they are in close proximity, and will no longer contribute to sustentation. If, on the contrary, this same wing be moved on its broader edge (Fig. 52) the currents of air cannot escape sideways, because they are pressed back by their neighbours, with the exception of those which are at the extreme edges. In this second arrangement, all the currents thus contribute to sustentation. Our wings,

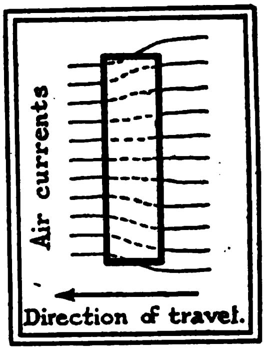


FIG. 52. A short and wide surface

which we have already been induced to make slightly concave, will therefore be disposed transversely.

This transversal arrangement of the supporting surfaces, moreover, is what we find with all the birds and flying insects; in birds particularly the "spread" of the wings is always considerable. (Fig. 53.)

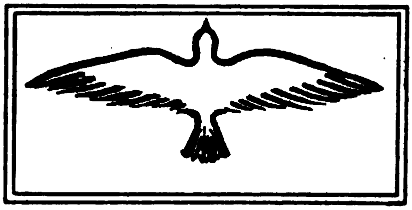


FIG. 53. Spread of a bird's wing

Besides, no matter what may be the extent of this spread, the supporting surfaces can be disposed in a horizontal manner, or form between them an angle more or less open, in the form of a very obtuse upright or overturned V ; this disposition of the wings in a V has been adopted notably by Captain Ferber for his aeroplane, whereas the wings of the Wright aeroplane are straight.

"SUSTAINING CAPACITY"

Now arises a very important point, which Colonel Renard introduced into the study of aviation, viz., the principle of "sustaining capacity."

Let us remark, first of all, that in any attempt at aviation there are two very distinct things. There is, first of all, the "sustentation" of the apparatus in the air, and then *propulsion* in a given direction. Now propulsion only requires very slight motive power, on account of the feeble density of the resisting centre; the principal effort to be made is that which must be expended for sustaining the apparatus in the air, or, in other words, to realise a power of lifting equal or superior to its weight.

Let us imagine an *orthogonal* aviator system, that is to say, one in which the lifting effort is achieved by surfaces vertically striking the air from top to bottom (like pistons in vertical cylinders, for instance); let us suppose that this contrivance weighs 100 kilogrammes, and has a total sustaining surface of 50 square metres; its load per square metre will be 2 kilogrammes. The *work of sustentation*, under these conditions, would be equal to what would be necessary to lift the apparatus with a speed, according to experiment of 4·90 metres per second.

Let us now suppose another aviation apparatus, conceived upon different ideas, and not belonging to the "orthogonal system," about which we have just spoken, but which, like it, had a total weight of 100 kilogrammes. The orthogonal apparatus, with its 50 square metres of surface, to sustain itself requires a work equal to that which would have to be expended for lifting its weight of 50 kilogrammes at a speed of 4·90 metres per second. If the new system, to sustain itself, requires a surface greater than that of the first—for instance, 75 square metres instead of 50—we say that its *sustaining capacity* is 0·66; it is therefore weaker. If, on the contrary, 40 square metres are sufficient, always under the same weight and work, to realise its sustentation, we shall hold its principle of construction as superior, and say that its *sustaining capacity* is 1·25.

The aeroplane, attacking the air slantingly, is a manner as simple as it is elegant for improving the capacity for keeping up; in the same manner, the lateral disposition of the supporting surfaces, their concave form towards the bottom, particularly improve this capacity.

MONOPLANES AND BIPLANES

We are led, by virtue of what has been said, to take light sustaining surfaces of a great superficies if we wish to raise a perceptible weight, as, for instance, a motor, propeller and aviator. Let us suppose that the calculation based upon the data of experiments shows us the necessity of a bearing surface of 50 square metres. Will this surface have to be employed in the form of a single transversal wing, or of two wings, or even three superimposed? Under these conditions the transversal "spread" is decreased, which, as regards the encumbrance of the apparatus and its working efficiency, may constitute an advantage; in other words, will the aeroplane be a "monoplane" or "multiplane"?

Birds are obviously monoplane, and they are, moreover, excellent monoplanes. Everything would therefore tend to design our aeroplanes as monoplanes were there not kites to recommend multiplanes, or at least biplanes; and the indications of this popular toy must not be neglected, for, as Captain Ferber has so truly said, "the kite is an anchored aeroplane." In fact, if the old kite is a monoplane, the "tail" constituting the stabilisating empennage, the modern kite is always at least a biplane, and the following will show by what series of trials one has been led to adopt this disposition, which experience has shown to be very advantageous.

Let us consider a kite (Fig. 54 A) which we are flying in a very steady wind. So long as we do not seek too great a height, the apparatus will behave beautifully. But if we wish it to go higher and higher it must not be forgotten that as we unroll the cord it has to bear a proportion of the always increasing weight. There will, therefore, be a height limit above which the weight of the unrolled cord will exceed the carrying surface, resulting from the thrust of the air upon the cloth of the kite, and the latter would fall. An arrangement, as simple as it is old, can then be employed, consisting of an auxiliary kite attached at an intermediate point of the main kite cord, which will thus support a proportion of the cord's weight. Such a contrivance will be able to rise to a much greater height than a single kite. The two kites may be placed a short distance apart, or be brought very close to, and parallel with, one another (Fig. 54 B), or they may be so made up as to form prisms covered with cloth; it is upon these lines, indicated by the Australian Hargreaves, that the modern kites of children (Fig. 54 C) are built, and those, larger and better constructed, which are used by meteorologists for carrying registering instruments into the upper atmosphere.

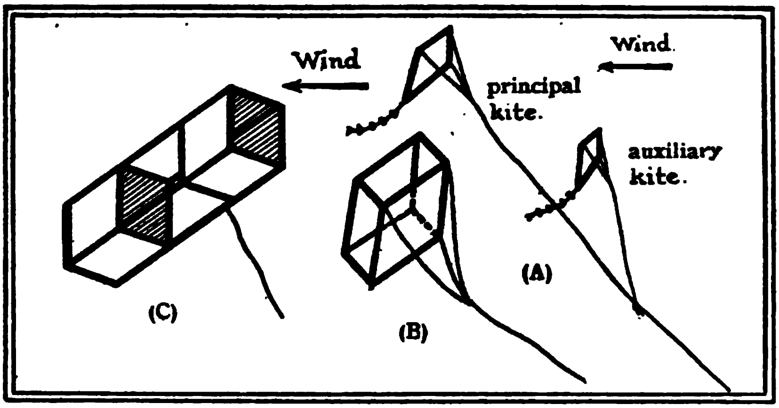


FIG. 54. Evolution of the cellular, from the multiple, kite

The "cellular" kite of Fig. 54 C is nothing else but a biplane aeroplane, provided with a "feathering tail," which secures its stability.

We can therefore distribute our supporting surface upon two superimposed parallel planes; such is the design of the Farman, Delagrange and Wright aeroplanes, whereas those of Blériot, Esnault-Pelterie, Gastambide, Santos-Dumont, and the "Antoinette" are monoplanes.

Naturally we can make triplanes or quadriplanes, but one must not proceed too far in this direction, as there would result a "pile of planes," the stability of which would be precarious. Here, as in all things, the happy medium must be found. An inherent objection to multiplane construction must, however, be pointed out; the rigid supports which connect the planes together present a large surface of resistance to the air, and for this reason monoplanes are much their superior.

LATERAL STABILITY: TURNING

We have obtained the longitudinal stability of the aeroplane by the use of the "feathering tail." But lateral stability must also be secured; in other words, the wings of the apparatus must not incline from right to left, or *vice versâ*, during travel; at any rate, if such an incline were perchance to occur, the apparatus must be constructed in such a way that it rights itself by its own effort.

Now an aeroplane must be considered in two phases of movement; that in a straight line and that in a curved line, otherwise called "turning."

In the case of the straight line movement, the lateral stability is, if not ensured, at least very adequately fulfilled by the spread of the supporting surfaces, the stretch of which counteracts sudden inclination. Moreover, the centre of gravity of the contrivance is always below the supporting planes (or the surface which would be equivalent to them) on account of the weight of the motor and passenger, a weight which would tend to right the apparatus if it were to incline unexpectedly.

But this is no longer the case when, describing a curved line, the aeroplane is turning. Then there intervenes a complex phenomenon which causes it to incline "within" the turn, that is to say towards the centre of the circle which the machine describes. This phenomenon is the unequal resistance of the air upon the two extremities of the supporting wings.

Let us consider an aeroplane (Fig. 55) turning about a centre, and let us suppose, to obtain a proper idea thereof, that the spread of this aeroplane is 10 metres; the circle which the centre of the machine itself describes will have, consequently, a radius of 15 metres. It is seen that, under these conditions, the extremity A of the wing turned towards the centre will describe during a certain time the arc of the circle AA′, in passing from position (1) to position (2), whilst the outer extremity B of the same wing will describe, *during the same time*, the arc of the circle BB′, double the length of AA′. The exterior extremity B must, therefore, travel twice as far during the turn as the interior extremity, that is to say, in one word, go at twice the speed of that of the inner edge, A; and as the resistance of the air is proportionate to the *square* of the speed, the result is that the interior extremity A, moving less quickly, will be subjected to a

PLATE XVIII

Photo, Raffaële

M. SANTOS-DUMONT'S FIRST TRIAL (AEROPLANE WITHOUT MOTOR TOWED BY THE "RAPIERE")

Photo, Raffaële

M. SANTOS-DUMONT'S FLOATING AEROPLANE

THE GASTAMBIDE-MANGIN MONOPLANE IN FULL FLIGHT

lesser resistance from the air, and therefore will be less "sustained" by the air than extremity B. Therefore, *during the turn, the aeroplane must incline itself more and more towards the centre of the circle which it describes, as the radius of the turn is decreased.*

We can confirm this by figures, and in a very simple manner. If the speed of the outer wing is 20 metres per second, that of the inner wing, in the example we have selected, will be only 10 metres. The lifting efforts will therefore be no longer equal, but will be between them in the proportion of the square of 20 with the square of 10, that is in a proportion of 400 to 100. It is, therefore, seen to what degree the equilibrium will be destroyed. It is true that an aeroplane will never have to make so "short" a turn, and we have purposely selected an extreme example; but such always exists, and lateral incline must absolutely be guarded against while turning.

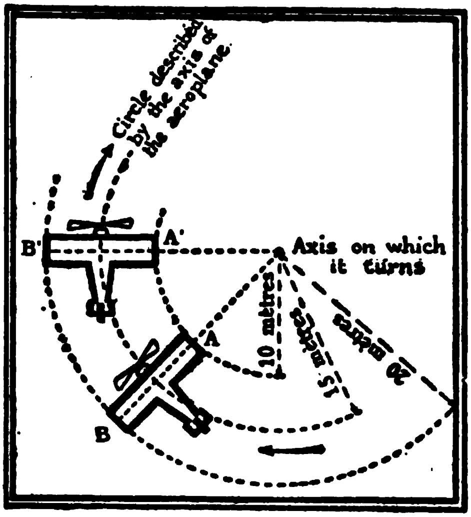


FIG. 55. An aeroplane turning

This natural incline, however, has its advantage; it appreciably counterbalances *centrifugal force,* which is unavoidable in any curvilinear movement, and is the more important in the aeroplane inasmuch as the surface of lateral resistance of the latter is weaker. Major P.

Renard even proved that inclination of the aeroplane was essential to combat the centrifugal effect. This inclination lowers the trajectory. Therefore, aviators must rise a little before making a "turn," if after doing so they desire to retain their previous altitude.

PRACTICAL MEANS OF PREVENTING LATERAL INCLINE: "AILERONS," PARTITIONS, WARPING

At all events, it is indispensable to keep up the horizontal supporting surface as much as possible throughout the trajectory, whether it be rectilinear or curvilinear. Several means may be utilised for this purpose.

First of all there is a very simple one, which I am surprised at not having seen experimentally used, or at least tried, as it seems very rational to me. Since the "lateral inclination" is a result of the unequal resistance on the two extremities, let us equalise these resistances; we cannot prevent speeds from being unequal during turning, but we can cause the supporting surfaces to vary in the opposite direction; we can increase the surface at the "inner point" A (Fig. 55) and decrease it at the outer point B. For this purpose it would suffice to carry at the extremity of the wings, varying surfaces, either arranged in the form of a fan and able to fold up in the same manner as birds' feathers, or of sliding ribs, one drawing back under the sails and the other extending by as much again. The surface of the inner wing which dips would thus be increased, while simultaneously that of the outer wing which rises would be decreased, and it would reduce the difference of the thrusts, that is to say, the cause of the inclination. These two movements could be produced automatically by a simultaneous movement of the steering rudder.

The celebrated American aviators, Wilbur and Orville Wright, have adopted another arrangement, "warping of the wings." The following shows in a few words how this is done.

The extreme angles of their aeroplane can be moved up or down (Fig. 56) absolutely like the "corner" of a visiting card. As the Wright aeroplane is a "biplane," wooden battens lift up the corners disposed one above the other at the same time, so that when a corner of the upper wing is lowered the corner of the lower wing placed below the first is also depressed. The whole is governed by a manœuvring lever pushed or pulled by the aviator, and when the corners on the left are forced down those on the right ascend, and *vice versa*. Under these conditions, it is easy to see how this arrangement permits of lateral inclination being dispensed with. A turn is taken, and the aeroplane has a tendency

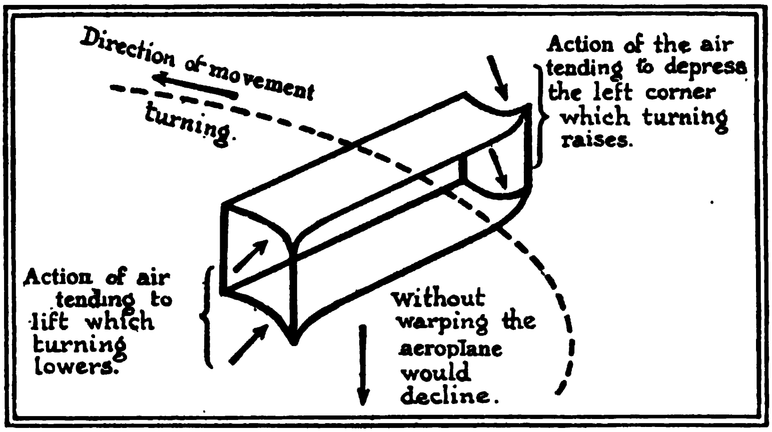


FIG. 56. Principle of warping the planes (Wilbur and Orville Wright)

to incline inwards; but the aviator immediately manœuvring his lever, lowers the corners on the inside of the turn and elevates those on the outer edge. And then, as is shown in the diagram, the effect of the air on the corners thus offered to its action rights the apparatus.

M. L. Blériot, the French aviator, evolved and adopted on his aeroplanes some time ago, long before the arrangements of the Wright Brothers had become known, a very reliable system, quite as ingenious, which does not require the wings to be deformed by warping: there is at each extremity of the fixed wings of his aeroplane, small subsidiary moving wings (Ailerons) (Fig. 57) capable of being inclined in relation to the surface by turning about a horizontal axis. When turning the small wing on the inside is lowered in the interior and that on the outer wing is raised; the effect is the same as by warping the wings, but this arrangement has the advantage of not bringing about any elastic deformation of the frame; this deformation, unavoidable in warping, must inevitably end in endangering the indispensable solidity.

These various arrangements for righting are governed by the aviator; it is therefore necessary for him to secure the readjustment of the apparatus himself to perform a special movement, completing that which he makes in steering to right or left when manœuvring the flier by the rudder. But an *automatic stabilisation* independent of the will of the conductor, and fulfilled by the construction of the aeroplane itself has been sought for; it is this solution which has been simply obtained by the Voisin Brothers, the French constructors who built the aeroplanes celebrated by the exploits of the aviators

Farman and Delegrange. The arrangement employed by them is "partitioning" (Fig. 58) and applies to multiplane aeroplanes. It comprises the introduction of rigid vertical partitions between the two parallel bearing surfaces. These partitions, owing to the resistance they offer to the air, oppose any deviation due to centrifugal force, and the surfaces combining with the supporting wings, add resisting effort to combat the lateral inclination which thereby becomes practically eliminated. The aviator, owing to this principle of construction has no longer to trouble about his equilibrium, he has only to think of steering. Let us remark, casually, that although it is true that the auxiliary surfaces of the partitions add a little weight to the apparatus, they do not increase, at least to any significant degree, its resistance to advance as they cut the air with their edges and are set in the direction of travel.

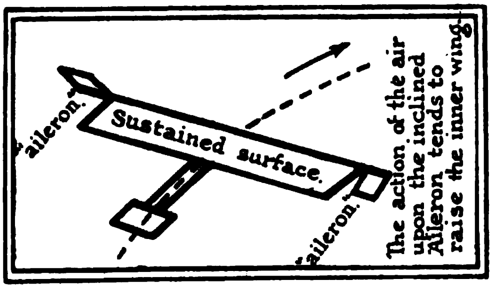


FIG. 57. The correcting ailerons (Blériot)

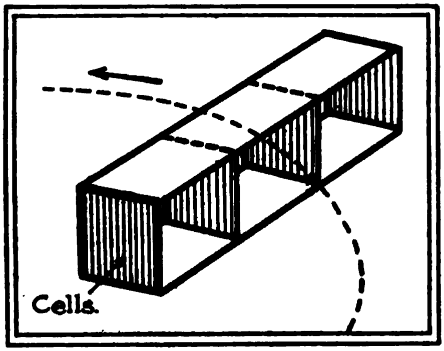


FIG. 58. Partitioning (MM. Voisin)

Lastly, there is the "artificial" stabilisation obtained by the stabilisating organs bringing forces other than the resistance of the air into action. This type of stabilisator is the *gyroscope*.

Every one knows those toys—"gyroscopical tops"—which once started at full speed maintain their balance on a point or on a thread, appearing to defy all the laws of weight and equilibrium. These gyroscopes, discs with a heavy circumference, have the very important mechanical quality of only being caused to deviate from the normal, the plane in which rotation is effected, by great difficulty and at the price of a very great effort. The extent of the latter to bring about this deviation becomes greater as the turning mass is increased, and its speed augmented. If, therefore, a gyroscope is mounted on an aeroplane and its rapid rotary movement maintained by the motor, an effort is necessary to change the rotating plane consolidated with the frame of the aerial vehicle, and one may thus hope, in an automatic manner, to obtain lateral stability. Theoretically this idea is excellent. In practice it is another thing.

First of all, a gyroscope when constructed on a large scale is a very dangerous apparatus; let it escape from one of the sockets between which the extremities of its axis revolves and it then becomes a destructive projectile both of men and everything else; serious accidents have already happened from this cause. In the second place, for it to be efficient, it must be fairly weighty, and in the matter of aviation, any extra weight is a very vital condition.

Then—and here is the greatest theoretical objection which may be urged against it—it might, if it worked efficiently, compromise the solidity of the light framework constituting the aeroplane. In fact, what causes the aeroplane to become inclined, is the effort resulting from the action of air resistance bearing upon all parts of its long surface, whereas the gyroscope only acts at one single point of its framework. It is, therefore, in supposing this means of stabilisation to be efficient, as if the aeroplane were pinched in a vice at one of its points and an inclining effort exercised upon the rest of its mechanism; what would happen then? Twisting would occur which might jeopardise the solidity of construction. For this reason, it seems to me that the gyroscope would be dangerous if it really acted; and if it does not act, it is a dead weight which it is useless to lug about in the air. Moreover, all this is only theory; experiments alone, many times repeated, will be able to supply us with really reliable data.

Let us add, that in order to increase the stabilisation the use of a double rudder at the bow and stern, moving in opposite directions at the two extremities of the aeroplane, has been suggested. Experiments have not as yet been sufficient to decide as to the practical value of this arrangement. Another means of automatic stabilisation is that which was evolved and tried a short while ago, comprising the automatic variation of the "angle of attack" by articulating the whole of the supporting wing around a horizontal axis. This wing is held in its normal position by a powerful spiral spring which resists the pressure of the air when the aeroplane is travelling at the required speed, but which gives way to this thrust, if the speed happens to increase suddenly, by diminishing the angle of attack. Experience will show what this ingenious conception is worth. In any case, the "natural" means of stabilisation are the most rational, because they act with effects analogous to those of the perturbing forces of equilibrium.

STEERING: THE RUDDERS

As we have spoken of turning, the means by which it is brought about must be indicated. This is the "steering rudder."

The steering rudder is similar to that used on boats and dirigible balloons; it is a light and resisting thin panel, turning about a vertical axis, operated by a "wheel" or motor levers, at the will of the aviator, who can turn it either to the right or left. The rudder is placed as far as possible to the stern of the aeroplane, and as far as possible away from the supporting surfaces (Fig. 59). When it is turned to the right or to the left, the molecules of air, striking its surface in an oblique manner, exercise a thrust which is all the more efficient in causing the body of the aeroplane to swerve, since it is placed at the end of a long lever. For this reason, it is most frequently placed at the rear end of the empennage tail. When it is desired to travel in a straight line, the steering rudder is brought back to the central position, that is to say in the longitudinal plane of the apparatus, and the air no longer acting upon its surface, no deviating action as regards direction results.

Let us remark that the steering rudder could only be efficient if the aeroplane present a "lateral resistance to drift." An aeroplane which had no opposing surface to a lateral movement, would not comply with the movement of the steering rudder. There must therefore be a lateral surface, if only effected by the "hull" of the

PLATE XIX

Photo, Raffaële

HENRI FARMAN AT THE WHEEL OF HIS AEROPLANE (THE PROW OF THE MACHINE IS TO THE RIGHT)

skiff. From this point of view, therefore, partitioned aeroplanes are really superior.

The "elevating rudder" is a similar device, but moving about an horizontal axis, and causes the aeroplane to deviate, not to the left or right, but upwards or downwards in its trajectory, in a word, which causes it to ascend or descend. Its operation is explained in the same manner as that of the steering rudder. This invention has been attributed to the Wright Brothers, but I believe erroneously, as Colonel Renard applied it to his airship *La France* in 1885, as is testified by the official documents published at that time, which contain the full description of the arrangement and also the explanation of its working.

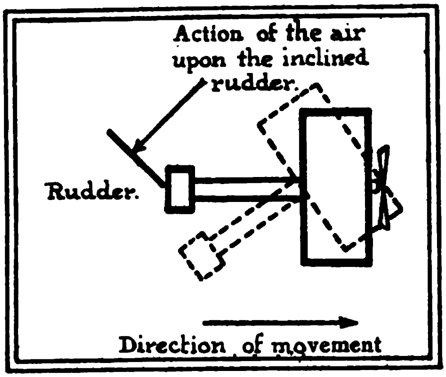


FIG. 59. The steering rudder

The steering rudder can be placed either at the bow or stern of the aeroplane; each disposition has its advocates and opponents. The Wright Brothers have placed it at the bow, and as people "went a trifle mad" on all that bore their names, it was concluded to be "necessary" to fit the elevating rudder at the bow, just because they placed it there. But Messrs. Esnault-Pelterie and Blériot, the constructors of the *Antoinette* aeroplane, to cite only these gentlemen, instal it at the stern, and it was, moreover, L. Blériot who made the first round aerial journey; it is his name that subscribes to the historical page of the first practical application of the aeroplane.

LAUNCHING THE AEROPLANE

Every one knows that principle of reasoning, extensively used in geometry, which commences, when a problem has to be solved, by the use of those honoured words, "Let us suppose the problem as solved."

Present industry offers us a number of various machines which, if I dare so to express myself, "can only go if they are already going;" for instance, the explosion motor, which must be "launched" with all one's might to start and to enable it to assume its normal speed.

The aeroplane is a new example of this method of procedure: the conditions of its equilibrium suppose its being already started: at rest, it remains on the ground. Therefore it must receive an initial impulse, which "launches" it into the atmosphere, and gives it that speed which, owing to the molecules of air gliding under its oblique wings, first lift and then sustain it. There are two ways of conceiving the launch; they may seek to endow the aeroplane with means enabling it to launch itself, in which case it would really be self-starting. On the contrary, it may be launched artificially with the help of a contrivance remaining at its point of departure; then the launching is easy, but the apparatus if it lands cannot start again, it must first return to its starting-point, under penalty of being condemned to rise no more into the air.

French constructors and aviators have courageously accepted the hard conditions which an aeroplane must fulfil to be "self-starting," and all our aviation apparatuses leave the ground by their own means. For this they are mounted on a frame-work with bicycle wheels, a carriage which must be as light and at the same time as strong as possible, since at the moment of landing, the shock of the apparatus coming against the earth, howsoever much it may be lessened through the skill of the aviator, falls entirely upon that framework. It is an additional load, which may vary from 50 to 80 kilogrammes, which any aviation apparatus desirous of launching itself without outside help, must carry with it.

But there is another extra weight imposed under this condition; it is the *increase of motor power* necessary for launching, which commences with a run along the ground, under the impulse of the propeller screw attacking the molecules of the air. The inertia of the motionless apparatus must first be overcome, and for this the motor must give a pull "at the collar" sufficiently strong to develop an excess of power on the part of the motor. This "collar pull" causes the aeroplane to roll along the ground, with increasing speed, until the latter is sufficient to bring about the lifting of the apparatus by the action of the air striking on the under part of the wings. Once the apparatus is in the air, but little effort is needed to sustain and propel it. However, it entails the transport of a motor, heavier than was really necessary, but the extra energy of which was indispensable for launching. This additional weight, in conjunction with that of the framework, requires the "self-starting" aviation apparatus to carry an excess of weight which may vary from 100 to 150 kilogrammes.

Quite different are the conditions of the aeroplanes which are launched in an "artificial" manner, such as those of the Wright Brothers. Freed from these severe conditions, the American aviators have required the fall of a weight for the necessary launching effort for their apparatus, and to avoid any extra weight, even that represented by the weight of the supporting truck, they glide their aeroplane, in order to start, along a "rail," attended with very little friction.

The idea of the launching weight is ingenious and effective, as it must impart to the aeroplane an increasing speed; now, the falling speed of a weight increases exactly in proportion with time; this is the first law concerning the fall of bodies. This weight, in its fall, in drawing the aeroplane along by a rope and return pulley system, will therefore impart to it a speed which will steadily increase. Relieved of the extra weight of 100 kilogrammes at least required for "self-starting," the aeroplane thus launched can use an ordinary automobile motor, a little heavier than the special type, but working more regularly, instead of the extra light motors used in French aeroplanes, in which, everything being sacrificed to lightness, there may sometimes be defects, especially in regard to endurance. The American aviators are therefore placed in better conditions, and have been able to accomplish feats which possibly they might not otherwise have achieved, with the same facility, feats limited, moreover, since they must land near their launching apparatus for fear of being rendered powerless and prevented from starting again.

THE DESCENT

When the aeroplane is in steady motion in the air, when it is soaring at its "regulating speed," everything is working normally, sustentation, advance, steering, in the manner we have explained. But the motor may happen to stop, either by the will of the aviator, or accidentally. Let us now examine what will occur in such an event.

By virtue of its acquired speed, the aeroplane continues to advance; but, propulsion failing it, the retarding resistance of the air will be felt more and more, and its speed will be rendered useless. It must therefore keep it up, and, no longer having a motor, it can only do so by descending in an oblique manner towards the earth; then its weight will serve as the motor; in this manner it will reach the soil as gently as the aviator desires. In the descent, moreover, the steering-rudder will permit the landing-point to be chosen, and the apparatus will come down quietly to the ground. Thus, theoretically, at least, an aeroplane effects a "descent," but never a "fall." This descending operation is effected in a ready manner by French aviators, who have become clever experts. It is needless to say that the greatest presence of mind is necessary to conduct an aviation apparatus; distraction may prove fatal. With this presence of mind and skill in manœuvring, "motor failure" is no longer dangerous to the aviator; it only interrupts his journey.

