AËRIAL NAVIGATION

ALBERT F. ZAHM

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A POPULAR TREATISE ON THE GROWTH OF AIR CRAFT AND ON AËRONAUTICAL METEOROLOGY

BY

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PREFACE

THE purpose of this work is to portray in popular terms the substantial progress of aëronautics from its earliest beginning to the present time. Beyond the introductory account, little note is taken of experiments, however picturesque or clever, which constitute no advance in the art, or lead to no useful result. At times some minutiæ are presented to complete the story of an important series of achievements; but the unproductive efforts of impractical zealots, however prominent or widely known in their day, receive scant, if any, attention. Failures and tragedies where introduced, are described for the lessons involved rather than for any curious interest investing them. The griefs and grotesque follies of aëronautic imbeciles form a long story, but a futile and unprofitable one, of slight concern in the evolutionary history of a veritable science.

A general history of aërial locomotion would naturally be divided into four parts, treating respectively of passive balloons, power balloons, passive flyers, and power flyers; but in this work a separate treatment has not been allotted to passive flyers because of their too backward state of development. Passive gliders which maneuver in the air merely by virtue of gravitational force, or acquired momentum, are familiar enough; but the much more interesting passive flyers of human construction, adapted to rise without motive power considerably beyond their initial level, or to soar far aloft, and sail long distances by virtue of favorable winds, are still in their infancy. It may be hoped, however, that the vulture's art which now is well nigh overlooked, because of the triumphant advance of dynamic flight, will soon receive such attention that future treatises may relate human achievements in soaring that shall rival the dexterous and marvelous feats of the condor and albatross, even as the majestic sweep of the dynamic aëroplane now rivals the powerful rowing flight of the strongest birds of prey.

Following the story of the evolution of air ships, a brief account of the medium they navigate has been added. In particular, the circumstances which affect the density and motion of the air have been studied; for the density of the air determines the static lift of air ships; the density and speed of impact of the air together determine the dynamic lift and the resistance to progression; while the velocity of the air current conditions the possible speed of travel in any direction. It is important, therefore, that the aëronautical student should have some acquaintance with the general properties of the air which affect its density, and some knowledge of the generation and prevalence both of the great currents of the atmosphere, and of the local winds and invisible turmoils which so nearly concern the safety and effective progress of the aërial navigator.

The French units of measurement have been freely used, as well as the English. This seems advisable because the official rules and records of international aëronautic events are partly expressed in the metric system. Moreover, the navigation of a universal medium seems to call for such universal standards. Indeed a peculiar mission of world travel is to eliminate provincialism, and to promote universalism of thought, of sentiment, and of custom.

In order to lighten the book for the popular reader, some interesting historical facts and much important quantitative data are placed in the Appendices, where they may be available to the technical or special student.

It is a pleasant duty to acknowledge here my obligations to the U. S. Signal Corps, the Smithsonian Institution, and the U. S. Weather Bureau, for much assistance in collecting the materials for this work. Dr. W. J. Humphreys, of the U. S. Weather Bureau, has very kindly read the manuscript for the chapters on the atmosphere.

My thanks are due also to the *Scientific American* and to *Aëronautics* for the use of photographs for the illustrations, as also to the manufacturers of various aircraft, and to Mr. W. J. Hammer, Mr. Carl Dientsbach, and Mr. A. S. Levino.

A. F. Zahm.

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FANCY AND FOLK-LORE

Of silver wings he took a shining pair,
  Fringed with gold, unwearied, nimble, swift;
With these he parts the winds, the clouds, the air,
  And over seas and earth himself doth lift.
Thus clad he cuts the spheres and circles fair,
  And the pure skies with sacred feathers clift;
On Lebanon at first his feet he set
  And shook his wings with rosy may-dews wet.

Tasso, Canto I, XIV.

How beautiful! May we hope ever to journey thus, on wings actuated by human power? It is an old question, once dear to the philosopher and fool alike, but now important mainly to the fool. Or say more kindly it is the affair of untechnical inventors —the amateur, the rustic, the man of chimerical dreams. For the wise aëronaut now numbers that project among the roseate illusions of his youth.[1]

Ovid relates a story, doubtless credible in his day, of a clever craftsman who with his son flew bravely aloft, the very first time they put on wings. Daedalus, a Greek architect, having fled from Athens for murder, went with his son Icarus to the island of Crete, where he built the celebrated labyrinth for Minos, the king. He offended that monarch and was cast into prison. In order to escape he made wings for himself and his son, with which they flew far

[1] With apologies to the California professor who will ride on wings worked by muscular force alone.

over the sea. But Icarus, in his elation, soared too near the sun, ruined his wings, fell into the sea and was drowned. For proof of this we have the Icarian Sea, named after the unfortunate boy. Also we have Ovid's charming poem:

> In tedious exile now too long detain'd
> Daedalus languish'd for his native land;
> The sea foreclosed his flight, yet thus he said;
> "Though earth and water in subjection laid,
> O cruel Minos, thy dominion be,
> We'll go through air; for sure the air is free."
> Then to new arts his cunning thought applies,
> And to improve the work of nature tries.
> A row of quills, in gradual order placed,
> Rise by degrees in length from first to last;
> As on a cliff the ascending thicket grows;
> Or different reeds the rural pipe compose:
> Along the middle runs a twine of flax,
> The bottom stems are join'd by plaint wax;
> Thus, well compact, a hollow bending brings
> The fine composure into real wings.
> His boy, young Icarus, that near him stood,
> Unthinking of his fate, with smiles pursued
> The floating feathers, which the moving air
> Bore loosely from the ground, and wafted here and there:
> Or with the wax impertinently play'd,
> And with his childish tricks the great design delay'd.
> The final masterstroke at last imposed,
> And now, the great machine completely closed;
> Fitting his pinions on, a flight he tries,
> And hung self-balanced in the beaten skies.
> Then thus instructs his child: "My boy, take care
> To wing your course along the middle air:
> If low, the surges wet your flagging plumes;
> If high, the sun the melting wax consumes.
> Steer between both: nor to the northern skies,
> Nor South Orion, turn your giddy eyes,
> But follow me; let me before you lay
> Rules for the flight, and mark the pathless way."

Thus teaching, with a fond concern, his son,
He took the untried wings, and fix'd them on:
But fix'd with trembling hands; and, as he speaks,
The tears roll gently down his aged cheeks;
Then kiss'd, and in his arms embraced him fast,
But knew not this embrace must be the last;
And mounting upward, as he wings his flight,
Back on his charge he turns his aching sight;
As parent birds, when first their callow care
Leave the high nest to tempt the liquid air;
Then cheers him on, and oft, with fatal art,
Reminds the stripling to perform his part.
These, as the angler at the silent brook,
Or mountain shepherd leaning on his crook,
Or gaping ploughman, from the vale descries,
They stare, and view them with religious eyes,
And straight conclude them gods; since none but they
Through their own azure skies could find a way.
Now Delos, Paros, on the left are seen,
And Samos, favour'd by Jove's haughty queen;
Upon the right, the isle Lebynthos named,
And fair Calymne for its honey famed.
When now the boy, whose childish thoughts aspire
To loftier aims, and make him ramble higher,
Grown wild and wanton, more embolden'd flies
Far from his guide, and soars among the skies:
The softening wax, that felt a nearer sun,
Dissolved apace, and soon began to run:
The youth in vain his melting pinion shakes,
His feathers gone, no longer air he takes:
"Oh! father, father!" as he strove to cry,
Down to the sea he tumbled from on high,
And found his fate; yet still subsists by Fame,
Among those waters that retain his name.
The Father, now no more a father, cries:
"Ho, Icarus! where are you?" as he flies;
"Where shall I seek my boy?" he cries again,
And saw his feathers scatter'd on the main;
Then cursed his art; and funeral rites conferr'd
Naming the country from the youth interr'd.

How tender and apprehensive that gentleman's farewell, compared with the modern vogue in like circumstances! Of the two Americans at Berlin who fell four thousand feet in a balloon, it is not recorded that they either kissed or wept.[1] But some Teutonic Ovid may yet adorn the tale with quaint embellishments.

Taking more serious note of Daedalus, it will be observed that he has had few imitators. It is because he never really flew, and no one else can fly, in such manner. That is to say, no man can achieve practical flight on wings actuated by his own muscular power. It may be physically possible for an athlete putting forth herculean energy for a few seconds to sustain himself on wings of enormous spread; but in every lightest zephyr he would be as helpless as a thistle seed.

The actual area of wing required for a man of given weight and power may be roughly estimated; at least its lower limit of size can be determined. Lord Rayleigh,[2] on purely theoretical ground, has computed that a man operating a screw propeller 280 feet in diameter, moving without frictional loss, could sustain his weight for a period of eight hours a day at a comfortable rate of work. But that estimate does not include the weight of the propeller. By exerting ten times his normal power the man could support his weight with a 28-foot propeller.

The physical basis of the computation is the same for every type of flyer, whether bird, man, or ma-

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[1] Mr. A. Holland Forbes and Mr. Augustus Post, in the international balloon race of 1908, used a balloon having too long a neck, thus causing such pressure at its top as to burst the bag. A dreadful plunge ensued, landing them on a house, but without injury, as the netting and collapsed bag dampened their speed of fall. It is reported that they crashed through the skylight, and that the lady of the house regretted not being there to receive them.

[2] *Mechanical Principles of Flight.*

chine. Its weight must be sustained by hurling the air downward. The humming bird in its aërial pause, the bee floating beside a blossom, rests on a down-driven column of air. The home-gliding eagle at dusk may encounter a medium in stillest repose, but he leaves behind him a down-flowing wake, viewless, maybe, but none the less real. In all cases the downward impulse per second given to the air must equal the weight supported by its reaction. If the wings be very extensive a proportionate mass of air may be struck down, and yield support with so much the less exertion.

Horizontal flight promises little more than direct screw lift, with the feeble energy of the human muscle. The best modern aëroplanes carry less than 100 pounds per horse power, while an average man must weigh, with a light machine, not less than 200 pounds, and must therefore exert upwards of two horse power during flight. Such an output of energy would exhaust a powerful athlete in a few seconds. Hence from every point of view it appears that Daedalean flight, which still has its devotees in some form, was and always will be utterly impracticable.

Ruskin finds another objection to the disciples of the winged arm. In his disquisition on the equilibrium of angels he complains that those of the traditional two-wing type are devoid of gravitational balance. Such creatures vex the imagination with apprehensions for their stability; hence they cannot be entirely beautiful. The centroid of an angel is in the small of its back, whereas the center of wing support is well forward; therefore the horizontal poise is absurd and unæsthetic. The scientific artist, consequently, views with pain the picture of a fair lady floating level through space supported only at her front end.

Milton adroitly forestalls this censure. In the conception of his glorious Raphael, he provides consummately for uniform and adequate support:

> Six wings he wore, to shade
> His lineaments divine; the pair that clad
> Each shoulder broad, came mantling o'er his breast
> With regal ornament; the middle pair
> Girt like a starry zone his waist, and round
> Skirted his loins and thighs with downy gold,
> And colors dipped in Heaven; the third his feet
> Shadowed from either heel with feathered mail,
> Sky-tinctured grain. Like Maia's son he stood,
> And shook his plumes, that heavenly fragrance filled
> The circuit wide.

Leonardo da Vinci, who was a gifted engineer as well as an artist, devised a flying gear for man which shows some dynamic improvement over the mechanism of the old-time angels, flying gods, and hobgoblins. As shown in the accompanying sketch, it provided for gravitational balance by use of an expanding tail projecting well to the rear. Moreover, the propulsion was to employ both arms and legs. This design is considered very remarkable for the time in which it was produced, probably a few years before the discovery of America; and yet it is but one of Da Vinci's quaint aëronautical inventions, as will appear later.

A less futile scheme of aviation may be to saddle the birds. If one eagle can float a child, a few may possibly carry a man. They are physically able; they are inexpensive; they are unweared, nimble, swift. Some harness, some tuition may be required; but these come to the industrious. Apparently, such locomotion is a sport worth developing; a royal art, if you please; for who would not course the sky in a purple palanquin borne by imperial eagles?

Kai Kaoos, the King of Persia, is credited with a voyage of this kind, as described in the *Shah-Nemeh,* or *King-Book,* written in the tenth century:

"To the king it became a matter of great concern how he might be enabled to ascend the heavens, with-

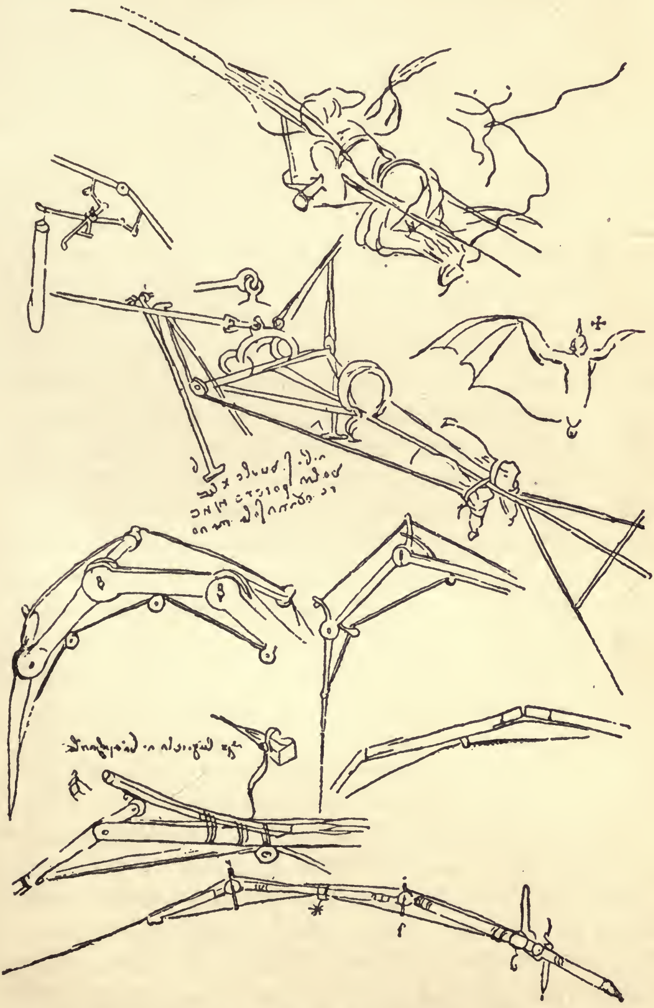

Fig. 1.—Da Vinci's Designs for Human Flying-Gear.

out wings; and for that purpose he consulted the astrologers, who presently suggested a way in which his desires might be successfully accomplished.

"They contrived to rob an eagle's nest of its young, which they reared with great care, supplying them with invigorating food.

"A frame of aloes-wood was then prepared, and at each of the four corners was fixed perpendicularly a javelin surmounted on the point with the flesh of a goat. At each corner again one of the eagles was bound, and in the middle the king was seated with a goblet of wine before him. As soon as the eagles became hungry they endeavored to get at the goat's flesh upon the javelins, and by flapping their wings, and flying upwards they quickly raised the throne from the ground. Hunger still pressing on them, and still being distant from their prey, they ascended higher and higher in the clouds, conveying the astonished king far beyond his own country. But after a long and fruitless exertion, their strength failed them, and, unable to keep their way, the whole fabric came tumbling down from the sky, and fell upon a dreary solitude in the Kingdom of Chin, where Kai Kaoos was left a prey to hunger, alone, and in utter despair."

One might prefer a single bird, which could be ridden bareback by a man or woman of common equestrian skill. The early philosophers, therefore, sought with some care for such a creature. The following is related by Bishop Wilkins:

"Cardan and Scaliger doe unanimously affirm, that there is a bird amongst the Indians of so great a bignesse, that his beak is often used to make a sheath or scabbard for a sword. And Acosta tells us of a fowl in Peru called Condores, which will of themselves kill and eat up a whole calf at a time. Nor is there any reason why any other body may not be supported and carried in the air, though it should as much exceed the quantity of these fowls as they do the quantity of a flie. Marcus Polus mentions a fowl in Madagascar which he cals a Ruck, the feathers of whose wings are 12 paces, or threescore foot long, which can with as much ease soop up an elephant as our kites do a mouse. If this relation was anything credible, it might serve as an abundant proof for the present quaere."

As the roc has proved a myth, one questions whether a saddle bird may not be evolved by judicious breeding. But opposed to this is the square-cube law of the Greek geometer, by which a learned geologist demonstrated that nature has reached the limit of her resources in the production of large flyers, the ostrich, for example, being too bulky to navigate at all. As a last resource, then, the human dwarf may breed his weight downward to accommodate the bird. Assuredly, the most powerful flyer can carry the lightest human dwarf without difficulty.

Such aërial cavalry has been projected occasionally, and if fairly developed might have interesting employment. Its military value, to say nothing of its civil uses, would be considerable. An aërial scout that could hide in a tree top, or small cloud, then flit home with full intelligence of the enemy, would be effective and unique. In aggressive warfare it would serve the plan of that ingenious Englishman who proposes to repel a German invasion by dispatching birds to peck holes in the enemy's war balloons. But here the dwarf might be omitted, if the birds were taught to have a definite interest in attacking aërial cruisers with their beaks, or with steel-armed spurs like those of the Spanish fighting cock, or with talons treated chemically to strike fire. Sparrows with sulphur-pointed toes could easily annihilate an aërial squadron at all combustible.

Recurring to the geologist, it may be added that, having discovered the major limit of feathered navigators, he concluded, as a corollary, that human flight is forever impossible. That was in the latter eighties. In 1901 a versatile astronomer adduced the same law to prove that an aëroplane could not be

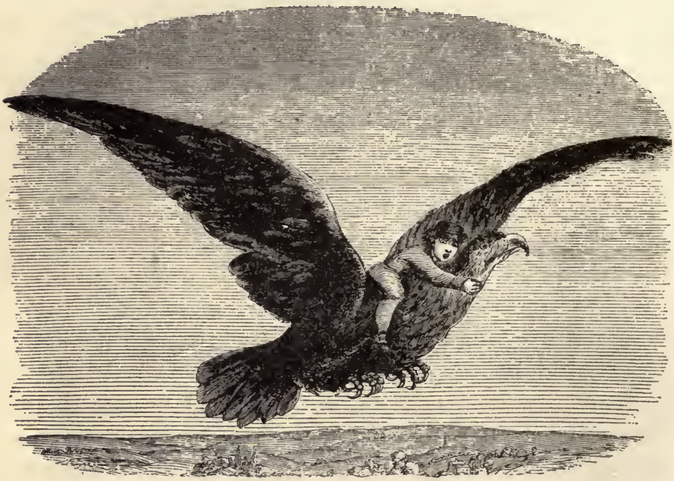

FIG. 2.—A POSSIBLE AIR-SCOUT.

made to carry a man. Presently, learning that this had been achieved, he proved, in a second mellifluous paper, that an aëroplane could not carry several men.[1] Having erred twice, he wrote a final article announcing that a flyer is fatuous, anyhow, because she cannot repair her engines in the sky!

Of the numerous daring and industrious inventors who, during remote generations, have launched

[1] The reader may like to know that the basis of so much confidence was that ancient Euclidean theorem connecting the surfaces and volumes of similar figures with certain powers of their homologous linear dimensions.

themselves in the air on some species of rigid or vibrant wings, a few were men of considerable equipment in philosophy, or mechanics, and enjoyed a sufficient measure of success to deserve passing notice; though it seems that no man before the middle of the eighteenth century made a permanent contribution to the real art of mechanical flight, if we except the ingenious suggestive devices of Leonardo da Vinci. However skilfully their flying apparatus may have been planned, or operated, the results were lost to the world, due to inaccurate or inadequate description. Such inventors were J. B. Dante, in the fifteenth century, and the Marquis de Bacqueville, in the seventeenth. Each of these made one, or more, considerable flights, if we may credit the unwavering testimony of their contemporaries; but neither has left a sketch of his device, nor a school of followers to continue his spectacular practice.

Jean-Baptiste Dante, a shrewd observer and profound mathematician, who flourished toward the end of the fifteenth century, a contemporary of Da Vinci and Columbus, is reported by the historians of that day to have sailed successfully through the air on nonvibrant wings designed by himself after a careful study of the great soaring birds. Perching above a steep crag on the shore of Lake Trasimene, he set his wings to the wind at a nice angle, as one sets the sails of a vessel; then, lifted by the swelling breeze, he rose grandly aloft and floated far over the waters. Again and again he repeated the experiment, until the fame thereof secured for him a request to make the demonstration at the marriage fêtes of the illustrious general, Barthelmi Alviano. He accepted the invitation, and, starting from the top of the highest tower in the city of Perugia, he sailed over the public square, and balanced himself for a long time in space, amid the shouts and acclamations of the multitude, attracted to Perugia by the novelty of his performance. But, sad to relate, the very first time he performed these wonderful maneuvers above the solid ground instead of the lake, one of the levers used to alter the impact angle of his wings gave way, disturbing his aërial poise, and causing him to pitch down upon Notre Dame church, breaking one of his legs. After this he taught mathematics at Venice, where he died of fever at the age of forty years.

In 1742, the Marquis de Bacqueville, at the age of sixty-two years, announced that on a certain day he would fly from his house on the Seine, traverse the river, and land in the Garden of the Tuileries. A great multitude assembled, crowding both shores and the two bridges. At the appointed moment the Marquis appeared with his pinions, and launched himself from the terrace. He sailed forth in majestic and serene poise, on graceful wings not unlike those of the traditional angels. He was gliding directly toward the Tuileries, and he enjoyed a happy cruise quite to the middle of the river. Then something happened; his movements became fitful and uncertain; he plunged downward and broke his leg on a laundry boat. The reason for his stopping there can only be surmised, for he had nothing to report. He did not quite fulfil his program, but he flew nine hundred feet delightfully, and he landed without getting wet.