Many persons ask aviators why their "heavier-than-air" apparatus is not provided with parachutes. This frequent question is answered fully by what we have just said. It is useless to fit a parachute to an apparatus which is in itself the most perfect parachute.

We will now study the practical arrangements of an aeroplane destined to fulfil everyday service and to possess qualities of safety, solidity, and speed.

CHAPTER III

AEROPLANE CONSTRUCTION

WINGS AND NERVES: MOTORS AND PROPELLERS: SAFETY: WIND AND THE AVIATOR: MUST WE FLY HIGH?

SUPPORTING SURFACES: THE "POWER OF PENETRATION"

SUPPOSING the aeroplane to be provided with a motor and a propeller as perfect as possible (we shall go further into the question of these two elements) its essential organ is the sustaining or supporting surface. This area is sometimes called the "set of sails," and the supporting surfaces are also known as "wings." We have seen that there is an advantage in making them slightly concave on the under side. Moreover, they must be placed transverse to the line of travel, whether in a straight line or a very much opened V. The supporting surface is formed of cloth stretched upon a light and strong wooden frame-work. The same india-rubber fabric which serves for the construction of dirigible envelopes is often used.

But all frame-work is formed of members which have a thickness; this offers to the wind a resisting surface; above all, the latter must therefore be reduced to the minimum; or, in other words, the "power of penetration" of the apparatus must be the maximum. It is preferable to have a heavy piece, entailing a greater load to be lifted and sustained in the air, if well thought out in regard to its shape relative to the resistance the air will bring to bear upon it.

It will therefore be advantageous to give the sections of the parts cutting the molecules of air fish-shaped profiles, with the larger end foremost (Fig. 60). These lines are followed particularly in sections of the wings of several existing aviation apparatuses; the wing framework is pisciform in section, and the panels of cloth are stretched on both sides of this skeleton.

For this reason it will be necessary to avoid too many stretched wires, ropes, manœuvring cords extending to the exterior, and cross-pieces; and if it is remembered that biplanes cannot do without the latter, which are indispensable for joining the supporting surfaces together, it will be understood how immense is the superiority of the monoplanes over the biplanes, at least from the air-resistance point of view. The latter in their various forms, in particular those of Voisin and Wright, offer to the air very needless resistance to advance, as only the supporting surfaces are efficient. For high speeds, which are the aim of aviation, I would therefore be tempted to believe in a much more brilliant future for monoplanes; those of Esnault-Pelterie and Blériot, and the *Antoinette* aëroplane already represent more than promises; their first exploits permit one to hope for results still more brilliant later on.

Apart from the transverse sections, there is the nature and character of the sustaining surfaces to be considered. The fabric of which the set of sails is made must be stretched upon the frame-work of the wings with the greatest care; the seams, knots, heads of nails must in

PLATE XX

Photo, Rol

CONSTRUCTING AN AEROPLANE WING (FERBER)

no way project; the surfaces must realise, as far as possible, their geometrical definition, and be of an absolute continuity and regularity, and the fabric, stretched to the maximum, must also be varnished in an extremely careful manner. It is these conditions, difficult to fulfil, which render the construction more or less valuable, according to how it is turned out with more or less "finish." It is this perfection of workmanship which is responsible for thc relatively high price of the present aeroplane; it is how the French constructors, who have carried it to the utmost limit, have acquired a reputation which ensures them a superiority which is equivalent to a real monopoly.

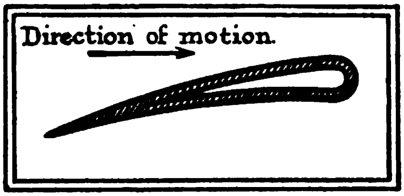


FIG. 60. Pisciform section of the wings

MOTORS EMPLOYED IN AVIATION

Aeroplane motors must be light, and only the explosion motor, working with the combustion of a mixture of air and petrol gas, fulfils the indispensable reduction in weight. As early as 1884 Colonel Renard showed that if the weight of the motor, everything included, was reduced to 5 kilogrammes per horse-power, one could realise dynamical sustentation and effect ordinary aviation. The colonel's prophecies have been amply attained, and even surpassed to-day, because the motor with a weight of 2 kilogrammes per horse-power is realised. In regard to mechanical apparatus, we are therefore equipped for the conquest of the air.

Nevertheless, too much must not be sacrificed to lightness. The motor, if one really wishes to "travel," must be strong and must have endurance. It must not get overheated, which demands its being properly cooled during the journey; in other words a sufficient supply of water must be carried, which, passing through a radiator of large surface, is quickly and thoroughly cooled; all this increases the weight to be lifted, and increases the weight per horse-power of the motor employed.

How is this indispensable lightness of the motor to be realised? Two different methods may be practised in this direction. First there is weight-reduction by the selection of materials. There are to-day steels of marvellous strength, and which allow cylinders to be manufactured with walls of insignificant thickness; for example, the barrels of our hunting rifles, which, with pyroxylised powders, resist enormous pressures and are not even a millimetre thick at their muzzle. It is therefore possible to have material both strong and light. A second means of obtaining weight-reduction is to dispense with all useless mechanism; from this point of view the "aviation motors" of the *Antoinette* make, those of M. Esnault-Pelterie, M. Renault, and even others, are absolutely remarkable. In particular, the design of the Esnault-Pelterie motor, having several cranks working upon the same shaft, and actuated by the piston-rods arranged in a radial manner, has ensured a considerable decrease in weight. One single cam ensures the working of the valves.

If lightness is the paramount condition which the motor must fulfil, it is yet inseparable from strength and regularity in working. With the beneficial realisation

PLATE XXI

Photos, Joanneton

THE JOANNETON APPARATUS FOR RECORDING THE SPEED OF AIRSHIPS

Photo, Branger

CARRYING 100 HORSE-POWER AVIATION MOTOR (ANTOINETTE)

of this last condition, it will be possible—it will even be advisable—to reduce the weight of the motor more and more, as absolute safety will only be acquired when it is possible, on a given aeroplane, to instal *two* motors, each being of a power alone sufficient to sustain and to propel the apparatus. Then the "break-down," the terrible break-down which inevitably brings about the descent, if not the fall, of the aviator, will no longer need to be feared; for if one of the motors should fail, the other, already running, may be speeded up; and as each one is, according to calculation, adequate to ensure sustentation, a fall will no longer be feared. The great development that has been realised for some time past in motors permits us to believe that this hope will soon become a reality.

There is another point to which constructors and inventors will have to devote attention: this is the perfection of the rotary motor. Shocks and unavoidable vibrations, due to the to-and-fro movement of the pistons in the motors such as are now used on aëroplanes and dirigibles, cause the framework to warp and forcibly tell upon the joints and bracings. These vibrations are, moreover, transmitted to the suspension and stretched steel wires, reducing the strength of the latter; in the event of a combined effect these vibrations might even bring about a rupture, by a phenomenon similar to that which has brought about so many accidents to suspension bridges.

The rotary motor, of which the "turbine" is a type, has the advantage of suppressing shocks. Will it be possible to accomplish with the explosion of gaseous mixtures, what has been done by steam in turbines? It is still impossible to say. But, in any case, the efforts of constructors must now be turned to this question.

THE PROPELLER: SCREWS

The only propeller used in aviation (except in the trials with ornithoptère apparatus) is the screw. We have explained its general properties in speaking of dirigible balloons; we have defined its "pitch," as well as the "slip," resulting from its working in the air.

But we must return to it a little in speaking of its application to aviation apparatuses.

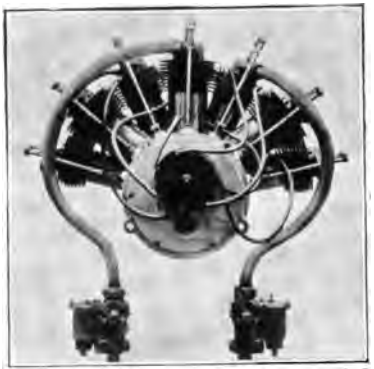
We are not at present very well supplied with really reliable "data" concerning aerial screws; the excellent works of Colonel Renard have cleared the question without solving many individual points. Experiment *alone* is able to furnish data as to the practical value of a screw, and then it works "at a fixed point," that is to say, moves upon an immovable dynamometer, which gauges its mechanical effort.

This data is not absolutely sufficient, as in aerial work a screw does not furnish the same useful effect as when working in a fixed point; in any case, this data is necessary, and therefore above all tractive experiments by means of a dynamometer for each screw must be made.

Once this result has been obtained, a serious question of vital importance arises, since, according as to how it is settled in one direction or the other, there will result an aviation apparatus presenting an appearance and qualities very different. This question is: Must the screw be of a very small diameter, and revolve at high speed, or must it, on the contrary, be very large, and turn "slowly"?

PLATE XXII

GOBRON LIGHT MOTOR



Photos, Rol

ESNAULT-PELTERIE LIGHT MOTOR

Photo. Branger

M. KAPFÉRER M. SABATHIER

BRIDGE AND CONTROLLING MECHANISM OF "BAYARD-CLÉMENT"

These two ways of planning the propeller have given birth to "two screw-propeller schools." Both solutions have been experimented. Large screws were the first to be used, especially on dirigibles, and in particular on those of Giffard, Dupuy de Lôme, and Renard. This condition, moreover, was compulsory at the onset, owing to the slow revolutions of the motors employed.

But when the explosion motor, with its very high speeds of revolution, entered aeronautical practice, preferences changed, and there was a rush on small screws turning very rapidly; there was a fear that the actual rotating speed of the motor would be "reduced," and it was desired to govern the screw directly by the engine by mounting it direct upon the shaft of the latter. Thus we see the Lebaudy dirigibles, the Voisin aviators, the immense airship of Count Zeppelin, fitted with small screws running at a speed ranging from 1000 to 1500 revolutions per minute.

The appearance of the *Ville de Paris* and *Bayard-Clément* airships, fitted with large screws running at from 300 to 400 revolutions only, and especially the remarkable performances of the Wright aeroplane, the two screws of which rotated at a fairly low speed, has served to support those who very justly maintain that the employment of screws of a large diameter is more advantageous. To-day there seems a more general tendency in the direction of screws of a greater diameter and revolving less rapidly.

Another question, quite as important, is to whether *one or two screws* should be used?

In principle, two screws, one forming a screw on the right, and the other a screw on the left, and revolving in opposite directions, are in every way preferable. In fact, with one screw only, the aeroplane tends to incline in the direction of its rotation, and its great surface alone prevents this inclination from becoming serious.

With screws of opposite pitch and direction, these two effects become neutralised, the one tending to incline the aeroplane to the right, and the other to the left. The motive effort is then quite symmetrical.

But the use of two screws may in certain cases present a great danger, and for the following reason: Let us suppose an aëroplane provided with two screws (Fig. 61A) driven by identical motors, or by equal transmission of the energy from a single motor; each has a turning effect following its axis, and as they are placed symmetrically with regard to the centre of the supporting surface, the resulting propelling effort is steadily applied at one point of the symmetrical plane of the whole contrivance. But if one of the two screws—the right, for instance—for some reason should cease to act (Fig. 61B), either through a fracture or failure of the motor-power which drives it, the aëroplane is instantly subjected to the action of one propeller alone—the left one; this movement is eccentric. The apparatus will, therefore, be subjected to a propelling effort whichwill itself be eccentric, and will tend to assume an oblique direction; it will take it too rapidly for the aviator to have time to correct it by means of the rudders, and a fall may be the result. This is, unfortunately, what happened with one of the Wright aeroplanes. Orville Wright, having on board an officer of the American Army, Lieutenant Selfridge, was a victim of this contingency. The aeroplane fell, the officer was killed, Orville Wright had an arm broken, and had to rest for two long months. The French aeroplanes, perfectly thought out, have never experienced such mishaps.

From the point of view of safety, the use of one screw alone is, therefore, very preferable. If it is absolutely desired to use two, it is essential that the disconnection or stoppage of one should stop the other, and with the aid of an *automatic* arrangement, for instance, the transmission of the power by a *single* chain. Under these circumstances, in the event of propulsion failure the aeroplane would be in the position of an ordinary "breakdown," and must descend by "gliding" upon the air, that is to say, by making an experiment in soaring flight.

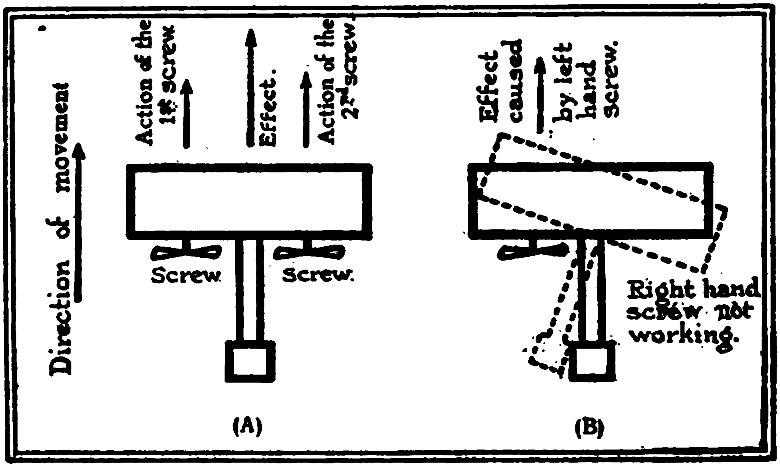


Fig. 61. Propulsion of an aeroplane by two screws: A, with two propellers; B, with one only

Lastly, one more doubt may arise in the mind of the constructor; must its screw or screws be placed at the bow or stern? Must one, in other words, have screws which "draw" or screws which "drive"? Opinions and arrangements are divided. In the apparatuses such as those of Blériot, Esnault-Pelterie, the single screw is at the bow. In the Farman aeroplane, it is at the stern of the supporting surfaces; this is also the arrangement which the Wright Brothers have adopted for their two screws, which are "driving screws." All these aeroplanes have shown different qualities, but such as are incontestable. It is therefore impossible to declare off-hand in favour of one or the other, and the position of the screw will depend upon the spread, the empennage, and more or less the long leverage of the latter.

THE "BODY" OF THE AEROPLANE

There is, also, one part of the aviation apparatus which we have neglected up to now, but which is nevertheless indispensable: it is the "body" which plays the part of the car of the dirigible, that is to say the space designed to carry the motor, the propeller, and the aviator, the "brains of the machine."

The "body," or "skiff" as it has sometimes been called, is the mechanism which represents the serviceable part of the aeroplane, since it contains the traveller; it has, however, dimensions, and however small it may be designed, these cannot be avoided; it will therefore present to the air a resisting surface, which must be taken into account.

In the Wright Brothers' aeroplanes there is no "body;" it is reduced to that of the aviator, sitting over empty space on a latticed seat, with the feet simply resting upon a cross-bar. This is a possible arrangement with operators as clever, as "artistic," as master of their nerves as Wilbur and Orville Wright, but in my opinion it is an arrangement to be condemned absolutely; aviation is already a sufficiently daring form of aerial travel without increasing the risk, by decreasing the conditions of safety. The Wright aeroplanes moreover have not yet made any "journey" properly speaking, either in Auvours or in Paris; they always limit themselves to performing evolutions, sometimes for a long time, above a test field. But practical aeroplanes able to extend real services, such as those of Blériot, Esnault-Pelterie, Voisin, &c. . . . all have a "body" serving as accommodation for the aviator and the machinery.

This body, thus being compulsory, it is necessary to utilise it to the best advantage for the balance of the machine. First of all, we must give it, undoubtedly, the shape of the body of a bird or fish, the large end to the front; under these conditions, and if the framework is carefully covered with fabric tightly stretched and very smooth, its resistance to advance will be reduced to the minimum. This body will, moreover, serve a useful purpose; it will increase the resistance on the sides, that is to say, oppose "drifting" and the action of centrifugal force when turning.

Thus planned, the shape of an aeroplane becomes closely allied to that of a soaring bird. The action of the air upon the various parts of this "body" must, however, be carefully studied as regards stability in the direction of travel, and here it is that Colonel Renard's works must be borne in mind. More than ever (as we have already said) the empennage is here indispensable for securing the safety of the apparatus.

AEROPLANES AND SPEED: AEROPLANES OF THE FUTURE

The real great advantage of aeroplanes in their application to aerial travel is *speed*.

In all trials wherein somewhat prolonged flights have been accomplished, it has been seen that the present speed of aviation apparatuses is at least 60 to 70 kilometres per hour, and in Farman's now historical journey from Rheims to Châlons, not only did the daring aviator achieve on his French Voisin-built aeroplane the first "aerial journey" worthy of the name, leaving a field of experiments and passing over villages and forests, but he even made it at a speed of 78 kilometres per hour. No dirigible, at least at present, can attain such a speed, and the speed record in the matter of aerial navigation therefore belongs to the aeroplane.

Can this speed be increased?

Not only *can* it be increased, but it *must* be increased, if it is intended to make really practical use of aviation. At an imposing conference held at the French Society of Aerial Navigation in December 1908, the engineer, M. Soreau, a former pupil of the École Polytechnique, dealt with this question in his highly competent manner; he selected as a type a "family" of aeroplanes of the kind constructed by the Voisin Brothers, and supposing them to be all provided with motors giving the same weight per horse-power, propellers having the same output, sails having the same co-efficient of efficiency he showed that the useful maximum weight would be obtained with an aeroplane having dimensions only 10 per cent. heavier than the original aeroplane; but its speed must be treble, that is to say must reach the figure of 180 to 200 *kilometres per hour*. Now the " useful " weight would reach one ton. M. Soreau has arrived at analogous results by studying a "group" of aeroplanes of the monoplane type constructed by Esnault-Pelterie.

But, when our "artificial birds" will have realised such speeds, when they will have to carry such weights, it will no longer be possible to be contented with this construction of slender frame-work, a marvel of lightness, certainly, but not sufficiently solid ; it will be necessary to make all its component parts very strong, and to enable them to resist even the greatest strains to which they may be submitted. Let us cite here M. Soreau's important conclusions ; " aeroplanes of large carrying capacity will have to be very stoutly built, not much larger than the present, at least for the next few years to come, but their speed will have to be double or treble that in vogue to-day. Now, for these new machines we shall be forced to employ other materials ; it will be necessary in particular to attend to the reduction of their resistance to advance ; in short, it will not be sufficient to be content with constructing aeroplanes based strictly upon the present apparatus. These new apparatuses, so soon as they are perfected and have received the sovereign sanction of experience, will thus become the first aeroplanes of a new family, and so on."

Aviation apparatus will therefore be perfected by evolution, which is the case in nearly all the great developments realised in physical science or applied mechanics.

What must be remembered in these conclusions of one of the cleverest aeromechanics of to-day is that before long, even very shortly, we shall see every day speeds of 200 kilometres per hour. Then it will be truly possible to say that "distance no longer exists."

WIND AND AEROPLANES

What we have said regarding the action of the wind upon dirigibles applies equally well to aviation apparatus; "Wind does not exist for the aeroplane which moves in the *atmosphere;* it is as if this atmosphere were immovable; the wind only exists on account of the aviator changing position *in relation with the ground beneath.*"

We shall consequently have to consider the same values in aviation as in aeronautics. If the independent speed of the aeroplane is less than that of the wind, it will only be able to approach the points of the space contained in the interior of a certain "approachable angle;" if its independent speed equals that of the wind it will be able to approach any point to leeward of the line perpendicular to the direction of the wind at its position of departure; lastly, if its independent speed is greater than that of the wind, it will be able to go anywhere. In all cases, its speed is governed by that of the wind to give its resulting movement. In an extreme case when it navigates exactly with "wind behind," its speed of travelling, with regard to a fixed guiding-mark taken on land, will be equal to the sum of the speeds of the wind and of the aeroplane. It will equal their difference if the aviator navigates against a "head wind.' As to-day the speed of 78 kilometres per hour is reached, it is seen that, *at present,* an aeroplane may travel, in Paris, on an average 352 days out of 365; when a speed of 150 per hour is reached, it will be possible "to go out every day."

I insist most particularly upon this notion, as it is often distorted or acquired in an incorrect manner. Thus, if an aeroplane is going in an easterly direction in a south wind of 20 kilometres per hour at a speed of 60 kilometres per hour (Fig. 62) it will *effectively* navigate with a speed of 60 kilometres per hour; but the "section of atmosphere" in which it will have effected these 60 kilometres will be displaced towards the north, by the effect of the southerly wind, by 20 kilometres; the aeroplane will then have followed an oblique trajectory, represented by the diagonal of the parallelogram constructed with the help of two speeds, its own independent speed and that of the wind.

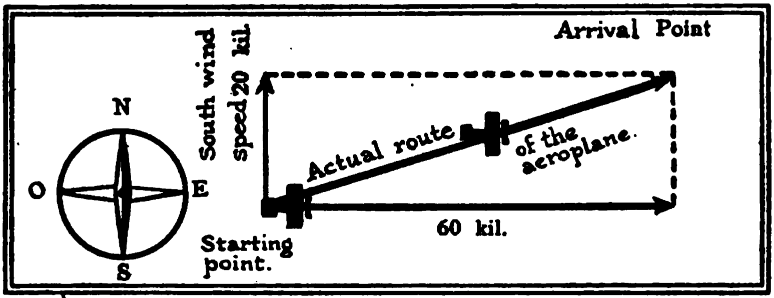


FIG. 62. Combined action of wind and propulsion speeds

This conception may even be "materialised," so to speak, in the following manner. Let us imagine an enormous aerostat, formed of a perfectly impermeable envelope, and maintaining its equilibrium high in the air (Fig. 63). We will suppose that this balloon has dimensions sufficiently large for an aeroplane to be able to describe evolutions in its interior atmosphere. This atmosphere will be forcibly sheltered from the action of the outer wind, since it is enclosed in an air-proof envelope; the aeroplane will therefore manœuvre in still air, and will go from A to B, but during the time it takes to accomplish this journey, the whole balloon has been transported by the exterior wind from (1) to (2): the aeroplane has therefore duly arrived at point B, but this point B has been transported without the aviator being aware of the fact to B^1; so that he will have no longer below him the part of the terrestrial surface which was below point B, but really that which was below point B^1. Let us now remove in thought the envelope which isolated the interior atmosphere of the aerostat; nothing is changed in the general conditions, but we can thus understand the true road of the aeroplane, AB^1.

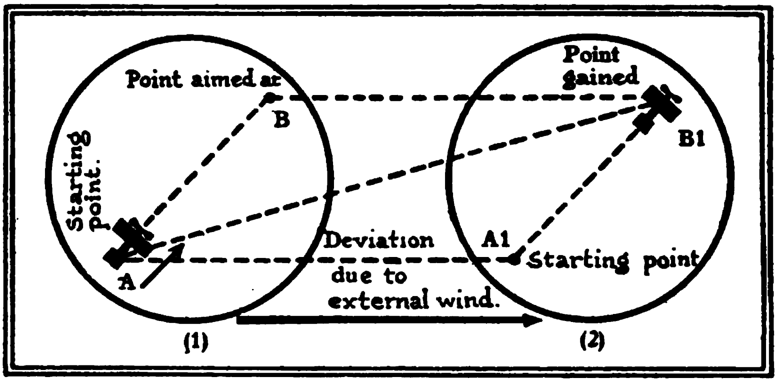


FIG. 63. Wind and the aeroplane: actual and relative routes respectively

HEIGHT AT WHICH IT IS ADVISABLE TO FLY: SAFETY

The height to which it is advisable to rise to practise aviation is intimately connected with the conditions of safety laid down by the aviator.

At first sight it may be imagined that it is essential to decrease the risks of accident by navigating very closely to the ground, to sweep close to the earth like swallows because, it is thought that "if one fall, one will fall from a lesser height."

This reasoning is admissible for risks entirely "experimental," when one is not quite sure of the stability of the apparatus in which one is to ascend. But once this apparatus has been tested, and once the efficiency of its equilibrium has been ascertained, it is necessary then to avoid too close a proximity to the ground, and to navigate at a certain height, say, at about 100 metres.

As a matter of fact, let us consider what takes place in the immediate neighbourhood of the ground (Fig. 64); the moving molecules of the air, the horizontal displacement of which constitutes the wind, are forced, when brought into immediate contact with the terrestrial surface, to follow all its superficial variations and to become deflected by its projections. The gaseous molecules, approximate to the undulations of the ground, will thus follow at one time an ascending, and at another a descending path, and if their speed is of little consequence, that is to say, if the prevailing wind is not very intense, these inflections of the currents of air cause "ascending winds" and "descending winds," as is illustrated in Fig. 64.

Now the aeroplane is so designed that the currents of air are met horizontally by its wings, and not so as to be struck in an oblique manner. These vertical winds will therefore be capable of "twisting" the aeroplane round, and so placing it that in its falling it will no longer meet the air by its extended surface, but with its side; this would mean a rapid fall, *i.e.*, certain death to the aviator.

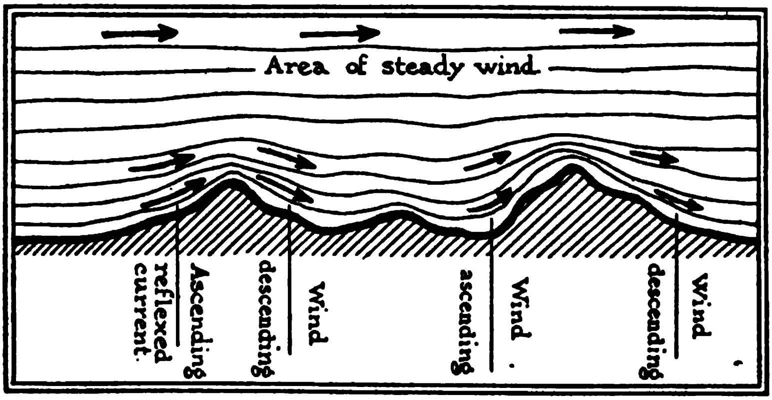


FIG. 64. Effect of inequalities of the ground surface upon the movement of the air

These atmospherical fluctuations disappear in proportion as one rises in the air, and at a certain height, as is seen in our sketch, the strata of air become steady and flow in a horizontal manner, being solely quickened by those "undulatory movements" so ingeniously described by M. Soreau. Consequently it will only be at these altitudes that the aviator will be sure to find the normal laws of the atmosphere; it will be at these heights that he will have to fly if he wishes his aeroplane always to be "in the happy medium" for which its various elements were calculated: lastly, it is where, in the event of a breakdown to his motor, he will be able to commence the "gliding" upon the air, which, with a soaring flight, will carry him harmlessly to the ground, whereas he could not effect such if he were struck by a current of ascending air which would capsize his aeroplane and infallibly precipitate a fall. This descending glide will be effected with the greater safety inasmuch as it will commence higher above the ground, and also because the aviator will be better able to select his landing-point.

Nevertheless, I believe that very great heights are impossible to aviation: the too rarefied oxygen would be insufficient for the combustion of the gaseous mixture, the explosion of which constitutes the motive power, and the *supporting surface*, as a result of resistance to a thinner air, would no longer be adequate to ensure sustentation of the aeroplane, which would become unstable. These objections do not exist with *average heights* (from 100 to 300 metres) which are easily accessible to an aeroplane; at 100 metres altitude the supporting power of the sails of an aeroplane is only reduced, on account of the decreased density of the air, by 1-80th of its value at ground level.

This question of safety is closely connected with that of landing, and the latter is, as may be easily understood, of the greatest importance to the aviator undertaking an aerial journey. "It is not all skittles, I must get out of this," said La Fontaine's fox; it is not only flying, one must regain the ground, and return to it without breaking one's bones.

Now, calculation, and calculation based upon experimental data, shows that for a given aeroplane, there is a minimum motive power necessary to obtain the "governing speed." So soon as a motive power exceeding the minimum is brought into play, two results and, consequently, two speeds are possible. Thus, if we have a motor the power of which exceeds the minimum speed by 4 per cent., the two speeds will, one of them, be 16-100ths in excess, and the other 17-100ths less than the governing speed, according to the inclination of the sails. If the motive power exceeds the minimum power by 15 per cent., the two possible speeds are, the one a third in excess of the necessary speed, the other one-quarter less, according to whether the sails are inclined more or less by the action of the elevating rudder.