Commentators have marveled as to the nature of the mechanism used by Dante and by De Bacqueville. Historians have strongly attested the fact of the flights, but have overlooked the means. The inventors must have employed aërial gliders of some kind, for adequate motive power was not available before the end of the nineteenth century. Even as an experiment in gliding, or soaring, the achievement of Dante was most daring and wonderful, eclipsing the best performances up to the twentieth century. It is strange that in that period of science the survivor of such an experience, and a college professor, should not have left to the world a careful account of such an extraordinary performance. The alleged flights, however, were unquestionably feasible, even in that remote period, for the construction of an aërial glider is a simple task not beyond the capacity of craftsmen in the fifteenth century A.D., or even the fifteenth century B.C., directed by a skilful designer.

Besides the wing-armed scheme of flight credited to Daedalus, and contemplated by Da Vinci, various other plans were evolved in succeeding years. Aërial chariots and flying machines were devised for the more advantageous use of muscular energy. In all these, of course, the passenger could be both power plant and captain of the ship.

One of the earliest authenticated devices of this kind was the invention of Blanchard, described by him in the *Journal de Paris,* August 28, 1781, nearly two years before the invention of the hot-air balloon, of which he became later an enthusiastic votary. As his device is but one of a large number that appeared before the close of the nineteenth century, and the advent of light motors, the reader who wishes fuller acquaintance with man-driven airships may be referred to Mr. Chanute's book, entitled *Progress in Flying-Machines,* which describes a large variety of such inventions, and discusses the merit and weakness of each.

Blanchard prefaces the description of his machine by answering some criticisms of his project, apparently ventured by his neighbors. "They object to me," he writes, "that flying is not the business of man, but rather of the feathered birds. I reply that feathers are not at all necessary to the bird for flight; any fabric suffices. The fly, the butterfly, the bat, etc., fly without feathers and with fanlike wings of material resembling horn. It is, then, neither the material nor the form that causes flight, but the volume and the celerity of the movement, which should be as lively as possible.

"They object, moreover, that a man is too heavy to lift himself alone with wings, much less in a vessel which of itself presents enormous weight. I reply that my ship is extremely light; as to the man's weight, I pray that attention be given to that which M. de Buffon says in his *Histoire Naturelle,* on the subject of the condor; this bird, though of enormous weight, easily lifts a two-year-old heifer weighing at least a hundred pounds, the whole with wings of about thirty to thirty-six feet expanse."

He then describes the vessel as a little ship four feet long by two feet wide, having on either side two posts, each supporting a wing ten feet long, the whole forming a parasol twenty feet in diameter. The construction was illustrated by an engraver, who had seen the vessel and was convinced of its practicability. In conclusion, the inventor writes that people shall see him cleave the air with more speed than the crow, and that without losing his breath, being protected by a pointed mask of peculiar construction. But, as he failed to make good his promises, he was subjected to ridicule, as well as praise, by the local press, one of the caricatures portraying him in the act of making an ascension before a concourse of bulging-eyed savants and long-eared jackasses, wearing spectacles to accentuate the appearance of wisdom and solemnity.

The scientific coterie of Paris were apparently impatient of the attention shown Blanchard by the press and people. Accordingly, in May, 1782, the distinguished astronomer, De Laland, of the French Academy, administered a mild rebuke to the editors of the *Paris Journal.* "Gentlemen," he wrote, "you have given so much time to air ships and divination rods that one might eventually think that you believe in these follies, or that the scientists who coöperate with your journal have nothing to say to dispel these absurd pretensions. Permit me, therefore, gentle-

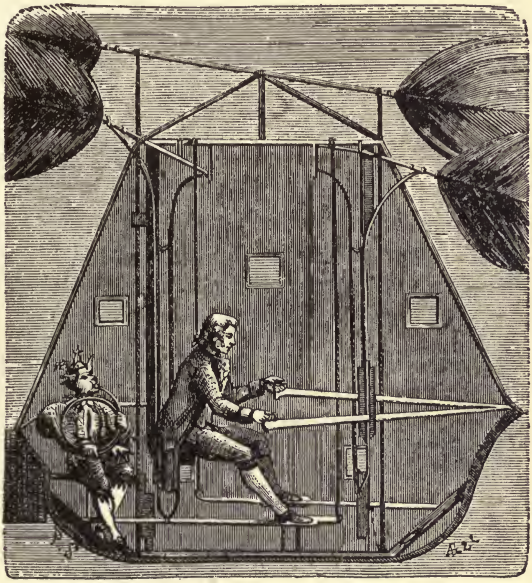

FIG. 3.—BLANCHARD'S FLYING-MACHINE.

men, to occupy some lines in your journal to assure your readers that if the savants are silent it is only because of their contempt.

"It has been demonstrated to be impossible for a man in any manner whatever to raise himself, or even to sustain himself, in the air. M. Coulomb, of the Academy of Sciences, at one of our meetings a year ago, read a paper in which he showed clearly, by calculating the power of a man, determined by experiments, that he would require wings two or three thousand feet long moved three feet per second; hence no one but an ignoramus would make an attempt of this kind."

Not many months after this lofty deliverance, Blanchard took De Lalande up in a balloon—"the dead borne by the dumb."

Coulomb's calculation that a man's pinions should be half a mile long must have been discouraging to those inventors who believed in him; for, granting that such wings could lift a man, who could lift the wings? And at that date the steam engine was only beginning to develop; the petroleum engine was hardly thought of. No wonder that people turned eagerly to the balloon when it finally appeared.

There has been some controversy as to what person first clearly conceived a feasible design for a balloon. The conception was certainly not new to the world in 1783, when Joseph Montgolfier made his classical experiment. Indeed, prior to that date three distinct principles of aërial flotation had been entertained by natural philosophers; first, that a boat could be so formed of heavy material as to ride on the upper surface of the atmosphere, as a metallic vessel floats on the water; second, that a closed hull, comprising a partial, or complete, vacuum, could be made light enough to rise; third, that a bag could be made buoyant by filling it with material lighter than air. Of course, it is now clear to men versed in mathematics that only the light-gas principle is mechanically applicable. But the vacuum principle still has adherents among inventors who are too "practical" to understand, or trust, exact computation; and the first principle, though now discarded by everyone, was plausible enough, even to accomplished scientific men, before the experiments of Torricelli, and his invention of the barometer, made in 1643. It may, therefore, be interesting to notice some of the proposed, or reported, air ships based upon these various principles. The following is from *Mendoza, Viridario, libri III, probl. 47:*

"Any brass vessel full of air, which otherwise would sink, is sustained on the surface of the water, though naturally of much greater specific gravity; consequently a wooden ship, or one of any other material, placed on the summit of an aërial superficies and filled with elementary fire, will be sustained in that position till the gravity of the vessel becomes greater than the sustaining power of the fire it contains."

This is a clear scientific exposition of a plan for navigating the atmosphere on its upper surface, assuming a distinct upper surface to exist. In commenting on this passage, the Jesuit Schottus, in his *Magia Universalis,* uses an expression which indicates his belief that a vessel can be made to *float in the air* by filling it with ether, or the element of fire. He says:

"In such terms has this matter been treated by Mendoza (died 1626); nor is there any improbability involved in his view, whether the element of fire be placed above the air, or, what is still more credible, the ether—that is, the purest air. Although any wood, iron, copper, lead, and such like metals are weightier than an equal volume of water, and for that reason will sink in water when placed there alone, yet if fabricated into hollow shapes, and filled with our impure and heavy air, they swim upon waters, and are adapted to the construction of ships, and are sustained by water without danger of immersion; thus, although these bodies are of greater specific gravity than our air, nevertheless, when shaped into a boat and filled with that very light material, they can *float in the air,* and are suitable material for the construction of small ships, because the entire work composed of the little ship and the ether can be made lighter than an equal volume of our impure air, even in the highest region."

As Roger Bacon proposed a similar device in 1542, Mendoza's was not entirely new and may not have been original. Bacon, describing his aërial vessel, says: "It must be a large, hollow globe of copper, or other suitable metal, wrought extremely thin, in order to have it as light as possible. It must then be filled with 'ethereal air or liquid fire,' and then be launched from some elevated point into the atmosphere, where it will float like a vessel on water."

In the year 1646 another learned Jesuit published a book, *Ars Magna Lucis et Umbræ in Mundo,* in which he relates an episode indicating that one of his order had made use of a hot-air balloon to intimidate some ignorant pagans. The following demonstration, if reported by a modern missionary, would be accepted as a matter of course; why, then, should we gravely question the story, since it describes an achievement quite possible at the time, assuming that the necessary materials were available? And even assuming the report to be fictitious, still it is a scientific description of a practicable hot-air balloon, presented and credited by a learned scholar and accomplished mathematician more than a century before the balloon was publicly exhibited by the illustrious Frenchmen. He writes:

"I know that many of our fathers have been rescued from the most imminent dangers amongst the barbarians of India by such inventions. These were cast into prison, and whilst they continued ignorant of any means of effecting their liberation, some one, more cunning than the rest, invented an extraordinary machine, and then threatened the barbarians, unless they liberated his companions, that they would behold in a short time some extraordinary portents, and experience the visible anger of the Gods. The barbarians laughed at the threat. He then had constructed a dragon of the most volatile paper, and in this he enclosed a mixture of sulphur, pitch, wax, and so artistically prepared all his materials, that, when ignited, it would illumine the machine, and exhibit the following legend in their vernacular idiom, *The Anger of God.* The body being formed and the ingredients prepared, he then affixed a long tail, and committed the machine to the heavens, and, favored by the wind, it soared aloft towards the clouds. The spectacle of the dragon so brilliantly lit was terrific. The barbarians, beholding the unusual motion of the apparition, were smitten with the greatest astonishment, and now, remembering the threatened anger of Deity and the words of the father, they were in fear of expiating the punishment he had prognosticated for them. Therefore, without delay, they threw open the gates, they suffered their prisoners to go forth in peace and enjoy their freedom. In the meantime the fire seized on the machine and set it in a blaze, and with an explosion, which was interpreted as an expiring declaration of satisfaction, it, apparently of its own accord, vanished from sight, as if it had accomplished its supernatural mission. Thus the fathers, through the apprehension which this natural manifestation inspired, obtained that which could not be purchased with a large amount of gold."

Perhaps the reader will permit another anecdote, not entirely for its scientific value, but because he may like to compare the attitude of people toward aërial navigation in the dark ages with the attitude of his neighbors at the opening of the twentieth century. In two histories by Jef le Ministre and De Colonia, of the town of Lyons, the following account is given:

"Toward the end of Charlemagne's reign, persons who lived near Mount Pilate in Switzerland, knowing by what means pretended sorcerers traveled through the air, resolved to try the experiment, and compelled some poor people to ascend in an aërostal. This descended in the town of Lyons, where they were immediately hurried to prison, and the mob desired their death as sorcerers. The judges condemned them to be burned; but the Bishop Agobard suspended the execution, and sent for them to his palace, that he might question them. They answered: 'Qu'ls sont du pays meme, que des personnes de consideration les ont forcés de se laisser conduire, leur promettent qu'ils verroient des chose merveilleuses; et qu'ils sont veritablement descendu par l'air.' Agobard, though he could not believe this fact, gave credence to their innocence, and allowed them to escape. On this occasion he wrote a work on the superstition of the time, in which he demonstrated the impossibility of rising in the air; that it is an error to believe in the power of magic; and that it has its existence in the credulity solely of the people."

One of the first men to make an aërial model like a fire balloon was the celebrated Brazilean, Bartholomeo-Lourenco de Gusmao, who in his day was nicknamed the "flying man," and who is reported to have made a remarkable experiment in aërial locomotion at Lisbon. The following account of it is found in a manuscript of Ferreira:

"Gusmao made his experiment on August 8, 1709, in the court of the Palace of the Indies, before his majesty and a large and distinguished audience, with a globe which lifted itself softly to the height of the hall of the Ambassadors, then descended in like manner. It was borne up by certain materials which burned and which the inventor himself had ignited."

All the details of this description, which was written a generation or more before the Mongolfier experiment, suggest at once a hot-air balloon. But a note printed in 1774 and cited by Cavallo explains that the globes must have been transported by gas. It is certain that early in 1709 Gusmao applied to the King for a patent and sole right to some such invention, desiring an injunction and severe penalty against all infringements. The application sets forth a machine capable of journeying through the air faster than over land or sea, competent to carry messages five or six hundred miles a day to troops, or the most distant countries, and even adequate to explore regions about the poles. Quite a modern promotor Señor Gusmao. The King in reply issued the following decree:

"Agreeably to the advice of my council, I order the pain of death against the transgressor. And in order to encourage the suppliant to apply himself with zeal toward improving the machine which is capable of producing the effects mentioned by him, I also grant him the first Professorship of Mathematics in my University of Coimbra, and the first vacancy in my College of Barcelona, with the annual pension of 600,000 reis during his life."

The "patent" seemed liberal enough, and yet Gusmao never resumed his aërial experiments. He was accused of magic, and may have feared persecution on that account; accordingly he engaged in naval construction till 1724, when he left Portugal.

The first vacuum balloon was proposed by the Jesuit father, Francis Lana, and described in his book *Podromo dell 'Arte Maestra Brecia,* which appeared in 1670. Though not a practical project like Gusmao's, it was very ingenious, and marks an interesting phase in the evolution of the fundamental idea of the air ship, or "balloon" as it was called by the inventor, who then coined the word now in common use. Lana proposed to use four copper spheres each 25 feet in diameter and 1/225 inches in wall thickness, quite well exhausted of air, to give ascensional force which he computed at 1,200 pounds aggregate for the four spheres. From these he would suspend the passengers in a boat having a mast and sail to propel the ship in time of favorable

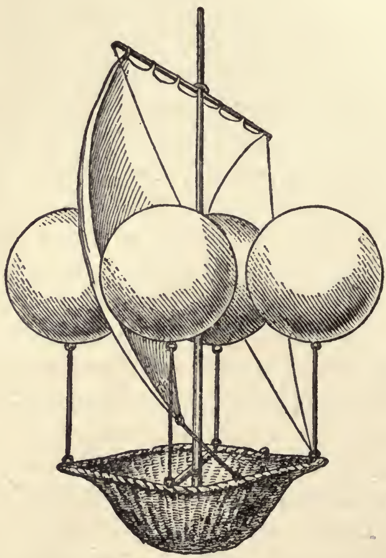

Fig. 4.—Lana's Proposed Vacuum Balloon.

wind. Having computed the buoyancy according to well-known physical laws, he could see no possible objection to his project "unless," he writes, "it be that God would never permit this invention to be practically applied, in order to prevent the consequences that would ensue therefrom in the civil and political government of men."

Of recent years inventors having less delicate scruples about embarrassing Providence, have revived Lana's project with improvements. It has been proposed to replace the sail by a motor-driven propeller, and to ensure the hull against collapse from the prodigious external air pressure—a ton per square foot—by ample internal bracing. Even within the past twelve months this scheme has been soberly advocated by several technical journals and by the author of an elaborate book on aërial warfare. To a mathematician this is amusing, when not too pathetic; for it can be rigorously proved that no vacuum balloon of present day material, whatever its design, can possibly resist crushing if made light enough to float.

In 1887 Walter Wellman described in the *Associated Press* a steel vacuum balloon 144 feet in diameter and 654 feet long in which a Chicago doctor proposed to carry passengers to the North Pole, at incredible speed, if they would furnish him $130,000 to meet the expenses of construction. "Here is a most excellent opportunity," wrote Wellman, "for all who would like to win fame by being one of the party which shall set foot upon that icy *ignis fatuus* of many nations and two centuries." Two decades later Mr. Wellman organized, after his own ideas, an aërial expedition to the North Pole; but he no longer favored starting from Chicago in a vacuum balloon with a party of stockholders.

It may be added that the inventor of the great steel vacuum balloon, after organizing the Trans-Continental Aërial Navigation Company, and failing to raise all of the $130,000, sought aid from the national government. Here was an interesting situation; a doctor ignorant of mechanics, with the plans for a mammoth and impossible balloon, appealing for aid to a congress, supremely shy of air ships, even though recommended by its ablest military advisers. But in this case there was a capable lobby. The bill for this physically impossible balloon actually passed the House, and was finally defeated only by the timely effort of a few scientific men who, by easy calculation, proved the absurdity of the invention. As the reader may like to see a mathematical proof of the impossibility of a vacuum balloon, since such projects arise frequently, the argument is given in Appendix I.

PART I

GROWTH OF AËROSTATION

CHAPTER I

EARLY HISTORY OF PASSIVE BALLOONS

Oh, that I could as smoke arise,
That rolls its black wreathes through the air;
Mix with the clouds, that o'er the skies
Show their light forms, and disappear:
Or like the dust be tossed
By every sportive wind till all be lost!

—ÆSCHYLUS.

IF desire is sometimes the mother of invention, doubtless the wish to "mix with the clouds," or "as smoke arise," suggested to man his first means of aërial locomotion. Indeed this is openly avowed by Joseph Montgolfier. "Smoke rises in the chimney; why not encage this smoke, and have an available force." But before describing his fundamental experiments of 1783, let us notice the less conspicuous ones, though not less philosophical, of his immediate predecessors in the development of aëronautic science.

It has been seen, that many years before 1783, inventors had clearly conceived the true principle of the balloon, and would be glad to avail themselves of an element of sufficiently low specific gravity for aërial flotation. The desired opportunity came when, in 1766, Henry Cavendish published his experiments, proving that hydrogen is many times lighter than air. Immediately after this, Dr. Black, the famous chemist and natural philosopher of Edinburgh, conceived the idea that a thin light vessel filled with hydrogen should be able to float and rise in the atmosphere, ideas that he conveyed to his friends and expressed in his lectures a year or two after the appearance of Cavendish's publication. But he contented himself with merely pointing the way to an obviously practicable invention, leaving, as a university professor should, the development of the scientific idea to inventors and constructive engineers.

Intermediate between Dr. Black, the pure scientist, and the Montgolfier brothers manufacturers, came Tiberius Cavallo, an Italian philosopher living in England, who made the first small hydrogen balloons. In a note presented to the Royal Society of London, June 20, 1782, he relates experiments that seem to entitle him to all the credit of inventing the balloon except success on a practical scale. He made hydrogen soap bubbles which rose beautifully in the air, an experiment that has been repeated throughout the world in every chemical laboratory since his day. He made a variety of gum bubbles and varnish bubbles inflated with hydrogen; but curiously enough these failed to rise, though it is known that such bubbles can be made to float handsomely.[1] He inflated carefully prepared gold-beater skin and failed, though gold-beater skin balloons, both large and small, are now a marketable commodity. Finally he constructed paper balloons which he tried to float by use of hydrogen, but without success, though a year later the Montgolfier brothers easily made paper bags arise with hot air, and Professor Charles ascended in a large silk balloon inflated with hydrogen.

[1] The writer has made hydrogen-inflated varnish bubbles a foot in diameter which ascended swiftly to the ceiling; also, air-inflated varnish bubbles a foot and a half in diameter which lasted an hour. These, if suitably heated, may be made to ascend; but this experiment is more difficult.

The cause of Cavallo's interesting failures reveals itself in his own account of one of his pioneer experiments. In his *History and Practice of Aërostation,* he relates that he constructed, of fine Chinese paper, a cylindrical balloon having short conical ends and a calculated buoyancy of twenty-five grains, when properly inflated with hydrogen. This bag, carefully deflated of air by compression between the hands, he suspended above a large bottle connected with it by a glass tube, and supplied with materials for generating hydrogen; in this case a mixture of dilute sulphuric acid and iron filings. When the hydrogen was evolving quite rapidly, he expected to see the paper sac expand and fill out with proportionate speed; but to his surprise it remained perfectly flat, while the room filled with the strong and disagreeable odor of the "inflaminable air." He then realized that the carefully made sac of paper, which could be so easily inflated with air, was very permeable to hydrogen, allowing it to escape instantly, as through porous cloth, or netting.

Cavallo desisted when the goal was within reach. His plans were practicable, but he abandoned them too readily. Why did he not varnish his balloon when it leaked? He could thus so easily have inaugurated the art of aërial navigation. But after salting the bird's tail he let it escape.

Various accounts have been given of the steps by which the Montgolfiers were led to their invention of the balloon. They are said to have studied and discussed projects for aërial locomotion a decade before hitting upon their first successful device; at one time filling a paper bag with smoke ineffectually; again with steam, and again trying, but in vain, to employ hydrogen. The following apparently reliable account is given by a friend of the Montgolfiers, Baron Gernando, in his biographical notice of Joseph

Montgolfier, having obtained the story from the inventor himself.

"Joseph Montgolfier found himself at Abignon, and it was at the time when the combined armies held the siege of Gibraltar. Alone, in the chimney corner, dreaming, as usual, he was contemplating a sort of cut that represented the work of the siege; he grew impatient observing that one could not reach the body of the place either by land or sea. "But could not one arrive there through the air? Smoke rises in the chimney; why not store this smoke in such a manner as to form an available force?" His mind calculated instantly the weight of a given surface of paper, or taffeta; he constructed without delay his little balloon, and saw it rise from the floor, to the great surprise of his hostess, and with a peculiar joy. He wrote on the spot, to his brother then at Annonay: "Prepare immediately a supply of taffeta and cordage, and you shall see the most astonishing thing in the world."

A quainter story is told by Brisson in his *Dictionary of Physics*. He says: "I can only repeat what the citizen Montgolfier himself told me, when he came to Paris to announce his discovery; that the citizeness Montgolfier having placed a skirt on an open-wicker basket, such as women use to dry linen, the skirt was lifted to the ceiling. It is from this fact that the citizens Montgolfier started."

Whatever the preliminaries, the Montgolfier brothers finally made the experiment of holding a paper bag over a fire fed with wet straw and wool. It is doubtful whether they purposed to fill it with smoke, or with hot air or an electrical cloud. They knew that a cloud of some kind rises from such a fire, and they wanted to harness it. Their first balloon took fire and went up as smoke. But they were rich paper manufacturers, and soon had another balloon of 700 cubic feet capacity. This rose from the fire to a height of 1,000 feet, carrying no fuel with it. Thus two practical[1] men had made fire lift a paper sac; let the Academy explain how. The baby Aërostation was born.

How fortuitous the primal steps of science! Galvanism from the twitch of a frog's leg; aërostation from the puff of a petticoat! There had been no year in thirty centuries when people could not easily have built a hot-air balloon. All the materials were available; only a little thought was wanting. A simple sketch sent to a Roman tailor, or tent-maker, could have furnished a woven bag competent to lift passengers from the heart of the Coliseum, to the wonder and delight of a hundred thousand spectators. Yet the genius that could design the Coliseum, or cover its vast enclosure with canvas, failed to think of the magic bag that would have enhanced so much the ingenious shows of a show-loving people. That device was an inspiration destined to a common Frenchman at no uncommon period of science. The hydrogen balloon arrived in the natural and logical order of scientific progression; but the hot-air bag might have presented itself at any time since the birth of weaving. It was a happy thought, like the ophthalmoscope, or jack-knife—quaint modern creations of constant use or comfort to mankind.

The public inauguration of aëronautics occurred on June 5, 1783, at Annonay, the home of the Montgolfier family, 36 miles from Lyons. The states of Vivarais being assembled at that place, were invited to witness the ascension. The Deputies and many spectators found in the public square an enormous

[1] Both had studied science in college. Stephen was an accomplished architect; Joseph, the author of many important inventions, among others the common lamp chimney, the hydraulic press, etc.

bag which, with its frame, weighed 300 pounds, and would inflate to a ball 35 feet in diameter. When told that this huge mass would rise to the clouds they were astonished and incredulous. The Mont-

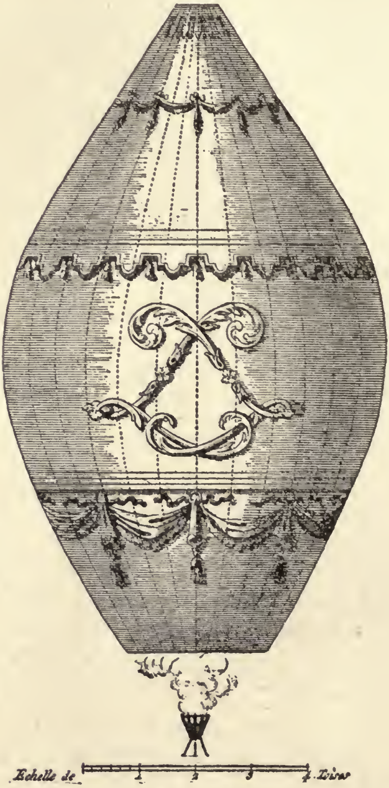

FIG. 5.—MONTGOLFIER'S EXPERIMENTAL BALLOON.

golfiers, however, lit a fire beneath and let the bag speak for itself. It gradually distended, assuming a beautiful form, and struggling to free itself from the men who were holding it. At a given signal it was released; it ascended rapidly, and in ten minutes attained a height of 6,000 feet. It drifted a mile and a half and sank gently to the ground.

When the French Academy learned of this event they desired to have an ascension in Paris, and at once started a public subscription to defray the expense of constructing and inflating a balloon. They placed the work in charge of the physicist Charles, after inviting the Montgolfiers to Paris, and finding they could not come immediately. Charles proved more than a substitute; he became a fertile inventor and a rival in the new field. Aided by the skill of the Robert brothers, he made a silk globe varnished with dissolved rubber, and filled it with hydrogen, which is many times lighter than hot air. The operation of filling occupied three days, consuming 500 pounds of sulphuric acid and half a ton of iron. The globe was 13 feet in diameter, and designated a "balloon," or big ball. This had next to be moved from the place of filling, in the Place des Victoires, to the Champ de Mars, two miles distant, in order to have space enough to accommodate the increasing crowd of spectators. Accordingly, on the 26th it was conveyed thither, in the dead of night, preceded by lighted torches, surrounded by a cortege, and escorted by foot and horse guards. Impressive and weird, indeed, was this nocturnal caravan of troops and towering globe advancing slowly through the dark and silent streets. The astonished cab drivers knelt humbly, hat in hand, while the procession passed.

The ascent of this, the first hydrogen balloon, was a popular and a memorable event. The field was lined with troops. The curious spectators had thronged every thoroughfare and darkened every housetop. It was an all day festival, inaugurating a peculiarly French science, with French animation. The booming of cannon announced to all Paris the impending flight of the balloon. At five o'clock, in the presence of 50,000 spectators, and in a shower of rain, the balloon rose more than half a mile and entered the clouds. The people overwhelmed with surprise and enthusiasm, stood gazing upward, despite the rain, observing every maneuver till the vessel had ascended and faded from view.

FIG. 6.—CHARLES' FIRST HYDROGEN BALLOON.

The landing of this little balloon did not leave it in a condition to exhibit proudly to future generations. After drifting three quarters of an hour, it fell in a field near Gonesse, a village fifteen miles from the place of ascension, apparently ruptured from overdistention. The villagers flocked about it with curiosity and trepidation, ignorant of its nature, whether of bird kind or monster; and doubtful of its origin, whether natural or satanic. They fell upon it with flails and pitchforks. When struck it smelt strongly of sulphur, indicating a diabolic source. They finally hitched it to the tail of a horse which galloping away in terror, badly damaged it.

Whether this destruction was wrought through fear or rustic hilarity, it induced the government of France to issue a notice to the public explaining the innocuous nature of a simple balloon.

In the meantime Joseph Montgolfier, having reached Paris, had constructed a waterproof linen balloon 46 feet in diameter and ornamented in oil colors, which was to be publicly launched at Versailles. On September 19, 1783, the king and queen, the court and a vast throng of people of every rank and age, assembled to witness the ascension. Montgolfier explained to them every detail, and finally lit the fire, about one o'clock. The great bag gradually expanded, rounding out in eleven minutes to a beautiful globular form, tugging upward with a force of seven hundred pounds. Beneath was suspended a wicker cage containing the first aërial passengers—a sheep, a rooster and a duck. The vessel rose majestically above the applauding multitude to a height of fourteen hundred feet, and drifted some two miles in eight minutes, descending gradually in the wood at Vaucresson. The animals were tipped out on landing; but, when found by two game-keepers, they were none the worse for their strange journey. The sheep was grazing and the cock crowing, says one report, while another relates that the sheep had trampled on the rooster and lamed him.

Stephen Montgolfier now wishing to send up human passengers, made a balloon of 100,000 cubic feet capacity. It was shaped like a full lemon pointing upward, with a cylindrical neck below, 16 feet in diameter. Around this neck was a wicker balcony three feet wide, to carry the aëronauts, bundles of straw for fuel, pails of water and sponges to extinguish incipient conflagrations, here and there in the balloon, during a journey. Through stokeholes in the side of the neck sheaves of straw could be forked to the grate suspended centrally below by radial chains. During inflation the base of the balloon rested on a platform, and its top was supported by a rope stretched between two poles. The vessel when completed, in a garden of the Faubourg St. Antoine, was 85 feet high by 48 feet across, and weighed 1,600 pounds. About its zone, painted in oil, were elegant decorations; portraits, cyphers of the king's name, fleur-de-lis, with fancy borders below and above; while higher still, on the arching dome of the bag, were all the signs of the celestial zodiac.

The handsome vessel was now ready; but what daring captain should navigate her? King Louis proposed two prisoners who were under sentence of death, and had to be killed somehow. But the brave Pilâtre de Rozier protested indignantly: "Eh quoi! de vils criminels auraient les premiers la gloire de senlever dans les airs! Non, non, cela ne sera point." He stirred up the city, and finally prevailed, through the entreaties of the Marquis d'Arlandes, who secured from the king permission to accompany his friend.

After some days of preliminary practice in maneuvering the tethered balloon, these gentlemen were ready for an aërial voyage. On November 21, 1783, the balloon was inflated in the garden of La Muette palace, and stocked with enough straw for an hour's journey. When all was ready Pilâtre de Rozier and the Marquis d'Arlandes stepped with eager courage into the gallery taking opposite sides to ensure proper balance. At two o'clock they rose splendidly, amid the acclamations of a vast throng of spectators, and at the height of 280 feet, removing their hats, saluted the surprised multitude. Encountering a south blowing wind, they drifted five miles in some twenty minutes, and landed safely in a field. The apparatus was soon assembled on a cart and returned to the Faubourg St. Antoine, where it

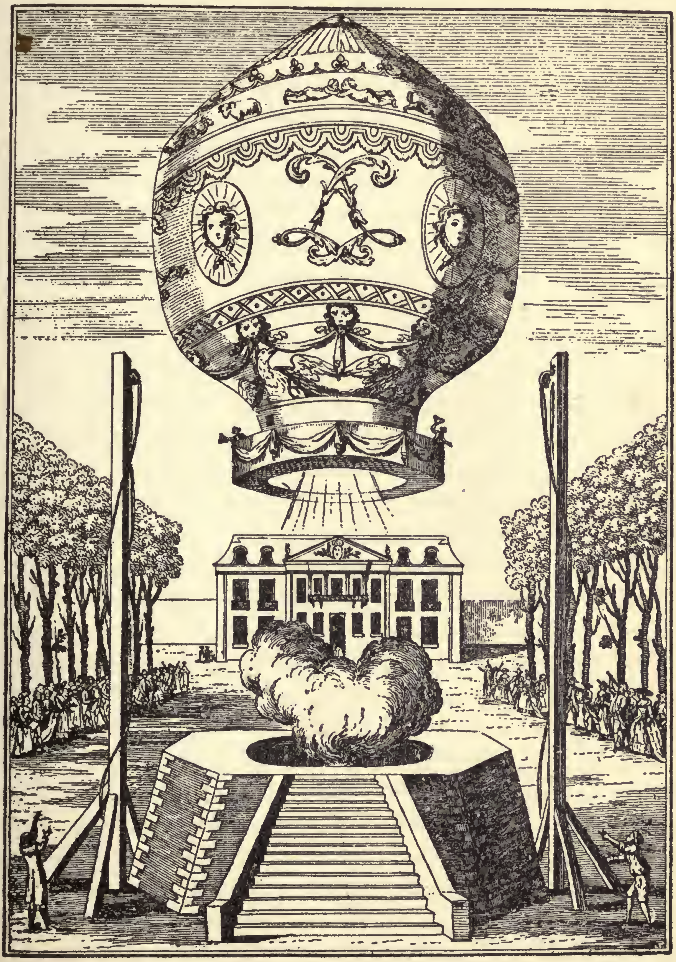

FIG. 7.—MONTGOLFIER'S PASSENGER BALLOON.

was originally constructed. The details of this first human voyage in a balloon are very interesting and well told in a letter written by the Marquis d'Arlande to a member of the French Academy.

"At this time M. Pilâtre said: 'You do nothing, and we shall not mount.' 'Pardon me,' I replied. I threw a truss of straw upon the fire, stirring it a little at the same time, and then quickly turned my face back again; but I could not longer see La Muette. Astonished, I gave a look to the direction of the river. . . . M. Pilâtre then said, 'See, there is the river, and observe that we descend.' 'Well, then, my friend, let us increase the fire;' and we worked away. But instead of crossing the river, as our direction seemed to indicate, which carried us over the house of the Invalides, we passed along the island of Cygnes, reëntered over the principal bed of the river, and advanced up it as far as the gate de la Conference. I said to my intrepid companion: 'See, there is the river &c.' I stirred the fire, and took with the fork a truss of straw, which from being too tight, did not take fire very easily. I lifted it and shook it in the middle of the flame. The next moment I felt as if I were lifted up from under the arms, and said to my companion, 'Now we mount, &c.' At the same time I heard a noise toward the top of the machine, as if it were going to burst; I looked, but did not see anything. However, as I was looking up, I felt a shock, which was the only one I experienced. The direction of the motion was from the upper part downwards. I said then: 'What are you doing? Are you dancing?' 'I don't stir,' said he. 'So much the better,' I replied, 'it is then a new current, which, I hope, will push us over the river.' In fact, I turned myself in order to see where we were, and I found myself between l'École Militaire and les Invalides, beyond which place we had already gone about 2,500 feet. M. Pilâtre said at the same time: 'We are on the plain.' 'Yes,' said I, 'and we advance.' 'Work on,' said he. I then heard another noise in the machine, which appeared to be the effect of a rope breaking. This fresh admonition made me examine attentively the interior of our habitation. I saw that the part of the machine which was turned toward the south was full of round holes, many of which were of a considerable size. I then said: 'We must descend,' and at the same time I took the sponge and easily extinguished the fire, which was round some holes that I could reach; but leaning on the lower part of the linen, to observe whether it adhered firmly to the surrounding circle, I found that the linen was easily separated from it, on which I repeated that it was necessary to descend. My companion said: 'We are over Paris.' 'Never mind that,' said I, 'but look if there appears any danger for you on your side—are you safe?' He said: 'Yes.' I examined my side, and found that there was no danger to apprehend. Farther, I wetted with a sponge those cords which were within my reach. They all resisted, except two, which gave way. I then said: 'We may pass over Paris.' In doing this, we approached the tops of houses very sensibly; we increased the fire, and rose with the greatest ease. I looked below me, and perfectly discovered the Mission Étranger. It seemed as if we were going toward Saint-Sulpice, which I could perceive through the aperture of our machine. On rising a current of air made us leave this direction, and carried us toward the south. I saw on my left a sort of forest, which I took to be the Luxembourg; we passed over the Boulevard, and then I said: 'Let us now descend.' The fire was nearly extinguished; but the intrepid M. Pilâtre, who never loses his presence of mind, and who went forward, imagining that we were going against the mills that are between Petite Gentilly and the Boulevard, admonished me.

I threw a bundle of straw on the fire, and shaking it in order to inflame it more easily, we rose, and a new current carried us a little toward our left. M. Rozier said again: ' Take care of the mills '; but as I was looking through the aperture of the machine, I could observe more accurately that we could not meet with them, and said: ' We are there.' The moment after, I observed that we went over a piece of water, which I took for the river, but after landing, I recollected that it was the piece of water, &c. The moment we touched the ground, I raised myself up to the gallery and perceived the upper part of the machine to press very gently on my head, I pushed it back, and jumped out of the gallery, and on turning toward the machine, expected to find it distended, but was surprised to find it perfectly emptied and quite flattened, &c."

While the foregoing experiment was in progress, plans were matured for the construction of a hydrogen balloon large enough to support two passengers and remain aloft many hours, without the need of carrying dangerous fuel. This type of balloon, called a *Charlière,* after its inventor, was destined largely to supersede the hot-air type, known as the *Montgolfière,* and indeed, to replace it entirely for free voyages of considerable endurance and for most power voyages. The construction after the plan of Professor Charles was delegated to two very intelligent mechanics, the Robert brothers who also had succeeded in dissolving caoutchouc, and thus producing a very superior balloon varnish. The project was first announced in the *Journal de Paris* of the 19th of November 1783. As usual in those days of public enthusiasm, a subscription was opened to defray the expenses of the experiment, estimated to cost about ten thousand francs.

This balloon was a truly scientific creation, which advanced aërostation from tottering infancy almost to full prime. The bag was a sphere $27\frac{1}{2}$ feet in

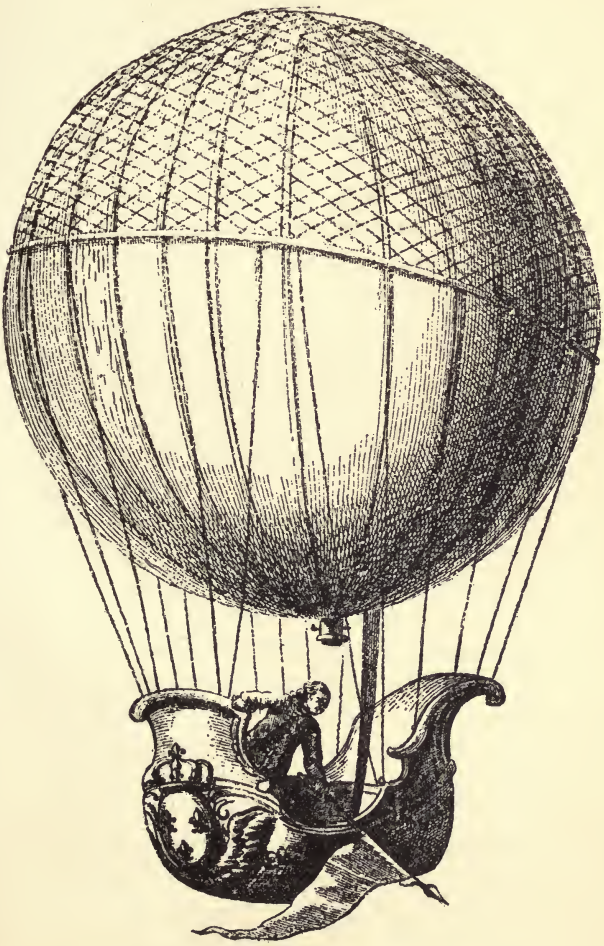

FIG. 8.—CHARLES' PASSENGER BALLOON.

diameter made of gores of varnished silk. A net covered the upper half and was fastened to a horizontal hoop girding the middle of the globe, and called the "equator." From the equator depended ropes which supported, just below the spherical bag, a wicker boat measuring eight feet by four, covered with painted linen and beautifully ornamented. The balloon had at the bottom a silk neck 7 inches in diameter, to admit the gas during inflation, and at the top, a valve which could be opened by means of a cord in the boat to let out gas during a voyage, so as to lower the balloon, or to relieve excessive pressure. In the boat were carried sand ballast to regulate the height of ascension, a barometer to measure the elevation, anchor and rope for landing, a thermometer, notebook, provisions, and all the paraphernalia of a scientific voyage. Barring the fancy boat, this is almost a description of a good modern balloon.

The inflation and ascension occurred in the Garden of the Tuileries, where the limp bag was initially suspended from a rope stretched between two trees. For three days and nights the hydrogen, drawn from twenty barrels containing iron and dilute sulphuric acid, poured upward through the silken neck into the distending globe, which swelled in volume to 1,400 cubic feet. Finally on a beautiful day, the first of December 1783, the Tuileries and all the neighborhood were crowded with spectators. A numerous guard of soldiers, stationed about the apparatus and grounds, preserved order. The fashion and nobility of Paris were there, in ample splendor, attracted by the novelty and importance of the experiment, and the fame of the inventor. Shortly before two o'clock Professor Charles presented to his friend, Montgolfier, a pilot balloon six feet in diameter, saying, "It is your prerogative to blaze the way through the sky." The pilot balloon was released, showing to everyone the direction of the aërial currents. Charles and Roberts stepped into the boat, seated themselves, and quickly rose into the sky. The multitude gazed in silent wonder. Presently they observed two pennants waving high above them, though the navigators were scarcely visible; whereupon they burst forth into wild enthusiasm and thunderous applause.

Immediately a cavalcade set out in hot pursuit of the venturesome sailors. It was the first chase after an air ship, and a most vigorous one. The balloon drifting northwestward at a speed of fifteen miles an hour, crossed the Seine, passed over several towns and villages, to the great astonishment of the inhabitants, and landed in a field near Nesle. Here it was securely held by friendly peasants, to await the advent of the official witnesses. Presently these arrived, drew up a certificate of descent and signed it. The Duke de Chartres, and the Duke de Fitz-James, who had followed less swiftly, now rode up and signed the formal document, to the great gratification of the aëronauts. The aërial journey had been a most delightful one, lasting about two hours and covering nearly thirty miles.

After receiving the felicitations of his friends, Charles determined to reascend, in order to obtain further scientific observations. Owing to leakage and loss of buoyancy, he must now leave behind his pleasant companion. He had proposed replacing with earth, or stones, a part of Mr. Robert's weight, but, finding none at hand, he signaled the peasants to let go, whereupon he rose with unusual speed. The remainder of this first and very remarkable scientific voyage is well told by the navigator himself:

"In twenty minutes I was 1,500 fathoms high; out of sight of all terrestrial objects. I had taken the necessary precautions against the explosion of the globe, and prepared to make the observations which I had promised myself. In order to observe the barometer and thermometer, placed at the end of the car, without altering the center of gravity, I knelt down in the middle, stretching forward my body and one leg, holding my watch in my left hand, and my pen and the string of the valve in my right, waiting for the event. The globe, which, at my setting out, was rather flaccid, swelled insensibly. The air escaped in great quantities at the silken tube. I drew the valve from time to time, to give it two vents; and I continued to ascend, still losing air, which issued out hissing, and became visible, like a warm vapor in a cold atmosphere. The reason of this phenomenon is obvious. On earth, the thermometer was 47°, or 15° above freezing point; after ten minutes' ascent it was only 21°, or 11° below. The inflammable air had not had time to recover the equilibrium of its temperature. Its elastic equilibrium being quicker than that of the heat, there must escape a greater quantity than that which the external dilatation of the air could determine by its least pressure. For myself, though exposed to the open air, I passed in ten minutes from the warmth of spring to the cold of winter; a sharp dry cold, but not too much to be borne. I declare that, in the first moment, I felt nothing disagreeable in the sudden change. When the barometer ceased to fall, I marked exactly 18 inches 10 lines (20-01 in. English), the mercury suffering no sensible oscillation. From this I deduce a height of 1,524 fathoms (3,100 yards), or thereabouts, till I can be more exact in my calculation. In a few minutes more, my fingers were benumbed by the cold, so that I could not hold my pen. I was now stationary as to the rising and falling, and moved only in an horizontal direction. I rose up in the middle of the car to contemplate the scene around me. At my setting out the sun was set on the valleys; he soon rose for me alone, who was the only luminous body in the horizon, and all the rest of nature in shade; he, however, presently disappeared, and I had the pleasure of seeing him set twice in the same day. I beheld, for a few seconds, the circumambient air and the vapors rising from the valleys and rivers. The clouds seemed to rise from the earth and collect one upon the other, still preserving their usual form, only their color was gray and monotonous from the want of light in the atmosphere. The moon alone enlightened them, and showed me that I was tacking about twice; and I observed certain currents that brought me back again. I had several sensible deviations; and observed, with surprise, the effects of the wind, and saw the streamers of my banners point upwards. This phenomenon was not the effect of the ascent or descent, for then I moved horizontally. At that instant I conceived, perhaps a little too hastily, the idea of being able to steer one's course. In the midst of my transport I felt a violent pain in my right ear and jaw, which I ascribed to the dilatation of the air, in the cellular construction of those organs, as much as to the cold of the external air. I was in a waistcoat and bareheaded. I immediately put on a woolen cap, yet the pain did not go off but as I gradually descended. For seven or eight minutes I had ceased to ascend; the condensation of the internal inflammable air rather made me descend. I now recollected my promise to return in half an hour, and, pulling the string of the valve, I came down. The globe was now so much emptied, that it appeared only a half globe. I perceived a fine ploughed field near the wood of Tour du Lay, and hastened my descent. When I was between twenty or thirty fathoms from the earth I threw out hastily two or three pounds of ballast, and became for a moment stationary, till I descended gently in the field, about a league from the place whence I set out. The frequent deviations and turnings about make me imagine that the voyage was near three leagues, and I was gone about thirty-three minutes. Such is the certainty of the combinations of our aërostatic machine, that I might have kept in the air at least for twenty-four hours longer."