Since it is thus possible, by means of a slight excess of power, to have two speeds at disposal, it will be possible, as the engineer M. Soreau remarked, to use the greater for the "travelling speed" of the aeroplane, and the lesser one for landing, which will thus be effected without danger, for when the apparatus has approached close to the ground, the fall caused by the excessive inclination of the sail will be appreciably deadened by the "mattress of air" interposed between the ground and the supporting surfaces. It is then, in coming into contact with the ground, that the mechanical absorbers, on which the wheels of the launching rolling-chassis are mounted, become indispensable. The landing of heavy aeroplanes undoubtedly will require elaborate precautions, and will demand on the part of the aerial pilot extreme cleverness and presence of mind.

How may accidents arise? From two different causes —the sudden stoppage of the motor, or the breakage of one of the essential elements of the aeroplane. This last possibility can scarcely be admitted, since, if the aeroplane is well planned, carefully constructed with first-class materials whose strength has been thoroughly determined by experiment, if, moreover, before each ascent all parts of the apparatus are carefully examined, and the mounting, connection, and assemblage have been inspected in detail, when built, the unexpected breakage of any essential part *should not* develop. But, you will say, there are the road accidents? No, not in aviation; for on the "highway of the air" there are neither shocks, bumpings, nor collisions to be feared, at least not at present; this road is wider than those which traverse the earth in all directions, and there is not only more room to pass others on one side, but it is also possible to keep clear of them "above or below." Moreover, at present our aerial roads are not overcrowded. Again, the governing speeds not varying very much, the movements of the various controlling mechanisms will not be subjected to much variation.

There remains failure of the motor; but we have pointed out, in speaking of explosion engines used in aviation, that their continuous development will bring about the desired reduction in weight. We shall, therefore, very soon have motors at our disposal, the weight of which will be sufficiently reduced for it to be possible to place two weighing no more than, and each of the power of, the single present machine; that is to say, each sufficient to sustain and to propel the aeroplane. Under these conditions, together with a device automatically setting the second motor in motion in the event of sudden stoppage of the first, engine failure is no longer to be feared.

In any case, should this occur, it would only be dangerous over towns, where the descent would be hazardous, if not fraught with danger, or above woods, owing to the trees, which would provoke injury to the passengers and prove disastrous to the supporting surfaces. There is, however, one part of "the terrestrial globe" which offers danger: when the descent occurs on *water.* The large surface of the wings can undoubtedly prevent the apparatus immediately foundering, but the aviator, pinned under the planes and "entangled" in the sails, may only be able to free himself from its ropes with difficulty. It will therefore be well to provide aeroplanes intended for long journeys with special safety contrivances, in view of descent upon water.

"Accidents" undoubtedly will happen, undoubtedly there will be daring pioneers of the air who sometimes will pay with their lives their desire to score another victory over the forces of Nature; but have not all the conquests of human genius—navigation, railways, the motor-car, even current industry—been made at the cost of heavy sacrifices! And are not the "accidents" of daily life as formidable as those to be feared in the new method of locomotion, which will, however, be attended with less mishap, because, having the reputation of being more dangerous, it will be practised with greater care?

OTHER FORMS OF AVIATION: HÉLICOPTÈRES AND ORNITHOPTÈRES

At the commencement of this study, we said there vere three classes of apparatus "heavier than air." We have investigated in detail those which so far have given the most practical results—aëroplanes. It now remains for us to speak about the other two.

The first is *hélicoptères*, that is to say, apparatuses which sustain themselves in the air, not through the vertical component of air thrust upon a moving surface, like kites, but by the direct sustentation effort of a motor-driven screw, with horizontal blades revolving about a vertical axis.

It was the hélicoptère which first haunted the imagination of aviators. As far back as 1852 Ponton d'Amécourt and de la Landelle, infused with the enthusiasm of Nadar, the celebrated photographer, maintained by Press campaigns, conferences, and publications, that the future of the "heavier than air" machine would be by means of the screw—the "sacred screw," as it was called by Ponton d'Amécourt. Their scientific support was Babinet, a member of the Academy of Sciences, and he it was who found the name of "hélicoptère" for baptizing the apparatus which he thought would realise the definite conquest of the air.

What gave weight to the assertions of these tireless apostles was the popular success of flying toys, real miniature hélicoptères, which went up in the air with the greatest ease, either through the effort of twisted india-rubber, or when launched by uncoiling a string, and seemed to defy gravity and to open to all the "highway of the air."

Intellects were fired; controversies furious; a study was made of the manner in which the screws must be arranged. To avoid the rotary movement which one single screw imparted to the body of the apparatus, there had been arranged, in certain toys, a vertical "resisting plane," which, resting upon the air, opposed rotation of the whole. The danger of this plane was soon grasped, as, remaining nearly vertical, it offered too considerable a purchase to the wind; the fundamental point in the construction of hélicoptères was therefore recognised to be the simultaneous use of two screws, one *screwing on the right*, the other *screwing on the left*, and turning in opposite directions around vertical axes. In this manner the effects of torsion, due to each of the two propellers, were equal and contrary; they therefore destroyed one another, whilst their lifting efforts were combined. An automotor hélicoptère was constructed on this principle by Dr. Hureau de Villeneuve; it was formed of a small steam-engine, driving two inverse screws revolving in opposite directions about the same horizontal axis. All the hélicoptères realised or planned hitherto comprise the use of an *even* number of screws of contrary pitch, revolving in opposite directions to one another.

Experiments were made with hélicoptères, and with little success; why is known to-day; the motors used were too heavy, and the intimate discussion of the problem, made scientifically by mathematicians, discouraged investigators from embarking on these lines for a long time, until Colonel Renard tackled the question, which, as usual, he enlightened in a new manner by publishing his works on *sustaining screws*.

Colonel Renard, in a communication which he made to the Academy of Sciences at the end of the year 1903, gave the results of his long researches, carried out at Chalais-Meudon, on screws employed for lifting a certain

PLATE XXIII

H. FARMAN'S AEROPLANE (VOISIN, CONSTRUCTOR)

H. FARMAN M. HENRI DEUTSCH

E. ARCHDEACON H. FARMAN

Photos, Raffaële

H. FARMAN WINNING THE DEUTSCH PRIZE

weight directly from the ground—that is to say, with "sustaining screws." Already he had previously demonstrated that aerial navigation by aeroplanes would be possible the day when the weight of the motor went down to 5 kilos per horse-power. Directly attacking the case of the hélicoptère, the learned colonel showed that the maximum weight which the screws of this apparatus were able to lift increases inversely to the sixth power of the weight per horse-power of the motor employed. This result strongly encouraged hélicoptère inventors, but we must reckon not with theoretical "limit" loads, which it would be impossible to exceed, but with the real loads compatible with the resistance itself of the screws. Under these conditions a really transportable load limit is quickly obtained, and these loads are lighter for the hélicoptère than the aeroplane; hence the very legitimate enthusiasm which has been manifested in this apparatus.

Colonel Renard, however, did not leave the question of screws, and even indicated in 1904 sustaining screws of 2·50 metres diameter, of perfect resistance, not liable to distortion under the effect of thrust, although their total weight was very small; he obtained this result by introducing a universal joint which permitted the screw-shaft to assume the resultant direction of the various efforts operating simultaneously upon it.

Amongst the various dispositions proposed for *hélicoptères*, there is one which has been realised under the auspices of H.S.H. Prince Albert of Monaco, which was conceived and constructed by Engineer Léger, and whereof Fig. 26 shows the principle. The two screws of opposite pitch, turning in opposite directions, are mounted upon two concentric axes; this axis being vertical, lifts the car itself; but, if the axis is inclined, as shown in the figure, an oblique movement through the atmosphere must be obtained.

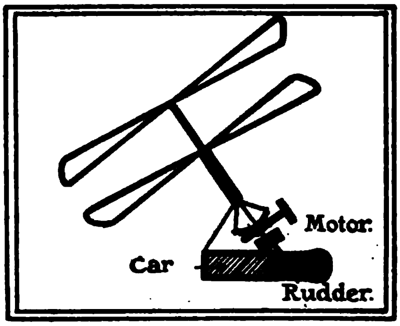


FIG. 65. Principle of the Léger hélicoptère

A composite solution was proposed, one of which Colonel Renard himself had thought; it is an apparatus which would be *héliocoptère* for lifting itself off the ground, and would become an aeroplane once in the air. Such a solution, if it were ever realised, would be that much sought for, as the great disadvantage of aeroplanes is the necessary space for "launching." So long as one remains on level ground, or even so long as there are broad roads, this is still feasible; but in wooded or mountainous country a landed aeroplane will no longer be able to re-start, whereas with screw and vertical axis, which would lift it "straight up," departure would be easy, and once lifted up in the air, the apparatus would have the advantages of an aëroplane. It is to be hoped that serious investigations will be made in this direction; they will constitute a great development and perhaps even the future of aviation. The "gyroplane," of which we speak later on, is the first step in this direction.

Ornithoptères, those apparatus with flapping wings, seeking to imitate exactly the process of lifting and sustentation which characterises the flight of birds, have been less tested than *hélicoptères*. The difficulties found in their construction are so much greater, and the vibrations and shocks to which their framework would be subjected would not fail to tell on the joints. Despite these difficulties, a Belgian aviating engineer, M. Adhémar de la Hault, has sought to realise an *ornithoptère,* of which we give a few photographs; the apparatus was able, in the latest experiments, to rise slightly and to leave the ground for a moment, but an accident to one of its parts interrupted the trials, which will be resumed later.

COMPOSITE SOLUTION: SOARING BALLOONS: CAPAZZA'S LENTICULAR

There remains another composite solution for us to speak about, consisting not in the combination of two systems of aviation, but a balloon and a soaring arrangement, a solution which recalls that of sailing-vessels known as "auxiliary" engine vessels, often used in trade and pleasure navigation.

Its inventor, M. Capazza, one of the French aeronauts who has had the finest "aerial" career (he was, in fact, the first aeronaut to cross the Mediterranean in a balloon from Marseilles to Corsica, which has not yet been repeated), conceived an immense aeroplane, but with its sustaining plane *lighter than air.* For this purpose, M. Capazza took a balloon, not of the ordinary spherical or pisciform form, but having the flat shape of a pendulum-bob. This is not symmetrical, however, as regards its centre; it is not a "surface of revolution," its greater thickness is brought to the bow, so that, cut in the direction of its axis, its section is that of a fish (Fig. 68). A longitudinal empennage forms, above and under this envelope, a kind of small wing, a "keel" which contributes to stability, which will be still more increased by an horizontal empennage at the stern. Besides, the whole of the stern part of this pendulum-bob, thinned to its back edge, constitutes a marvellous natural empennage.

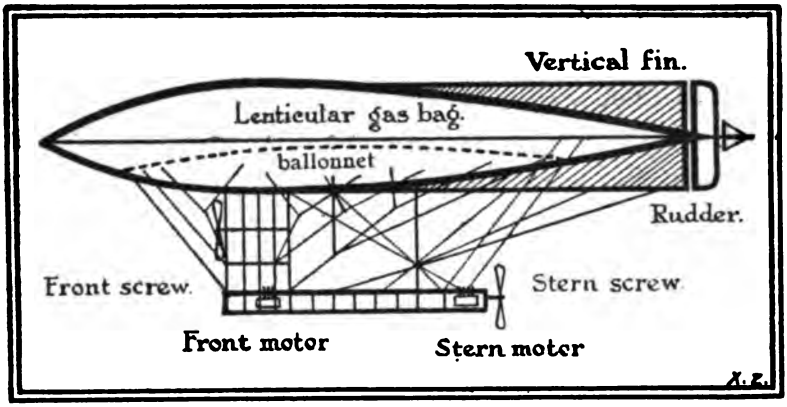


Fig. 66. Side elevation of the Capazza lenticular balloon

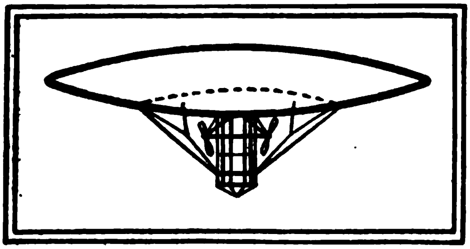


Fig. 67. Front view of the lenticular balloon

The total capacity of this bob is to be 15,000 cubic metres, and will be reinforced internally by metallic circles; it will carry a car in which will work three motors of 120 horse-power each, driving three screw-propellers; the weight of the car is carried below the greater thickness of the balloon, *i.e.*, well forward of the centre of the bob, as is shown in the diagram. The interior metallic circles distribute the load upon the whole surface of the envelope.

The apparatus, at first sight, must therefore work like a dirigible ; but, on account of the flat and non-symmetrical shape of the envelope, it will possess special properties. Let us imagine a movement of ascent or descent being imparted to it ; the apparatus will immediately become

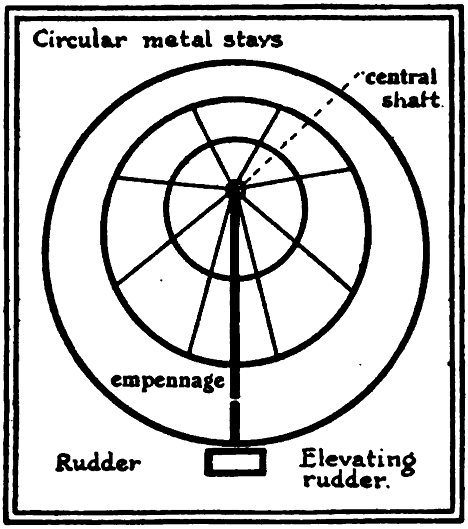


FIG. 68. Plan of Capazza's lenticular balloon

inclined, as the two areas, that of the bow and that of the stern, will be unequally pressed by the air ; the back area offers a greater resistance to ascent or descent than the front. If, for instance, the movement is an ascending one, the back part will be depressed, the bow will rise up, and the movement of vertical ascension will find itself transformed into an oblique displacing movement towards the bow. The screws add their propelling action to what is thus obtained, and contribute, according to the classic expression of artillerymen, to "extend the trajectory." The direction of the balloon becomes the more horizonal as its independent speed increases.

Let us now suppose that at a given moment the *total* weight of the apparatus, envelope, car, motors, passengers, and cargo, for some reason or another, exceeds the weight of air displaced, either because the lenticular balloon in rising has gone beyond its zone of equilibrium on account of its acquired speed, or because physically the inner gas has contracted, which the ballonnet will have replaced with air: the balloon will immediately tend to descend, but an inverse phenomenon will occur. The greater surface of the stern part will lift it, and the balloon will become inclined; it will go down, but in gliding in an oblique manner upon the molecules of air in the manner of an aeroplane, will utilise this descending movement to progress horizontally. This effect will be added to the speed imparted by the screws, the propelling force of which will thus be increased by successive ascents and descents.

Such is this ingenious apparatus, which is so original in its conception, and which it would have been impossible to let pass without saying a few words about it. It would be very interesting to see it realised, for, independently of the services which it would render as an airship, it might become a veritable experimental laboratory for everything concerning aviation.

CHAPTER IV

DESCRIPTION OF SOME AEROPLANES

I. BIPLANES

French and American design: The Voisin and Wright aeroplanes: Comparison of their efficiencies and disadvantages

THE VOISIN AEROPLANES (FLOWN BY MESSRS. FARMAN AND DELAGRANGE)

We will now describe, somewhat more in detail, the various types of aeroplanes, at all events, those which have accomplished brilliant performances, and consequently have thereby demonstrated the actual existence of their efficiency. And it is necessary, in all fairness, to begin with the admirable aeroplanes, swift and sure, built by the Voisin Brothers, the eminent French constructors. Their name, as a matter of fact, is inseparable from those of the audacious sportsmen who, in France and consequently in Europe, definitely opened the highway through the air by their magnificent achievements: I mean Messrs. Henri Farman and Leon Delagrange. The details given in the preceding chapters will enable the reader to appreciate and compare better the different machines which we will now successively describe.

The Voisin aeroplanes are of the "cellular" *biplane* type, that is to say, between the two parallel supporting surfaces which constitute the sails or planes properly so called, are vertical walls, formed of fabric stretched over the cross members, designed to oppose lateral deviation and to maintain automatically the equilibrium of the aeroplane in turning. The general arrangement of this system is shown in Fig. 30.

The design combines strength and lightness. The wings are of india-rubber sheathing stretched upon a diagonally-braced ashwood frame. The spread of the wings is 10·20 metres; their depth 2 metres; and of the "stays" which vertically maintain the distance between the two supporting surfaces, 1·50 metres. These surfaces are slightly curved, the concave face being presented towards the earth. When the apparatus is in flight, the "chord" of the arc formed by the profile of the wings makes an angle varying from 6 to 8 degrees with the horizon. The surface of this plane is about 40 square metres.

The whole of the supporting surfaces, called the "central cell," has a stabilisating apparatus or "empennage," comprising a "rear box" following also the form of a biplane, of less spread than the central cell; 3 metres only by the same depth of 2 metres, spaced 1·50 metres apart, and curved like those of the principal planes. This rear cell is placed 4 metres behind the central cell: and between its two surfaces is placed a plane moving about a vertical axis which constitutes the *steering rudder*. The superficies of this rear cell is thus 12 square metres, which brings the total area of the planes to 52 square metres. The "body" of the aeroplane is a wooden framework with cut-water or wedge-shaped ends covered with carefully stretched canvas. Its greatest width is 75 centimetres, length 4 metres. The seat of the aviator is so placed that the centre of gravity when he is seated is at a point which extends vertically 25 centimetres from the front edge of the supporting surface; in front of the seat are placed the wheel and the pedals controlling the rudders.

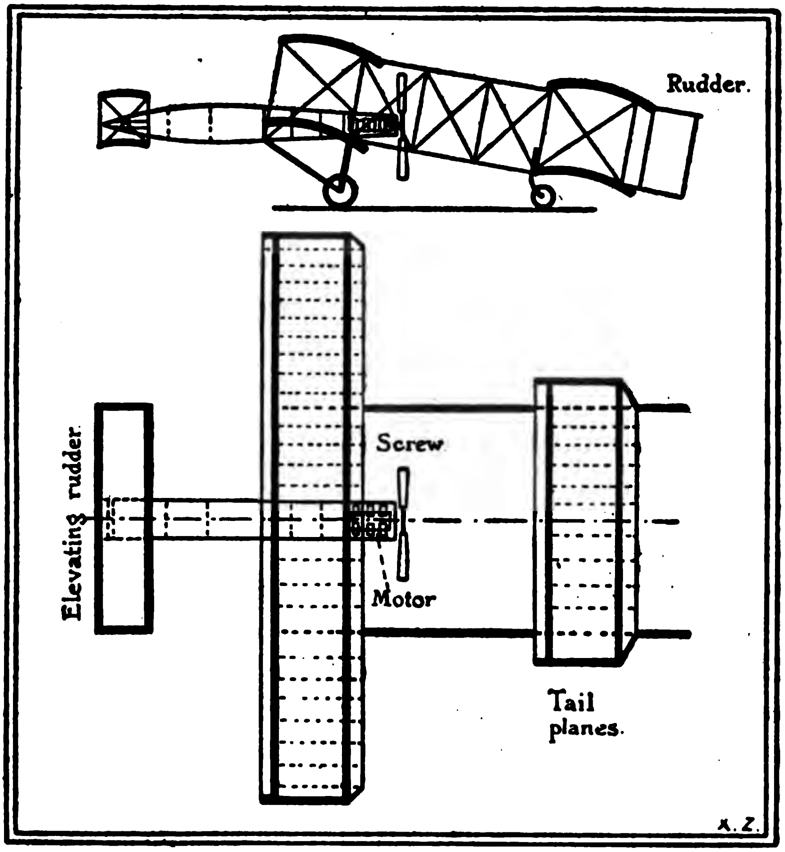


FIG. 69. The Voisin aeroplane (H. Farman's type)

The body supports the *elevating rudder* composed of two surfaces projecting on either side of the prow and moving upon a common horizontal axis. Their shape is plane-convex, the plane being always turned towards the earth, the convex side to the sky.

The engine is an eight-cylinder "Antoinette" motor developing 40–50 horse-power; it weighs 80 kilogrammes. It is mounted upon the framework in such a way that its centre of gravity is a trifle forward of the rear edge of the supporting surfaces.

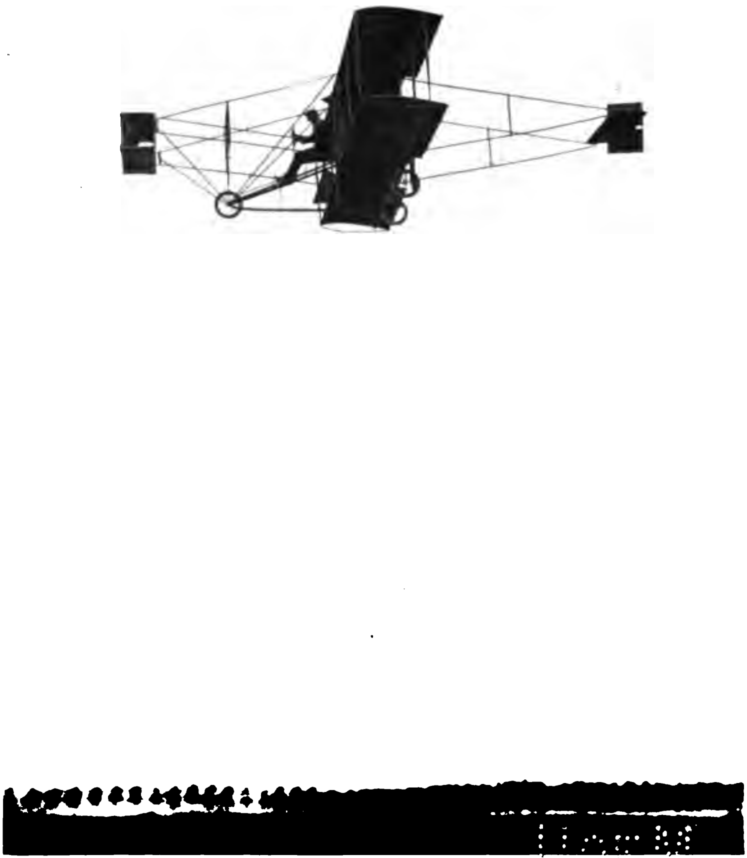
The screw-propeller is double-bladed; it is placed astern of the central cell. It is built up of tubes of steel covered with sheet aluminium. Its diameter is 2 metres; it is coupled direct, without any reducing gear, upon the motor shaft, and runs at a speed of 1050 revolutions per minute.

The whole is carried upon a rolling-chassis built of tubular steel having four pneumatic-tyred bicycle wheels; those in front which directly support the central cell and motor are of 50 centimetres diameter; the rear only of 30 centimetres diameter. The total weight of the apparatus together with the aviator is 530 kilogrammes.

Such is the simple and solid aeroplane with which Henri Farman has demonstrated the prowess of which we spoke in relating the history of aviation. This aeroplane has undergone some modifications; its pilot has fitted a third surface above the first two, thus converting it into a "triplane"; but the enthusiastic aviator seems to have renounced this adjunct, and to have reverted apparently to his original biplane. This machine attained a speed of 70 kilometres per hour in the journey from Châlons to Rheims, covered at an average height of 40 metres (27½ kilometres in 20 minutes).

The Delagrange aeroplane (Fig. 70) vividly recalls the Farman aeroplane in its broad lines, which is not surpri-

PLATE XXIIIA



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MR. GLENN CURTIS, WINNER OF THE GORDON-BENNETT CUP, RHEIMS, 1909

MrtoU

sing, seeing that it came from the workshops of the same constructors, save that there are only 3 metres between the central cell and the rear stabilisating cell.

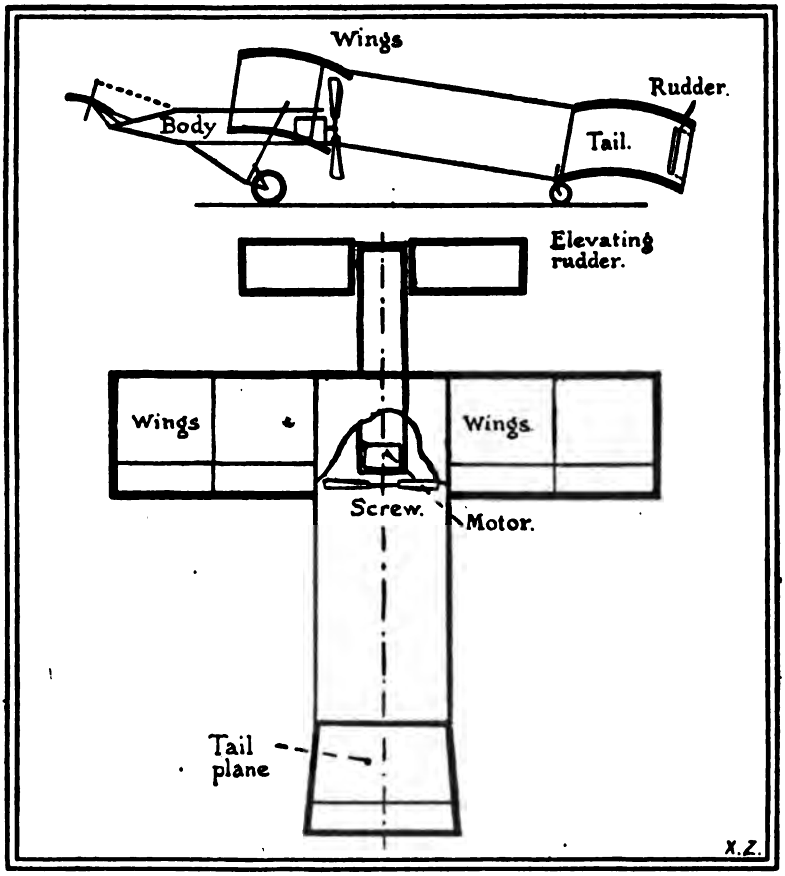


FIG. 70. The Voisin aeroplane (Delagrange type)

Having given the details of the Farman aeroplane, the diagram sufficiently explains itself, but for which further details of the Delagrange aeroplane may have been necessary. Its total surface is 60 square metres, and it has attained with a 50-horse-power Antoinette motor, and a screw of 2·10 metres diameter, a speed of 70 kilometres per hour. Its total weight is 450 kilogrammes. It was likewise upon an aeroplane built by Voisin and driven by a 50-horse-power Antoinette motor that M. Zipfel, one of the youngest French aviators, went to Berlin in 1908, and carried out some very useful aviation experiments: the high standard of the engine and the competency of the aviator were highly appreciated by the Berlin public, who for the first time witnessed trials with a heavier than air apparatus.

THE WRIGHT BROTHERS' AEROPLANE

We have seen a remarkable biplane aeroplane of French construction which fulfils automatic stability, be it longitudinal or lateral. Let us now give, with some details, a description of the famous aeroplane which created widespread enthusiasm during the summer of 1908, and the prowess with which (we are apt to forget, perhaps a little too quickly, this attribute of the French aviators) would seem to open decidedly the "path through the air." We will compare the American aeroplane with those which we have already described.