Further interesting details of the first balloon experiments at Paris are furnished by Dr. Benjamin Franklin, then American Minister to France, in his letters written to Sir Joseph Banks, President of the Royal Society of London, and presented in Appendix II of this book. These quaint and substantial stories are well worth perusal as the expressions of a great diplomat and philosopher who, in the midst of social and political activities, found time for scientific correspondence with his friends in both hemispheres.

Aërial navigation was now become a practical art which should advance rapidly in popularity, in both Europe and America. Very soon ascensions were made everywhere, for private amusement and for public exhibitions. Not a few were made for scientific, for military and for topographical purposes; thus giving the art a utilitarian as well as a sporting feature. It will be interesting to note some of the more conspicuous ascensions, voyages and improvements made in passive balloons subsequently to the invention of *Montgolfières* and *Charlières*.

The largest hot-air balloon ever constructed, *La Flesselle*, was launched from the suburbs of the city of Lyons on January 19, 1784, just two months after the ascent of the first human passengers. It was also one of the most troublesome to assemble and keep in repair. Day by day, for more than a week, the balloon was inflated for the purpose of attaching the ropes to support the great gallery. But the wind blew dreadfully at times; rain and snow fell on the machine; frost and ice covered the huge bag; many rents ensued, demanding frequent repairs. On one occasion, when fed too freely with flame from straw sprinkled with alcohol, the monstrous ship rose so vigorously as to drag fifty men with it some distance along the ground. Finally on the 19th of January, when the weather moderated, the operators built small fires under the scaffold below the balloon, and thawed away the ice from the drenched and frozen bag. Then they stocked its gallery with straw and pitchforks, with fire extinguishers, and other provisions for the journey. The inflation beginning about noon, occupied but seventeen minutes. The balloon swelled out rapidly, with the roaring flames ascending inside, and at last stood forth huge and majestic before the admiring multitude—a towering thing of magic growth, 100 feet in diameter by 130 feet high.

The ascension of this gigantic vessel was immensely spectacular; but it was also most adventurous and foolhardy. The great bag, which at best was made of poor materials, was in bad repair after its frequent inflations. But of the six passengers in the gallery not one could be induced to remain behind to lessen the risk to the others. Their pilot, M. de Rozier, remonstrated with them; the proprietor M. C. Flesselle wished them to cast lots; but no one would abandon the journey. So, with fear and reluctance, the pilot ordered the mooring ropes to be cut. Just as the ascent began, a seventh passenger, M. Fontaine, sprang into the gallery and sailed aloft with the others. By vigorous stoking the aërial sailors urged their fiery vessel upward three thousand feet, whence, apparently without fear, they waved their hats to the vast throng below.

The spectators were now in a frenzy of excitement. For more than a week they had vacillated be-

FIG. 9.—*La Flesselle.*

tween hope and disappointment; but now they saw the huge ship soaring into the sky, perhaps on her way to destruction. They heard the blast of martial music and the booming of mortars. Then the accumulated emotion of the multitude burst forth. Exclamations of joy, shrieks of fear, thunders of applause resounded above the sea of people. Finally the balloon began to burst, a dangerous rent running vertically along her side. The machine descended with great rapidity, to the alarm of everyone. It is reported that not fewer than sixty thousand people ran to the place of landing, with the greatest apprehension for the lives of the travelers. But the adventurous men stepped forth from the gallery, after a fifteen minutes' voyage, without hurt of any kind, save an insignificant scratch borne by Joseph Montgolfier, who on this occasion made his first and last ascension. This was also the first and last ascension of that gigantic fire balloon; for although it furnished a world of delirious emotion and excitement, the trouble of inflating the vessel was too great to be repeated.

The crossing of the English Channel by balloon had been contemplated many months by various adventurous spirits; and at length, on a fine day, the seventh of January, 1785, this feat was attempted by two intrepid men, the French aëronaut, M. Blanchard, and an American physician, Dr. Jeffries, who had graduated at Harvard in 1763, and was practicing medicine in England. Starting from the perpendicular cliff at Dover Castle, at one o'clock, they sailed in the direction of Calais, having with them only thirty pounds of sand ballast. This was too little for so long a voyage; but it would doubtless carry them a few miles, in the favorable breeze then blowing. To their surprise, the atmosphere seemed to grow lighter as they advanced over the water, letting them sink too freely. As they approached mid-channel they were compelled to discharge all their ballast in order to maintain their level. But the balloon still descended, seemingly attracted by the water. Then they ejected a parcel of books to gain a moment's relief. When three-fourths across the Channel they sighted the French Coast, which now they yearned to see at closer range; for the balloon was contracting and sinking rapidly. They threw out from the boat everything available, wings, anchors, cords, provisions; yet they saw the vessel persistently approaching the sea. Finally they cast off part of their clothing, fastened themselves to the cords suspended from the balloon-ring, and prepared to cut away the boat. But presently approaching the coast near Calais, they began to rise; then ascended rapidly, soaring in a magnificent arch above the high grounds. At last they descended gradually above the forest of Guines, seized the branches of a tree to stop their flight, and at three o'clock were happily landed. It was a thrilling voyage of two hours, and made a profound impression at the time. As a mark of appreciation the King presented Blanchard a sum of 12,000 francs and a pension of 1,200 francs per year. The people erected a monument on the place of landing to commemorate this extraordinary voyage.

This splendid achievement incited two Frenchmen to attempt a counter voyage which ended disastrously. On June 15, 1785, Pilâtre de Rozier and M. Romain set out from Boulogne on a voyage from France to England, in a compound balloon composed of a hydrogen balloon forty feet in diameter, below which was suspended a fire balloon ten feet in diameter. They hoped by judicious stoking of the lower balloon to obviate the sinking tendency suffered by Blanchard and Jeffries. But the smaller globe proved a fatal auxiliary. Scarcely a quarter of an hour after launching, the whole apparatus was aflame at an altitude of 3,000 feet, and presently fell in charred and hideous fragments upon the seashore. M. Romain still showed some signs of life, but Pilâtre de Rozier was completely dead and all his bones were broken. They were the first martyrs in the cause of the new science. Poor De Rozier knew on starting that his apparatus was in bad condition, but he had received for the purpose a sum of money from a distinguished patron, and therefore felt obliged in honor to attempt the voyage. He was twenty-eight years old and engaged to be married to a young lady in the convent at Boulogne, who eight days after the catastrophe which robbed her of her fiancé, died brokenhearted and in convulsions.

CHAPTER II

PRACTICAL DEVELOPMENT OF PASSIVE BALLOONS

THE next important advance in practical ballooning was made by the substitution of coal gas for hydrogen. This was England's contribution to an art which previously had not greatly flourished west of the Channel. It was a contribution following the natural growth of science; for in 1814 coal gas began generally to be used for lighting London, and seven years later for inflating balloons. This valuable innovation was made by the famous aëronaut, Charles Green, on the occasion of his first ascension, made July 19, 1821, the coronation day of George IV. The new method largely superseded the old, extending throughout the world with the spread of gas lighting; and it gave a powerful stimulus to aëronautics by rendering inflation cheap and convenient. Mr. Green himself made 526 ascensions during his life, or at the rate of one cruise a month for nearly forty-four years. In due time, every country had its professional aëronauts, and finally its amateurs, who, forming themselves into aëro clubs, devoted themselves to racing in free balloons, inflated quite usually from a city gas supply.

In 1836 Mr. Robert Holland organized an expedition designed to test the utmost capabilities of the balloon of his day, particularly in points of endurance and control. Engaging as pilot the first aëronaut of the age, Mr. Charles Green, and employing the largest gas balloon that ever had been constructed, stocked with provisions enough to last three men a fortnight, he invited a third person, Mr. Monck Mason, to join them on a cruise from London to wherever the wind would take them, but preferably

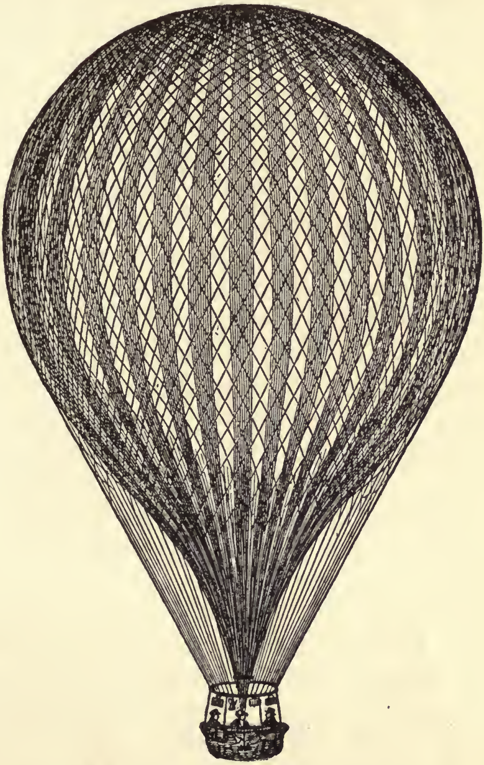

FIG. 10.—THE GREAT BALLOON OF NASSAU.

to land near Paris, as the balloon was to be delivered there after the voyage.

The vessel selected for that famous cruise was *The Great Balloon of Nassau,* then recently built by Mr. Green and representing all that his skill and experience could devise. It was of pear shape, formed of the finest crimson and white silk, "spun, wove and dyed expressly for the purpose," and comprising when distended a volume of 85,000 cubic feet. From its stout balloon-ring six feet in diameter was suspended a wicker car measuring nine feet long by four wide, having a seat across either end, and a cushioned bottom to serve as a bed, if such should be needed. Across the middle of the car was a plank supporting a windlass for raising or lowering the guide-rope, that is a heavy rope which could be trailed over land, or water, to keep the balloon at a nearly constant level without expenditure of ballast, and to check its speed on landing. This valuable device invented by Mr. Green in 1820, was now to receive adequate trial, which, indeed, formed one of the chief purposes of the cruise. Other paraphernalia of the voyage were food and drink, warm clothing, lamps, trumpets, telescopes, barometers, a quicklime coffee-heater, a grapnel and cable, and a ton of sand ballast in bags.

The voyage proved well worthy of the elaborate preparations. At one-thirty o'clock on November 7th, the three navigators arose from London, in presence of a mighty multitude, and drifted in a southeasterly direction traversing the cultivated plains of Kent, and in two hours passed the environs of Canterbury. Here they dropped a parachute with a letter for the Mayor, which he duly received. Continuing their journey they floated leisurely above the tree tops, talking to the inhabitants of the country, startling the fleet-winged quail, terrifying a colony of rooks, and finally reaching Dover at sundown, where they again dropped a letter for the Mayor of the city, which also was duly delivered.

Without a moment's pause they drifted over the Channel into the gathering darkness. Before them rose a huge wall of vapor and black clouds standing on the bosom of the sea; behind them the twinkling lights and the music of breakers rolling on a hospitable shore. Presently they were immersed in a region of absolute silence and impenetrable darkness. At times this deep stratum would slowly dissolve, revealing a glimpse of the dusky ocean and a passing ship; then some huge wreath of vapor would involve them in bottomless gloom, without perspective, without apparent motion, without a sound to cheer or mark their dubious course. Now to avoid the risk of settling too near the sea, as Blanchard and Jeffries had done, they were preparing to let down the guide-rope with floating ballast attached, when suddenly they emerged from the pall of darkness, and were greeted by the glittering lights of Calais, and the gentle sound of waters dashing upon the beach. They had crossed the Channel in one hour, and were soaring serenely three thousand feet above the ocean, not having to lower the guide-rope to preserve their elevation.

Now came the preparations for a night voyage over an obscurely defined land route. A simple rope one thousand feet long without ballast was allowed to trail beneath them. A lamp was lit. Coffee was heated by the slacking of quicklime. An ample store of viands and wine was spread on the board in the middle of the car. The strenuous period of thought and labor was past, and now three hungry men sat leisurely at dinner, after a fast of twelve long hours. However sparing of bones and bottles, which later might serve as ballast, they were not economical of food and wine that evening. For the present they had only to live and be happy as bachelors. Muffled in soft garments, well fed, abundantly served with divine beverages, hot or cold; what finer picture of masculine comfort and delight?

They were now floating tranquilly in the vast solitude of heaven, over a teeming continent mantled in night and mystery. Far along earth's sable surface gleam the scattered fires of many villages; and above it the lovelier fires of a moonless sky. Unseen, unsuspected, they survey kingdoms and cities, trailing their long rope serpent-like over woodland, field and quiet homestead. Now on the horizon before them looms a greater fire, like a distant conflagration, widening as they approach. Gradually it expands into a model city, shooting out long lines of illuminated streets; here the public squares, markets and theatres; there the rumbling iron mills with blazing furnaces. They are above Liege at her festive hour, murmuring with animation and busy life. Again they drift into the dark regions of slumber, lapped in silence and deep tranquillity, where the lights of men are extinguished, and the stars, redoubling their lustre, gleam whitest silver in heaven's jetty dome. Midnight involves the world; an abyss of darkness enfolds it; their solitary lamp seems to melt its way through solid space of blackest marble. For hours they undulate over the rolling hills, rising and falling a thousand cubits, held always to earth by the trailing rope. At times they are so near as to trace the landscape dimly; here a white tract covered lightly with snow, here a dark valley or forest, here a tortuous river, probably the Rhine, with its multitudinous thunder of waters. But in all that weird and obscure wandering no joyous note of human or animal life ascends ere dawn to cheer their solitary course in the sky.

At last the paling of the morning star, and a faint tingeing of the eastern cumuli, announce the expected day. With sudden bound the great ship mounts aloft twelve thousand feet, into the glory of the blazing sun, new risen among clouds of amber and purple. Far below, twilight and mist still mantle the half-awakened world, presenting a stupendous panorama, vast as an empire. Presently down they plunge into the vaporous and obscure atmosphere, drifting carelessly, but soon reascending into the splendor of morning. Thus after making the sun rise three times and set twice, they float contentedly along the misty landscape, marveling what region lies below them, whether a barren wilderness, or the abode of civilized life, with human comforts and a ready means of transportation. A hot breakfast would be very welcome now; for they had accidentally dropped the lime pot and had spent the latter half of the night without warm beverage in a region where oil and water had frozen.

At length through the clearing vapor they perceive the country well tilled and populous; a good place to land to shorten their route to Paris, and avoid the wide plains of Poland or Russia. They raise the guide-rope, lower the cable and anchor, open the valve, and descend in a grassy field near Weilburg, in the Duchy of Nassau. It is now seven-thirty o'clock, just eighteen hours since starting; and they have traveled five hundred miles, the longest aërial voyage thus far recorded. Very soon they are surrounded by a wondering crowd of pipe-puffing, shaggy-headed, German peasants, by whose willing aid they finally deflate the balloon, pack it in the bottom of the car, and mount it on a one-horse cart for Weilburg. Thence the aëronauts, after a week of festivities in their honor, and distinguished attentions from the highest officials of the town, embarked with their balloon for Paris. This famous craft now bore its permanent title; for a few days previously the lovely daughter of the Baron de Bibra, with seven other young ladies and Mr. Green, had stood within the air-inflated vessel, poured a generous libation of wine, and christened the hardy cruiser *The Great Balloon of Nassau.*

It was in truth a great balloon in various ways; in solidity and strength, in workmanship, in completeness of appointment, in endurance and control. Having accomplished that long journey without a sign of weakness or defect, it was still in prime condition, proudly heading for the farthest verge of Europe. It had not, of course, the instrumental equipment of a modern balloon; but it did possess the elements essential for a long and hard cruise. Since the day of its launching many additions have been added to the art, but these, for the most part, are special adjuncts. The more important features of a good balloon are practically the same to-day as when they were first introduced by Professor Charles and sturdy old Mr. Green.

A still more elaborate and colossal air ship was the *Geant,* constructed in 1863, for A. Nadar of Paris. It was made of a double layer of white silk, had a volume of 215,000 cubic feet and a buoyancy of 4½ tons. The car was a wicker cabin 13 feet wide by 7 feet high, with a wicker balcony round the top so that the roof could be used as an observation deck—a delightful place to loll in the starlight, or watch the morning sun "flatter the mountain tops with sovereign eye." The closed car comprised two main rooms with a hallway between them, one containing the captain's bed and baggage, the other having three superposed berths for passengers. Minor divisions of the car were reserved for provisions, a lavatory, photography and a printing press, the latter to be used for the dissemination of news from the sky, as the navigators floated from state to state. A compensator balloon of 3,500 cubic feet, just below the main bag and connected with it, received the escaping gas during expansion with increase of temperature or altitude, and gave it back on contraction. In fact as well as in name, Nadar's vessel was a giant. Curiously enough, he called it the "last balloon," for he expected to realize enough money by exhibiting it, to inaugurate successful flying by means of the

FIG. 11.—CAR OF NADAR'S BALLOON.

helicopter, and thus banish ballooning from the world of futile effort to the domain of bygone dreams and chimæras.

The first ascension, made on Sunday, October 4, 1863, was one of magnificent promise. In the midst of a vast holiday throng on the Champ de Mars, the great globe towered aloft nearly two hundred feet, held to earth by one hundred men and twice as many sand bags. In the car were fifteen notable passengers including one lady, the fair young Princess de la Tour d'Auvergne, in morning toilet and a pretty hat. "Lachez tout!" shouts Captain Nadar, the effervescent photographer of Paris. Away they soar, heading for St. Petersburg, with provisions enough to sail beyond the polar sea.

The captain was now in supreme control, with the key to the victual and liquor room in his pocket, and his twelve commandments duly signed by all aboard. They had pledged themselves not to gamble, not to carry inflammable materials, not to smoke unduly, not to throw bottles overboard, not to quit the balloon without permission, but to descend if so ordered, etc. They had sailed at five o'clock in the evening and all was going merrily. But presently trouble came. The valve rope gave way, the vessel was sailing in the dark, and the Godards declared she was drifting to sea, whereas she was drifting in quite the opposite direction. To be on the safe side they threw out the anchors by permission of the commander. One anchor broke, but the other took hold and checked the balloon in spite of the strong wind blowing. At last after three violent bumps on the ground they landed near Meaux at nine o'clock in the evening, one passenger sustaining a broken knee, the others various bruises. It was a grand adventure and all were pleased.

Two weeks later a second voyage was begun in similar style, and again from the Champ de Mars, this time in the presence of the King of France and the young King George of Greece; but now Nadar took along, not the Princess with the pretty hat, but Madame Nadar, his wife. To entertain the crowd before starting, thirty-two persons were first sent aloft 300 feet and drawn back to earth. Finally at five o'clock Sunday evening, October 18th, a party of nine passengers soared proudly northward, well provisioned as before, and eager for a long voyage. They disappeared in the gathering night, leaving their friends much concerned for their safety and ultimate destination. At half past eight they were over Compiegne, seventy-eight miles away, drifting near the ground to say " All goes well " and have the good tidings transmitted to Paris. At nine they crossed the Belgian frontier; at midnight they were over Holland; at sunrise they skirted the Zuyder Zee and entered Hanover; at eight they were coursing headlong toward Nienburg and the North Sea in the current of a swift west wind.

They were now in great peril. If they went to sea they might all be drowned; if they came to earth at such horizontal speed they should be terribly pounded. Choosing the latter evil, they opened the valve and threw down the grappling irons. " To the ropes," shouted the Godard brothers. Assembling on deck all clung to the suspension ropes to mitigate the shock of landing. Nadar put his arm about his wife to protect her. The anchors snatching a tree, uprooted and dragged it along; then caught and tore off the roof of a house; threshed into a telegraph line pulling down the wires and poles; struck into some firmer obstacle and broke off completely, leaving the huge monster to sweep unchecked in the violent ground current. Owing to trouble with the valve, the gas could not be liberated quickly; the great vessel again and again plunged to earth and rebounded high in air, its ponderous basket crashing through heavy timber, and breaking down whatever opposed its course. For nine miles they pounded over the plain by Nienburg toward the sea, dashing into pools, bogs and thickets, their limbs sprained or broken, their bodies bruised, their faces splashed with mud. Presently through loss of gas the rebounding ceased, the basket dragged along the earth squeezing some of the passengers beneath it, and dumping others out on the ground, leaving them behind. Those remaining tried to assist Madam Nadar to land, but they were tumbled out and she was caught under the basket from which she was extricated with much difficulty, when the balloon was finally halted. Thus their memorable voyage of seventeen hours, covering 750 miles, had a terrific, though not fatal ending. One had a broken femur, another a dislocated thigh, others numerous scratches and contusions. But no complaint was uttered; for the afflictions were regarded as natural concomitants to such interesting sport. After some days tender nursing by the Germans, and solicitous inquiries from the King of Hanover, they returned to Paris; some indeed on their backs, but for all that, none the less admired by their countrymen, as survivors of a marvelous adventure.