The aeroplane of the brothers Wilbur and Orville Wright is, like the Voisin aeroplanes, a biplane, with an elevating rudder in front and a steering rudder at the stern. Its main feature is the absence of a fixed stabilisator. The "foundation," that is to say the total length of the system longitudinally, is 9 metres. The two surfaces of the biplane have a spread of 12·50 metres each, by 2 metres breadth. The fabric of which they are made is stretched to the maximum upon two wooden frames formed of two longitudinal members strength-

PLATE XXIV

WILBUR WRIGHT AT THE HELM OF HIS AEROPLANE
(THE TWO STEERING LEVERS MAY BE DISTINCTLY SEEN)

Photos, Branger

THE WRIGHT AEROPLANE ISSUING FROM ITS GARAGE AT AUVOURS CAMP
THE PROW IS TO THE RIGHT

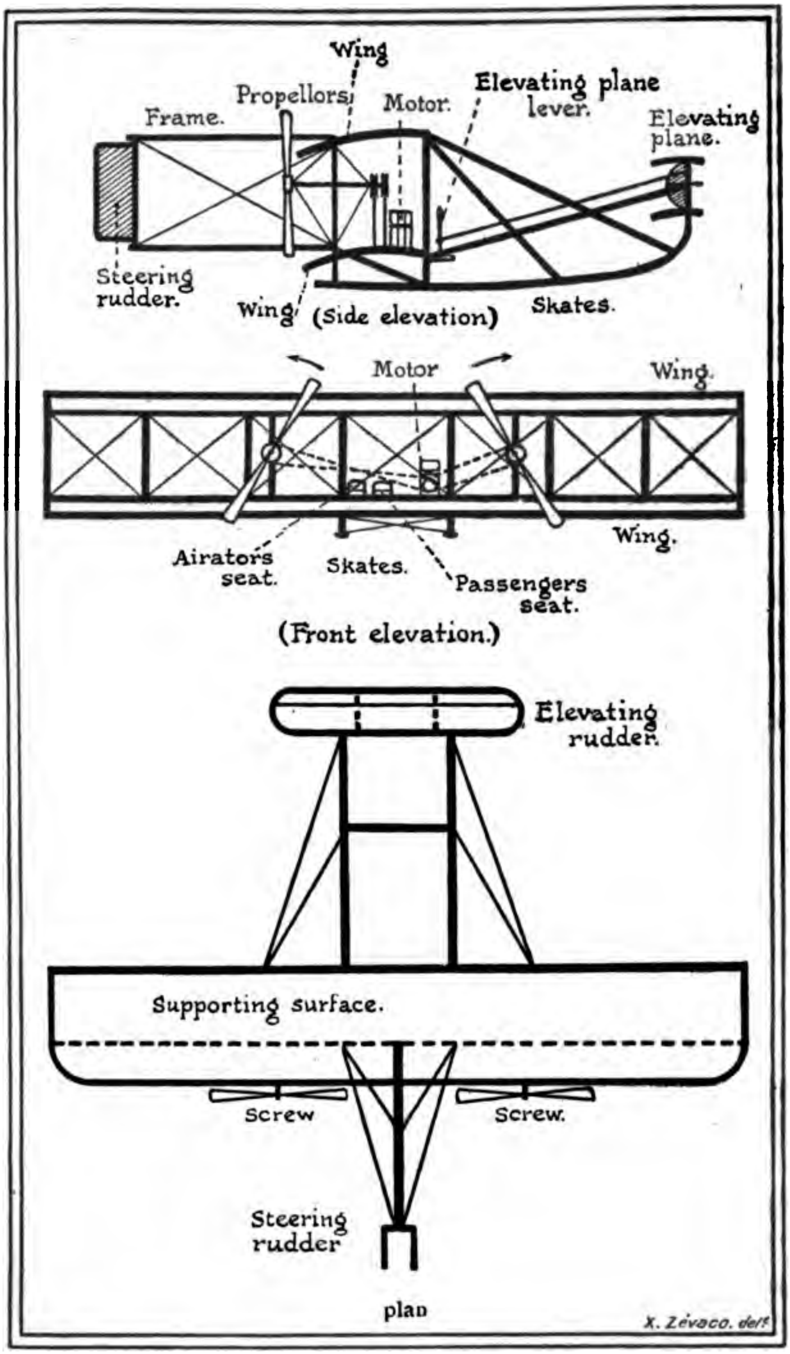


FIG. 71. The Wright Brothers' aeroplane

ened by a series of transverse pieces. Each of the latter is double, and formed of two incurved laths, which are kept taut by wedges at the stern. This latter, very fine, very thin, extends to the rear part of the wings a certain elasticity, a sufficient suppleness, to facilitate the "warping," by which means the celebrated American aviator secures the lateral stability of his aerial vehicle. Steel wire stretched diagonally ensures the indeformability of the wings. The fabric is riveted to the front edge of the plane members; at the back, to secure the finest possible finish, they are sewn together. The two planes are 1·80 metres (6 feet) apart, and this spacing is secured by vertical bracings, some of which are rigid and others articulated. Those of the centre, by means of diagonal supports, constitute indeformable parallelopipeds, in such a way that those of the extremities, fixed to the wings by screw rings, are able through the articulation to submit to warping which will deform the extremity slightly.

The planes rest upon two skids which form a kind of sleigh, because—it may be necessary to point out at once—the apparatus of the brothers Wright is not *self-starting:* there is no rolling-chassis to give it the impetus to rise.

This latter is artificial, and requires an extraneous force. These skates act as the part of the apparatus which is brought into contact with the earth in landing; furthermore, they are curved, like those of sleighs which travel upon the ice.

The skids form also the "foundation" of the aeroplane; at the front they carry the elevating rudder, and at the stern the steering rudder. The Brothers Wright have adopted an elevating rudder very similar to that laid out by Colonel Renard, which he used for the first time on *La France* in 1885. They have set it in such a manner that its concavity may be varied as desired by the pilot in synchrony with the movements which he may have to give to the aeroplane. The inclination of this rudder is controlled by a lever which the pilot holds in his left hand.

The steering rudder, comprising two vertical planes, is fitted at the stern. As the principal biplane is not divided into compartments, and there is no cellular stabilisator, the action of the rudder would be futile, and turning impossible, if the inventors had not disposed, between the two surfaces of the elevating rudder, two small vertical planes which help to support the whole system when turning, and to enable the rudder to move efficiently to turn the aeroplane. The two planes of which the rudder is composed are 1·80 metres high, 60 centimetres in breadth, and are spaced 50 centimetres apart. The rudder is operated by a second lever, having double articulation in this case, held in the right hand of the aviator.

Thus, the pilot seated on the edge of the under frame (the Wright aeroplane has no "body"), his feet upon an open foot-rest, as is plainly shown in the photograph (Plate XXIV.), holds a lever in each hand; with the left hand he inclines as desired the elevating rudder to cause his apparatus to ascend or to descend: with the right hand according to whether he pushes the lever backwards or forwards he can make his machine turn to the right or left. But, in addition, he can give this lever an independent sideways movement, whereby he warps the wings at will. We will see by what means.

Fig. 72 shows in detail the whole mechanism for warping the wings, when he moves the lever L^1 on the left-hand side of his seat A. In the case of the diagram we suppose that the lever L was pushed towards the left as shown by the curved arrow. Instantly the square bent-end *m*, which answers this movement, is turned also to the left and pulls in the direction of the arrows the controlling wires which are on its right: it thus depresses the right-hand rear corner of the upper supporting surface. This corner in depressing also pushes downwards the rear right-hand corner of the lower plane by means of a rigid and articulated member, which maintains the distance between the two planes. This right-hand rear corner in depression pulls the cord, which is on its left, in the direction indicated by the arrows, and through intermediate pulleys raises the rear left-hand corner of the lower supporting surface; the latter in this operation raises by means of the spacing member between the planes the left-hand corner of the upper plane, and so is obtained the warping which will cause the aeroplane to turn to the left. In pushing the lever L^1 towards the right, the warping action is reversed and tends to incline the aeroplane towards the right. The same lever L′ controlling also the steering rudder by its movement to and fro, compensates through the play of the latter the irregular rotations which might produce warping. The total depression of the extremities of the wings by the warping action is about 1 foot (30 centimetres).

A cursory glance at these two levers the aviator holds in either hand shows what prodigious *sang froid*, what absence of nerves he must have: a false movement, a turn or an inclination in this aeroplane, having no "body," no forward cells or empennage, would bring about most terrible accidents. We had a striking example of this on May 6, 1909, in the alarming mishap which just failed to cut short the life of the Italian Lieutenant Caldera, one of Wilbur Wright's pupils, who was thrown to the ground by his unmanageable appa-

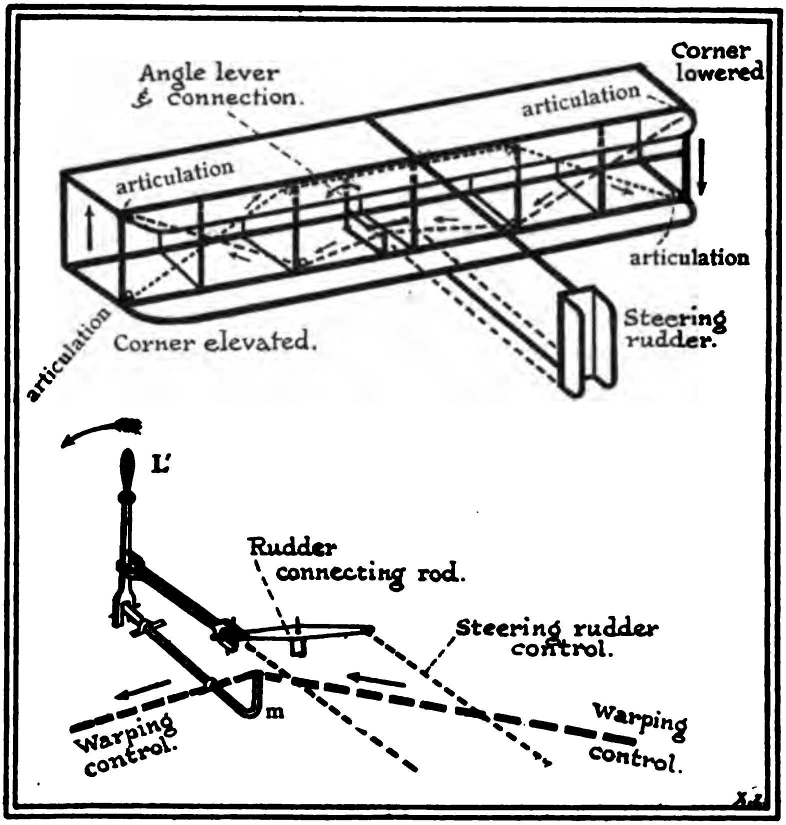


FIG. 72. Details of the wing warping action in the Wright aeroplane

ratus capsizing. Also one can incontrovertibly state that undoubtedly it is Wilbur Wright himself who constitutes by his presence at the helm the greatest part of the value of his aeroplane.

Let us turn to the mechanical installation. The engine is a 4-cylinder petrol motor developing 25 horsepower. It runs at a speed of 1400 revolutions per minute and its weight is from 95 to 100 kilogrammes. Set a little to the right of the aviator its weight balances the former when in his seat, which is on the left.

Propulsion is obtained by means of two screws of the same pitch and of the same diameter; they are wooden and their diameter is 2·60 metres. Owing to a convenient reducing gear they run in opposite directions, making 400 revolutions per minute; chains transmit the power from the motor to the propeller shafts. We have pointed out the danger of such an arrangement as this, which in the case of one of the screws breaking, leaves the other revolving, and submits the aeroplane to an eccentric movement causing it to capsize. Wilbur Wright, since the accident which befell his brother and in which the American Lieutenant Selfridge was killed, has, it appears, happily modified this dangerous system.

In order to start the Wright aeroplane a *rail* and *pylon* are necessary. The rail upon which runs a roller-carriage supporting the aeroplane is 70 feet (21 metres) long; it is laid on the ground and faces the wind. The rail is connected with the "pylon," a kind of pyramid framework, to the top of which is hoisted a weight of 800 kilogrammes held in position by a trigger. In falling this weight releases a cord, which through an arrangement of pulleys hauls the aeroplane along the rail with increasing speed, since the velocity of a falling body is proportionate to the extent of its drop, which explains the uniformly accelerated movement.

This means of launching is ingenious, but it deprives the American system of much of its practical value, relegating it chiefly to the category of appliances for research and experiments. It is an ingenious, an excellent, demonstration apparatus for mechanical investigation, but so long as the Brothers Wright refuse to make avail of this launching "rail," so long as they do not openly accept the conditions that prevail among all French aeroplanes, that is to say, start *unaided* and by their own means, they will hold an inferior position, and their machines will lack the features of "practical" utility. It is said that why they do not do so is because they do not wish it; such is to be regretted. It is true that twice they set out without the aid of the falling weights, but they were "sped" along their rail by men who could push the aeroplane rapidly. And then, it is not so much the weight, it is the rail, because it decreases to an enormous extent the friction at the start. We see this every day in the goods stations; along rails a horse draws a heavily laden waggon, whereas upon the road the same animal could not even pull the waggon empty.

The Wright apparatus moreover is rather dangerous because stabilisation, as much when travelling directly ahead as when turning, must always be secured by the aid of the aviator, whereas in aeroplanes of French construction, especially in the excellent monoplanes, it is only *lateral* stability with which the aviator is concerned, longitudinal stability being ensured by means of the "empennage." Also can one explain the difficulty that the American aviator has experienced in training his pupils? He has taught some how to manipulate his "bird" it is true; but this instruction was commenced at the Auvours camp during the month of August 1908, *lasted over seven months*, and it was not until March 18, 1909, that the American aviator for the first time dared to permit his pupils to manage their apparatus themselves; and even the insistency with which it is announced that the pupils have at last flown "alone" should suffice to show the difficulty of the task. On the contrary the French aeroplanes are so stable, that consequently four or five lessons suffice to render an aviator capable of operating them with safety (Latham with the Antoinette aeroplane for instance).

Nevertheless the Brothers Wright are entitled to considerable praise. They have perfected one important point in aviation, that of lateral equilibrium by the ingenious solution of the warping of the wings, and they have given a striking example of perseverance, for they built every part themselves, including their motor. Moreover, by their enthusiasm they have shown the true path which must be followed by aspiring aviators; they served their "flying apprenticeship" in practising, at first, straight flight, by numerous "glides" carried out with aeroplanes without a motor. Thanks to these glides they were able to discover, one by one, the necessary arrangements to obtain the best sustentation, the minimum resistance.

But, after all, in this they were preceded in America by Chanute, in Germany by Otto Lilienthal. In France Louis Blériot found a brilliant solution which gives the lateral equilibrium as surely as warping of the wings—the use of "ailerons" or "winglets."

To sum up, the Wright aeroplane, owing to its simplification of the arrangements, has been able to accomplish some magnificent "records" in height and speed. Through not having to carry with him some 60 or 80 kilogrammes more weight, represented by the running-chassis of the French aeroplanes, freed from the great effort necessary to start, and consequently the increased weight of the motor, he has been able to use an ordinary automobile engine, possessing greater reliability, and as a result better able to secure the records for altitude and duration. But he has not yet carried out a single real "voyage" because handicapped by the necessity of his launching rail he is compelled to return to his pylon to re-start; if he comes to earth *en route* he cannot rise again.

This is where Blériot triumphs, for on October 31, 1908, he accomplished the first aerial voyage in what may be described as a closed circle from Toury to Artenay and back, *descending twice during the journey and re-starting under his own power*, passing over roads, villages, and woods. Such is an "aerial tour" in the fullest sense of the word, and that date, October 31, 1908, constitutes in our opinion *the historical date in aviation.*

MAURICE FARMAN'S AEROPLANE: THE BREGUET BIPLANE

M. Maurice Farman, the brother of the celebrated "champion of the air," had an aeroplane built at the

Mallet workshops which was exhibited at the Aeronautical Salon in December 1908.

This apparatus, very well conceived, is a "biplane." Like the Wright apparatus, it admits of warping of the wings; but meanwhile by means of a stabilisating tail, it possesses the automatic longitudinal stability of the French apparatus (Fig. 73).

The two similar, and superimposed supporting planes, spaced vertically 1·50 metres apart, are vertically strengthened by 8 pairs of ashwood uprights. These supporting planes have a spread of 10 metres by 2 metres breadth. Their individual superficies is consequently 20 square metres, and the aggregate sustaining surface 40 square metres.

These planes are built up of light and rigid stays upon which is stretched, on both sides, a varnished cotton fabric weighing only 85 grammes per square metre.

The "wings" are mounted upon a spindle-shaped "body" of rectangular section, in which are placed respectively the pilot's seat, the motor, and the manœuvring and steering controls. The motor and screw are placed *behind* the aviator; the wheel controlling the elevating and steering rudders as well as the *lever for warping* the wings are set in front of him.

The "stabilisating tail" is a "rear cell" connected to the planes forming the "front cell" by four long members cross-braced and stiffened by tightly stretched steel wire. The rear cell has a spread of 3 metres, by 2 metres breadth, which in view of the fact that it is composed of two planes spaced 1·50 metres apart, gives a total surface of 12 square metres. The curvature of these two

THE WRIGHT AEROPLANE FLYING

Photos, Branger

THE WRIGHT AEROPLANE AT THE MOMENT OF LAUNCHING BY THE DROP OF A WEIGHT FALLING FROM ITS "PYLON"

surfaces is calculated in such a way that they are slightly "supporters" as well as being stabilisators.

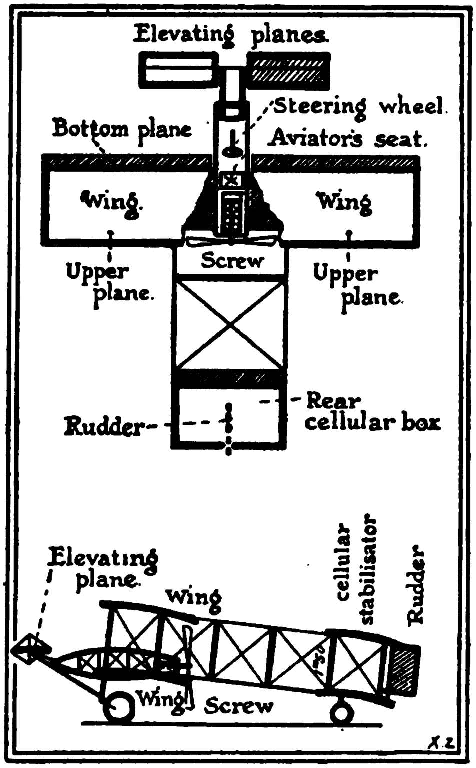


FIG. 73. Maurice Farman's aeroplane

The elevating rudder is at the front. It is a unique type, comprising a plane of 4·90 metres spread, by 90 centimetres wide. It is divided into two panels, on either side, at the extremity of the body of the machine. With regard to the steering rudder this is formed of a vertical plane, moving between the two horizontal surfaces of the rear cell.

The engine has been specially designed for aeronautical purposes by Rénault Brothers, the well-known motor-car manufacturers. This motor comprises 8 cylinders in two series of four, working upon a common shaft: the cylinders, in pairs, are arranged in the form of a V, the shaft being at the apex of the angle. The cylinders are air-cooled. All complete, the motor weighs 178 kilogrammes, and has developed, under dynamometer tests, 58 horse-power, which gives a weight of 3·100 kilogrammes per horse-power. A special reducing gear driven from the motor shaft reduces the engine speed from 1600 revolutions to 800 revolutions per minute at the screw propeller.

The screw is of wood. It was built by M. Chauvière, who designed the remarkable propeller of the *Bayard-Clément*. It is of the type which its distinguished designer calls "integral screw," measures 2·50 metres in diameter, with a pitch of 2·50 metres. It is placed immediately astern of the two carrying surfaces, the exterior edge of which is slightly indented to afford free passage for the revolution of the two blades.

The whole apparatus is carried upon a *running-chassis* which serves for launching and landing. It is four-wheeled, the two under the front cell being of 70 centimetres diameter each, and the two under the rear cell a little smaller. As the figure shows, the articulated forks upon which these wheels are mounted are fitted with absorption springs to allow descent without injury to the aeroplane.

Fitted with the Rénault motor and carrying the aviator weighing 80 kilogrammes, the apparatus has a total weight of 528 kilogrammes. At Buc it made some very successful attempts at flight which served to demonstrate the actual possibilities of the machine.

It will be remarked that the cells are not divided into compartments. The body of the aeroplane is the only surface opposed to lateral drift and giving a fulcrum for turning. M. Maurice Farman, however, will box his front cell should practice demonstrate the advisability of such an arrangement.

In closing this description of biplane aeroplanes we will mention the apparatus which M. Louis Breguet, the eminent mechanician and one of the inventors of the Breguet-Richet "gyroplane," of which we will speak later, built and exhibited at the Olympia Show in London.

Breaking away from the general lines followed by the Parisian designers, M. Breguet built his machine entirely of thin tubular steel of large diameter. The supporting wings have 12 metres spread, and are furnished with a special differential warping evolved by the inventor. This warping assists the wings in turning, and can also serve for lateral balancing as well as acting as an elevating rudder.

The motor built by the automobile house of Gobron-Brillié is of 60 horse-power. It drives a two-bladed screw 2·50 metres in diameter, the total weight of which is only 6 kilogrammes, and which in starting gives a propulsive effort of 250 kilogrammes. It will be able to attain a speed of 90 kilometres per hour.

An outstanding feature of this apparatus is the possibility of *folding the wings* by the most simple mechanism. In this manner the bulk of the aeroplane, when it is not in aerial service, is no more than that of a vehicle having the same wheel-base as the supporting wheels of the aeroplane. The whole is carried upon a three-wheeled running chassis fitted with springs.

This notable aeroplane is calculated to lift two passengers and a "useful weight" in the form of fuel and oil to the extent of 80 kilogrammes. It is therefore an apparatus possessing real features of practical utility.

CHAPTER V

DESCRIPTION OF SOME AEROPLANES

II. MONOPLANES

THE BLÉRIOT, ESNAULT-PELTERIE, AND "ANTOINETTE" AEROPLANES: CONSTRUCTION AND OPERATING MECHANISM

THE BLÉRIOT AEROPLANE

LET us now investigate the construction of the "monoplane" aeroplanes, that is to say, those in which the bird is imitated by only a single supporting surface instead of two, as in those already described.

The aeroplane of the engineer Louis Blériot is justly famous; it is an historical aeroplane, since even the English nation desired that it should be preserved at the South Kensington Museum. In fact it has enabled the illustrious aviator to accomplish that double feat (the glory of which no one can even attempt to rob him); in the first place he completed the first "aerial journey" in a closed circle with intermediate descents, and subsequently, on July 25, 1909, he accomplished that performance which created admiration throughout the whole world; achieving in a single flight the passage of the Channel between Calais and Dover. Moreover, Louis Blériot is entitled to a dual distinction; not only did he evolve his aeroplane, but he constructed and experimented with it himself; all the arrangements are his own work, and we will show how ingenious, simple, and effective they are.

The Blériot aeroplane in its general lines recalls a huge bird (Fig. 74). The supporting surface, set out in a single plane, is divided into two wings, one on either side, and it is between these that the aviator takes his seat. The wings have at their tips small movable "ailerons," *winglets*, which serve to right the machine when it dips. The spread, body and small wings included, is only 9 metres, and the supporting surface has a total superficies of 26 square metres, the rear corners of the wings being slightly rounded.

The wings are made of stiff parchment, and they are mounted upon a framework built of mahogany and poplar. The shape of the wings varies as they extend from the body, but they always present a concave surface turned towards the earth. The planes cut the air at an angle of 8 degrees. At their outer extremities are the stabilisating "ailerons" turning upon an horizontal axis, and their movement is controlled by the aviator by means of a device which we will describe presently.

The wing frames are connected to the aeroplane "body." The latter comprises a long spindle forming a "strengthened beam" with the front section rectangular, and triangular at the stern. The longitudinal members are cross-braced by ashwood struts, the whole being further strengthened by tightly stretched steel wire. The lattice structure thus obtained is of extraordinary lightness and solidity.

At the stern of this slender body is placed the stabilisating "empennage." This is rigid, and the length of the leverage at the end of which it works is a guarantee of its efficiency. The elevating governor is similarly carried at the rear extremity of the body. It may be pointed out that, in addition to this principal elevating rudder, the aviator can use also the two "ailerons" attached to the extremities of the two wings; turned one upwards the other downwards, they restore the apparatus in case of lateral inclination; moved both in the same direction they give ascent or descent and act in the same manner as the elevating rudder. Accordingly one in ascending or descending in a straight line can operate these two mechanisms in such a manner that their actions are combined.

Lastly at the extreme rear end of the body is the steering rudder, a rigid plane turning about a vertical axis. The pilot takes his seat in a space provided in the body between the two wings, having in front of him the novel lever by means of which the whole of the various movements of control are actuated.

This *unique* manœuvring device of the Blériot aeroplane is one of rare ingenuity and simplicity. It is a *lever and drum* which we will now describe in detail.

No one will deny the importance of maintaining surely and easily the direction of an aviating apparatus. The extreme mobility of the aeroplane in the atmosphere demands that the apparatus should absolutely answer to its controlling mechanism, because therein depends not only the regularity of the aerial route followed, but also the security, even the life, of the aviator.

We have seen, *à propos* of the Wright aeroplane, the inconvenience of a multiple lever system, which is so complicated and the management of which requires such prolonged practice, for each lever movement performs a definite operation.

M. Blériot thought that directly the aeroplane becomes a moving plane in space the most simple device for maintaining a direct line would be one where a centrally placed connecting-rod, answering a decided action by the aeronaut would be that in which the actuation of one plane was communicated to the other, so that they moved together. This is the only example yet perfected for controlling the one moving plane by another.

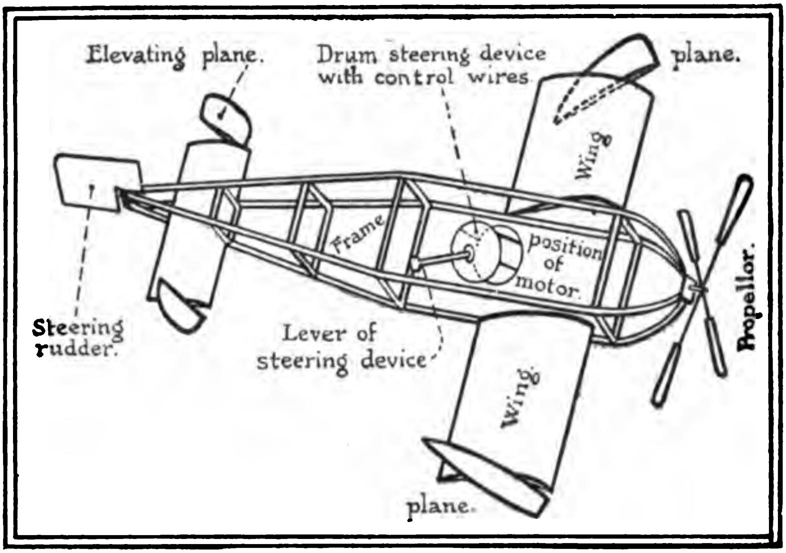


FIG. 74. L. Blériot's monoplane

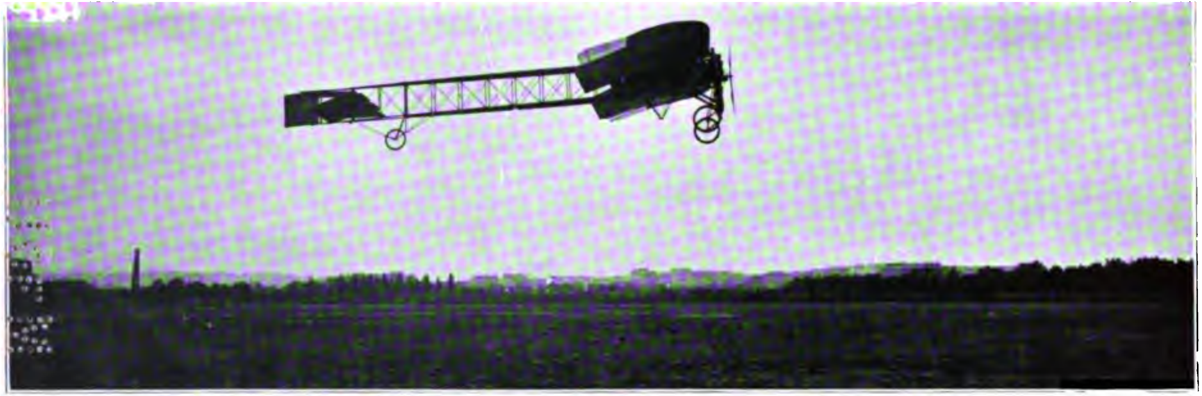
The principle of this system is shown in Fig. 74. Close examination will suffice to show that the aeroplane corrects by itself any deviation from stability, while travelling in a straight line, whatever inclination the apparatus may assume, irrespective of the number and position of the rudders, provided that the latter be correctly connected to the controlling plane. Thus is effected in one action, and to any desired extent, the stability of the aerial vessel, and all without depriving the aviator of the control of his apparatus or compelling him to maintain that much-desired automatic stability which, despite some attendant advantages, is not free from many dangers.