Another valiant English leader in aërostation was James Glaisher, member of the British Association for the Advancement of Science. As one of a committee of twelve appointed by that body in 1861, to explore the higher strata of the atmosphere by means of the balloon, he volunteered his services as an observer, when no other capable man could offer to do so. With a professional aëronaut, Mr. Coxwell, and a new balloon specially constructed for the work, cubing 90,000 feet, he made eleven ascensions for the society, four from Wolverhampton, seven from Woolwich. Incidentally he made seventeen other ascents of various altitude; not at the expense of the committee, but as a scientific passenger in public balloon ascents advertised beforehand.

The objects of the enterprise were first to study the physical conditions of the atmosphere; secondly to study the effect of the higher regions upon the passengers themselves, and some pigeons, which they carried along; thirdly to make some observations in acoustics and magnetism, particularly to determine the period of oscillation of a magnet at various altitudes. The specific study of the atmosphere itself was to comprise observations at all altitudes, of the temperature of the air, its pressure, and percentage of moisture; observations of the velocity and direction of the wind, the constitution of the clouds, their height, density and depth, the constitution and electrical properties of the air. They were also to collect samples of the air at different elevations, which later might be examined in the laboratory. Thus the voyages were systematically planned for scientific research, and were the first thorough attempts in England, though similar efforts had been made previously in France. It may be added that Glaisher's observations were the most important made during the first century of aëronautics, and may be found fully detailed by that hardy investigator himself in the British Association Reports for 1862–66.

Mr. Glaisher's most interesting voyage of that memorable series occurred on September 5, 1862. Starting from Wolverhampton at three minutes after one o'clock, they soared swiftly upward, passing through a cloud eleven hundred feet thick and emerging in a glorious field of sunlight with an amethystine sky above and a boundless sea of vapor beneath; a sea of rolling hills and mountain chains, with great snow-white masses steaming up from their surface. They had left the noisy bustle of earth in the comfortable temperature of 59°; in three quarters of an hour, they were five miles aloft in a deadly silent atmosphere, two degrees below zero, and approaching one third its usual density, the balloon neck white with hoar frost, the men gasping for breath. Here the observations became increasingly interesting but immensely more difficult. They are graphically told in the following extract from Mr. Glaisher's classical report:

"I asked Mr. Coxwell to help me to read the instruments, as I experienced a difficulty in seeing. In consequence, however, of the rotatory motion of the balloon, which had continued without ceasing since the earth had been left, the valve-line had become twisted, and he had to leave the car and mount into the ring above to adjust it. At this time I looked at the barometer, and found it to be 10 inches, still decreasing fast; its true reading therefore, was 9¾ inches, implying a height of 29,000 feet. Shortly afterwards I laid my arm upon the table, possessed of its full vigor, and on being desirous of using it, I found it powerless; it must have lost its power momentarily. I tried to move the other arm, and found it powerless also. I then tried to shake myself, and succeeded in shaking my body. I seemed to have no limbs. I then looked at the barometer; whilst doing so my head fell on my left shoulder. I struggled and shook my body again, but could not move my arms. I got my head upright, but for an instant only, when it fell on my right shoulder, and then I fell backwards, my back resting against the side of the car, and my head on its edge; in this position my eyes were directed towards Mr. Coxwell in the ring. When I shook my body I seemed to have full power over the muscles of the back and considerable power over those of the neck, but none over either my arms or my legs; in fact I seemed to have none. As in the case of the arms, all muscular power was lost in an instant from my back and neck. I dimly saw Mr. Coxwell in the ring and endeavored to speak, but could not; when in an instant intense black darkness came, the optic nerve finally lost power suddenly. I was still conscious, with as active a brain as at the

PLATE I.

GLAISHER AND COXWELL.

PARSEVAL KITE BALLOON.

present moment whilst writing this. I thought I had been seized with asphyxia, and that I should experience no more, as death would come, unless we speedily descended; other thoughts were actively entering my mind, when I suddenly became unconscious as in going to sleep. I cannot tell anything of the sense of hearing; the perfect stillness and silence of the regions six miles from the earth (and at this time we were between six and seven miles high) is such that no sound reaches the ear.

"My last observation was made at 1 h. and 54 m., at 29,000 feet. I suppose two or three minutes fully were occupied between my eyes becoming insensible to seeing fine divisions, and 1 h. 54 m., and then that two or three minutes more passed till I was insensible; therefore I think this took place at about 1 h. 56 m. or 1 h. and 57 m. Whilst powerless I heard the words, 'temperature' and 'observation,' and I knew Mr. Coxwell was in the car speaking to me, and endeavoring to arouse me, therefore consciousness and hearing had returned. I then heard him speak more emphatically, but I could not see, speak or move. I heard him again say, 'Do try—now do.' Then I saw the instruments dimly, then Mr. Coxwell, and very shortly saw clearly. I rose in my seat and looked round, as though waking from sleep, though not refreshed by sleep, and said to Mr. Coxwell, 'I have been insensible;' he said, 'You have; and I, too, very nearly.' I then drew up my legs, which had been extended before me, and took a pencil in my hand to begin observations. Mr. Coxwell told me he had lost the use of his hands, which were black, and I poured brandy on them.

"I resumed my observations at 2 h. 7 m., recording the barometer reading at 11.53 inches, and temperature—2°. I suppose three or four minutes were occupied from the time of my hearing the words 'temperature' and 'observation' till I began to observe; if so, then returning consciousness came at 2 h. and 4 m., and this gives seven minutes for total insensibility. I found the water in the vessel supplying the wet-bulb thermometer, which I had by frequent disturbances kept from freezing, was one solid mass of ice; and it did not all melt until after we had been on the ground some time.

"Mr. Coxwell told me that whilst in the ring he felt it piercingly cold; that hoar-frost was all round the neck of the balloon. On attempting to leave the ring he found his hands frozen, and he had to place his arms on the ring and drop down; that he thought for a moment I had laid back to rest myself; that he spoke to me without eliciting a reply; that he then noticed my legs projected and my arms hung down by my side; that my countenance was serene and placid, without the earnestness and anxiety he had noticed before going into the ring, and then it struck him I was insensible. He wished to approach me, but could not, and he felt insensibility coming over himself; that he became anxious to open the valve, but in consequence of having lost the use of his hands he could not, and ultimately did so by seizing the cord with his teeth and dipping his head two or three times until the balloon took a decided turn downwards. This act is quite characteristic of Mr. Coxwell. I have never yet seen him without a ready means of meeting every difficulty, as it has arisen, with a cool self-possession that has always left my mind perfectly easy, and given me every confidence in his judgment in the management of so large a balloon.

"No inconvenience followed the insensibility; and when we dropped it was in a country where no conveyance of any kind could be obtained, so that I had to walk between seven or eight miles.

"The descent was at first very rapid; we passed downwards three miles in nine minutes; the balloon's career was then checked, and we finally descended in the center of a large grass-field belonging to Mr. Kersall, at Cold Weston, seven-and-a-half miles from Ludlow.

"I have already said that my last observation was made at a height of 29,000 feet; at this time (1 h. 45 m.) we were ascending at the rate of 1,000 feet per minute; and when I resumed observations we were descending at the rate of 2,000 feet per minute. These two positions must be connected, taking into account the interval of time between, viz. 13 minutes, and on those considerations the balloon must have attained the altitude of 36,000 or 37,000 feet. Again, a very delicate minimum thermometer read—12, and this would give a height of 37,000 feet. Mr. Coxwell, on coming from the ring, noticed that the center of the aneroid barometer, its blue hand, and a rope attached to the car, were all in the same straight line, and this gave a reading of 7 inches, and leads to the same result. Therefore these independent means all lead to about the same elevation, viz. fully SEVEN MILES.

"In this ascent six pigeons were taken up. One was thrown out at the height of three miles, when it extended its wings and dropped as a piece of paper; a second, at four and five miles, and it fell downward as a stone. A fourth was thrown out at four miles on descending. It flew in a circle, and shortly alighted on the top of the balloon. The two remaining pigeons were brought down to the ground. One was found to be dead, and the other, a 'carrier,' was still living, but would not leave the hand when I attempted to throw it off, till after a quarter of an hour it began to peck a piece of ribbon which encircled its neck, and was then jerked off the finger, and flew with some vigor toward Wolverhampton. One of the pigeons returned to Wolverhampton on Sunday the 7th, and it is the only one that has been heard of."

This was the loftiest ascent ever made up to that time; and thus Glaisher, or rather Coxwell, who was in the ring above him, could be called the "highest man" of the first century of aëronautics. Their greatest elevation, however, is now generally estimated at much less than seven miles, and probably below six miles, due allowance being made for inaccuracies of estimate made by Mr. Glaisher. His results, nevertheless, were considered valuable, revealing as they did, that the balloon may be used safely up to the neighborhood of five miles; that the temperature of the atmosphere does not, as previously supposed, decline one degree for each 300 feet of ascent, but often declines more rapidly, and sometimes even increases with the elevation for considerable stretches; that the moisture percentage is extremely slight at an altitude beyond five miles; that at all elevations attainable by man the dry- and wet-bulb thermometers can be used effectively, etc.

A still loftier ascent was made by Professor Berson of Germany, aided by the respiration of oxygen. On July 31, 1901, accompanied by Dr. Süring, he ascended from Berlin in the balloon *Preussen* to an elevation of 10,800 meters, which at present constitutes the world's record for altitude. The balloon had a capacity of 300,000 cubic feet, and left the ground two thirds filled with hydrogen, and carrying 8,000 pounds of ballast in the form of sand bags attached to the sides of the basket, so that they could be cut loose with the slightest physical effort.

The *Preussen* was one of the largest passive balloons ever constructed. In cubic capacity it was comparable with the colossal *Montgolfière*, *La Flesselle*, already described, and the huge free balloon

Le Geant, constructed by Nadar in 1863. But all were eclipsed by the great balloon of Henri Giffard. This latter measured 450,000 cubic feet, and even to-day ranks as the largest captive balloon ever constructed. It was a familiar object at the Paris Exposition of 1878, where it was installed by the famous inventor Henri Giffard, to give sightseers a bird's-eye view of Paris. It could take up forty persons at one time, or eight more than once ascended in Nadar's *Geant*.

No serious attempt has been made to surpass the altitude flight of Professor Berson and Dr. Süring; for though it is easily possible to carry human beings to a greater height than seven miles, the results seem hardly to justify the cost. To ascend very much higher would require an enormous and costly balloon, and to ensure the comfort of the passenger might require an air-tight car, or armor supplied continuously with fresh air, or oxygen. Such a suit, or car, however, can be made very light, since its pressure must naturally be internal; and it would admit of an extremely rapid change of elevation without discomfort to the passenger. A steel bottle weighing fifty pounds, and filled with compressed air, or oxygen, would supply a passenger several hours, and allow him to breathe under normal pressure. The total weight of a bottle and air-tight car, or suit, need not exceed the weight of a man. Moreover, the ballast could be largely dispensed with, thus admitting of a very rapid ascent from the earth. A celluloid car would have the advantage of transparency, though it might become too brittle at very low temperatures. A suit, or car, with glass portholes would serve in lieu of a celluloid car for transparency. The usual balloon and basket, carrying a steel bottle, furnishing air at normal pressure to a man in a rubberized silk suit is a sufficiently simple and practicable device; the air entering the suit near his mouth and leaving below through a check valve regulated to maintain the desired internal pressure. An air-tight silk fabric capable of enduring safely a tensile stress of 150 pounds per running inch would answer the purposes. But at present there seems to be no incentive to attempt a balloon trip exceeding the heights already attained, unless it be that of notoriety or sentiment.

The French meteorologists have devised a much simpler and cheaper method of exploring the upper atmosphere, by use of small balloons carrying recording instruments. An ordinary silk or goldbeater skin balloon, partly inflated, ascends to a great height with the instruments, drifts away losing gas, and on landing is found by some one who returns it according to written directions accompanying the craft. Another method, introduced by Professor Assman, is to employ closed rubber balloons which at great altitudes burst by the expansion of the hydrogen within them, and allow the instruments to descend in parachutes softly to the ground. Instrument-carrying balloons of the above type are called "sounding balloons," or *balloons sondes*, whereas if they carry no instruments, but merely show the course of the wind, they may be called "pilot balloons." Such sounding balloons have been used to explore the temperature of the atmosphere to an altitude of 18 miles.

In the preceding pages some extended balloon voyages have been described. These were considered very long in their day, but in recent years have been surpassed frequently, first by the professional aëronauts, then by the amateurs and members of various aëronautic clubs practicing aërostation as a sport, and stimulated by attractive prizes. But the man who achieved the longest balloon flight during the first century of the art, seems to have been Mr. John Wise, America's foremost pioneer balloonist.

Mr. Wise was a rare composite of showman, scientist, sport and dare-devil, who during the four decades succeeding his first ascension at Philadelphia in 1835, made no fewer than 440 voyages. At first the aërial art captivated him by the beauty and sublimity of the natural panoramas witnessed from on high; then he amused himself by dropping things from the basket and hearing them whistle through space; and finally he coquetted with the balloon itself, in various ways to observe the result. On one occasion the neck was choked and the valve could not be operated, so that when the hydrogen expanded with increasing altitude, it overstretched the cover and started a rent in the side of the bag. The balloon descended rapidly, but landed without injurious shock.

The audacious aëronaut then decided to make an ascension and deliberately burst the balloon, by confining the gas in it and throwing out ballast. But first he tried the experiment on a dog, taking him up 4,000 feet, dropping him in a small collapsed balloon and watching him settle slowly to earth. Then rising to an altitude of 13,000 feet he stood debating whether to follow the example of the dog. The balloon quickly ended the question by exploding at the top. The hydrogen rushed out with a tempestuous sound, and the great vessel sank swiftly with a moaning noise of the wind in her rigging. In a few seconds the bag was empty and collapsed on the top of the net thus forming an effective parachute. After an exciting fall of more than two miles, Mr. Wise landed on a farm, with a lively thump, which overturned the basket, and threw him sprawling on the ground. It was fine sport; he decided at once to advertise a repetition of it, and thus was led by degrees to the invention of the ripping panel.[1]

Mr. Wise firmly believed that a steady wind from west to east prevails at a height of two miles. He wished to use this for long voyages, and even contemplated crossing the Atlantic; for he trusted his varnish to hold hydrogen a fortnight if need be. Accordingly in 1873 the New York *Daily Graphic* paid the cost of a balloon to carry him and two others on that hazardous voyage. The bag had a capacity of 400,000 cubic feet, but was too frail in construction to receive Mr. Wise's approval, and actually burst during inflation when slightly more than three fourths full. Fortunately, perhaps, for Mr. Wise, he never had an opportunity to attempt the trans-Atlantic voyage; but on one occasion he enjoyed a memorable cruise in the great west wind which so took his fancy. Rising from St. Louis on June 23, 1859, he sailed northeastwardly for twenty hours, and landed at Henderson, N. Y., having traversed a distance of 809 miles, measured directly. But in attempting another long voyage with two companions, in September, 1879, he passed over Lake Michigan, where all were drowned.

In recent years Mr. Wise's long voyage has been exceeded several times. In 1897 M. Godard sailed from Leipsic to Wilna, a distance of 1,032 miles in 24½ hours; but this was not an official flight nor in a direct course as the crow flies. In October, 1900, M. Balsan voyaged from Vincennes, France, to Rodom, Russia, a distance of 843 miles in 27 hours and 25 minutes, and De la Vaulx starting from the same point landed at Korosticheff, Russia, having traversed 1,193 miles in 35¾ hours. This latter is the

[1] A long patch on the balloon that can be ripped open for the sudden release of gas.

longest balloon flight thus far recorded. A close second to this record was made by A. R. Hawley in his spherical balloon *America*, aided by Augustus Post, in the Gordon Bennett International Balloon Race

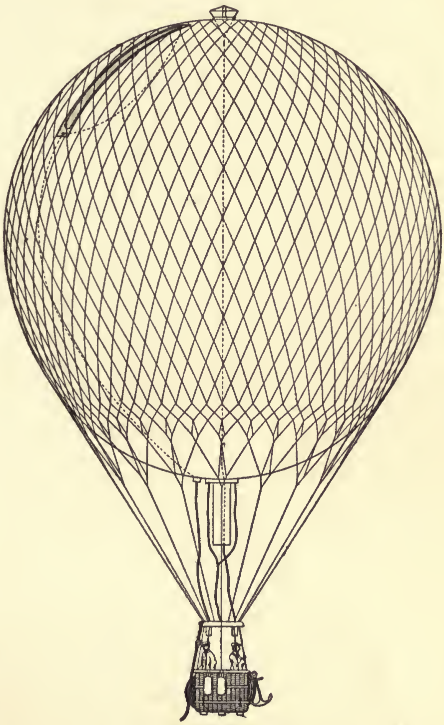

FIG. 12.—DIAGRAM OF A MODERN SPHERICAL BALLOON WITH RIPPING PANEL.

of 1910. Sailing from St. Louis, October 17th, they drifted 1,172.9 miles from their starting point, and landed in a great forest at Peribonka River, North Lake Chilogoma, Canada, where they were lost for several days.

Quite as eventful was the ocean voyage of Walter

Wellman, who left Atlantic City October 15, 1910, for Europe in a motor balloon with a drag rope, or equilibrator, voyaged with favorable wind to a point 140 miles northeast of Nantucket Island, then was driven by adverse wind toward Bermuda, and finally rescued by a passing steamer, after 69 hours in the air and a journey of about one thousand miles. A full account of this strange voyage is given in the New York *Times* of October 19, 1910, and in the *Scientific American* of subsequent date.

The recent advances in aërostation, though not radically changing the balloon itself, contribute much to its usefulness and convenience. Improvements have occurred in the means of inflation and deflation, in devices for making topographical and meteorological observations, as also for transmitting and receiving signals. Hydrogen shipped in steel tubes is now available for easy and rapid inflation, the process of obtaining it on a large scale making it practically as cheap as illuminating gas. The ripping panel, invented in 1844 by America's foremost pioneer aëronaut, John Wise, is a simple and an excellent practical device. This is a long patch running longitudinally above the equator[1] of the balloon, feebly sewed to the envelope, and having a cord, called the "ripping cord," extending down to the car along the outside or inside of the bag, so that the pilot on coming to earth can let out the gas quickly by tearing a rent in the balloon, thus flattening it promptly on the earth's surface, so as to avoid dragging and bumping if any wind prevails. During an ascension the rise or fall of the vessel may be instantly noted on the dial of the statoscope, the temperature, pressure and moisture of the atmosphere may be read on recording instruments, messages may be sent by tele-

[1] The equator of such a balloon is its horizontal great circle.

graph and telephone either by wire or through space, and sky or landscape may be photographed if there be sufficient light. The bag itself has been improved by making it of special fabrics formed of several layers of silk, or cotton, with thin layers of rubber vulcanized between them to render the cloth impermeable, also the bag, when not designed to cleave the wind, is usually given a spherical form which is the figure of greatest volume for a given surface, the figure originally used by the inventor of the gas balloon; but when designed to be tethered in a wind, it is given a longish shape and a tail so that it may ride the wind like a kite. This type of balloon, though first proposed by Douglass Archibald about 1845, was first made a practical invention by Captain von Sigsfeld and Major von Parseval. In a certain sense it is a tethered motor-balloon, just as a kite is a tethered aëroplane.

CHAPTER III

EARLY HISTORY OF POWER BALLOONS

Directly after the first launching of human passengers in a crude aërostat, numerous schemes for controlling the course of a balloon were evolved. Apparently mere flotation afforded less contentment to the early pioneer aëronauts than to the free balloonists of the present hour. Many were eager to apply propelling mechanism to their gas bags, expecting thus to achieve practical locomotion through the air, even a generation before the advent of practical steam navigation. Magnificent dreams they had, indeed, but none the less futile. Few suspected the enormous power required to propel swift balloons of the very best shape and size; still fewer realized the impossibility of driving spherical bags at a practicable velocity.

On the other hand, it must be said, to the credit of that era of investigators, that certain noted scientists, after computing the power required to drive a balloon at high speed, promptly recognized the inadequacy to that task, of any motors then available. In conjunction with favorable aërial currents something might be effected; that they fully grasped; for they knew that the wind frequently has different directions at different levels. They believed, therefore, that by causing the craft to rise or fall to a suitable stratum, by use of various then known devices, it could be made to travel in any direction at the will of the pilot. Likewise they deemed that the rise and fall of a balloon, due to change of buoyancy, could be used to propel it, if sails attached to the vessel were set obliquely to the motion, so as to receive fair pressure; or if the balloon were made flat, or longish, so as to glide horizontally, like a kite or parachute.

Several devices for changing the altitude of the balloon were proposed or tried. If the vessel were a *Montgolfière*, the mere increase or lessening of the fire would promptly cause it to rise or fall. If a gas bag were employed it could be sent up or down by casting out ballast or opening the valve; or again, as proposed by Pilâtre de Roziere, by having a *Montgolfière* underneath the gas balloon, and lifting or depressing the whole by altering the intensity of the flame. Finally, an air balloon within a gas balloon was proposed by the Roberts, and a gas balloon within an air balloon was proposed by General Meusnier, in either of which combinations, a change of level could be effected by pumping air into, or letting it escape from, the air bag. All of these devices can be effected and practically operated by a competent balloon maker and pilot; and yet they have not enabled man to realize his dream of navigating the air in all directions without motive power.

The first attempts at balloon propulsion could not be seriously regarded by trained engineers, even at the inception of aëronautics; but still, as infantile steps in the new art, they may deserve passing notice.