With the lever and drum command, the base of this barrel acting as the indicator, and turning in any desired direction, control is absolutely "instinctive," and the aviator cannot possibly make a mistake. Moreover, in combining this control with a level such as one uses in photography, the pilot can discern immediately which way he must move his lever to correct the aeroplane and thus preserve absolutely perfect stability while travelling.

Control is effected by means of a drum connected with a control lever with ball-and-socket coupling, and consequently able to move in all directions. The drum and lever are thus connected together. At the base of the drum are attached all the flexible steel wires which actuate the different mechanisms for "governing" the direction of the aeroplane. There are connected to the manœuvring arm two levers for the simultaneous control of the motor, which must, indeed, work in concert with the movements of the elevating rudder for fear of terrible accidents, such as loss of speed in ascending, or excessive speed in the descent.

The motor is of 50 horse-power, of the Antoinette, 16-cylinder type, with forced petrol feed. The radiator is carried in the tapered body of the vessel. The motor drives a four-bladed metal screw mounted on a lay shaft, has a diameter of 2·10 metres, and 1·40 metres "pitch." This screw is mounted at the front of the body; therefore it "draws" the aeroplane.

PLATE XXVI



Photo, Branger

LOUIS BLÉRIOT'S MONOPLANE IN FULL FLIGHT (THE FOSTER-CHASSIS AND THE "AILERON" AT THE TIP OF EACH WING ARE PLAINLY SHOWN)

The whole apparatus rests upon a running chassis for launching, and to ensure descent without shock. This chassis has two bicycle wheels placed under the front of the tapered body. A third auxiliary wheel near the stern secures balance of the apparatus when it rests upon the ground. The chassis is built up of a rigid cross-braced framework of wood and tubes of steel. This frame carries the body of the aeroplane (Fig. 75), which reposes in quite a springy manner upon a pair of coupled parallel wheels turning about vertical axes. The connection between the chassis proper and each of the two wheels is by means of a collapsible triangle, the apex of which is at the centre of the wheel, a trifle below the principal leg, and in which the third slides in a vertical tube, and bearing in its movement against the head of a spring fixed to the chassis. By this arrangement the whole, although not weighing more than 35 kilogrammes, can absorb at landing a blow of several hundred kilogrammes. Fig. 75 shows the side elevation of the tapered carriage with the wheeled frame under the front, and also the rear wheel.

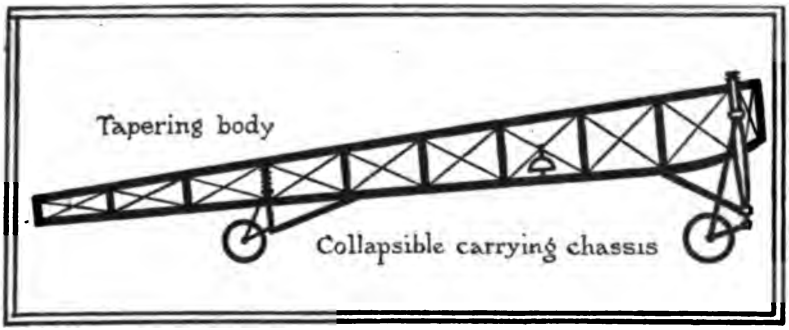


FIG. 75. The rolling chassis of the Blériot aeroplane

Having given the general outlines of this remarkable aeroplane, known as *Blériot IX.*, let us now conclude by saying that the total length from end to end is 12 metres. Its complete spread is 9 metres; supporting surface 26 square metres; weight, including aviator and supplies of fuel, 480 kilogrammes; and its initial speed 70 kilometres per hour.

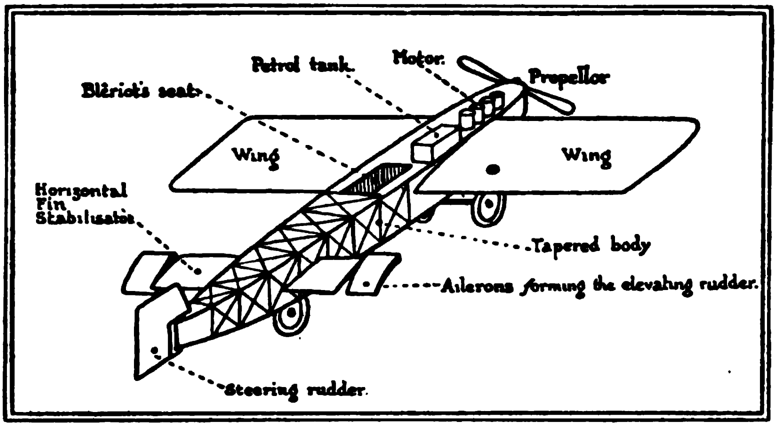


FIG. 75B. Blériot's monoplane

M. Louis Blériot has built a slightly different aeroplane, *Blériot XI.*, in which the small wings (*ailerons*) of the supporting surfaces are abandoned in favour of simple warping. The ailerons are retained at the two extremities of the rear stabilisator, and form the elevating rudder. The dimensions of this new aeroplane are much less than its predecessors, being: length, 8 metres; spread, 7·20 metres; supporting surface, reduced to 12 square metres; angle of cutting edge, 7 degrees; motor, 7-cylinder, 30 horse-power, Esnault-Pelterie (R.E.P.). Under these conditions the supporting surface will have to sustain an effort of 27 kilo-

PLATE XXVIA

THE BLÉRIOT AEROPLANE PREPARING TO LEAVE THE FRENCH COAST (THE AVIATOR STANDING ON HIS BIRD, AND THE WOODEN PROPELLER AND MOTOR CAN BE PLAINLY SEEN)

BLÉRIOT CROSSING THE CHANNEL, JULY 28, 1909

M 10U.

grammes per square metre, but such is the perfection of construction that this end is successfully achieved, the speed of the apparatus attaining 80 kilometres per hour.

It was by slightly modifying this aeroplane that Monsieur L. Blériot built the admirable apparatus which enabled him to cross the Channel in twenty-seven minutes on July 25, 1909. The following is the detailed description of this historical monoplane (Fig. 75B).

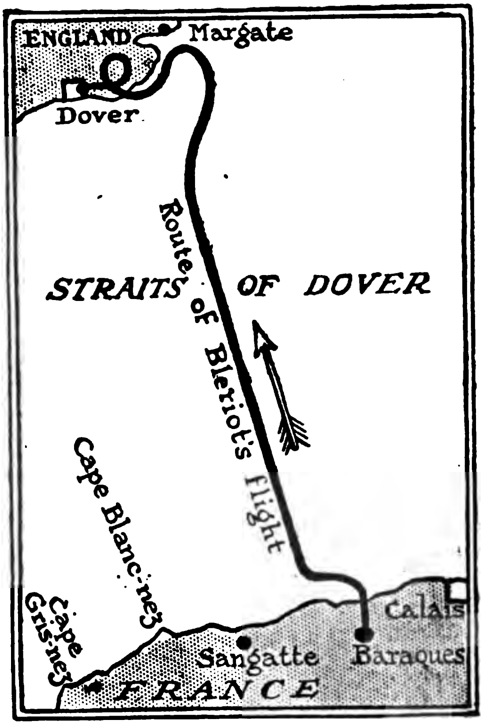


FIG. 75C. Map of Blériot's Channel flight

The ailerons are suppressed in the carrying planes, and are replaced by a slight warping of the wings. These ailerons are confined to the rear on each side of the horizontal empennage; they thus constitute an elevating rudder.

The wings have a spread of 8 metres; their length in the direction of travel is 1·80 metres (exactly 6 feet); total length is 7·20 metres (24 feet). The superficies of the supporting surface is 14 square metres. The inclination of the cutting edge (angle of attack) is 7 degrees. The screw is at the prow.

The motor, built by the engineer Anzani, is remarkable; it develops 20 horse-power.

Under these conditions the supporting surface sustains a weight of 27 kilogrammes per square metre.

THE ESNAULT-PELTERIE AEROPLANE

We have already pointed out the tendency among aviators to reduce the superficial area of the supporting surfaces, to avoid increasing their resistance, which must balance the more and greater stresses. This tendency we see manifested a second time in one of the most remarkable aeroplanes among those which have yet been built, that of M. Robert Esnault-Pelterie, which its inventor, borrowing the three initials of his name, describes under the abbreviation "R.E.P."

Among the already important group of French aviators M. Esnault-Pelterie occupies quite a distinct position. Though very young, he set out on the "path through the air" as far back as 1903, when the rumour of the exploits, mysteriously held in secret, of the Brothers Wright roused ambitions in him which led to success—became resolved into persevering, continued, and rational experiments. The young aviator (who at the time of his appearance felt himself to be, nevertheless, one of the oldest) sought nothing from anybody. He himself, by his own means, conceived, constructed, and tested his aeroplane, which he knew to be a marvel of construction at the time from the point of view of appearance and solidity. And, moreover, being a practical mechanician, he created and made every part of a new type of explosion motor, absolutely novel because of its compactness, exceptional lightness, and at the same time reliability of action. So in the aviating apparatus that he fashioned and brought to success everything bears the imprint of his personality—the general lines, construction, motor, and even the arrangement of the running launching chassis.

The Esnault-Pelterie aeroplane is a monoplane, distinguished by its flexible warping wings, and stern supporting surface fulfilling the function of the elevating rudder. It is fitted with a stabilisating empennage, and its rolling chassis is mounted upon two wheels "in tandem," which support its weight, the tips of each wing carrying a wheel for contact with the ground.

The shape of the body of the aeroplane is fusiform. It is built up of steel tubes (bicycle tubes), autogenously welded together; moreover, they form a triangular network similar to strengthened trelliswork, which assures complete indeformability of the system, as well as rigidity and strength.

The wings have a total spread of 9·60 metres, and their design is in accordance with the results of lengthy experiments carried out by the inventor. Their surface is 15·75 square metres; as they support the whole weight of the apparatus, which aggregates 420 kilogrammes, this represents a proportion of 26·600 kilogrammes per square metre, the same, be it noted, as in the new aeroplane, *Blériot XI.* The wings are of wood, flexible, strong, and light. They are made in slips, strengthened lengthwise by steel and aluminium. Over these wings is stretched the fabric, which is the surface offered to the resistant action of the air. Each of these wings is stretched underneath by two sets of ropes converging to a point beneath the chassis, and by which the warping is accomplished. Each of these sets of ropes supports a fourth of the weight of the apparatus. They are plainly shown in the photograph, Plate XXVII.

Viewed from above, the Esnault-Pelterie aeroplane strikingly resembles a bird, with its fan-shaped tail formed by the spreading of its feathers. The surface thus shown (Fig. 76) has a variable inclination at its rear end, thereby forming the elevating rudder, under which is placed the well-balanced steering rudder, turning about its vertical axis; it is what is called in marine practice a "compensated" rudder, because the axis of rotation passes through its centre instead of at one or other of its sides. Under the body is a veritable "keel," which secures longitudinal stability. The pilot has his seat towards the front of the body of the aeroplane, and the screw is at the extreme prow; therefore it "draws" the machine through the air. The pilot, owing to the tapering of the prow, has a clear view of the ground in front of him when the aeroplane is running along preparatory to launching.

The steering and manœuvring control are by means of levers and pedals. The manipulation of an aeroplane comprises two essentially different operations, corresponding to two widely divergent requirements. There is first assurance of stability at starting, and afterwards the maintenance of forward direction. For each of the two manœuvring operations M. Esnault-Pelterie has provided a vertical lever. Stability itself also comprises

PLATE XXVII

Photo, Rol

THE ESNAULT-PELTERIE MONOPLANE

two variants; longitudinal and lateral stability respectively. The lever which controls stability has two movements, one to and fro, the other from left to right.

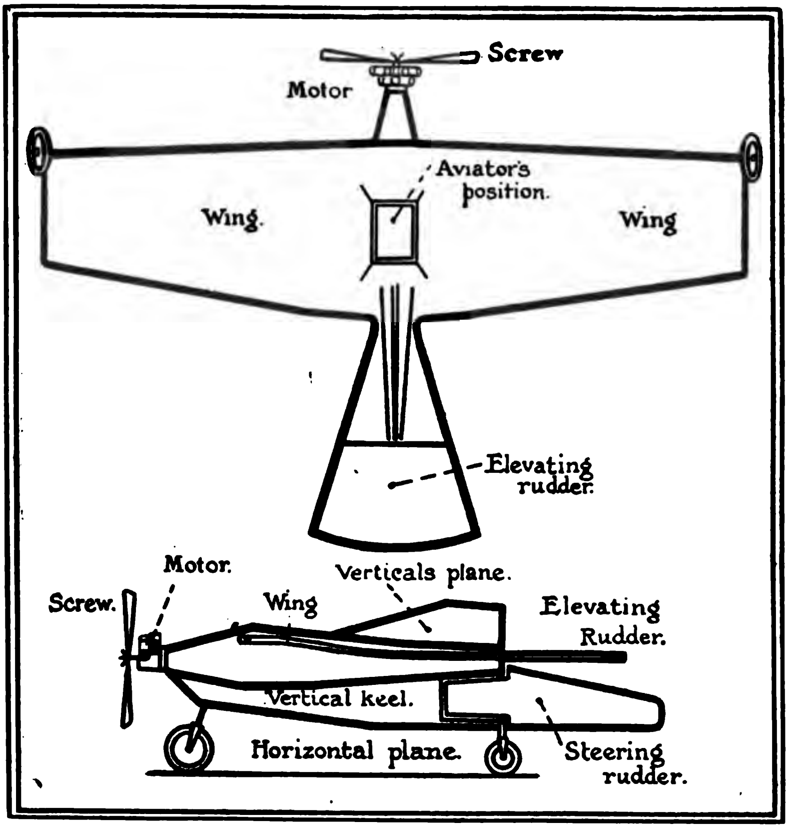


FIG. 76. Esnault-Pelterie's monoplane

For this purpose it is fitted with a universal joint, and is set to the left of the aviator. When he moves it from left to right, or inversely, it warps the wings through the four sets of under-stretched ropes; when he moves it from front to back, or *vice versa,* it actuates the elevating rudder, and as a result enables the aviator to recover his longitudinal balance, or, if he so desires, to ascend or descend.

The second lever is placed in front of the pilot; controlling lateral direction, it is moved transversely, and commands the steering rudder. One can see what ingenuity and rational simplicity have accompanied the design of these steering devices; the aviator must push the levers in the direction in which he wishes his aeroplane to go; the movements which he has, therefore, to carry out himself for this purpose are, so to speak, reflexive, and error is impossible. Finally, two pedals allow the aviator to control his motor, one acting upon the gas inlet, the other upon the propeller connection.

So far as the motor is concerned, we have already had occasion to describe it. The Esnault-Pelterie (R.E.P.) engine is one of the most original and one of the best-conceived that there is in aviation circles. When this excellent engine was completed La Société des Ingénieurs Civils awarded their prize to the inventor. It is of 30–35 horse-power, and its cylinders, numbering five, seven, or ten, according to the power, are disposed in two "semi-stars," but in such a manner as to be all above the horizontal diameter of the figure. In this manner lubrication is perfect. The valves are of the sliding type, and, according to their position, permit admission and exhaust; there is one to each cylinder, and they are operated by a single cam. There is no water-circulation, the cylinders being fitted with fins, and at a speed of 45 kilometres per hour cooling is very perfect. The motor, of 30–35 horse-power, weighs 68 kilogrammes complete. An oil reservoir of 6 litres and a fuel tank of 40 litres suffice for two hours' continuous flight under the propulsion of a four-bladed screw 2 metres in diameter, mounted direct on the motor shaft.

In completing our description of this remarkable aeroplane, it is only necessary to say a word about the rolling chassis used for launching and landing. The body of the apparatus is carried upon a pair of wheels arranged in "tandem"; under these circumstances it falls to the left or right; but the tip of each wing being fitted with a special wheel, permits the apparatus to run along the ground without bringing the wings into contact with the latter. Immediately the apparatus is launched, the aviator, by the aid of the warping lever, lifts the wing which is trailing, and the equilibrium of the machine is established. The front carrying-wheel is mounted upon an "oil-pneumatic brake," assisted by a spiral spring. Under ordinary circumstances the weight of the apparatus is flexibly supported upon this spring. Vibrations caused by the unevenness of the ground are absorbed by an air cylinder, in which moves an air-compression piston. Finally, the shock in landing is taken up by an oil brake, in which this liquid, compressed by the blow, is forced through a very small orifice: this brake, which weighs only 6 kilogrammes, can absorb 350 kilogrammes. One can see, therefore, that it is very efficient for the landing of the aeroplane.

THE "ANTOINETTE" AEROPLANE

Among aeroplanes of the monoplane type, the *Antoinette* deserves particular mention.' Every one knows that the motors of this make have already furnished aviation with an engine powerful combined with lightness carried to such a degree that a 100-horse-power motor can be transported by an average man. The builders of these engines have also undertaken the construction of aeroplanes, and in their choice fixed upon the monoplane.

They started building the aeroplane *Gastambide-Mengin*, which served them as a means of investigation and research, and, by improvement upon improvement, they at last produced a striking type, which is known as *Antoinette V*.

These constructors, like so many other aviators of to-day, preferred the monoplane because of its extreme simplicity, facility of construction, and greater efficiency, requiring less power for progression through the air under the same conditions of weight and speed.

One of the most remarkable features of the *Antoinette* aeroplanes is the design and build of their supporting surfaces. These, divided into two elements constituting wings in every sense of the word, have the form of trapeziums, the larger base being contiguous to the body of the machine. When seen from the front the apparatus has the appearance of a very open V.

The section of these wings is of such form as to secure the maximum of "power of penetration." Their surfaces are covered on both sides, and the fabric is mounted upon a framework which is certainly a marvellous piece of work from the triple standpoint of rigidity, solidity, and lightness. This framework is composed of an assemblage of longitudinal and transversal ribs, intersecting one another so as to form a series of triangles, the whole being consolidated in a rigid manner by riveted aluminium "gussets." The wing surface is 25 square metres, and yet their weight is scarcely 30 kilogrammes. One can thus see that the total supporting surface is 50 square inches. The extreme spread is 12·80 metres. It is very interesting to note that the builders have designed their framing upon the lines and methods of the constructors of metallic bridges and the Eiffel Tower, which consists of subjecting every part to tension and compression.

The body is triangular in section; it is a long girder, ending at the front in a pyramid, prismatic at the wings, and then tapering towards the tail of the apparatus. It is likewise built upon the principle of metal bridges; at the same time it is light and rigid. Body and wings are covered with fabric, carefully stretched and given several coats of varnish: this imparts to the surfaces moving through the air a remarkable smoothness, reducing to the minimum the friction of the molecules of air coming into contact with the force which displaces them.

The constructors of the *Antoinette* aeroplane have abandoned warping the wings for the following reason. With Louis Blériot, though in a slightly different form, they have adopted the ailerons fitted to the tips of the carrying surfaces. These ailerons, which one may see very distinctly in the photograph of this aeroplane, are connected to the back edge of the wings, and when at rest form a prolongation thereof. They are connected with the latter by an articulated system which lowers one while it raises the other. This produces the same effect as warping, but with greater power and without the inconvenient danger of fatiguing the wing framework by twisting or bending a part of its construction. These ailerons assure the utmost lateral stability.

In regard to the longitudinal stability, this is obtained by an "empennage." It extends horizontally and vertically beyond the surfaces of the empennage properly so-called, and carries two rudders for elevating and steering respectively. The great length of the apparatus, which is 11·50 metres, gives to this empennage a very great efficiency, securing a remarkable stability in the direction of travel.

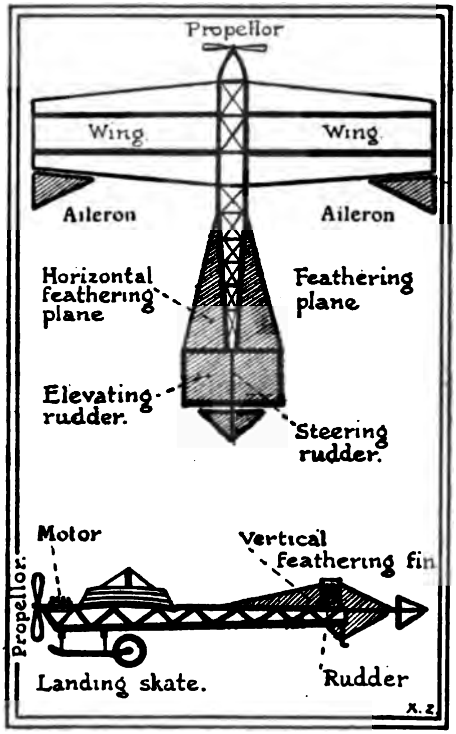


FIG. 77. The "Antoinette" monoplane

Control is effected by three wheels. One may not refrain from thinking that such is too much for an aviator who has only *two* hands. Two of them, controlling steering and the ailerons respectively, are close together, it is true, so that the hand can pass easily from one to the other. For my part, I think that it would be perhaps wiser to have recourse to a control arrangement of the Blériot aeroplane type. That is the only criticism which I can offer of this apparatus, the conception and the construction of which from all points are remarkable. In addition, two handles control the ignition and the inlet

PLATE XXVIIA

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MR. LATHAM, WINNER OF THE HEIGHT COMPETITION AT RHEIMS, 1909

throttle of the motor, and there is a foot-brake to stop the engine.

The whole apparatus is carried upon a supporting chassis composed of a "roller skate" placed under the front of the body, two "shores," one at the right and the other at the left centre of each wing, and a "butt-end" under the tail. The "shores" and "butt-end" are set in the direction of travel. The "roller-skate," comprising a bicycle wheel at the back and a roller at the front, owing to an ingenious and solid suspension spiral spring, admits of absorbing to the maximum the severe shocks which are produced at the moment of landing. The skate-wheel, almost under the centre of gravity of the apparatus, is so placed that the strain upon the tail is reduced to the minimum. With regard to the "shores," not only do they preserve the wings from all rough contact with the ground, but they serve as an anchoring point for the upper consolidating ropework. Moreover, a vertical piece serves as a straining support for the cords stretched over the upper face of the supporting surface.

When one wishes to launch the apparatus, one starts the motor and connects the propeller: the aeroplane is supported on the ground by its skate, shore, and stern butt-end. As the speed increases it is the butt-end which first leaves the ground; after some lateral oscillation the shores in their turn rise. Released, the apparatus gradually balances itself while poised upon its roller-skate, until at last it definitely rises.

The motor is, naturally, an "Antoinette." It has eight cylinders disposed in a V, and develops 55 horse-power. It is placed towards the front, and drives a two-bladed prow propeller of 2·20 metres diameter. This screw is of metal; its shaft is a steel tube with blades of aluminium riveted to the boss, which is flattened out into the shape of a fan. Its pitch is 1·30 metres, and it runs at 1100 revolutions per minute. One can change the set of the two blades, and consequently modify the pitch. By means of experiment one can thus ascertain the most advantageous pitch for the best regulation of the track of the aeroplane.

With regard to the pilot's seat, exceptional precautions have been observed to secure ample accommodation for the aviator: the position is well sprung, so as to preserve him as far as possible from all shocks, and at the same time allow him the greatest freedom in movement.

Such is the superb monoplane, the construction of which from all points of view is striking. Perfected by M. Welferinger, it was taken to the camp as at Châlons, and there placed in the hands of M. Demanest, who served his apprenticeship as pilot.

After five lessons only, the young aviator was able not only to "fly," but to win, on April 8, 1909, the latest prize of the Aero Club of France for 250 metres. M. Henri Farman, passing through the camp at Châlons, officially timed the trip, and warmly congratulated the new aerial navigator.

And on June 5, 1909, the *Antoinette* aeroplane accomplished another performance: M. Latham, scarcely familiar with the management of this remarkable aeroplane, flew for *one hour seven minutes*, darkness only stopping him then. The following day, not content with having beaten the world's record in a monoplane, he set out with a passenger. The day after he performed an unprecedented achievement in aerial flight, for, besides himself, he carried two passengers, MM. Fournier and

Santos-Dumont, and demonstrated once and for all by his marvellous skill, the safety and facility of manipulation, and consequently the absolute superiority, of the French aero-monoplanes.

Finally it was with this aeroplane that Hubert Latham was able to cross the Channel, after M. Blériot, and to reach within less than a mile of the English coast.

This feat, so rapid, this safety, so promptly acquired, demonstrates better than words how great is the security of the French aeroplanes, and how much easier they are to control than the apparatus which, like those of the Brothers Wright, demand *everything from* the aviator. And this rapid initiation is not the only one; upon the *Blériot*, *Esnault-Pelterie*, *Voisin*, and *Antoinette* aeroplanes flying can be learned in a few lessons. This exemption from a long, laborious, and perilous apprenticeship is therefore quite a triumph for French aviation.

M. TATIN'S AEROPLANE, THE "BAYARD-CLÉMENT": THE VENDÔME AEROPLANE: SANTOS-DUMONT'S "DEMOISELLE"

Among the apostles of aviation is a man who, one can safely say, has devoted his life to the advance of "the good fight" in favour of transport by machines *heavier than the air;* not only has he contributed some remarkable works upon this subject, but he built an aeroplane model, which was tested at the Chalais-Meudon riding-school in 1879 before a number of officers; this model was propelled by a screw driven by a compressed-air motor. As a result of his efforts, Tatin deserves to be placed beside Penaud, Langley, Richet, Marey, and the other notables of the "Pleiade" of initiators.

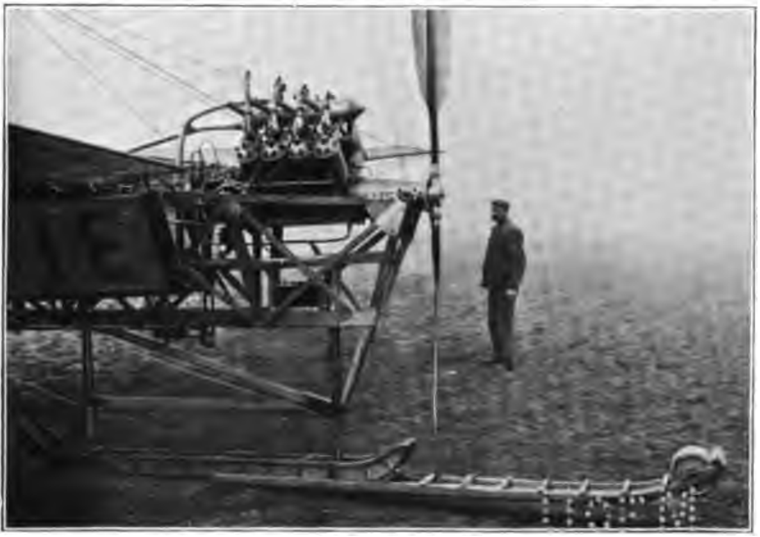
Some time ago, Victor Tatin conceived a type of monoplane in which he sought to emulate the bird by a "soaring plane." M. Clément, the automobile engineer, of whom we have already spoken in connection with our description of the magnificent dirigible in the first part of this book, enabled the inventor to carry out his idea, and the *Tatin* aeroplane which, like the dirigible, will be known as the *Bayard-Clément*, is now building at the workshops of M. Chauvière, the accomplished and skilled designer of aerial screws. It is impossible to pass in silence this aeroplane, of which much has been said prior to its appearance, and on the subject of which M. Tatin has written a very excellent book entitled *Eléments d'Aviation*.

Seeking to imitate the soaring bird, the *Tatin* aeroplane is perforcedly a monoplane. The inventor has pointed out that in the soaring plane the tips of the bird's wings are bent slightly upwards. He has consequently imparted this form to the transverse profile of his wings, which, instead of being separated from one another, constitute by their combination, a continuous surface which projects horizontally, forming an elongated ellipse. The surface of the rear empennage takes this form also; the spread is 12·50 metres.

The general appearance of the *Tatin* aeroplane is totally different from any we have yet seen. It is distinguished by the elimination of all parts capable of offering resistance to movement and not acting as sustaining surfaces, recalling on the whole the general outline of the bird known as the martin. The wings are

PLATE XXVIII

MONOPLANE "ANTOINETTE IV"



Photos, Rol

MOTOR AND SKATE OF THE "ANTOINETTE" AEROPLANE

curved, their convexity being turned towards the ground; the supporting surface has a span of 25 square metres. The stabilisating tail is 4·40 metres from the wings, has the same curved form as the latter, and its surface is 7 square metres.

The body of the apparatus is rectangular in section, the sides being 90 centimetres. It is 6·50 metres long; it is really a "strengthened girder" carrying the motor, the aviator, and tanks for petrol and oil. As it is imperative that these resistance surfaces should be held taut by shrouds, there are two thin vertical members and eight steel wire shrouds, so arranged that they meet above the surface of the tail for this purpose.

The front of the aeroplane is connected to the stern by two wooden members spaced a sufficient distance apart to permit of the propeller revolving between them. The latter is of wood; placed at the stern of the body it is of 2·40 metres diameter, and has a pitch of 2·50 metres; it revolves at 700 revolutions through a reducing gear mounted on the motor shaft. It is built up of thin superimposed sheets let into the framing and assembled in such a manner that the true form of the structure is preserved. The whole is covered with varnished Japanese silk.

The motor, specially constructed at M. Clément's ateliers, after the designs of M. Clerget, can develop 60 horse-power, which can at will be reduced to 30 horse-power. It is placed behind the aviator, and has radiating cylinders.

The stabilisating tail serves at the same time as the elevating rudder. For this purpose it can be slightly inclined upwards or downwards. A vertical rudder fixed to the tail secures lateral steering.

When the apparatus is in full flight it does not require more than 25 horse-power, and will fly under such effort at 72 kilometres per hour. By using the whole of the available motor power this speed will be possible of increase: the aggregate horse-power is a little more than twice 25, which will multiply the foregoing speed by 1·3 thus giving a speed of 90 kilometres per hour. This aeroplane will thus be one of the fleetest. Well thought out, as a result of prolonged study by its author, marvellously constructed by the engineer, Chauvière, it is now completed, and its tests are keenly anticipated.

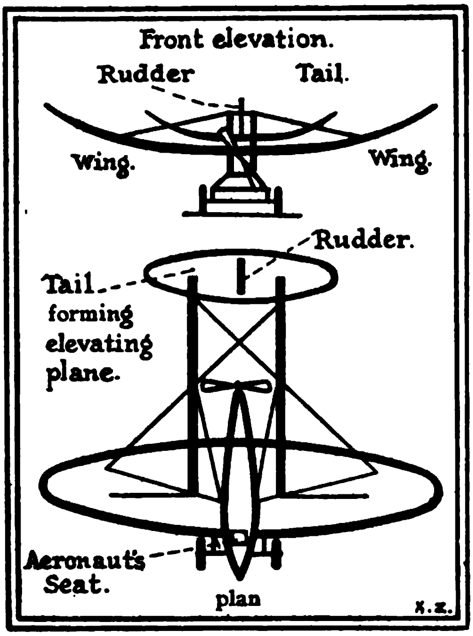


FIG. 78. V. Tatin's monoplane aeroplane, the *Bayard-Clément*

Another very interesting aeroplane is that which has been built and successfully tested by M. Vendôme. Here we find again that tendency, of which we have already spoken in *Blériot XI.* and the *Esnault-Pelterie* aeroplanes, which consists in reducing the spread by the decrease of the superficies of the wings, and the augmentation of speed. This tendency we shall find more accentuated still in Santos Dumont's very ingenious little flying apparatus.

The *Vendôme* aeroplane is fitted with two separate wings, symmetrically placed on either side of a fusiform body, having a quadrangular section. The membrane of these wings is of very light, tightly stretched, unvarnished fabric. The wings are disposed upon new and quite original lines. M. Vendôme has sought to combine the "ailerons" with the warping action, thereby making use of both these systems. To this end each wing can be pivoted upon itself, *independently of the other*, by one of the control levers. This is equivalent to warping the *whole* of the supporting surface and ensures the maintenance of transversal stability. In manœuvring the two levers simultaneously one can change the angle of incidence of the wings and so ascend or descend. Moreover the two wings present, as in the *Antoinette* aeroplane, the form of a very open V. A stern tail obtains longitudinal stability of the apparatus and acts likewise as the elevating rudder.

There is no steering rudder; turning even in a very short radius is obtained by means of the extreme ailerons placed above each wing. When at rest the "ailerons" lie upon the supporting surface; the pilot, by the aid of pedals, raises them when he so desires, producing a dissymmetrical resistance to the air, thereby securing his horizontal line of travel. The motor is of 50 horse-power; it drives direct a hollow screw of hickory wood veneer, mounted on canvas, of 2·43 metres diameter, and of which the weight is only two kilogrammes. The whole apparatus rests upon a three-wheeled running chassis fitted with absorption springs.

The whole apparatus is 12 metres long, and has a spread of *9 metres* only. The supporting surface is 24 square metres, and the total weight does not exceed 310 kilogrammes. On January 16, 1909, at Bagatelle, this machine made several flights at a speed of 76 kilometres per hour.

Smaller still is the latest aeroplane designed by M. Santos Dumont, the *Demoiselle,* as it has been christened by its author: 6 metres long, 5 metres spread only, and 150 kilogrammes in total weight, such is this remarkable engine, with which at St. Cyr, early in April, the Brazilian aviator .completed several successive flights aggregating 2500 metres!

Thus is demonstrated the fact that one can fly without the use of immense surfaces, of weighty and cumbersome machines. Before long, thanks to the explosion motor, the artificial bird of less weight and volume will be able to go anywhere. A little more progress and every one will fly.

THE TWO SCHOOLS OF AVIATION

We see from the foregoing that we are confronted by two schools of aviating apparatus: the American school, represented by the Brothers Wright, which demands *everything* of the aviator, and the French school, Voisin, Blériot, Esnault-Pelterie, Antoinette, which requires, on the other hand, the *minimum* from the pilot.

Which of the two is correct?

The best way to reply to this questien is to quote the words of Paul Painlevé, Sorbonne Professor, and member of the Académie des Sciences. M. Painlevé is not one of those abstract mathematicians who confines himself to differential symbols or the study of elliptic action. He has probed into aviation practice, has flown in turn with

Wright at Auvours, and with Farman at the Châlons camp, and this is how, in a subsequent article, he expressed himself upon the subject:

"Aviation is the most burning mechanical problem appealing to mankind to-day. *Its solution is achieved.* To-morrow it will be commercial; in a few years it will commence to transform the world. This solution one can now indicate upon broad lines.

"Two schools are represented: the French and the American, or if one so prefers—for it is confined to the two constructors who have effected the most impressive results—the Voisin and the Wright systems respectively.[1]

"In the first place an aeroplane to be able to support itself in the air must travel quickly, and at such a speed that the resistance of the air, increasing with the speed, prevents it from falling, whence the necessity of a motor, powerful, light, and regular in action at one and the same time. The more swiftly an aeroplane travels the more stable and capable will the apparatus be of combating the caprices of the wind. The perfection of an ideal motor is no more than a question of months.

"Then it is imperative (and this is the gravest difficulty) that the apparatus neither dips forwards nor backwards, neither to the right nor left; it must not even deviate from its direction of travel. In a word, the aeroplane must not pitch or roll, or swing round suddenly, or else the pilot must be able to restore such unbalancing movements as soon as they develop.

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[1] At the time the eminent mathematician wrote these words (*Le Matin*, October 28, 1908) M. Blériot had not made his "historical journey" in a *closed circle* by monoplane, and Latham had not accomplished his well-known brilliant triumphs on his "Antoinette" monoplane.

"Here are the means of obtaining this stability, which are different in the two schools.

"Wright has sought above all simplicity and lightness, but *the equilibrium of his apparatus is entirely in the hands of the pilot.* Three distinct movements combat the three possible perturbations; warping of the wings particularly counteracts rolling.

"In partitioning the two wings like the cells of a kite in the form of a cigar-box, Voisin, on the contrary, secures lateral stability. *In turning their apparatus assumes itself to the most convenient inclination.* Two operations instead of three are all that is necessary to control this machine: that of the steering rudder, and that of the elevating rudder. *Yet this last control is now very simplified by the addition of a long tail, which opposes pitching.*

"Lastly, the utilisation of the motive power through the large slowly-turning screws of the Wright, or the shorter and higher speed of the Voisin, appear comparable.

"The Voisin apparatus is decidedly heavier than the Wright (650 kilogrammes instead of about 500), due in the first instance to the tail, and secondly to the running chassis (80 to 100 kilogrammes) necessary to enable the apparatus to raise itself under its own effort.

"These differences, well specified here, are the result obtained by the two apparatuses. Wright holds the record for distance by himself and with a passenger. *He has never yet raised himself by his own effort.* He will be able to do so though when he so desires, but *will it be without increasing weight?*"

The Voisin apparatus, piloted by Farman, holds the

PLATE XXIX

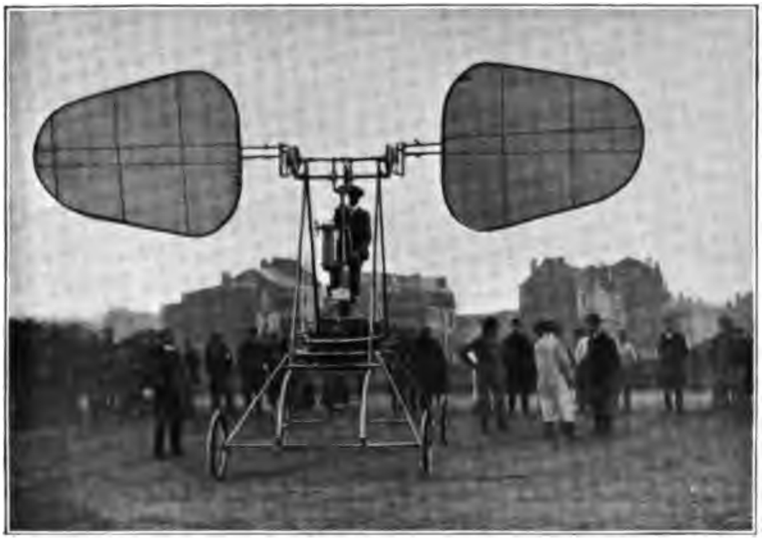
Photo. A. de la Hault

DE LA HAULT'S ORNITHOPTÈRE


CORNU'S HÉLICOPTÈRE

record for speed: 70 kilometres per hour at least; but it must be pointed out that it is always self-lifting by means of its running chassis, weighing 80 kilogrammes.

Before my own eyes Farman flew in a violent wind (October 28, 1908) above the camp at Châlons; he made the first long distance flight that had ever been attempted in an aeroplane; he flew not only in public, but before some officers who attempted to overtake him at the gallop. He repeatedly described his usual circuit at great altitude, frequently exceeding 40 metres. Lastly, notwithstanding the weight of his running chassis, it lifted itself and me *by its own effort,* and traversed a distance of 1600 metres, and the apparatus completed a turn showing as perfect a stability as if the pilot were unaccompanied.

"A magnificent day's work for French genius!" wrote a young officer who was overcome by enthusiasm at these experiments.

It would be useless to add a line of comment to this criticism by one of our most learned mathematicians, a criticism formulated on October 28, 1908; and two days later Farman and Blériot substantiated his statements by completing, on the 30th and 31st of the same month, the two "first aerial voyages" from town to town. That is a distinction of which none can ever attempt to deprive them; they were the two first "tourists of the air."

One can by means of so exact a comparison intimately grasp the fundamental difference between these two "schools" of aviation. We see that the American school demands *everything* of the aviator, longitudinal, as well as lateral, stability, whilst the French school assures the longitudinal stability by means of an empennage and a long leverage arm, which is an important point. The two schools may best be likened to those two machines, the monocycle and the bicycle respectively: neither has lateral equilibrium, and the rider must secure it in the same manner upon both, but upon the monocycle he must also obtain longitudinal stability, whereas, on the other hand, with the bicycle this is inherent, owing to the two supporting points on the ground.

Consequently while every one can control the bicycle, only those expert in balancing will risk themselves upon a monocycle.

Our French aeroplanes: *Blériot*, *Voisin*, *Antoinette*, are the bicycles of the air; every one will be able to use them, and the latest exploits of Latham at the Châlons camp where, after only a few lessons, he was able to remain in the air on his *Antoinette* aeroplane for *sixty-seven minutes*, to lift two passengers, &c., demonstrate the facility and safety of their management. Lastly, it was on a *Blériot* monoplane and an *Antoinette* monoplane that the sea was crossed for the first time with apparatuses *heavier than air*, mounted by Blériot and Latham towards the end of July 1909. On the other hand, one knows the long practice, the skill that is requisite to use a *Wright*. Wilbur Wright possesses this skill to an extreme degree, but it cannot be acquired by every one, no more than any one can become a monocyclist: the serious accidents that have been precipitated by the American aeroplane demonstrate this fact in an overwhelming degree.

APPARATUS OF AVIATION: HÉLICOPTÈRES AND ORNITHOPTÈRES: THE BREGUET GYROPLANE

A word remains to be said about aviation apparatus based upon principles other than these of the aeroplane; there are, first of all, the hélicoptères, or apparatus with sustaining screws. Until now these apparatus have not given decisive results; it is true one succeeded in lifting fairly heavy apparatus from the ground on several occasions, even with the aviator; but what is difficult, and what is so far only promise, is the constant direction of the apparatus through the air. The efforts of investigators have been confined almost exclusively until now to sustentation by screws. We have mentioned the works of Colonel Renard upon this subject, and the hopes inspired by rather hasty interpretations of the formulas which summed up his calculations. To-day a few trials of direct sustentation by helixes have been realised, and the most important are those of Engineer Léger (Monaco), M. Paul Cornu, and M. Louis Breguet. We have already spoken (p. 181) of the first of these apparatuses. Let us now say a few words about the two others, which have furnished interesting results.

We know what the "slip" of a helix is; similar to a screw, the propeller turns in the air, but the mobility of the molecules of the latter causes the apparatus only to advance a fraction of its "pitch." The difference defines the *slip*.

Until now, in the sustaining screws tried with hélicoptères, attempts were made to render the slip as small as possible, and to do this by decreasing the pitch of the screw. This slip, however, cannot be entirely overcome.

M. Cornu therefore, not being able to avoid it, sought to use it for the horizontal propulsion of the aviation apparatus. This is the principle of his apparatus.

A frame carries a motor, which transmits its power to two screws through endless belts, one to the right and the other to the left, and turning in opposite directions to annul torsion efforts. These are the "sustaining" screws devised to lift the apparatus into the air. The effect of their slip produces back-thrust of the air towards the bottom, whereas their useful effort secures the sustentation of the apparatus. This driving back of the air is used for horizontal propulsion by means of inclined planes placed under the screws; these inclined planes receive the rush of air driven from the top downwards, and their oblique surfaces transform this vertical effort into a horizontal component which may displace the apparatus in a given direction. By differently inclining two series of these planes placed on both sides of the axis, turning and inclination may be obtained. Such is the principle of the Cornu apparatus. Plate XXIX. represents its real construction. The results seem encouraging; the apparatus rose once with its aviator

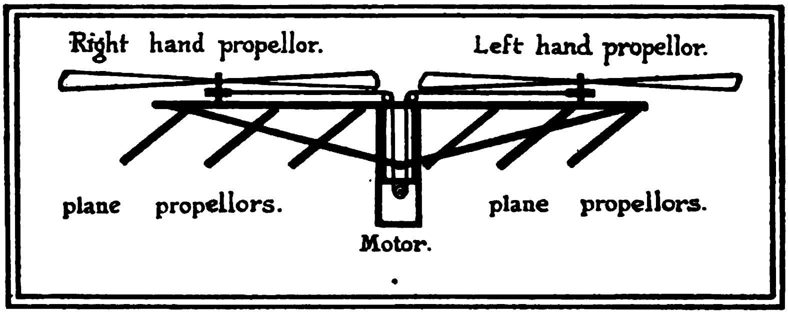

FIG. 79. Principle of the Cornu Hélicoptère

on board; a second time with two men, the total weight lifted being 328 kilos. This sustentation lasted one minute. The propulsion, according to the horizontal effort exercised upon the oblique planes, was weak: only 12 kilometres an hour. It may be seen from the foregoing that this hélicoptère is amongst the most interesting, and such researches must be encouraged, as it is from this development that the perfect sustaining screw will doubtless be evolved, and which, perhaps, some day it will be possible to associate with the aeroplane.

It is necessary to mention specially a very interesting aviation apparatus, the *gyroplane* of Messrs. Breguet and Richet, realising in a happy manner the combination of the aeroplane and the hélicoptère. This apparatus comprises an association of *fixed* wings and of *revolving* wings. The photograph enables their arrangement and operation to be very clearly understood.

The total surface of the revolving wings is 11 square metres each; the surface of the fixed wings is 50 square metres, which, in the event of a vertical descent, provides a total area which would form a parachute of approximately 72 square metres. The oblique disposition of the screw shafts is seen; the reaction of the air upon the fixed surfaces gives in this manner, as soon as the propellers are in motion, a double effort: an upholding vertical effort, and a horizontal effort serving for forward propulsion.

With aviator and petrol for one hour, the apparatus weighs 600 kilos; the engine is an "Antoinette" motor of 40 horse-power. A warpable equilibrator placed at the bow, and lateral small wings, ensure stability, and allow the aviator to regain such in the event of accidental inclination. A steering rudder is placed at the stern of the apparatus body, and acts as the vertical empennage. The fixed and revolving surfaces are supple, and constructed upon very ingenious principles; they are covered partly with very thin aluminium sheets, and partly with special waterproof and non-hygrometrical paper.

The apparatus has been successfully tested at Douai, on ground purposely selected as unsuitable for the launching of ordinary aeroplanes; the area was beetroot fields. The apparatus rose, however, straight into the air with the greatest facility. An accident interrupted the experiments, but the results are most encouraging, and of a nature to induce the authors of the apparatus to persevere in the path they have selected.

The *ornithoptère* has been studied and constructed upon rational lines by a Belgian aviator, Mr. Adh. de la Hault. Without seeking to "fly" right away, this distinguished constructor first set to the study, working, and efficiency of the "flapping" wings, and constructed an ingenious apparatus, which, with organs of a very elegant mechanical conception, realise the movement in the form of the figure 8, according to the curve which mathematicians call "lemniscate." Thanks to this complex movement, the author hopes to realise the double function of the bird's wings, both propelling and sustaining. The apparatus of Mr. de la Hault figured in the 1908 Brussels Exhibition, and the mechanical part, quite remarkable, was much admired by engineers. The inventor is now pursuing his researches, and important results will certainly be obtained.

There remains but to point out an American *ornithoptère* with flapping wings, provided with Venetian blind blades, which close when descending, to rest upon the air, and open in ascent. We have no data regarding the practical results of this apparatus.

Finally, to conclude this history of the principal aviation apparatus as constructed up to now, we may say with confidence that the aeroplane has alone, so far, furnished really practical results, and that in its various forms it has shown an absolute superiority over the two other aviation systems. This justifies the enthusiasm it has provoked and which its continuous development is maintaining. What it is necesssry to do is to ascertain how either supporting screws or propelling surfaces could be added to it. One can therefore see, with the aeroplane in its present form so full of promise, that aviation, the "heavier than air" science, is far from having said its final word ; it has barely said its first.

CHAPTER VI

EARLY DAYS OF AVIATION

FORERUNNERS AND PIONEERS: STRUGGLES, TRIUMPHS, AND THE VICTORS

THE FORERUNNER: SIR GEORGE CAYLEY

LET us now, knowing the conditions that must be fulfilled by an aviation apparatus, realising the difficulties that one encounters in seeking to evolve, raise and control it, glancing back to see how the traveller has arrived profitably at the end of his journey and instructed in all that it is necessary to do, we shall be better able to appreciate the immense effort of those who were the creators of " heavier than air " aerial locomotion.

Let us at once reassure the reader we will not hark back to Icarus or legendary history: we will take aviation only from its modern origin; start from the time when methodical ideas were sufficiently calculated so that investigators were able to proceed on serious and rational lines, instead of aimlessly groping about in the dark.

The first serious investigations relative to aviation date only from the commencement of the nineteenth century, and it was the aeroplane which then occupied attention. By a curious coincidence, even as the first projected airship, that of General Meusnier, was " complete," and in a single stroke anticipated all the necessary equipment, so was the first aeroplane conceived "complete" and everything indicated by its author.

This inventor, this incontestable forerunner of aviation was an Englishman, *Sir George Cayley*, and it was in 1809 that he described his project in detail in *Nicholson's Journal*. In the course of an excellent paper presented to the Société des Ingénieurs Civils, M. Soreau recalled this date, when he remarked how sad it was to think that such a valuable invention as this had not been possible of application immediately upon its conception. In fact "everything" was there in Sir George Cayley's idea —the wings forming an oblique sail, the empennage, the spindle forms to diminish resistance, the screw-propeller, the "explosion" motor, the calculation of the centre of thrust, and demonstration of the fact that displacement takes place towards the front. The author even described a means of securing automatic stability! Is

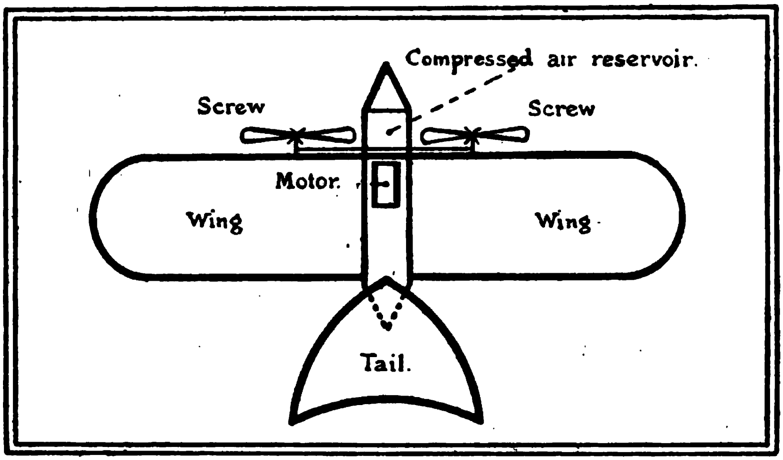

FIG. 80. Victor Tatin's aeroplane model driven by compressed air, which flew at Meudon in 1879

not all that marvellous, and is it not a complete specification for everything in aviation?

Thus it is necessary to inscribe the name of Sir George Cayley, in letters of gold, at the beginning of the history of the aeroplane. Besides, the learned Englishman did not confine himself to "drawing-paper": he built the first apparatus without a motor which gave him results full of promise; then he built a second machine, this time with a motor, but unfortunately during the trials it was smashed to pieces. In 1842 another Englishman, Henson, attempted to build a model aeroplane upon this principle, but without success, and one must pass on to the year 1856 to see the first experiments with apparatuses that "lifted," that is to say with a passenger on board; it was only a matter of sustentation from a huge kite, hauled by a vehicle, but it was a French navigator, *Le Bris*, who carried out this initial tentative effort. The first attempt to glide aerially by a "soaring plane" was made with what was really a triplane by *Wenham* in 1866, which constituted, in short, the apparatus which was used thirty years later in the experiments of Chanute, Wright and Archdeacon. Nor must it be forgotten that it was towards 1860 that Nadar, Ponton d'Amécourt and de la Handelle carried out their "heavier than air" campaign, and that it was in 1862 that the first steam hélicoptère was built by Ponton d'Amécourt, a model, it is true, but a working model, which is preserved in the archives of the French Aerial Navigation Society. Another steam hélicoptère, a small model, due to *Enrico*, driven by a small steam engine, weighing all told 3 kilogrammes, lifted itself from the ground and remained in perfect equilibrium without any material contact with the earth in 1878.

The three first aeroplanes or models of aeroplanes which truly "soared" were the small apparatuses of *A. Penaud* which followed the lines of a monoplane with empennage tail (Fig. 43); and the aeroplane of Victor Tatin constructed and tested in 1879 at Chalais-Meudon. The latter was driven by compressed air and its trials were absolutely convincing: held by a cord at the centre of a small circular track, it ran round the latter stretching the cord, and lifting its weight. Subsequently in 1906 the celebrated American physicist, Professor Langley, contrived an aeroplane weighing 13 kilogrammes, carrying a small steam engine, and formed of two pairs of wings placed, not one above the other, but one in front of the other, in "tandem" (Fig. 45). This aeroplane although it did not lift itself, accomplished the first aerial journey; it covered 1½ kilometres through the air. A second aeroplane was built some time after (in 1903), it rose this time, but undoubtedly owing to the inexperience of the aviator, it fell into the Potomac.

Yet the investigators were continually working, and two names are inscribed in the golden book of aviation, both well known in industry. One is that of Sir Hiram Maxim, the famous inventor of quick-firing guns, who expended over £40,000 in the constructien of a very large steam-driven aeroplane. This apparatus, notwithstanding the great achievement of its inventor in regard to the lightness of the steam engine (15 kilogrammes per horse-power) only displayed a "tendency to lift itself," but it never actually rose.

The other industrial magnate was M. Clément *Ader*, well known by his great developments in the construction of telephonic apparatus. In 1890 and 1896 he built two aeroplanes which he christened *Avion.* On both occasions the apparatuses *lifted themselves from the ground*, and at Satory in 1896, before officers delegated by the Minister of War, the apparatus *effected a flight of* 300 *metres* after leaving the ground under its own effort. If, therefore, the honour of having *conceived* the first aeroplane remains with an Englishman, the merit of having *constructed* the first apparatus that effectively flew, rests with a Frenchman: such is a glorious example of the *entente cordiale* associated with the history of human progress.

THE "HUMAN BIRDS": LILIENTHAL, CHANUTE, CAPTAIN FERBER, THE BROTHERS WRIGHT

Whilst some engineers were seeking "to break in" machines for sustaining in the air, other investigators were compelled to seize the mechanism of the "soaring plane," and upon these motorless gliders utilising only their weight and the resistance of the air, served their "bird-apprenticeship." Foremost among these persevering and audacious men, must be placed the rightly renowned name of the German, *Otto Lilienthal*, who long before the Brothers Wright (who no more than followed in his footsteps in their preliminary attempts), accomplished some remarkable experiments in this direction, in the course of which he lost his life in his devotion to aviation science.

Lilienthal, a Berlin engineer, built some veritable birds'-wings, fixed to his body, with which he sought to achieve the "soaring flight" of birds of which

PLATE XXX

Photo, Neurdieu, Fr.