Blanchard, on March 2, 1784, made the first real effort to steer a balloon, using for that purpose a spherical gas bag and car provided with aërial oars and a rudder. As he was about to ascend, however, from the Champs de Mars, a young officer with drawn sword persisted in accompanying the pilot,

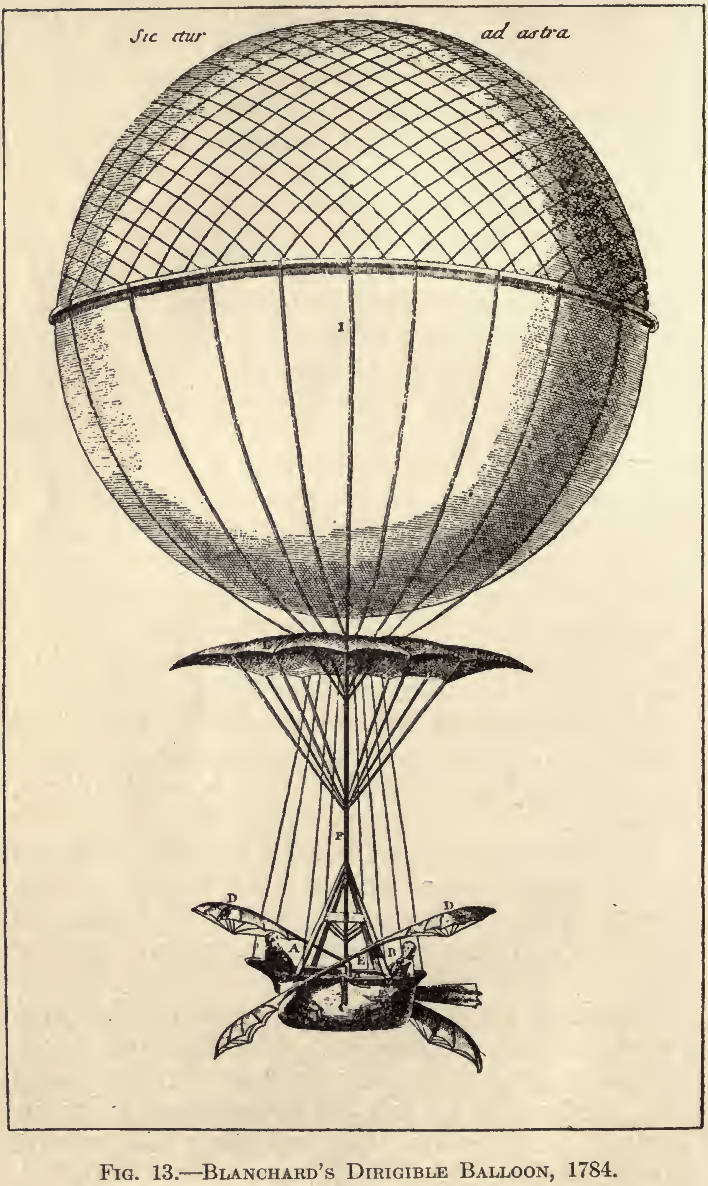

Fig. 13.—Blanchard's Dirigible Balloon, 1784.

thus compelling Blanchard to leave his wings on earth to allow sufficient buoyancy for himself and his obtrusive guest. His first trial was, therefore, frustrated; but subsequent ones made with that inadequate contrivance also proved futile under the best circumstances; for the scheme was evidently puerile, though tried by various grown-up men besides M. Blanchard.

A no less simple and quaint device for propulsion was that of the two physicists, the Abbé Miolan and Janinet. The balloon was a *Montgolfière* with a large hole in one side, through which the hot air was to escape with such strong reaction as to drive the bag forward, on the principle of a lawn sprinkler, or of Newton's reaction wagon. The projectors failed, however, to make an ascent, and the crowd becoming furious destroyed the balloon.

A more reasonable plan for practical navigation was devised and tried by the Robert brothers. A melon-shaped balloon, fifty-two feet long by thirty-two feet in diameter, was made of silk and inflated with pure hydrogen. Beneath was suspended a longish car of light wood covered with sky-blue silk. This elegant ship was to be rowed through heaven by means of six silken oars actuated by sturdy sailors. A silken rudder should guide her at pleasure when the winds were asleep, or softly playing in the placid sky. She was a fairy bark, indeed, a soaring castle lovely to behold.

After a preliminary trial, accompanied by their patron, the Duke de Chartres, they were ready for a substantial journey. On September 19, 1784, the vessel was inflated and taken to the Garden of the Tuileries, in front of the palace, where its cords were held by Marshall Richelieu and three other noblemen. At eleven forty-five the two Roberts and their brother-in-law arose and drifted beyond the horizon on a seven hours' cruise. Before coming to earth, they plied the oars vigorously, and described

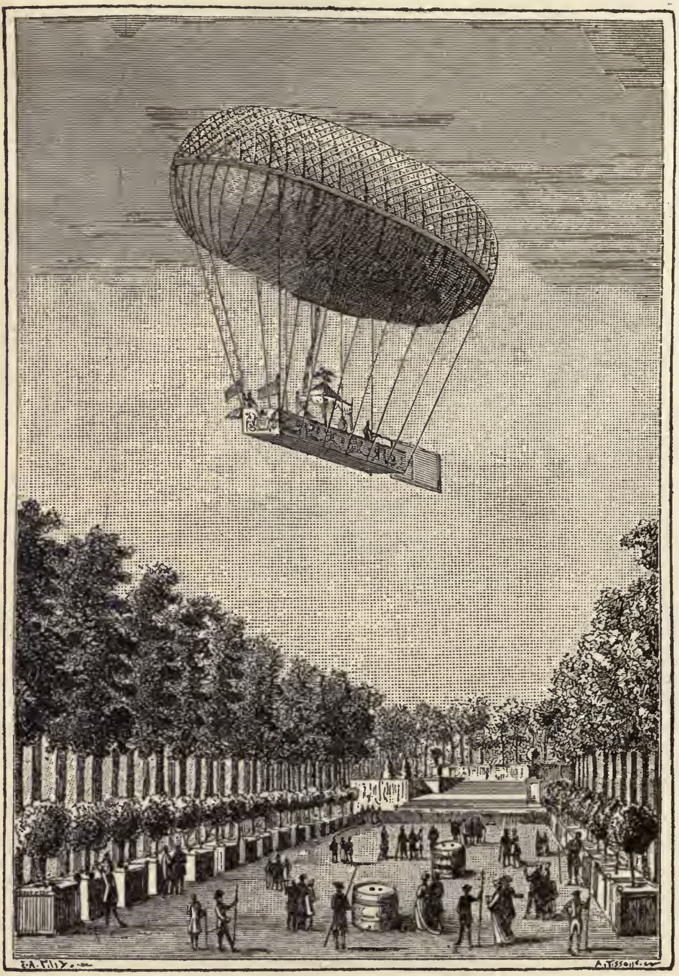

FIG. 14.—ROBERT BROTHERS' DIRIGIBLE, 1784.

a curve of one kilometer radius, thus deviating 22° from the feeble wind then prevailing. In a lighter wind they could deviate still more. They considered, therefore, that the experiment was a complete success. They had constructed the first elongated balloon, and had "solved the problem of aërial navigation." In very happy mood, therefore, they landed at dusk among the delighted inhabitants of Artois, where they were graciously met and hospitably entertained by the Prince de Ghistelles-Richbourg.

The Robert brothers were the first to employ in practice an air bag inside a gas bag. This was held within the balloon by ropes and connected with the outer atmosphere by a tube, the idea being to regulate the internal pressure of the balloon by introducing air into, or withdrawing it from, the smaller bag. But during an ascension with their patron, the Duke de Chartres, they entered a violent eddy which tore away the oars and rudder, at the same time agitating the balloon so violently that the internal air bag broke its sustaining cords and fell upon the bottom of the gas bag, thus throttling the connection with the external atmosphere. The vessel rose swiftly and the gas expanded dangerously near to the bursting pressure. At a height of 16,000 feet the Duke de Chartres, perceiving the imminent danger of an explosion of the envelope, drew his sword and cut a rent ten feet long in its lower part. A part of the gas immediately rushed forth, and the balloon sank rapidly, but after the discharge of the ballast, landed safely without further mishap. The Duke acted wisely enough, but he was afterwards ridiculed for his apparent lack of courage. If he had possessed more bravery and less caution he might have allowed the balloon to burst and descend as a parachute, thus anticipating the spectacular performance of John Wise, in 1838.

Simultaneously other inventors were evolving designs of no less importance in the ultimate perfection of the dirigible. In a letter written to Benjamin Franklin on May 24, 1784, Francis Hopkinson of Philadelphia proposed to build a balloon of spindle shape and to drive it by means of a wheel-like propeller at the stern, consisting of vanes set at an angle to the line of progression, like the common smokejack. This proposed craft, the harbinger of the modern screw-driven motor balloon, far antedated the screw-driven boat and the submarine torpedo which it most resembles.[1]

While Blanchard and other aëronauts were paddling their globose bags in search of favorable winds, vainly hoping thereby to direct their course in the air, General Meusnier of the French army, and member of the Academy of Sciences, made a systematic study of the requirements for practical air navigation. After some research on forms suitable for aëronautic hulls, he designed a power balloon having a pointed car suspended from a bag of goose-egg form, this latter embodying his idea of the best shape for a balloon that must cleave the air swiftly and resist deformation. The propulsion was to be effected by means of three coaxial screw propellers, supported on the rigging between car and bag, and actuated by eighty men, for lack of a

[1] A similar suggestion was made by Thomas Jefferson in a letter to Prof. James Madison, and dated from Paris in 1785: "I went some time ago to see a machine which offers something new. A man had applied to a light boat a very large screw, the thread of which was a thin plate, two feet broad, applied by its edge spirally around a small axis. It somewhat resembled a bottle brush, if you will suppose the hairs of the bottle brush joining together, and forming a spiral plane. This, turned on its axis in the air, carried the vessel across the Seine. It is, in fact a screw which takes hold of the air and draws itself along by it; losing, indeed, much of its effort by the yielding nature of the body it lays hold of to pull itself on by. I think it may be applied in the water with much greater effect and to very useful purposes. Perhaps it may be used also for the balloon."

light artificial motor. He thus hoped to obtain a moderate velocity which, combined with skillfully selected air currents, would enable the ship to reach her destination in ordinary weather.

General Meusnier introduced important special features in the design of dirigibles for preserving

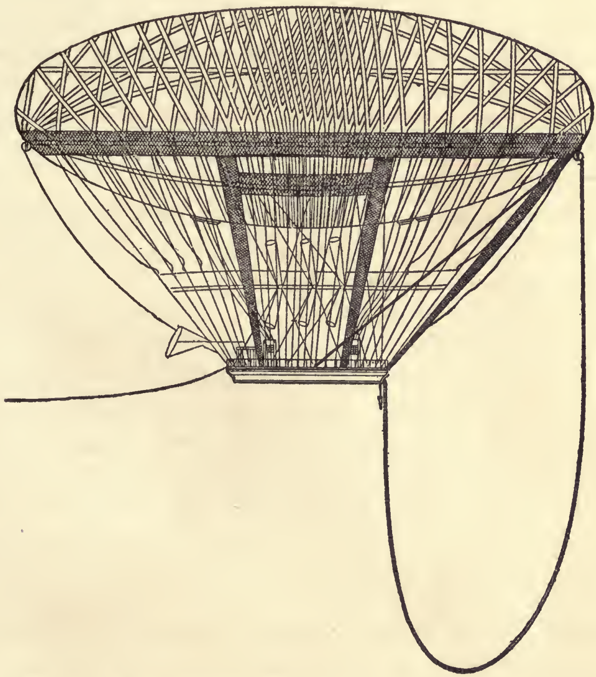

FIG. 15.—GEN. MEUSNIER'S PROPOSED DIRIGIBLE, 1784.

their form and poise. He insisted that the bag and boat should be so rigidly connected that one could not swerve from alignment and relative position with the other. He also emphasized the necessity of preserving the vessel from deformation during flight, in order to diminish its resistance. To that end he proposed to provide the hull with a double envelope, the inner one thin and light but impermeable to hydrogen; the outer one strong and air-tight; the space between the two envelopes to be pumped full of air under pressure sufficient to preserve the form of the bag when beating its way swiftly against a buffeting wind. This was an important invention which in later years was adopted in many of the most powerful motor balloons—for all, indeed, except those of the rigid type. He also proposed the use of stabilizing planes to control the poise of the vessel, thus anticipating the Lebaudy brothers by more than a century. Like the Robert brothers he proposed to raise or lower the vessel in search of suitable currents, by altering the quantity of air in the space between the inner and outer envelope, by use of hand bellows.

Apparently General Meusnier and his colleagues were endowed with constructive genius sufficient to have developed a practical motor balloon, had they been able to secure a light engine. Lacking this the early aëronauts could do little more than describe their projects, and await the growth of the collateral arts and sciences. Accordingly no substantial advance in motor balloons beyond Meusnier's designs was effected till after the middle of the nineteenth century; and until then the art of aëronautics remained in the hands of showmen. Hundreds of projects, indeed, were advanced, some exciting considerable interest and expectation, but nevertheless of such paltry value as hardly to deserve comment. One notable exception to these was the invention of Porter in America.

In 1820 Rufus Porter, a Yankee inventor, and later the original founder of the *Scientific American,* patented an air ship of very promising appearance for that early day. Its hull was a long, finely tapering symmetrical spindle, suspending a car of similar shape by means of cords, which were vertical at its middle but more and more slanting toward its ends. Midway between the hull and car was a large screw propeller actuated by a steam engine in the car. A model of this dirigible exhibited in Boston and New York, some years later, is reported to have carried its own power, at fair speed, and to have obeyed its helm satisfactorily.

The inventor, being too poor to develop his air ship alone, did little with the patent during its life; but in 1850 he organized a stock company to realize

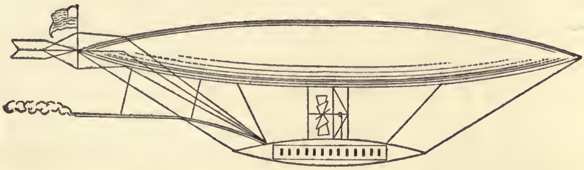

Fig. 16.—Rufus Porter's Dirigible, 1820.

the needed funds. From the sale of 300 five-dollar shares he expected to raise $1,500, and with this sum build an "aëroport," 150 feet long, capable of carrying five persons sixty miles an hour, the whole to be completed in six weeks. Once this was in operation he would easily command funds sufficient to build a full-sized vessel adapted to regular passenger service. For, after careful calculation, he reported that: "It appears certain that a safe and durable aërial ship (or aëroport) capable of carrying 150 passengers at a speed of ninety miles an hour, with more perfect safety than either steamboat or railroad cars, may be constructed for $15,000, and that the expense of running it would not exceed $25 per day."

The language and project seem very modern, even at the present time, and might well be copied now by a promoter of that identical project. But it must be observed that the most successful European experimenters, after spending hundreds of thousands of dollars on giant air ships, have not yet attained one half the speed contemplated by that ambitious and chimerical Yankee. The picture was handsome and alluring, none the less. It may even be said to excel in outward design any of the airship plans produced in either hemisphere before the middle of the nineteenth century.

In 1850 a clockmaker and skillful workman, Jullien by name, exhibited in the Hippodrome, at Paris, a torpedo-shaped model balloon of goldbeater's skin, provided with a screw propeller at either side of its bow, and a double rudder at its

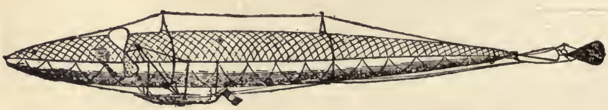

FIG. 17.—JULLIEN'S MODEL DIRIGIBLE, 1850.

stern. It measured 23 feet in length and weighed 1,100 grammes complete. The propellers were actuated by spring power, and proved able to drive the tiny vessel against a moderate wind. The most suitable form for the bag was determined by towing models through water.

Aërodynamically considered, this tiny motor balloon was by far the best in design of any that appeared during the first century of aëronautics. It may be regarded as the harbinger of the swiftest modern French balloons. It was also an inspiration to Henri Giffard who assisted Jullien in constructing his clever model, and shortly afterwards built the first dirigible ever driven by a heat engine.

The illustrious Henri Giffard was perhaps the first aëronautical engineer adequately endowed and circumstanced to realize, on a practical scale, General Meusnier's well pondered and truly scientific plans for a motor balloon. He had studied in the college of Bourbon, and had worked in the railroad shops of the Paris and St. Germain railway. He had further equipped himself by making free balloon ascensions, under the auspices of Eugene Godard, for the purpose of studying the atmosphere; and by building light engines, one of which weighed

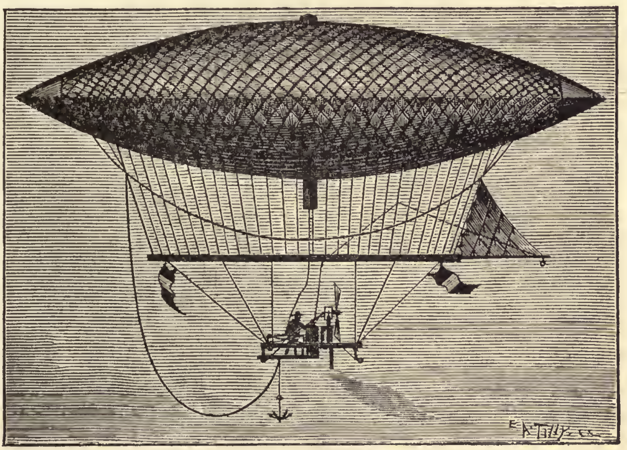

FIG. 18.—GIFFARD'S STEAM DIRIGIBLE, 1852.

100 pounds, and developed three horse power. Finally in 1851 he patented an air ship, consisting of an elongated bag and car, propelled by a screw driven by a steam engine. He had not the means to build such a vessel, but he had the genius and training necessary to construct it, and at the same time enough enthusiasm and persuasive power to induce his friends, David and Sciama, to loan him the requisite funds.

Giffard's first dirigible was successful in both design and operation. It consisted of a spindle-shaped bag covered with a net whose cords were drawn down and attached to a horizontal pole, from which the car and motor were suspended, and at the end of which was a triangular sail serving as a rudder. To guard against fire, the furnace of the vertical coke-burning boiler was shielded by wire gauze, like a miner's lamp, and the draft, taken from its top through a downward pointing smoke pipe, was ejected below the car by force of exhaust steam, from the engine, thus obviating, as Giffard asserted, all danger from the use of fire near an inflammable gas. The car hung twenty feet below the suspension pole, and carried a three horse-power engine driving a three-blade propeller 11 feet in diameter, making 110 turns a minute. The motor complete, including the engine and boiler without supplies, weighed 110 pounds per horse power. The bag measured 143 feet long, 39 feet in diameter, and 75,000 cubic feet in volume. Giffard reports of his first voyage, made from the Hippodrome in Paris at five fifteen o'clock, September 23, 1852, that although he could not sail directly against the strong wind then blowing, he could attain a speed of six to ten feet per second relatively to the air, and he could easily guide the vessel by turning her rudder. He continued his journey till nightfall, then made a good landing, near Trappes, and by ten o'clock was back in Paris.

This vessel was but a prelude to mightier projects. After some further experience with dirigibles of moderate size, Giffard designed a colossal air ship calculated for a speed of forty-four miles an hour. Its hull was to be of torpedo shape, measuring 2,000 feet in length, 100 feet in diameter, and 7,000,000 cubic feet in volume. It was a most audacious project, one worthy of the genius and energy of that illustrious engineer, the most original and daring inventor known in the aëronautical world during the nineteenth century.

Stimulated by this huge enterprise, Giffard's first step was to pay his debts and make a fortune. He soon acquired a hundred thousand francs from the sale of small high-speed engines of his own construction, and with this, settled his account with David and Sciama. Next he realized several million francs from his world-famous injector, a device by which steam flowing from a boiler is made to drive in feed-water against the same pressure.

He now made definite plans to build a motor balloon of one and a half million cubic feet capacity, driven by a condensing engine drawing steam from two boilers, one fired with oil, the other with gas from the balloon, so as to keep the vessel from rising with loss of weight. His designs were complete, and everything was provided for. He had deposited a million francs in the Bank of Paris to defray the estimated cost. But, in the words of Tissandier,[1] "above the human will and foresight are the fatal laws of destiny to which the strongest must submit." The great inventor was visited with a painful affliction of the eyes; his sight waned, unfitting him for work; he became disconsolate, pined away with pain and grief, and in 1882 ended his life by taking chloroform.

Giffard was succeeded in France, first by Dupuy de Lome; then by Gaston Tissandier, well-meaning projectors of steerable balloons, but too cautious to effect an important advance in the art. The first of these gentlemen, an eminent marine engineer, in 1872, completed a gas balloon for the French government, resembling the one designed by General Meusnier in 1784, and like that also driven by mus-

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[1] *La Navigation Aerienne,* Gaston Tissandier.

cular power actuating a screw, and kept rigidly inflated by use of an internal balloon, or ballonet. The car was suspended from the bag by a close fitting cover instead of a net, in order to lessen the resistance, and it was kept in alignment by use of crossed suspension cords. A speed of but six miles an hour was attained by the industrious work of eight men operating an ample screw propeller. A decade later Tissandier, with a balloon of like design,

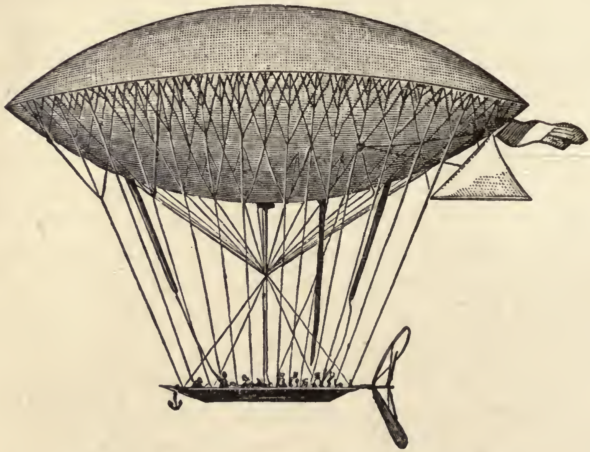


FIG. 19.—DUPUY DE LOME'S DIRIGIBLE, 1872.

but driven by the power of an electric motor and bichromate of potash battery, attained a speed of six to eight miles an hour.