HENRI FARMAN'S VOYAGE FROM CHALONS TO RHEIMS

we spoke in the first chapter. These wings, of which the photograph (Plate XVII.) gives a very good idea, were formed of an osier framework, covered with light, stretched fabric. Two horizontal rudders, forming a bifurcated bird's tail were at the rear, surmounted by a large steering rudder of rounded form. Lilienthal, well poised in the centre of this framework, jumped from the top of a low tower, against the wind. The inclination of his body and legs enabled him to shift the centre of gravity of the whole system. In this manner he carried out some remarkable flights, some of which attained 300 metres in a horizontal direction. After he had made about a thousand such Lilienthal changed the form of his "flier." Abandoning the *monoplane* he built a *biplane* and in a fatal fall from a height of 80 metres broke his neck in 1896.

The experiments of the unfortunate German engineer were of incontestable value in demonstrating the efficiency of supporting surfaces and the possibility of realising under the best conditions equilibrium during flight. The Americans followed in his footsteps and among the first of those who, in the United States, sought for the solution of the problem by the study of the soaring plane must be mentioned a Frenchman, long resident in New York, M. Octave Chanute, born in Paris in 1831 of French parents. Chanute, although well advanced in age continued the experiments of Lilienthal. He emphasised the *biplane* and happily conceived the first disposition of the stabilisators.

In 1899 *Ferber*, captain of artillery, commenced in France a series of very beautiful experimental researches in glides at first, afterwards in the conditions of equilibrium. He even tried an aeroplane fitted with a "manœuvring" motor, that is to say describing a circular movement about a fixed point to which he was mechanically connected. His work, his writings, place him prominently among those to whom we owe so much, and it is inspiring to see a French officer occupy a distinguished position in the glorious ranks of these "forerunners," who planned out the path so well.

So, when, in 1900 the brothers Orville and Wilbur Wright, bicycle makers of Dayton, set out to tackle the problem they found the ground well prepared. Lilienthal had opened the way, Chanute had indicated the arrangements, the Brothers Wright perfected them, and they "strove for the point" with great judgment, skill, and, above all, an extraordinary determination to become "human birds." They commenced by carrying out numerous aerial glides with their biplane so as to secure aerial equilibrium. These glides suggested to them many happy modifications, and encouraged by the *doyen* of aviators, Octave Chanute, they built, in 1903, their first motor-driven aeroplane with which they performed several flights in a straight line. It was not until 1904 that they effected their first turn, from which point they readily made long flights of many kilometres at an average speed of from 60 to 65 kilometres per hour. Their experiments were surrounded by such mystery that many would not believe them. In France, Captain Ferber, M. Rodolphe Soreau, M. Henri Letellier were among the few persons who really credited the performances of these two transatlantic aviators: M. Letellier, in view of its military possibilities, even sent one of his collaborators M. Fordyce to America to negotiate with the two inventors for the cession of their apparatus to the French Government. These negotiations were not successful and it was not until the summer of 1908 that Wilbur Wright came to France at the request of a group of financiers with whom he had been in treaty. He carried out his first trials at Mans, at the camp of Auvours, upon the Hippodrome des Hunandières, where he executed numerous flights all under "experimental" conditions: but never once setting out under his own effort, and without accomplishing actual trips. Nevertheless it must be remembered that thanks to his aviating skill Wilbur Wright completed some flights of very long duration, and among them he succeeded in repeating the exploit of the Frenchman, Delagrange, by carrying a passenger with him, notably M. Paul Painlevé, of the Académie des Sciences, with whom he remained in the air for over an hour.

Overwhelmed by great publicity these experiments created an immense sensation, and one began to forget somewhat the French aviators when two of them established a record, unique to-day, and had too the glory of completing an "achievement" the merit of which they cannot possibly be deprived of, because this "raid" recorded two historical journeys in aviation by the completion of the two first aerial voyages" in an apparatus "heavier than the air" on October 30 and 31, 1908.

EXPLOITS OF THE FRENCH AVIATORS: SANTOS-DUMONT, VOISIN, DELAGRANGE, &c. THE MÆCENE: HENRY DEUTSCH, E. ARCHDEACON, ARMENGAUD

The flights of the Brothers Wright were very beautiful demonstration experiments, but none the less the aeroplane of the Americans is not perfect. Its stability demands a constant effort on the part of the aviator, because of the suppression of the empennage tail, and the apparatus for this reason is dangerous. In America it caused a serious accident to Orville Wright, and brought about the death of one of its passengers, the American Lieutenant Selfridge in the autumn of 1908. In the spring of 1909 the Italian Lieutenant Caldera was thrown to the ground through a capsize due to the inherent instability of his aeroplane; moreover, as we have said, and as we repeat, the apparatus is not up to the present self-starting.

French aviators, however, were quietly working towards the solution of the problem, and to its *complete* solution, that is to say, to the perfection of a *self-starting* aeroplane, able to rise from the ground under its own effort, and to set out again after having landed, without either rail or pylon.

At the end of 1903, the ardours of our audacious aeronauts were revived. Colonel Renard pointed out that year, that, if the weight of the motor fell below 5 kilogrammes per horse-power, realisation of flight by means of "heavier than air" machines would be possible. The great authority, the sureness of the views of the illustrious and learned officer were more than a hope; they were a guarantee for the pioneers of the air who set out towards the conquest of the atmosphere.

Distinguished among the most prominent of ardent sportsmen was Ernest Archdeacon, who, as far back as 1904, made some experimental glides with an aeroplane among the dunes at Berck-sur-Mer. What perseverance was necessary at that time to pursue, without faltering, this struggle with the uncontrollable element! What faith in the future, not to allow one's self to be turned away by the criticisms and the more or less witty satires of the detractors always more numerous than the "actors!" But the latter were enthusiasts; nothing would stop them. Voisin built and tested with Archdeacon, Ferber and Santos-Dumont; the latter sought to forge the "connecting link" between the aeroplane and the kite. He constructed a biplane which could float upon the water, and had it towed along the Seine by the *Rapière*, one of the fastest motor boats. The apparatus rose, carrying the aviator, thus excelling courageous efforts of many persevering workers. Hereafter the possibility of aviation was established. Also the experiments in aviation multiplied.

It is necessary—it is essential—to point out that nothing had transpired concerning the experiments of the Brothers Wright, whose existence was scarcely known; a stronger reason for not knowing any details of their mysterious machines was that their authors jealously preserved them from prying eyes. Also does not the merit of the French aviators stand alone? Not only have they done *as well* but they have done *better*. What more can one ask?

The first to succeed was M. Santos-Dumont. The intrepid Brazilian aeronaut was the first to carry off the prize which the generous Mæcene of aviation established in 1906? With what is this date to be compared! In 1906 not a motor-driven or self-starting aeroplane had left the ground. One can appreciate that he who could accomplish a flight of *100 metres* would achieve an admirable exploit, and "the prize for 100 metres" was carried off by Santos-Dumont at Bagatelle on November 12, 1906; by a flight of 220 metres Delagrange and L. Blériot some time after won the prize for 200 metres.

Then appeared on the scene two gentlemen who by their brilliant generosity have greatly contributed towards the development of aerial sport—MM. Henry Deutsch and Ernest Archdeacon. The flights so far accomplished were in a straight line; the aviators hesitatingly refrained from risking turning. They saw the difficulties, as we have already pointed out. MM. Deutsch and Archdeacon offered a prize of £2000 to the first aviator who accomplished a *circular* kilometre: the prize was won by Henri Farman, at the Issy-les-Moulineaux manœuvring grounds, on January 13, 1908.

Thereafter the triumphs of the persevering aviator continued without interruption, and on July 6, 1908, by remaining in the air for twenty-one minutes, he won the prize so spiritedly offered by the engineer, M. Armengaud, to the aviator who could remain aloft for a quarter of an hour.

THE TWO HISTORICAL AVIATION VOYAGES BY FARMAN (OCTOBER 30) AND BLÉRIOT (OCTOBER 31, 1908) ACCOMPLISHING THE TWO FIRST "AERIAL JOURNEYS" FROM TOWN TO TOWN: BLÉRIOT REALISES THE FIRST SEA PASSAGE BY CROSSING THE CHANNEL ON JULY 25 1909

All the preceding records were doomed, however, to be well broken by the two exploits of H. Farman and L. Blériot.

Up to this time aeroplanes had simply described evolutions above race-courses or manœuvring spaces, where, the ground purposely levelled, offered the best facilities for the launches and descents of the French aeroplanes; these advantageous conditions were not sufficient for the American aeroplanes, because it was necessary for them to have also a pylon and launching rail. The aeroplane had thus to demonstrate its possibilities of endurance, to show that it possessed really practical utility, and that it did not require special facilities at halting-places in its aerial passage.

It was MM. H. Farman and L. Blériot who had the unquestioned and indisputable distinction of fulfilling this demonstration, anticipated by the whole world. They proposed to embark upon an actual journey from *town to town* and they succeeded. On October 30, 1908, Henri Farman left the precincts of his hangar at Bouy, near the Châlons Camp, at 3.50, and set out for Rheims. The wind was E.S.E. The aviator immediately gained a height of about 50 metres, which was necessary, owing to the stretches of tall poplars barring his path. Thus he passed over rivers, villages, woods, &c., and, after being twenty minutes on the journey, reached Rheims, where he landed with the most perfect ease in a park between the cavalry barracks and Pommery House. During this twenty minutes he covered 27 kilometres, which gave a "start to stop" speed of 79 kilometres per hour.

And on the following day, October 31, 1908, Louis Blériot completed a still more sensational and more perfect "journey." Leaving Toury (Eure-et-Noir) at 2.50, he steered towards Artenay (Loiret), a point situated some 14 kilometres from the starting-point. There he had caused to be installed some captive balloons, to indicate the point where he was to turn.

Flying a dozen metres above the ground, the aeroplane passed over Château-Gaillard and Dambrou, and the automobiles which were following him were speedily "scattered" along the roads. Eleven minutes after the start a fault in his ignition caused him to alight; he landed without difficulty, *repaired his magneto, and set out again under his own effort*, after a descent lasting an hour and a half, to continue his journey; and now, holding more to the west, passed Pourpry, and made a second descent of some minutes at Villiers Farm, near Santilly. *He re-started a second time*, passed Pointville at five o'clock, and returned in quite a matter-of-fact manner to his starting-point, having accomplished the first "cross-country" voyage with descents. During this flight his aeroplane acted marvellously well, attaining a velocity of *85 kilometres per hour* (Fig. 81).

Louis Blériot thus demonstrated that the French aeroplanes mounted on wheels are complete apparatuses, truly self-starting, practical, and capable of resuming their flight when it is interrupted; he showed the services that aero-locomotion could render us, illustrated that aviation from that time henceforth could enter into everyday practice.

Certes, one had been so persuaded, but a good practical demonstration is worth more than exhaustive arguments: *contra factum non valet argumentum.* Consequently Farman and Blériot were absolute demonstrators, and definitely opened for us "the Highway of the Air"; and it was a fair act of the Académie des Sciences to divide the Osiris prize between Blériot and Voisin, the creators of these marvellous aviation apparatuses.

But these exploits came to be surpassed! By a remarkable flight Blériot crossed the English Channel on July 25, 1909, in 27 minutes 27 seconds.

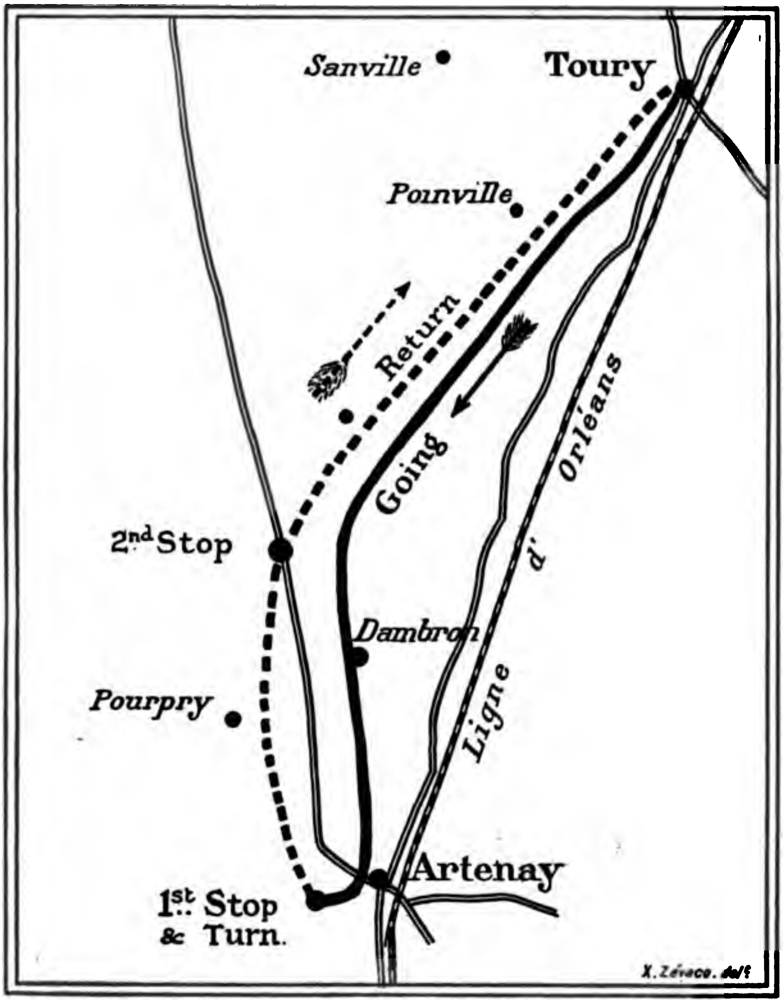

FIG. 81. The first "aerial voyage" effected in a closed circle between Toury and Artenay with descents, by Louis Blériot (October 31, 1908).

Starting from Baraques, on the French coast, at 4.35 A.M., his objective was Shakespeare's Cliff, but the fog compelled him to seek a landing-point on the Margate side.

This achievement heralded the definite conquest of the air by man in the world's history. England and the city of London gave Blériot a reception such as is extended to a victorious general, and this honour accorded by the English public, was appreciated by the French people. When Blériot returned to Paris the French capital welcomed him as one of its most glorious sons, and received him with an enthusiasm which will never be forgotten.

And two days after Blériot, on July 27, Hubert Latham, on his *Antoinette* monoplane, crossed the Strait from the French side, but unfortunately fell into the sea when only a mile from the English coast.

Yes, truly! Man has now definitely conquered the atmosphere!

THE ENTHUSIASTIC PUBLIC MOVEMENT IN FAVOUR OF AERIAL NAVIGATION

From the day when Farman won the Deutsch-Archdeacon prize aviation created an indescribable enthusiasm among all classes of society. For a year the shops and vendors of post-cards sold nothing but photographs of aeroplanes, portraits of aviators, and illustrations of motors; the widespread publicity with which the managers of the Brothers Wright surrounded the experiments of the American aviators, helped to maintain this movement, and the numerous excursions of the *Bayard-Clément* airship, which on more than forty occasions went and described evolutions over Paris, prolonged the absorbing interest of the people, provoked by the success of aviation.

At Auvours enormous crowds flocked from all parts to assist the Wrights' flights; at Issy les Moulineaux the use of a manœuvring ground had been very niggardly spared to the French aviators; another was liberally placed at the disposition of the foreign aviators; notwithstanding the early hour (from 5 to 7 A.M.) that was imposed upon our investigators, thousands of the curious were always there to assist a flight or a descent. Cinematographs have reproduced and popularised the most successful flights; the annual reviews have extensively introduced the aeroplane into their pictures.

But it was in the imagination of the young folks that aeronautical schemes were conceived; they dreamed of nothing but aviation; at college they made paper aeroplanes under the cover of their desks, to guard them against detection by their tutor; whilst the latter, studying for his science degree, was occupied on his part in calculating the elements of some flying-machine that would revolutionise the field of aerial travel!

Aeronautical construction shops sprang up on every side, and aeroplane constructors have already issued catalogues of aviation apparatus, "payable after trial by the customer," whilst—sign of the times—agencies have been established to facilitate such transactions.

This movement was interpreted, some years ago in France at any rate, by the foundation of an aerial *League*, which had the happy inspiration to have resort to the knowledge of Professor Paul Painlevé. But it has shown itself especially by redoubled efforts among the Societies which are so actively concerned in aeronautics: the *Société française de navigation aérienne*, presided over by M. Soreau, generally recognised as the oldest, since it was founded in 1872; *l'Aéro Club de France*, equally publicly appreciated, presided over by

M. Cailletet, of the Académie des Sciences, the efforts of which have been so fruitful in the diffusion and development of aeronautics in all its branches; *l'Aéronautique Club*, *l'Académie Aéronautique de France*, *l'Aviation Club*, and other societies have appreciably increased the number of their members. At Brussels, *l'Aéro Club de Belgique*, ably presided over by M. Jacobs, a learned double of Mæcene, has followed the example of its French brothers, and is progressing in a remarkable manner. In Germany, England, and Italy the same activity is manifested. And in turn, special newspapers and journals have been created; let us recall, first, the two original organs of aerial locomotion, *l'Aéronaute*, founded in 1866, and *l'Aérophile*, that remarkable paper directed by so great an authority as M. Georges Besançon. These two periodicals, as much for the past as for the present, constitute the archives of aerial navigation, and we have largely drawn upon their files, with the requisite permission, in writing this book; to their editors we extend our thanks. Around them have been born—*l'Aéro*, *la Revue aérienne*, *la Revue de l'Aviation*, *l'Avion*, *l'Aviation illustrée*, &c. In Belgium two excellent reviews, *La Conquête de l'Air* and *l'Aéromécanique*, have a wide circulation; it is the same in London, Berlin, and Italy.

And all this is the result of the triumphs achieved during the past few years. What is the outlook for to-morrow? and how striking is the consciousness of mankind of the value of the great inventions which are perfected to modify in a far-reaching manner the conditions of existence and of social life!

What is the future of aerial navigation? That remains to be investigated in the following chapter.

CHAPTER VII

THE FUTURE OF AERIAL NAVIGATION

AERONAUTICS AND AVIATION: APPLICATION TO WAR, CIVIL LIFE, AND SCIENTIFIC INVESTIGATIONS: ECONOMIC IMPORTANCE OF AEROLOCOMOTION

DIRIGIBLES OR AEROPLANES?

IT now only remains for us to ascertain what is the future of this aerial locomotion, which at present is so full of promise and has developed with a rapidity never before witnessed in the evolution of any other invention?

And, above all, it is necessary to examine individually the possible applications of the two forms of aerial locomotion, and the two types of atmospheric vehicles—dirigible balloons and aeroplanes. To which shall we give the preference, and what is the future of each?

If one were only to be guided by public enthusiasm, a trifle "packed," so strenuous in exaggerating the merits of an invention when it "succeeds," as it is often slow to recognise it in its infancy, then aeroplanes, the last to come into popular favour, would be the only machine capable of widespread application; the scientific writers of the Press have already put them to all kinds of work, and they hasten to anticipate all the services which they must fulfil in the very near future, whilst they cannot defend themselves against a shade of disdain for the large airships which we saw perfected "yesterday" in the eagerness for that of "to-day."

It is necessary to allay a trifle this premature enthusiasm, which is prone to be overdone. It is necessary to avoid again, in the desire to advance too quickly, those galling experiences that occurred with motor-boats when the fanatics hailed them as the torpedo-boats of the future: the ridiculous venture upon the transmediterranean race, which a little consideration would have avoided, and in the course of which all the boats participating, except one, were lost, must serve as a lesson and give food for thought to those organisers of too premature, sensational trials.

Let us say at once that the future is immense, so immense that it is impossible to set it out in detail. But it will be by evolution, and all that one can actually do is to sketch out its broad lines.

In the first place, there must be no exclusion of either of the two systems, balloons or aeroplanes: both have their *raison d'être* because they correspond to different requirements.

When it is necessary to travel very rapidly, when, above all, progressive development has assured the perfect security of aviation apparatus, one will have recourse to the aeroplane, and without doubt we shall see "aeroplane liners" of huge dimensions, carrying numerous passengers, securing sustentation with nothing but their enormous speeds. But these velocities would be truly attended with dangers in case of landing, or, above all, a "mishap to the machine," because, if the apparatus sustains itself by great speed, it would not have sufficient supporting surface to keep soaring without the motor.

Perhaps for this reason aeroplane liners will be reserved even for transatlantic passages, as the "hull" with which they must necessarily be equipped will render landing less dangerous upon the water. Transatlantic journeys would then be made at speeds exceeding 200 kilometres per hour; that is to say, *one would travel from Europe to the United States in a single day!*

But when this speed is unnecessary, it appears scarcely possible to disclaim the envelope charged with light gas, this "bladder," as it is disdainfully called by some aviators, because, if it travels at less speed, it has nevertheless the advantage of sustaining the aerial navigator in the atmosphere without the need of mechanical energy. Consequently here is safety, and should the motor of an airship break down one is always master, or able to continue the journey "before the wind," if the latter is in the right direction, or to land, which with a good aeronaut will always be possible without very great risk. Moreover, an airship can carry many more passengers; it can convey them in greater comfort; when it will have attained its independent speed of 60 or 70 kilometres per hour, instead of 40 or 45, it will be able to set out practically at any time. Lastly, it can "stop" at any determined point in the aerial ocean, which the aeroplane, tributary to an indispensable sustaining speed, cannot do. Also, I do not deceive myself in stating that its career is far from ended. It has no more than begun, and it will develop side by side with the aeroplane. Let us now examine some of its applications to aerial navigation, and we will then see which is the type of locomotion best adapted to each case.

MILITARY APPLICATIONS

The perpetual tendency which nations have always had to threaten to destroy one another by the most perfected means has resulted, first and foremost, in the application of aerial navigation to warfare.

We all know how completely France secured an advantage over all other countries by the possession of a military dirigible, *La France*, in 1885, whereas no other nation had one at its command; and during these last few years the successive appearances of the *Lebaudy*, *La Patrie*, *Ville de Paris*, and the *République* (I omit all but the best) have shown Europe that France has an "aerial navy" in being, available for the defence of her coasts.

What form of aerial vessel will best serve the needs of warfare? Airships or aeroplanes? As "combatants" or "scouts"?

I fear, after what I have heard from officers who are more competent on this subject than I, that as a combatant it will not often be used. Aerial battles do not appear imminent because the installation of any artillery whatever on board dirigible balloons would be extremely inconvenient; with regard to aeroplanes, their requisite high speed, and the impossibility of "pulling up," practically prevent the use of cannon except of small calibre.

There is one good use for the airship in war: that is dropping melinite shells (or some other still more devastating explosive that may be invented) from a height within a fortified area or a beseiged fort. Here we are in the realm of the possible, and this utilisation of the airship is not chimerical; it is only requisite to consider if the "result" would be very advantageous.

Let us point out that the range for the projectiles would not be very correctly known because the balloon would be forced to hold itself at great altitudes so as to be able to escape the fire of the enemy. Moreover these projectiles, to produce a sufficiently destructive effect, would have to be of considerable weight—50 to 100 kilogrammes at least. Now a balloon suddenly lightened by 50 or 100 kilogrammes would take much too rapid an ascensional a movement, and the operation would not be without danger to the aeronauts. So far as concerns aeroplanes, the impossibility of "pulling up" practically precludes them from this form of action without speaking of the certain peril which would result from the fatal upset of their equilibrium caused by the sudden unballasting.

Moreover, let us point out at the same time that aerial vessels, on the other hand, have little cause to fear hostile projectiles, because of the altitude at which they are able to float, and the aeroplanes because of their speed. During the siege of Paris in 1871, only one balloon was captured by the German troops, and then the pilot who controlled it was but little experienced in aerostation.

Pausing to consider the possibility of an "aerial combat" between isolated units, it is certain that if two hostile aerial vessels met in the air they would seek to destroy one another; but if they were two aeroplanes, and unless the gun-fire of a mitrailleuse of one put the motor of the other out of action, or rendered the aviators *hors de combat*, they would be unable to withstand the collision; then there would be no conqueror, no conquest, there would be only two simultaneous catastrophes.

Would dirigibles, always massive and relatively slow, much dread the pursuing speedy aeroplanes? I do not think so, because when the aviator chased him in his speedy aerial skiff, the aeronaut would avail himself of a resource the efficiency of which is certain: *rise* by throwing out ballast; he would then fly up in a vertical line, that is to say, very rapidly, whilst the aviators could only rise obliquely, and then in a slight slope, thereby executing zigzags, in a word, "vertically tacking"; moreover, the motor of an aeroplane will run slower and slower in accordance with the progress of its ascent, owing to the decreased supply of the oxygen necessary for the combustion of the gaseous mixture which drives these engines. Lastly, whilst making its vertical tack to come up with the airship, the latter, more stable and able to carry, if not guns, at least a quick-firing weapon, or in any case grenades, would have ample time to riddle it and much more easily than it could fire upwards, the more so, because the artificial bird would offer to the fire of the airships the large target of its supporting wings.

For these reasons I fear, therefore, that aerial vessels will be poor combatants. On the other hand, they will be useful scouts, and there will lie, in all truth, their principal *rôle* in the time of war. The dirigibles, able to carry instruments of precision, capable of stopping to take a photograph or make telemetric measurements, will be extremely valuable to the chief of an army who has them at his command. The aeroplanes, owing to their great speed, will be the instruments *par excellence* for rapid reconaissances, for "raids" carried out over great distances; moreover, their capability of returning very speedily to recount what they have seen will thus render them more indispensable than their larger brethren to the general of the future war. For communication with besieged positions the aerial vessels will be without rival, and it will no longer be possible to completely isolate a fortress, what with wireless telegraphy and a fleet of airships, or a flotilla of aeroplanes.

With regard to uses in naval warfare, these will be numerous, without a doubt. A cruiser can always have on board one or several aeroplanes; it has even the mechanical energy necessary to launch them. It can consequently send one into the air to sweep the horizon, and a hostile fleet could not easily conceal itself. Undoubtedly submarines will not be increased in number, for the aeroplanes peering vertically into the waters of the ocean will perceive the torpedoes and submarines at a very great depth, whereas from the surface of the sea they could not be seen at all, owing to the obliquity of the visual rays coming from less distant points.

Will battles then be solely decided under the waters? Mystery and horror! Let us hope that these events will never come to pass.

APPLICATIONS TO CIVIL LIFE

What will be the "civil" applications of locomotion in the air? Evidently they will be numerous and varied, and it will be possible to travel either by "public service" or private vehicles.

Undoubtedly the latter will first come into vogue; private airships and aeroplanes will for a long time yet be the vehicles *de luxe,* I may even say of great luxury, and only those privileged by Fortune, or those who wish to appear so, will be able to make avail of their use. But did we not see the same development in the case of the automobile? and will not the desire to appear, like "our friends," in a dizzy aeroplane, turn society upside down? without speaking of the attractions of the "special costume" which the enterprise of our great dressmakers will not fail to bring out at the happy moment, and to charge accordingly! It cannot be denied that speed has an irresistible fascination; it produces peculiar sensations, a veritable intoxication, and to taste these sensations combined with a decrease in the time occupied on a voyage will be one of the next forms of refined luxury. Besides, does not the reduction in the length of a journey increase the available time for other things, and therefore does it not, in an indirect manner, lengthen the span of life?

Among these vehicles *de luxe* the aeroplanes will be the "racers": they will go rapidly; will be able to carry two, three, or more persons. They will replace the extra-rapid automobile with which fanatics hurtle along at some 80 kilometres per hour; only in the air it will be "some 200." So far as concerns those who are desirous of travelling quietly and in company, and possessed of "the means," they will use the dirigibles which before long will proceed at 60 or 70 kilometres per hour. Certainly it is highly enjoyable to have an extensive uninterrupted view. Let us point out, moreover, that if by a head wind the speed of the wind curtails that of the balloon, on the other hand, when the wind is following, the two speeds will have to be added; and in choosing his wind—that is to say, the day for his trip, which is

PLATE XXXI

Photo, Bréguet

THE BRÉGUET

Photo, Bourée

LIGHT HÉLICOPTÈRE (THE PROPELLERS)

Photo, Bourée

LIGHT HÉLICOPTÈRE (MOTOR AND STEERING)

possible to those of independent means—one will make "some 100 per hour" in an airship, with the additional advantage of comfort that will obtain with this "travelling coach" of the air. Then, without doubt, numerous hangars—"hostelries for balloons"—will be staked out along the great highways, and one will be able to stop *en route* as one actually does in motor-trips.