The two vessels were safe but of no practical value, for lack of sufficient power to cope with the wind. Their motors were fundamentally unadapted to the purpose of swift propulsion, and incapable of development to very great lightness and strength. Furthermore, the vessels themselves were unsuitably designed for speed; their shape being one of too much resistance, and their dynamic balance being that of a pendulum, or clumsy parachute, rather than that of a vessel adapted to cleave the air with celerity, grace and steadiness. If there had been danger of fire from placing the motor and screw near the gas bag, that might justify or excuse the clumsiness of design in the craft of De Lome and of Gaston Tissandier; but, having perfectly safe motors, it is astonishing that they did not place the center of mass and the line of thrust more nearly in the line of resistance. This obvious requirement was duly recognized by several of their contemporaries, notably by Hänlein in Germany, and by Captain Renard of the French War Department, and had been observed by Jullien.

Captain Charles Renard proved to be a worthy inheritor of the dreams, experience and inventions of the first century of aëronautical votaries. He did not, indeed, have the picturesque madness displayed by some of his predecessors; he did not project schemes of marvelous originality or boldness; but he manifested uncommonly good judgment and excellent scientific method in combining the researches and contrivances of others with those of himself and his collaborator, Captain Krebs. As a consequence they produced the first man-carrying dirigible that ever returned against the wind to its starting point, and the first aërial vessel whose shape and dynamic adjustment even approximated the requirements of steady and swift navigation in a surrounding medium presenting various conditions of turbulence or calm. Captain Renard had been studying and designing dirigibles since 1878 in coöperation with Captain La Haye and Colonel Laussedat, president of an aëronautic commission appointed by the Minister of War; and had endeavored to secure from the latter an appropriation sufficient to construct a dirigible; but his request was at first denied, owing to the waste of funds on similar projects in 1870. However, with the help of Gambetta, who promised a sum of $40,000, Renard was enabled to proceed. In the meantime he had been made director of the laboratory at Chalais Meudon, seconded by Captain Krebs.

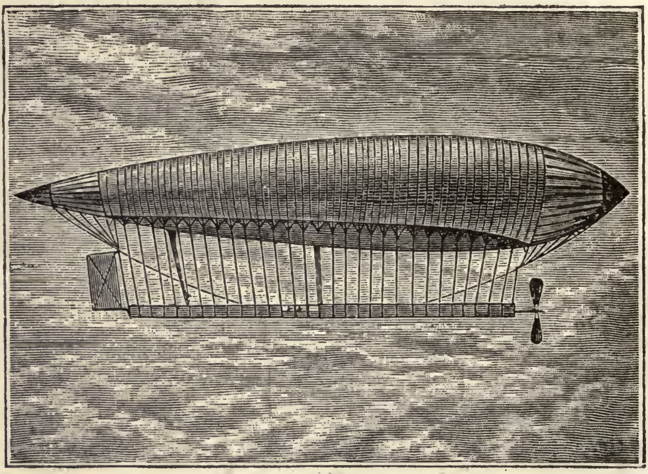


FIG. 20.—RENARD'S DIRIGIBLE, *La France,* 1884.

These officers first worked out the separate elements in the design of their motor balloon before proceeding to build on a practical scale. They chose the torpedo form for their gas bag, thereby ensuring in the hull itself, projectile stability, and diminution of resistance. They placed the car near the envelope, thus minimizing the disturbing moment of the screw thrust, and the resistance of the suspension cords. They employed an extraordinarily powerful electric motor actuating a large screw so as to obtain a strong thrust with the least effort. In addition they adopted the best ideas of their predecessors in aëronautical design; the internal ballonet of Meusnier, and the close fitting cover of De Lome, with crossed suspension cords. But unfortunately they used an electric motor instead of some light engine. Finally, having carefully computed its requisite dimensions, they proceeded to construct the elegant air ship, *La France,* which was tested in 1884 and aroused anew the hope of ultimately conquering the air.

Further details of this successful ship are of interest. Its hull was 165 feet long, 27.5 feet in greatest diameter, at one fourth the distance from its front end, and cubed 66,000 feet, thus having a buoyancy of two long tons. It was kept rigid under varying conditions, by means of a ballonet filled with air driven in by a common fan blower coupled to the motor. Beneath the envelope, a long narrow rectangular car made of bamboo, covered with silk, was suspended from the cords of the balloon cover which embraced the hull throughout nearly its entire length. The car was 108 feet long and 6 to 7 feet across, carried at its forward end the propeller, at its rear a rectangular rudder, and between them the aëronauts and the batteries and electric motor. A sliding weight was used to alter the poise of the ship, and a guide-rope to soften its descent.

The electric motor and battery which furnished the propulsive power were designed expressly for such use, and were considered at the time to be remarkably light and effective. The motor, which was designed with the assistance of M. Gramme, weighed 220.5 pounds, and developed nine horse power. The battery, composed of chlorochromic cells, was the result of the researches of Renard himself. Having made a careful study of the best geometrical arrangement of the parts of the cell, Renard found that this battery would deliver to the shaft one horse power for each eighty-eight pounds of its weight. Thus the power plant rivaled in lightness the steam engine of Giffard, and at the same time was free from danger; but apparently it could not be much reduced in weight, whereas Giffard's steam-power plant could be reduced tenfold, as shown by Renard's contemporaries.

The trials of *La France* in 1884–85 were most successful and encouraging; not that they represented or pointed to the complete mastery of aërial navigation, but because they so far surpassed all previous achievements. The vessel moved through the air as steadily as a boat on the water, and obeyed her rudder perfectly, heading against the wind, or at any angle to it, or turning entirely about, at the will of the aëronauts. On her first voyage from Chalais, August 9, 1884, she traversed a distance of four and one half miles in twenty minutes, made various evolutions in the air with the greatest ease, and returned to her point of departure. The following account of this voyage is given by Renard:

"As soon as we had reached the top of the wooded plateaus which surround the valley of Chalais, we started the screw, and had the satisfaction of seeing the balloon immediately obey it and readily follow every turn of the rudder. We felt that we were absolutely masters of our own movements, and that we could traverse the atmosphere in any direction as easily as a steam launch could make its evolutions on a calm lake. After having accomplished our purpose, we turned our head toward the point of departure and we soon saw it approaching it. The walls of the park of Chalais were passed anew, and our landing appeared at our feet, about 1,000 feet below the car. The screw was then slowed down, and a pull at the safety-valve started the descent, during which, by means of the propeller and rudder, the balloon was maintained directly over the point where our assistants awaited us. Everything occurred according to our plan, and the car was soon resting quietly on the lawn."

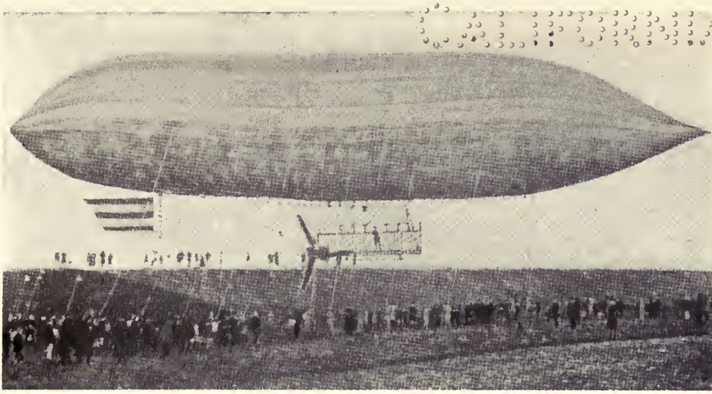
Six other similar voyages were made within the two years following, and we have as a result, that in five out of the seven trials, the balloon returned to its point of departure. Its failure to return in the other two trials was due, in the one case, to the breaking down of the motor; in the other, to the resistance of a strong wind which made it necessary to land at a distance from the starting point. The last of these remarkable voyages was performed in presence of the Minister of War, on September 23, 1885. The balloon started from Calais and sailed against the wind directly to Paris, passed over the fortifications, described a graceful curve and returned to its place of departure, recording an average speed of 14.5 miles an hour.

The torpedo form of hull, chosen by Renard and Krebs, has two important advantages; one is projectile stability, the other is economy of propulsive power. Owing to the blunt bow and long tapering stern, the center of mass is well forward, while the center of side wind pressure is more to the rear. As a consequence, if the vessel should encounter a quartering wind-gust, or have her nose slightly turned from the course, she would promptly right herself like a dart, or an arrow. If on the contrary, the hull were a symmetrical spindle, the vessel would move forward in unstable equilibrium, and, once slightly diverted from her course, would tend to deviate further, like an arrow with unloaded head.

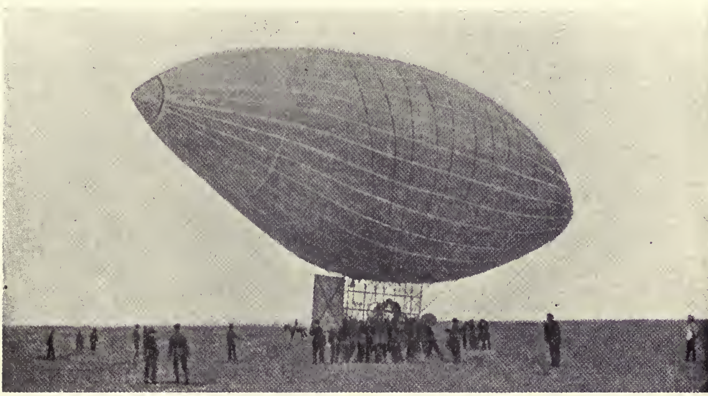
The second advantage mentioned is also worth attention, viz.: that at ordinary transportation speeds a longish spindle has less resistance with a blunt bow than with a very sharp one. Renard and Krebs did not account for this fact; but the present writer, by determining separately the skin friction and the impactual resistance of the air, proved that in sharpening the bow beyond a certain best form, its friction increases faster than its head resistance diminishes, the most suitable shape being that of a torpedo whose nose has a radius of curvature of about two diameters, and its stern a radius of about twelve diameters.

While the successors of Giffard in France were thus engaged in developing dirigibles driven by muscular or electric power, a few German experimenters were applying gas and benzine engines to such vessels, with better promise of ultimate practical success and usefulness. The first of these was Hänlein, who in 1872 advanced the meritorious project of driving a well shaped balloon by means of a gas engine taking its fuel from inside the balloon, and making good the loss by pumping air into the ballonet. This balloon was of far better design for swiftness and kinetic stability than the contemporary one of Dupuy de Lome. Its hull was a well pointed cylinder 164 feet long, 30 feet in diameter and of 85,000 cubic feet capacity, made air-tight by a thick coating of rubber inside, and a thin one outside. The car was rigidly suspended near the envelope and carried a 6 horse-power Lenoir gas engine actuating a large screw. Notwithstanding that the buoyancy was small, owing to the use of coal gas, this air ship attained a speed of 15 feet per second. By employing hydrogen, a much larger engine could have been carried, entailing a much swifter speed. During its trial the balloon was kept near the earth's surface, held loosely by ropes in the hands of soldiers. The air ship was remarkably successful for that early date, and had the potency of greater achievement than its contemporaries in France; but owing to lack of funds its capabilities were not fully

PLATE II.



HAENLEIN'S GAS-DRIVEN DIRIGIBLE.



WÖLFERT'S BENZINE-DRIVEN DIRIGIBLE.

SANTOS-DUMONT'S DIRIGIBLE, *NO. 16*.

Photo E. Levick, N. Y.

developed. If it had been inflated with hydrogen, and propelled by use of gas and petrol, so that the loss of weight would compensate for the loss of buoyancy, it might have anticipated the speed and endurance of the best air ships built toward the close of the nineteenth century, or later.

In 1879, Baumgarten and Wölfert in Germany built a dirigible equipped with a Daimler benzine motor, but otherwise not possessing any special merit. An ascension was made at Leipsic in 1880, but owing to improper load distribution the vessel reared on end and crashed to earth. After further experiments, an ascension was made on the Templehofer field, near Berlin, in 1897, but this ended disastrously; for the benzine vapor ignited; the fire spread to the balloon, and the vessel fell flaming to the earth, killing Wölfert and his assistant. Baumgarten had died some years before.

In 1897, an aluminum air ship invented by an Austrian engineer, named Schwartz, was launched on the Templehofer field. Its hull was of cylindrical form with conical ends, made of sheets 0.008 thick, and stiffened with an internal frame of aluminum tubes. Being leaky and inadequately driven, it voyaged but four miles, drifting with the wind, then fell to earth with considerable shock. The pilot, a soldier of the Balloon Corps, escaped by jumping, before the vessel struck ground, but the frail unbending hull was soon demolished by the buffeting of the winds as it lay stranded on the unyielding earth. This was the second air ship built after the plans of poor Schwartz, the first having collapsed on inflation. He had, however, the credit of being the first to drive a rigid air ship with a petrol motor, and thus to inaugurate a system of aërial navigation capable of immense development, in the hands of sufficient capital and constructive skill. Thus the rigid type, conceived and crudely tried by Marey Monge and Dupuis Delcourt in the early part of the century, began to approach practical realization toward the end of the century.

The process of inflating with hydrogen such a rigid hull is interesting. Schwartz's plan, carried out by Captain Von Sigsfeld, was to place the hydrogen in one or more sacs inside the hull, thus expelling the air and filling the space, then withdrawing the sacs and leaving the hydrogen within. A better plan is to have a single sac inflated with air just filling the hull like the lining of an egg, then to force the gas between the lining and metal wall of the hull, thus expelling the air from the sac, which when completely collapsed can be removed. Practically the same result can be obtained by use of a thin fabric covering one half the inner wall, like the lining of an egg. Further provision can easily be made for manipulating the ballonet in such a case.

CHAPTER IV

INTRODUCTION OF GASOLINE-DRIVEN DIRIGIBLES

We have now traced the art of balloon guidance and propulsion from its earliest inception to the close of the nineteenth century. It was a period of extravagant hope and chimerical scheming, but withal a period fruitful in devices of fundamental value. The best experiments paid no dividends, but they prepared the way for really useful vessels. The methods of manipulation and control had been sufficiently developed to answer immediate needs. The air ship was at least dirigible, if not practical. It kept its shape, obeyed its rudder, rose and fell according to the operator's will. It was, however, a fair-weather machine, beautiful in appearance, but helpless in any considerable wind. Speed was now the desideratum, and the attainment of this involved new difficulties. The storm-proof balloon was still a dream.

Naturally one inquires what velocity makes a dirigible air ship really practical, assuming all other requirements satisfied. The minimum allowable speed depends largely upon the locality and season. On Long Island an assured velocity of forty to fifty miles an hour would seem desirable; for there the winds are swift and the water near. In Washington, or Berlin, thirty miles an hour is enough, though each additional mile per hour must be regarded as a considerable gain on a small margin of progress in facing a stiff breeze. Colonel Renard has estimated, from a study of the wind records near Paris, that a dirigible is practically useful in that locality if it can maintain a speed of twenty-eight miles an hour for ten or twelve hours; since in that case it can maneuver 81 days in 100.

Renard's own graceful ship attained a speed of but half that much. In order, therefore, to give his vessel the desired usefulness its speed must be doubled. This would require an eightfold [1] increase of motive power without increase of weight. Evidently then the cardinal requisite was a light durable motor of extraordinary output. Such motors fortunately were now coming into the market, owing to the development of gasoline engines for automobile racing.

The year 1898 witnessed the commencement of two famous systems of navigation by the lighter than air, one in France, the other in Germany, destined quickly to revolutionize the art, and to establish it on a practical basis. The leading exponents of these two systems were Señor Don Alberto Santos-Dumont, a rich young Brazilian living in Paris, and Count Ferdinand von Zeppelin, Germany's stanch old admiral of the air. Both achieved success by applying the gasoline engine to the propulsion of elongated balloons, but by very different methods. Santos-Dumont, apparently ignoring, or fearing to adopt, the excellent hull and car designed and used by Renard, began where Tissandier left off, with a symmetrical hull and low-hung car, thus producing a safe aërial pendulum, if not a racing machine; then by degrees he gradually felt his way to something more efficient. Zeppelin began with a long cylindrical hull pointed at the ends, rigidly framed

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[1] The motive power equals the product of the speed and resistance. But in the assumed case, the speed is doubled and the resistance quadrupled; hence, the power required is eightfold.

like that of Schwartz, and supporting its car and propellers well aloft near the line of resistance. His was a bold and effective design but difficult to execute. Santos-Dumont scored the first success, and startled the world by his spectacular flights; but ere long he was surpassed by other builders of non-rigid balloons. Zeppelin won his success slowly and by heroic perseverance in the face of enormous obstacles, finally emerging as the most successful and illustrious figure in the history of aëronautics. The achievements of these two pioneers and colleagues make the first decade of the twentieth century memorable in the annals of aërial navigation.

Santos-Dumont, who spent his early years on his father's large coffee plantation in Brazil, had, during boyhood, dreamed of navigating the air, and in 1897, at the age of twenty-four, made in France his first ascension in a spherical balloon. While living at Paris during that year he gave much time to motorcycling, automobiling and operating spherical balloons, of which he possessed two constructed after his own ideas; one, the smallest in the world, designed for solitary voyages, the other large enough for more than one person, intended for social excursions. Thus by way of amusement, and probably by impulse rather than deliberate purpose, he was equipping himself to become both the designer and the pilot of his future dirigibles.

Having acquired experience and skill in operating both balloons and engines, the young enthusiast set about realizing his boyhood dream of navigating the air independently of the course of the wind. His first dirigible was designed to carry his weight of 110 pounds and a 3½ horse-power petroleum engine taken from his tricycle, and reduced in weight to 66 pounds. The hull was a cylinder of varnished Japanese silk, 82½ feet long including its pointed ends,

$11\frac{1}{2}$ feet in diameter and 6,354 cubic feet in gas capacity. A ballonet, or air pocket, occupied the lower middle of the envelope. The basket for the little pilot, engine, and two-blade propeller was suspended far below the hull, to which its cords were attached by means of small wooden rods inserted into hems along each side of the envelope, for a great part of its length. The poise of the vessel was controlled by shifting weights fore and aft, while the turning right and left was effected by means of a silk rudder stretched over a steel frame. On the whole it was a crude and primitive affair, but of considerable interest as the first dirigible of a young man destined to give a strong impulse to the development of motor balloons of the non-rigid type.

After some preliminary tests, the little air ship and pilot soared away from the Zoölogical Garden in Paris, on September 20, 1898, rising in the face of a gentle wind, to the wonder and delight of a large crowd of witnesses, some of them professional aëronauts and very skeptical as to the outcome of this venturesome experiment. The ship maneuvered round and round overhead of the applauding throng, steering readily in all directions. Then the green navigator ascended a quarter of a mile and merrily continued his evolutions in the direction of the Longchamps race course. But when he wished to descend he observed the envelope contracting in volume, and was appalled to find that he could not pump air into the ballonet fast enough to keep the hull distended. It became swaybacked, and "all at once began to fold in the middle like a pocket-knife; the tension cords became unequal and the balloon envelope was on the point of being torn by them." As he was falling swiftly toward the grassy turf at Bagatelle, he called to some boys who were flying kites, to grasp his guide-rope and run against the wind.

They understood and ran so swiftly with the canted balloon that it played kite, and descended with a moderated fall, landing the frightened aëronaut safely on the turf.

Except for the doubling of his long balloon, Santos-Dumont's first voyage was satisfactory, and he returned to Paris elated. He had found it easy to steer in all directions. He could change his level hundreds of feet without discharge of gas or ballast, by merely canting his balloon, and allowing it to run obliquely up or down grade. He had stemmed the wind and gone whither he pleased, at such speed as to make his clothes flutter. And best of all he had found no danger in using a gasoline motor near an inflammable gas bag. The mere buckling of the long bag was a trifle, to be remedied by using an air pump adequate to maintain the flabby thing well inflated. He felt, therefore, that he had the conquest of the air well in hand, and that he was drifting into air ship construction as a life work. Small wonder that he continued his conquests till he had built, in less than one decade, fourteen motor balloons.

Santos-Dumont No. 2 was closely patterned after its predecessor, but was a little larger and carried a rotary fan worked by the motor, to keep the balloon plump by filling the air pocket, or ballonet. On May 11, 1899, an ascension was made from the old starting place, but in rainy weather. As the vessel rose its hull contracted faster than air could be pumped into the ballonet, the long bag doubled worse than before, and dropped into the trees with its chagrined but fearless rider.

The *No. 3,* which followed, was a short, thick vessel, 66 feet long by 25 feet in diameter, having in outward appearance the features of Dupuy de Lome's very stable and very slow dirigible. It was apparently a safety ship for a scared young man who had not yet learned fully to appreciate Renard's elegant design. It served for a few pleasant trips, while the inventor was screwing up courage to build another cylindrical vessel, and gradually realizing the advantage of an elongated car such as Renard had employed in *La France.* Not only was the hull short and thick, but it was further secured from buckling by a horizontal stiffening pole placed between it and the basket, and from which the latter was hung. After some voyages in *No. 3*, which the captain found very tractable, and probably capable of fifteen miles per hour, he was ready to begin a new vessel.

The *No. 4* was a compromise between the better features of *No. 3* and its predecessors. The elongated hull and ballonet were resumed, and the stiffening pole was elaborated into a longish car resembling Renard's, but of triangular cross section. On this long trussed frame were placed the motor, propeller, rudder and the rider in his basket. A seven horse-power engine turning, at one hundred revolutions per minute, a screw propeller having two blades, each 13 feet across, gave a thrust of 66 pounds. Frequent trials of the ship during the summer of 1900, in presence of the Exposition crowds, brought the inventor into extraordinary prominence, and secured for him the "Encouragement Prize" of the Paris Aëro Club, consisting of the yearly interest on one hundred thousand francs, this being one of M. Deutsch's numerous foundations for the promotion of aëronautics.