Let us remark though, without delay, that for some time yet the greater bulk of the population will have to go on foot, by motor, boat, or railway, and the great aerial speeds will be a luxury or sport. The conveyance of merchandise will always be by land or water; these will be accelerated, but I do not think for many, many years one will consider despatching goods by the aerial highway.

But one minute: there is one phase of transport—the "post"—which will use the highway of the air, and perhaps more so than we anticipate. I believe that before long "mail" will be sent aerially, and for this aeroplanes will be vastly superior to balloons. Being able to set out at any time, travelling at enormous speeds, they will carry letters and valuables; it will be easy to despatch them at any time, one after the other, in all directions; and thus we shall have "hat-bands" for "aeroplane messengers," who will go straight from city to city every hour, or even more often. The only interruptions to such will be those days of heavy storms. Then it will be necessary to trust the messenger to express trains, which will travel at far greater speeds than now, and yet distant points will complain bitterly of an unacceptable delay.

Undoubtedly the appearance upon the scene of aerial vehicles will profoundly modify the conditions of our existence, but it is not necessary to count upon this change coming too quickly. It will be some time before we see "aero-taxis," and the transit in towns will be maintained for many years yet by terrestrial vehicles. But it is certain that some day house-designers will feel the necessity of catering for the aerial vehicle by elevated mooring-stations. Roofs will disappear in favour of flat terraces suited to launching and landing stages. Probably, however, departure will not entail more than a short start. They will be made *in situ*, because the flying apparatus will be, without a doubt, combinations of the hélicoptère and the aeroplane, an association which assures security in the descents of the aerial vehicles in confined areas and at a very great speed; and perhaps upon these flat roofs of large hotels we may even see garages for airships! What is certain is that the "future city" will not have quite the same appearance that it has to-day, and wealthy residents will always turn their ambition towards the clearer, healthier, and less congested air.

SCIENTIFIC APPLICATIONS: EXPLORATION OF UNKNOWN COUNTRIES

One of the first applications of the new locomotion will be scientific, and more especially geographical. The facility of moving above all the obstacles with which the surface of the earth bristles renders it eminently suited to the exploration of unknown continents, to traverse which no means of communication exist.

One knows how difficult and dangerous is the explora-

PLATE XXXII

CHALAIS-MEUDON PARK

Photo, Schelcher

THE EIFFEL TOWER

Photo, Schelcher

THE PLACE VENDÔME

tion of these mysterious countries, such as those of Africa, the centre of Asia, Central South America, whilst the torrid climate, the dense vegetation forming impenetrable obstacles, dangerous animals, the hostile natives, seem to league against the explorer bold enough to penetrate for the first time those territories where the foot of a European has never trodden.

Also, what blanks still exist upon the maps of Africa, Asia, Australia, South America, and the Polar regions, Arctic and Antarctic, and how slowly, in fact, are geographical discoveries effected when it is necessary to explore the details of our planet by "crawling," so to speak, over its surface. When the explorer advances through the torrid equatorial regions, when he must toil through the bush, it is as much as he can cover 15 to 20 kilometres per day; this is the average progress of an exploring expedition; if a passage must be cut through the dense primeval forest by hatchet and axe, to clear the way, to cross very closely tangled stretches of tropical vegetation the advance is slower still. When one explores the glacial lands of the Poles, the "ice-fields" of Greenland, Spitzbergen, or of the Antarctic, it is not always in kilometres that the distance between the daily halting-points is figured, and in the meantime the privations and the dangers are as a result proportional to the road travelled over each day.

What are the data which the geographical traveller secures at the cost of such innumerable perils? Does he bring back the complete map of the country he has traversed at the risk of his life? No, unfortunately, because in order to prepare a complete survey of a region it is necessary to stay there a long time, and to travel in all directions; more often than not the explorer only shows merely his itinerary, that is to say, only a "fringe" of the country along the path which he followed. Certainly he will record what he sees to the right or left of this route, will indicate the hills and mountains which he has perceived on one side or the other, with their distances and heights, estimated according to "bearings." But they will only slightly widen his "fringe" without giving a general map; moreover, the regions described in this manner will be rather more indicated than charted with the necessary geographical precision.

In reflecting upon these difficulties one can understand the existence of these "white spaces" in our atlas; what is marvellous is that man has been able to gain such actual knowledge of the Earth, in face of this passive hostility of the unknown country.

All this time, however, although we have been powerless to learn the details of the surface of our planet, astronomers have succeeded in gathering all the details of the surface of the sky, to enumerate up to a very extended limit the brilliant stars which are sprinkled above us; in a word, they have made *a map of the heavens.*

They have prepared it, moreover, through a unanimous understanding among the civilised nations; they have prepared it by a surveying method which furnishes indisputable testimony: photography. The photographic plate, as was happily said by Janssen, is the "retina of the savant," but a retina which retains the impressions it receives.

Up to now, certainly, it has been impossible or, at the very least, difficult to apply photographic processes to the representation of terrestrial surfaces in the same manner as it was in the preparation of the map of the heavens; one had, in short, no means of "seeing the earth from above." The balloon, and captive at that, was the sole means available, and it was scarcely able to provide more than "local" views of the country beneath. Moreover, to obtain sufficiently numerous photographs it would be necessary to tow a captive balloon across the continent to be explored, and consequently to transport it, and his accessories, by means of a caravan; up to now this difficulty has never been overcome.

To-day, on the other hand, the dirigible balloon furnishes us with the solution so much sought after, and I believe that it will fulfil it in a complete manner, thanks to the addition of topographical photography in the form so excellent and so precise devised by Colonel Laussédat about 1852.

Let it be pointed out at once that taking only the road traversed, and even if it were kept within certain limits, the dirigible aeronaut-explorer, by vertically photographing the earth above which he manœuvred, would be able to obtain a *route survey* of a superior character to that which explorers travelling over the surface of the ground would be able to procure. Indeed if, for example, he stood at a height of 1000 metres while photographing the earth underneath with an apparatus of which the wide-angled lens had a "field" of 90 degrees of angle, and a focal length of 20 centimetres, he would thus have a photograph which would be a topographical map on the scale of $\frac{1}{5000}$; but this map would be both exact and complete. Numerous photographs would be able to be obtained, and by placing them side by side one would thus have the detailed and correct topography of the route followed by the airship; as, moreover, the latter travelled at 58 kilometres per hour, the explorer would take in one hour more maps than the ordinary explorer would make in three days, and it would be done without danger, without fatigue, safe from the attacks of natives, and protected above all from the onslaughts of poisonous insects, from marshy miasmæ, which are the greatest enemies against which explorers have to contend. To-day a balloon (as the *Zeppelin* has demonstrated) can travel for 38 hours without descent; therefore it would be able to make an outward journey for 19 hours, with 19 hours for the return journey, stop for the night, and in this manner explore the country within a radius of a circle of 1000 kilometres, which would take a traveller from 40 to 50 days to pass over.

But by this simple means, notwithstanding the already very marked superiority of an aerial voyage from the point of security, speed, and the data obtained, one might wonder whether the results would justify the despatch of a dirigible to an accessible point of the continent which it is desired to study. But then one can and must rely more and rather upon the collaboration of the dirigible and the camera.

Let us state at once that the dirigible will be greatly improved within a very short time; its present speed of 50 kilometres per hour will be easily increased to 60; its volume will be augmented, and in place of 3000 to 3500 cubic metres it will be given 5000 to 6000 cubic metres while still preserving its "elastic" construction and not falling into the drawbacks of the rigid balloon; already an airship of this volume is under construction in Paris. If, under these conditions, one is content with a speed of 50 kilometres per hour, which is magnificent, one will be able to carry sufficient fuel for a continuous voyage of 50 or 60 hours, which means 25 to 30 hours for the outward and the same for the return journey.

But in 25 hours a balloon travelling at 50 kilometres per hour would cover 1250 kilometres. It can descend during the night when photography is impossible, setting out again the next day and even stopping *en route* if necessary. The perfection of the special balloon "fabrics," the judicious use of the air-ballonnet, enables the balloon to remain in the air without any loss of gas, and the airship *Patrie* which was perceived floating in the North Sea ten days after the storm tore it from its bonds, shows the strength of the modern airship. *We are able to say that there is in course of realisation, in the field of aeronautical construction, airships of from* 5000 *to* 6000 *cubic metres volume, and having from* 1000 *to* 1200 *kilometres "radius of action."*

Consequently, in choosing convenient "centres" for establishing *aeronautical stations*, centres which will coincide with inhabited and accessible points to which one can easily convey the material and *personnel*, one will be able to cover a continent with a network of circles of from 1000 to 1200 kilometres radius, each of which can be traversed in 20 or 25 hours, by an airship carrying the explorers and their instruments. Fig. 82 shows how one can apply this system of exploration, which is so simple, so rapid, and so safe, to a prescribed region; to the African continent, for example.

The centres indicated are accessible; two are in French, two in English, and one in Belgian territory. They are Timbuctoo, the shores of Lake Tchad; Leopoldsville, for the Belgian Congo; Dongola and Lake Albert for the English stations. In tracing round the centre of these circles of 1100 kilometres radius it is seen that the whole of Central Africa can be covered thereby, and the circles may even "overlap." The exploring traveller in his dirigible, therefore, can actually touch every part of the unknown country. The provision and the maintenance of the aeronautical stations can even be dispensed with for the immediate return journey, as it can halt at a different centre to that from which it set out, which might be of great value in case of an unexpected storm. In this instance I have confined myself to Central Africa; by adding a sixth centre at Dakar the whole Mauretania would become "explorable."

Would the airships which accomplished these expeditions be limited to securing "route photographs"? No, they would do much better, thanks to Colonel Laussédat's process, the principle of which I will explain in a few words.

In 1852, Colonel (then Captain of Engineers) Laussédat, impressed by the advantages that photography would afford in the compilation of maps, evolved a means of preparing topographical surveys by means of Daguerre's invention; for this purpose he employed not one photograph, but two, taken from the extremities of a long-known so-called base. If one knows the angle of the lines of vision of the two apparatuses which, from the two extremities of this base, have their optical axes turned towards the same point, one has a triangle, the two photographs taken simultaneously from which enable one to build up the actual structure. It is in fact "plane table" topographical surveying, with this difference, that instead of carrying out the graphic work upon the spot, one "carries the ground with him" and completes the work at his desk.

This excellent method is even capable of simplification. It suffices to place at the two extremities of a "base," the length of which is absolutely known, two cameras, the objectives of which have their axes absolutely parallel, and to actuate their shutters at the same moment, which is a very simple matter with a battery and two electromagnets. From these two photographs one could compile the map of the country up to the limits of the visible horizon by means of Dr. Pulfrich's remarkable instrument, the *stereocomparateur*, built by Zeiss, the eminent optician, and one of which is retained in the museum of the Conservatoire des Arts et Métiers. A most renowned German Geodesian Professor, O. Hecker, of the Potsdam Geodesical Institute, has shown how one can make the most of this process.

And this simultaneous use of the parallel two cameras at the ends of a base of known length is essentially possible on board a dirigible of the *Bayard-Clément* type, for example. The rigid and indeformable car, of which the length is 28 metres, will be the base, the two cameras will be permanently fitted at the two extremities, and their distance apart is at one and the same time definitely known and invariable. The photographic data necessary for the compilation of the map by the aid of the stereocomparateur in consequence will be absolutely correct, and in this manner it will no longer be merely photographs of the subjacent ground that the aeronauts will bring back with them; these are the component parts for a "geographical map" as far as the limit of the visible horizon, a map correctly "fixed" both vertically and in distance for planimetry. Thus a few aerial expeditions made in the interior of one of the circles of which we have spoken will more than suffice to furnish the map of the entire country included therein.

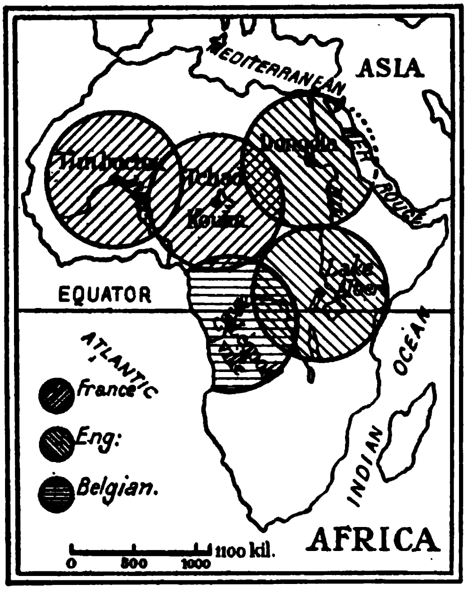

FIG. 82. The exploration of Central Africa by dirigible

But in order to render this endeavour practicable, the assistance of several nations is necessary: the map (Fig. 82) shows that for Central Africa that of France, England, and Belgium would suffice. The cost of an expedition of this nature will be infinitely less than that attending ordinary expeditions achieving the same results; the time will be perhaps one hundred times less, the precision will be superior, and the dangers very appreciably diminished.

So far as concerns the country adjoining the French North African possessions, no places would be missed where one would be able to establish dirigible depôts.

This system of working is not only applicable to Africa: the whole of the "Matto" of South America, the interior of Australia, as well as of Asia, would be able to be explored in this manner with material results through the co-operation of the interested Governments, and it will thus be possible to complete the "map of the earth," which, indeed, is the least that might be done, inasmuch as the photographic map of the heavens has been carefully completed.

With regard to the North and South Polar Regions, undoubtedly it will be in this manner, and in this manner only, that we shall be able to learn their geography completely and rapidly. We know how slowly explorations are able to proceed after the vessel is left—that is to say, in the same manner as one explores a new country. It is only by heroic effort that polar explorers have made their perilous discoveries. Consequently it will be by dirigible that it will be possible to study the glacial regions, not only in the vain curiosity "to reach the pole," but to learn scientifically the geography of the axial caps of our terrestrial globe. To have dreamed of this five years ago would have been madness, but in view of the achievements of the airships *Patrie*, *Bayard-Clément*, and *Zeppelin*, it is a feasible achievement. The distance from Spitzbergen, where one would be able to have a station, to the North Pole, is only 1300 kilometres (720 knots). It is thus within the limits of possibility of actual dirigibles, when they have been perfected. Likewise, to solve the problem of the complete exploration of Greenland, a station at Uperniwick would be adequate; for the Arctic archipelago of North America a station on Hudson Bay would permit the aerial exploration of almost its entire area.

Let us point out that in the Polar regions, in the time of the solar summer, the day is continuous; the balloon, therefore, would not be subjected to variation in its ascensional effort, and would have no need to descend, so that photography would be possible throughout the journey. Conditions for safety on the voyage among these deserts of ice, destitute of all resources, would only demand the use of many airships, following one another at some distance, and capable of extending mutual assistance in case of necessity. So far as the Antarctic is concerned, its exploration would be more difficult, owing to the extent of its surface, and, above all, the remoteness of its shores from civilisation. It would be necessary to establish special stations, and the "raids" that would have to be carried out by the airships would exceed 2000 or 2500 kilometres outward, as well as return. Undoubtedly, therefore, this will be the last part of the terrestrial globe that will be made known.

Be that as it may, the aerial exploration of unknown continents is quite possible by means of dirigibles. I do not think that aeroplanes will take part therein so long as they are not provided with sustaining screws to permit them to remain in the air, and in their present form their impossibility of "stopping" prevents recourse to *photo-topography* by them. But they will be valuable auxiliaries in the sense that by rapid reconaissances made at high speeds, they will be able to indicate the most interesting points of which it will be useful to have a detailed map, and upon which the dirigibles, after their indication, can be engaged.

One other application of dirigibles and aeroplanes, a sphere in which their use will be extended, is the necessity to learn, by careful study, the laws of atmospheric circulation in the highest and middle altitudes. As a matter of fact we scarcely know the laws of this movement in the immediate neighbourhood of the earth, and but for the work of the Prince of Monaco upon the ocean, and those of M. Teisserenc de Bort by means of kites, France would be very much behind other nations.

If it is desired that aerial navigation should develop as it ought, it is therefore urgent to pursue the exploration of the higher atmosphere, and the further knowledge that we shall acquire in this way will be completed, if not exclusively furnished, by savants travelling in dirigibles and aeroplanes.

THE INDUSTRIAL MOVEMENT CREATED BY AERIAL NAVIGATION

Not one of the least benefits to locomotion through the air is the creation in a few months, as if by the wave of a magic wand, of a new industry, and the development of a considerable commercial movement the significance of which it is impossible to indicate.

In the first place the generous initiative of M. Henry Deutsch speedily found many imitators: there are actually over £64,000 offered to aviation in France alone. Moreover, the Osiris legacy endowed aeronautics by £4000, which the/Académie des Sciences divided between the constructors, Blériot and Voisin, and, through the generous and active initiative of M. Barthou, Minister of Public

Works, whose brother, M. Léon Barthou, is an aeronaut as audacious as militant, the public purse has voted a subvention of £4000 to aerial navigation. Let us add £8000 already won, and that makes *£80,000!* Yet that is only for "encouragement!" May we see a little of the amount effectively disbursed.

The French have at the present time three military dirigibles—*Lebaudy*, *République*, and *Ville de Paris;* the *Patrie* was carried away by a storm, but it has been replaced, and there are under construction the *Liberté*, and *Colonel Renard.* In addition to these there are the *Bayard-Clément*, *Belgique*, and *Russie* (built in French workshops). That totals in all ten important dirigibles built in four years. When one recollects that each costs on the average £12,000, that makes £120,000; but it is more than £120,000 if one takes into account the *garages* and the money expended upon experiments. I do not take into consideration the numerous efforts of MM. Santos-Dumont and Comte de la Vaulx; of the attempts of MM. Malécot, Marçay, and others; by adding all together one obtains for this period of infancy and experiments something like £400,000. This is an economic aspect of the question that one must not overlook, especially if one reflects that we are yet only in the early stages.

And aeroplanes! It is by the hundred that one now counts their construction; the money circulated for an aviation apparatus is less than for an airship, that is certain, but it is precisely for this reason that a very large number of persons are participating therein, and it is by hundreds that it is necessary to enumerate them at this moment. If one admits that each, including the trials, represents an outlay of £800 (and we under-rate the truth), we thus arrive, under this head, at many thousands. And here it has been more rapid since the true experiments in aviation do not date back more than eighteen months. If one keeps account, moreover, of the money expended in fruitless experiments, in repairs, in expenses of all kinds, the balance-sheet of aerial navigation, both dirigibles and aeroplanes, shows a money movement during the past five years of more than £800,000! That is excellent for a start.

And this is only in France; the whole world knows that Germany has expended enormous sums upon its military dirigibles: it exceeds 12,000,000 marks already. In England, the United States and Italy the movement is equally important. Aerial locomotion has therefore given birth to an industry which appears likely to undergo a tremendous expansion. This industry creates a financial reflex because in France alone *ten limited companies* have been actually established, representing a total capital of over *£200,000.* There are many others, also very important, abroad, and the Bourse is entangled because, rightly or wrongly, speculations have already taken place in these new stocks.

WHAT REMAINS TO BE DONE?

Now what progress remains to be accomplished in order that aerial locomotion may maintain its excellent prospects for the future, in order that new conquests may justify the enthusiasm provoked by its glorious *début?*

In connection with dirigibles the first condition will be to obtain at once the speed of 60 kilometres per hour at least, so as to reduce to twelve or fifteen days per year the period of compulsory idleness. It will then be necessary to increase their volume so as to allow the increase of fuel-carrying facilities for participation in lengthy voyages; in a word their *radius of action* must be extended to 1000 or 1200 kilometres; I consider this indispensable. Then it will be available for armies and exploring expeditions, of which services we have already spoken.

But as the possibility of any accident to the motor must be prevented, it will be necessary to provide them with two independent engines and two propellers; in this manner the failure of one engine would not bring about disablement, or compel landing at some place where an accident might result. The balloon fabrics will be still more perfected, and will assure to an airship the possibility of remaining inflated in the air for fifteen, twenty, or thirty days without taking another charge of gas. Their construction will certainly be improved, and one will learn the best means to avoid the cause of that "fermentation" of the rubber which is incorporated therein, and which may render the dirigible's envelope useless.

But one thing which will be indispensable, in fact necessary, will be the construction of *garages*, landing stations and shelters; by this means, and by this means, only, will the airship render great service, not only in France but in the colonies.

With regard to aviation apparatus much remains to be accomplished. At first it will be necessary to increase to a great extent their security, and to assure their lateral and automatic equilibrium. We have seen that it is compulsory to increase their speed up to

150 or 200 kilometres per hour, velocities which we shall witness soon without a doubt. And at the same time it will be necessary to reduce the dangers of shocks at landing, dangers which will increase in proportion as the supporting surface will be diminished, because of the progressive increase of the speed of the aerial vehicle. It will be essential, more so than in balloons, to equip aeroplanes with two *independent* motors, each of which *alone* will suffice to assure sustentation and propulsion. In this manner only will it be possible to reduce to the minimum the risks of an aerial journey. The number of the devices for steering and control of the motor must be restrained to the minimum, so that the pilot has less to do; the facilities for accommodating passengers must be improved; it will be necessary to increase the radius of action which scarcely equals two or three hours' actual travelling at 80 kilometres per hour; special safety arrangements for cases where the aeroplane would have to descend upon a lake, a river, or the sea must be provided.

And above and before all, the necessity of *launching* from level ground must be suppressed, as such may be unavailable, as, for instance, in a mountainous or forest country; if this obligation be persisted in, it will be a serious obstacle against the general application of aviation.

This is the goal to which the efforts of the investigators must now be directed. Flying machines must be able to "rise from the spot"; then they will have an immense future, and maybe we shall see *aeroplane-liners* ploughing the air with numerous passengers, whereas as yet we have only *aeroplane birds*. Possibly this development will be the first fruits of that "aeronautical institute," for the foundation of which M. H. Deutsch offered a million francs to the Université de Paris, at the same time as M. Zaharoff gave £28,000 to found there a chair of aviation.

Now we arrive at the last lines of this volume; I have not been able in writing it to defend myself from a feeling of "human" pride, and I am sure that the reader will share it. As a matter of fact, is it not magnificent to think that man, so insignificant in Nature, so feeble in comparison with the forces of the universe, even so weak in reference to many of the living species, has been able, thanks to the inspiring effort of his brain, to tame the elements, to conquer them, and to become their master? That domain of the air, which seemed prohibited to him, he has penetrated, soon will govern it as he holds sway upon the earth, as he prevails upon and under the waters! Certainly the history of all his conquests is magnificent, but I think that undoubtedly the most fascinating is that which we have described; it is that by which man has at last freed himself from servitude upon terrestrial soil; he has broken the fetters that the laws of balanced weight imposed upon him by the speed of his machines, and now, henceforward free of all shackles, he will be able to dash without hindrance along the "Highway of the Air."

APPENDIX

APPENDIX

SOME of our readers perhaps will be desirous to learn in a more precise form the laws concerning the resistance of the air. For such we set forth in the following lines the essential formulæ for aeronautics and aviation.

(*A*) RESISTANCE OF THE AIR.—In the case of a surface of which the plane stands perpendicular to the direction of displacement, the resistance of the air is given by the relation

$$(1) \qquad R = \phi S V^2$$

in which S is the moving surface, expressed in *square metres*, V the velocity of displacement in *metres per second*, R the resistance in *kilogrammes* and ϕ a *co-efficient* of which the value is only known with doubtful certainty (it varies according to the experimenters, between 0·08 and 0·16. Marine engineers for calculations concerning the propulsion of vessels by the wind take the number 0·125, the result of very ancient practice. Still the number 0·08 is the mean of more recent investigations by Le Dantec, Renard, Eiffel, Cailletet and Colardeau).

The formula (1) corresponds to the case of Fig. 1.

(*B*) RESISTANCE OF THE AIR UPON AN OBLIQUE SURFACE.—This is the case of the theoretical aeroplane, corresponding to Fig. 44, in which we designate by i the angle of the surface of the aeroplane with the direction of movement (angle of attack).

The thrust P moving against the oblique surface is expressed

$$(2) \qquad P = \phi SV^2 f(i)$$

$f(i)$ being an action of the angle i. This action is simple and must be of the form

$$f(i) = \lambda \sin i.$$

With regard to the value of λ, it is given by formulæ which differ according to the *savants* who have enunciated them. Here are the three which are the most used:

$$(3) \qquad \lambda = \frac{2}{1 + \sin^2 i} \qquad \text{(Colonel Duchemin)}$$

$$(4) \qquad \lambda = a - (a - 1) \sin^2 i \qquad \text{(Colonel Renard)}$$

in which a is a number between 1 and 2 and more in the neighbourhood of 2;
and lastly,

$$(5) \qquad \lambda = \frac{1 - m \operatorname{tg} i}{\frac{1}{(1+m)^2} + \frac{2m}{1+m} \operatorname{tg} i + 2 \operatorname{tg}^2 i} \qquad \text{(Soreau)}$$

formula in which m is the ratio, $\frac{1-h}{1+h}$ if one calls $2l$ *the spread* of the surface and $2h$ its dimension *in the direction of travel; m* consequently depends upon *the elongation* of the surface as well as λ.

At all events λ varies with the angle i. Let us call λ_0 its *mean* value and let us admit:

$$K = \phi \lambda_0$$

we have then for expression of the normal thrust bearing upon a flat sail, in the case of an angle of attack small enough to draw it without confounding the arc with its sine:

$$(6) \qquad P = KSV^2 i$$

the angle i was expressed in the function of the radius.

N.B.—Many authors often confound K and ϕ; it is important to avoid this confusion.

(*C*) Position of the CENTRE OF PRESSURE (or centre of thrust).—In reverting to Fig. 48 which graphically expresses as the result of experiment that the centre of thrust is drawn more to the front edge of the moving surface, one has to calculate the distance d between this centre and the centre of the diagram of the moving rectangle, the formula conceived by the engineer M. Soreau.

$$(7) \qquad d = \frac{h}{2(1 + 2\,\mathrm{tg}\,i)}$$

$2h$ being the dimension of the rectangle in the direction of travel. Avanzini's formula, a little simpler, is the following:

$$(8) \qquad d = 0{\cdot}6\,h\,(1 - \sin i)$$

(*D*) M. BERGET'S SPEED FORMULA FOR DIRIGIBLE BALLOONS.—This formula is

$$(9) \qquad \mathrm{V} = \mathrm{C}\sqrt[3]{\frac{\mathrm{F}}{\mathrm{S}}}$$

in which V is the speed in *myriametres per hour*, F the engine effort in *horse-power*, S the surface of the maximum transversal section *in square metres*, and G the *coefficient of advantage* of the airship (see Table on page 113).

(*E*) MEASURING THE SPEED OF AERIAL VEHICLES.—This operation, indispensable to aeronauts, and which will be to aviators also as soon as they can undertake voyages of some duration, is simply effected by means of the apparatus of the engineer Joanneton of which front and back views are shown in Plate XXI.

The apparatus is a copper quadrant of which one face carries an engraved "table" over which moves a rule. This rule indicates by the aid of ½-ratio gearing, the part of the angle at which turns a mirror with which it is solid and which projects from the back face. The aeronaut by the aid of a small telescope sees in this mirror the image of some arbitrarily chosen point upon the ground (a tree, steeple, building or what not) and follows this object *for one minute* while turning the mirror in such a manner that the image always rests in the field of the telescope. There is nothing more to do than look upon the "table," to see the intersection of the rule with the line of altitude shown by the barometer; the abscissa of the corresponding point indicated upon the horizontal edge of the quadrant gives the speed in kilometres per hour.

The apparatus weighing about one kilogramme suspends itself by its weight in the desired position: it is sufficient to hang it up by a cord and a ring to the suspension ring of the car.

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