In the spring of 1900, M. Deutsch de la Meurthe had established another prize which Santos-Dumont now greatly coveted, and hoped ere long to win. This was a cash sum of one hundred thousand francs to be awarded by the Scientific Commission of the Aëro Club of France to the first dirigible that, between May 1 and October 1, 1900, 1901, 1902, 1903, 1904, should voyage from Saint Cloud to and around the Eiffel tower, and return within half an hour. The distance to the tower and back, not counting the turn, was nearly seven miles, and the estimated speed required to fulfill the conditions for winning the prize, even in calm weather, was 15½ miles per hour.

As Santos-Dumont thought his *No. 4* scarcely swift enough to win the Deutsch prize, he enlarged it by inserting an additional length of sixteen feet at its middle, supplied it with a stronger car, and applied a larger engine, naming the new vessel so formed, his *No. 5*. Its hull was 109 feet long, 17 feet in largest diameter and cubed nearly 20,000 feet. A four cylinder air-cooled petroleum motor driving a screw propeller having two blades, each 13 feet across, gave a thrust of 120 pounds, at 140 revolutions per minute, and produced such draft as to give the inventor pneumonia. Among other novelties water ballast was used, and piano wires replaced the old-time suspension cords.

The *No. 5* proved so powerful and swift that on July 13, 1911, Santos-Dumont attempted to win the Deutsch prize. Starting from the Aëro Club grounds at Saint-Cloud in presence of official witnesses, at half past six in the morning, when the air is usually stillest, he turned the Eiffel Tower in the tenth minute, thus gaining twenty minutes for the home stretch. But on his return he encountered an unexpected head wind, and after a terrific struggle reached the timekeepers at Saint-Cloud in the fortieth minute.

To add to the romance of this voyage, the genii of the upper elements stopped his motor, shortly after his return, and the bold sailor in his shining ship landed in a stately chestnut tree very near the house of the Princess Isabel, daughter of Dom Pedro. She very thoughtfully arranged a breakfast for him and sent it up in a basket, where he was at work disengaging the balloon, at the same time inviting him to call and relate to her the story of his voyage. A few days later she sent him a medal of St. Benedict "that protects against accidents." He wore the medal, and on his very next trial escaped without a scratch from an appalling accident which might have terminated fatally. He continued to wear the gift of that gracious princess, on a thin gold chain circling his wrist, and many a time thereafter endured unscathed the most dreadful accidents, as if he possessed a charmed life.

On August 8, 1901, the dauntless aëronaut again sailed for the coveted prize, at the same still morning hour, sacred to duels and aërial contests. In nine minutes he turned the tower and headed bravely for home. But soon a leaky valve let the balloon shrink and the wires sag into the whirring propeller, which therefore had to be stopped. Santos-Dumont now had the choice of drifting back against the tower and destroying his vessel high in air, or of descending at once, by allowing the balloon to sink without discharge of ballast. He chose the latter course, hoping to land on the Seine embankment; but instead his balloon struck the top of the Trocadero hotel, exploded and fell in fluttering shreds into the courtyard. Some firemen who had been watching the flight from a distance, came with a rope and found the long car leaning like a ladder against the wall of the court, the balloon shreds hanging from it in graceful folds, and Captain Santos-Dumont perched aloft in his wicker basket wearily waiting for St. Benedict's further aid. As usual, he was rescued intact.

On the evening of his fall on the roof of the hotel

Santos-Dumont issued specifications for his famous *No. 6,* which surpassed all its predecessors in safety and speed. It had the shape of an elongated ellipsoid with pointed ends, measured 110 feet in length, 20 feet in major diameter, 22,239 cubic feet in volume, and had an absolute ascensional force of 1,518 pounds. It was driven by a twelve horse-power four-cylinder water-cooled engine which gave the propeller a thrust of 145 pounds. To insure against buckling of the gas bag, an air pump connected with the motor, kept the ballonet under constant pressure, regulated by an escape valve through which the excess of air passed outward. To secure the envelope against rupture, due to the expansion of the hydrogen at unusual elevations, a stronger valve was used to let the gas escape from the envelope into the atmosphere. Thus the air escape valve kept the pressure constant in the partially distended ballonet, and consequently also in the surrounding gas envelope itself; while the stronger gas valve in the envelope opened only in an emergency, when the gas pressure had fully collapsed the internal air pocket and was threatening to explode the envelope. With all its improvements this new vessel was finished and inflated by August 4, being a work of twenty-two days, and after some preliminary trials was ready to try for the Deutsch prize.

The day of triumph followed quickly. On October 19, 1901, at 2.45 P. M., Santos-Dumont again headed for the Eiffel Tower in presence of the official witnesses. In spite of a wind of six meters per second striking him sidewise, he held his course straight for the goal, and turned it in the ninth minute, as in his preceding attempt. On the return he had to struggle against a quartering wind and the caprice of his motor, which sometimes threatened to stop, and again spurted so actively as to turn the ship upward at a steep angle. The mighty throng below, in the Auteuil race track and the Bois de Boulogne, sent up immense applause, then suddenly held its breath in alarm, as the vessel pitched violently. But the hardy little rider was self-possessed and at home on his vaulting Pegasus. Alert to every prank he held his course straight for the timekeepers and passed over their heads at exactly twenty-nine and one-half minutes after starting.

His unmercenary disposal of the two rich awards which he had won seemed no less commendable than the dauntless industry which achieved such rapid success. The Deutsch prize amounting in all to one hundred and twenty-five thousand francs he divided into two unequal parts. The greater sum of seventy-five thousand francs he gave to the prefect of police of Paris, to be used for the deserving poor; the remainder he distributed among his employés. The Encouragement Prize of four thousand francs a year, mentioned before, he also declined to retain, but instead he founded with the money a new prize at the disposal of the Aëro Club. As a second reward for his triumphal voyage around the Eiffel Tower, he received from the Brazilian government one hundred and twenty-five thousand francs and a beautiful gold medal bearing appropriate and very complimentary inscriptions.

Now that the stimulus and excitement of striving for the Deutsch prize was over, the ardent inventor was free to develop and test his air ships in a deliberate and scientific manner. He therefore set about building specialized types of motor balloons, and practicing with them over all kinds of territory, smooth and rough. Within the next six years he constructed eight more air ships making altogether fourteen, besides his various free balloons, to say nothing of the aëroplanes and hydroplanes which he found time to develop. But before indulging in these new luxuries he would have more experience with his *No. 6*.

When the cold weather set in, following his victorious flight about the Eiffel Tower, Santos-Dumont went with his *No. 6* to Monaco, to practice air cruising over the Mediterranean. The Prince of Monaco had erected for him an "aërodrome," or balloon shed, facing the sea and very near shore. On pleasant days the daring pilot would cruise up and down the bay, not far from shore, trailing his guide-rope over the waves with the greatest ease, and to the applause of thousands of spectators. But on February 14, 1902, he set forth on a pleasure cruise over the bay with insufficient gas pressure, and thus came to grief. The bag grew flabby; the hydrogen poured to its higher end; the vessel reared up so steeply that the propeller had to be stopped to avoid its cutting the envelope. Rather than drift at the mercy of the wind, the pilot opened the valve and sank slowly to the water where he was rescued by a boat. On the following day the parts of his *No. 6* were fished out of the sea and sent back to Paris. His few days' practice had taught him the delights of guide-roping over the waters, and his accident induced him in future to sew unvarnished silk partitions across his balloons, to prevent the hydrogen passing too suddenly from one end to the other.

Returning to Paris he built for himself an "aërodrome," provided with great sliding doors like the one at Monaco, and equipped with a hydrogen plant, constructive appliances, and everything needed for the rapid rebuilding or repair of air ships. It stood in a vacant lot surrounded by a high stone wall and was made of posts covered with red and white canvas, so that it looked like a great striped tent. Inside, the central stalls were 31 feet wide, 165 feet long, and

$44\frac{1}{2}$ feet high,[1] the whole enclosure having accommodation for seven dirigibles all inflated and ready for instant service. When completed, in the spring of 1903, it was at once used to harbor three new air ships. These were the *No. 7,* designed for racing contests; the *No. 9,* called the Runabout, a minim air ship used for calls and short pleasure trips; and the *No. 10,* called the Omnibus, intended for several persons, with ample supplies for a considerable journey.

The *No. 7,* which excelled its predecessors in length and bulk, was intended greatly to outstrip the best of them in velocity. The first air ship had attained fourteen miles per hour, the *No. 6,* nearly twenty miles an hour in winning the Deutsch prize, and over twenty miles per hour on subsequent occasions, though provided with a motor rated at only 12 horse power. The new vessel which had little greater resistance than *No. 6,* was to carry four times the internal pressure, or about 12 centimeters of water, and to be propelled by an engine of 60 horse power. The inventor expected therefore to attain a speed of between forty and fifty miles per hour. A very lofty expectation for that day, and one still unrealized for many years.

The racing air ship, or *No. 7,* was of cigar form, supporting a long car beneath, and generally resembling the *No. 6,* but slightly more tapering. Her length was six times her major diameter, and her volume 45,000 cubic feet. The envelope was made of two layers of the strongest French silk, four times varnished, and was built exceptionally thick at the stern, where the differential outward pressure is greatest in flight. The propulsion was effected by a 60 horse-power water-cooled four-cylinder Clément engine actuating two screw propellers $16\frac{1}{2}$ feet in

[1] Santos-Dumont, *My Airships.*

diameter, one in front the other at the rear of the car. The poise and maneuvering were to be controlled in the usual way, by means of the rudder and shifting weight. The inventor seemed not to realize that the bow of his vessel was too sharp to cleave the air with minimum resistance, though his predecessor, Jullien, in 1850, had discovered experimentally that a torpedo form is better for speed than the symmetrical spindle form used by Santos-Dumont in his racing vessel. He did, however, in time, learn that the torpedo form of hull is better for stability of forward motion, and hence adopted that form in his little *Runabout*.

The *No. 9* was a thick torpedo-shaped air ship originally cubing only 7,770 feet, though later enlarged to 9,218 feet. It was so thick as to appear nearly egg-shaped. In order to make it respond promptly to the rudder Santos-Dumont drove it through the air blunt end foremost, but with apparent regrets, thinking that it would cleave the air more easily than sharp end foremost. In this he was mistaken; for the writer has shown that a body of such shape encounters much more resistance—roughly one hundred per cent more—when driven sharp end foremost than when driven blunt end forward. This fact furnishes one reason why most whales and swift fishes have blunt bows and long tapering sterns. However this be, the practical man felt his way to success, whether right or wrong in his theory of resistance. When actuated by a three horse-power Clément motor, weighing 26½ pounds, the little air ship carried its jaunty pilot twelve to fifteen miles an hour on many a merry trip about Paris and its environs.

The *No. 10,* or *Omnibus,* was a well shaped vessel of nearly eighty thousand cubic feet capacity, and amply provided with steering devices. Its hull tapered slightly from front to rear, terminating in projectile-shaped ends, and had a length of nearly six times its major diameter. Underneath was suspended a long car provided with aëroplane surfaces, in addition to the usual rudder, for controlling its movements.

Its arrow-like appearance was suggestive of some of the greatest German balloons of the decade. Indeed, the *Omnibus,* if well powered, might have proved a very swift vessel, in addition to a powerful carrier. But she was designed merely for easy going passenger service, for the purpose of popularizing aëronautics and stimulating its growth.

Santos-Dumont now had three typical air ships, a spacious and well equipped "aërodrome," and ample facilities for advancing the science of motor balloons on a moderate scale. He could not, however, maintain the ascendency in this branch of science in France; for he encountered the rivalry of great wealth employing highly trained engineering and constructive talent. He could, however, still promote the art as a pioneer and a popularizer. This he continued to do. With his little *Runabout* he would one day guide-rope along the boulevard, another day take up a little boy, another day send up a beautiful young lady to navigate the air alone for a short distance, another day voyage over the military parade grounds and with his revolver fire a salute of twenty-one shots to the President of France, and give exhibitions to arouse the interest of the War Department. But he could not keep pace with the new giants in aëronautics, and he did not attempt it. Nor did he ever build a vessel of sufficient power, speed and durability to be purchased by the French nation. That honor went to his opulent contemporaries who had not failed to take cognizance of his contributions to the aërial art.

CHAPTER V

PRACTICAL DEVELOPMENT OF NON-RIGID DIRIGIBLES

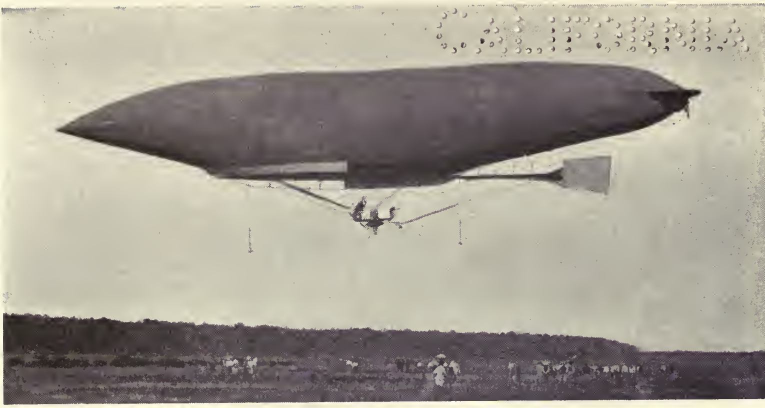
In 1899 the Lebaudy brothers, wealthy sugar refiners in Paris, commissioned their able engineer, Julliot, to make investigations and develop plans for a large and swift air ship. This he did with the assistance of Surcouf, a well-known manufacturer of balloons at Billancourt, Paris. Emulating the example of Santos-Dumont and certain German aëronauts in making their plan, they adopted the light petroleum engine for motive power, but experimented on a larger scale, thus creating a new era in military aëronautics in France. Their first vessel was the *Jaune* whose bag was built at Surcouf's place, and its mechanical part at the Lebaudy Sugar Refinery. When launched, in 1902, it so pleased the owners that they determined to continue the experiments on a larger scale. Their second air ship, called the *Lebaudy,* after fulfilling various tests, was accepted by the French government and formed the beginning of its modern aërial fleet.

Moisson, near Paris, where the balloons were kept, now became quite an aëronautical center. Here, under military supervision and the skillful management of the aëronaut Juchmes, other dirigibles were built in rapid succession. Of these the *Patrie* was launched in 1906, and the *Republique* in 1908, both fine swift vessels capable of voyaging many hours and carrying many passengers. The Lebaudy vessels were the first air ships of the "semi-rigid type," in which the long and flexible envelope, or hull, is provided with a rigid keel or floor, from which the car is suspended with its machinery and passengers. They are, therefore, of unusual interest both for their scientific design and for the stimulus they imparted to the growth of aërial fleets. For this reason they may well be studied in some detail.

The first Lebaudy air ship, called the *Yellow,* because of its color, had an envelope constructed of a rubber-treated cotton fabric, made in Hanover and covered with a yellow coating of lead chromate, to ward off the sun's actinic rays from the rubber, and thus prevent deterioration. Her hull, which was cigar shaped and inflated with hydrogen, measured 183 feet in length, 32 feet in diameter, and 80,000 cubic feet in volume. She was propelled by a 40-horse-power Daimler motor actuating twin screws, and attained a maximum speed of twenty-six miles an hour. During her first year's service she made many ascensions, returning to her starting point twenty-eight times out of twenty-nine. Her longest voyage, made at Moisson, June 24, 1904, was sixty-two miles in two hours and three quarters, with an average speed of twenty-two miles an hour. But in November, 1902, while landing in a high wind at the end of her voyage from Paris to Chalais-Meudon, she was wrecked by colliding with a tree. Her motor, however, was uninjured, and a new envelope was at once prepared.

The second vessel, called the *Lebaudy,* and brought out in 1904, though resembling her predecessor, had a number of improvements in detail. Her hull was somewhat larger than the *Jaune,* and no longer pointed at the stern, but rounded off to an ellipsoidal shape, and provided, like the rear of an arrow, with guiding, or steadying planes. It meas-

PLATE III.



THE *LEBAUDY*.

Photo E. Levick, N. Y.

LA PATRIE.
(Courtesy E. L. Jones.)

LEBAUDY'S *MORNING POST*.

ured 190 feet in length and 94,000 cubic feet in volume. It was provided with two windows for internal inspection, and had an air bag of 17,650 cubic feet, divided into three parts. This air bag was inflated by a rotary fan near the main body, driven by the motor during flight, and by a storage battery when at rest. Suitable horizontal and vertical sails were used to steady and guide the vessel; also a guide-rope and anchor were carried. The car, suspended by steel ropes, ten feet below the hull, carried the passengers and supplies; also the motor actuating twin propellers, one on either side. At night an abundance of light was available, each passenger carrying a small lamp fastened to his clothes, the car itself bearing a powerful acetylene projector in its front, and two other lamps of 100 candle power each, to illumine the vessel. It was an elaborate affair, costing fifty to sixty thousand dollars, and was the outcome of experiments costing ten times that sum.

The *Lebaudy,* with these various improvements, gave much satisfaction to her owners, and received favorable recognition from the French War Department. During the thirty ascensions and voyages of her first year's service, she proved herself a swift vessel, easy to control, very stable, and safe to land on solid ground. The Minister of War, who had followed her developments with much interest, appointed a commission to test her value for military service, with a view to her adoption by the government. The test required that the balloon remain in active service three months, always being anchored in the open, and that it perform certain prescribed maneuvers and voyages. In one of these it sailed with three persons on July 3, 1905, from Moisson to Meaux, an air-line distance of 57 miles in two hours and thirty-five minutes, at an average speed of 22 miles an hour, thence to Chalons, 61 miles in three hours and twenty minutes. Here it was anchored to some trees, but presently was caught in a strong wind, lifted high in the air, then dashed violently against other trees, with the complete destruction of its envelope. Within eleven weeks it was repaired in the military riding school at Toul, nearby; then, after some evolutions, returned to its harbor at Moisson. Other maneuvers were made subsequently, in which five officers were carried at one time, and interesting experiments were tried, such as dropping a sand bag upon a given spot, photographing fortifications, etc. The Minister of War, accompanied by two officers and other passengers, made a trip on October 24th, which was the seventy-sixth voyage of this stanch vessel. On November 10th, the hard-worked and successful air ship went into winter quarters, being now the property of the French government, and the first of her modern aërial cruisers.

The *Patrie* and the *République,* planned on the general lines of the *Lebaudy,* but in ascending scale of magnitude, were built expressly for the French government, and experienced brilliant if ill-fated careers. Both vessels had whale-shaped hulls, with rather sharp-pointed noses and rounding sterns. The original volume of the *Patrie* was 111,250 cubic feet, which was later increased to 128,910, by the insertion of a cylindrical section at the major diameter of the hull. The *République* had a volume of 2,000 cubic feet more than the *Patrie,* and a length of 200 feet, or a little less than the enlarged *Patrie.* She also had a diameter of 35½ feet as against 33¾ in the sister vessel. As the technical reader may like more complete details of these two noted air ships, a fuller account is given in Appendix III.

The *Patrie* was a swift and graceful ship which, during its brief activities in 1906–7, made many remarkable trips at an altitude of about half a mile, and frequently maneuvered with the troops. She sailed with excellent stability, had a speed of about 28 miles an hour, and, with four men, had a radius of action of 280 miles. In November, 1907, carrying four passengers, she voyaged from Paris to Verdun, on the German frontier, where she was to be stationed. In spite of a quartering wind, the total distance of 175 miles was traversed in seven hours and three quarters, or at an average overground speed of 25 miles an hour. But while at Verdun, after some maneuvers, she was too insecurely anchored to the ground by means of iron stakes. A strong wind came, tore out the pickets, and overpowered the soldiers, some two hundred in number, who were trying to hold the vessel. As she was pulling them along the ground, they were ordered to let go. The huge ship bounded high into the air, soared across France, England, Wales, and part of Ireland, then far out over the Atlantic where she vanished, leaving no trace behind.

The *République* also had a brilliant but ephemeral career, from July, 1908, to September, 1909. She surpassed the *Patrie* not only in bulk and buoyancy, but also in power and speed. She had an 80-horse-power motor as against the *Patrie's* motor of 60 to 70 horse power. She could carry eight to nine men, had a speed of about thirty miles an hour, and a radius of action of 500 miles. She made a number of long flights and manifested satisfactory steadiness and stability. But on September 25, 1909, while maneuvering near Paris, one of her propellers broke and tore a great gash in her envelope. At once, with outrushing gas and collapsing hull, the great ship fell 500 feet crashing to the earth, a total wreck, and killing her crew of four officers.

This disaster illustrated forcibly the advantage of the cellular system of balloon construction, and drew more favorable attention to the rigid type of air ship cultivated in Germany.

The famous firm that produced the *République* brought forth, in 1909, two other fine vessels patterned after it, the *Russie* and *La Liberté,* built respectively for Russia and France. The *Russie* made her first voyage on May 29th, ascending 600 feet with eight passengers, and maneuvering under perfect control. After her official trial, in June, she was sent to St. Petersburg, being the first dirigible furnished to a foreign government by a private concern. The *Liberté* was launched the last week in August and, after various practice and official tests, was accepted by the French government two months later. On a notable voyage, made on September 20th, she sailed ten hours with her Panhard motor constantly working.

The escape of the *Patrie* was a loss keenly felt by the French people, but soon compensated by the generosity of M. Deutsch de la Meurthe. This liberal patron of aëronautics had a dirigible of excellent design, whose hull, based on the plans of Colonel Renard, was contrived and built by E. Surcouf, director of the Astra aëronautic establishment, along with H. Kapferer, while its other parts were built by Voisin, both of Billancourt. In September preceding the accident to the *Patrie,* he had offered the use of his air ship, the *Ville de Paris,* to his government, which accepted the gift with the understanding that it was not to be delivered except in case of war or emergency. When, therefore, in November, 1907, the disaster occurred to the *Patrie,* M. Deutsch at once placed his dirigible in the hands of the military authorities.

The *Ville de Paris* showed considerable resem-

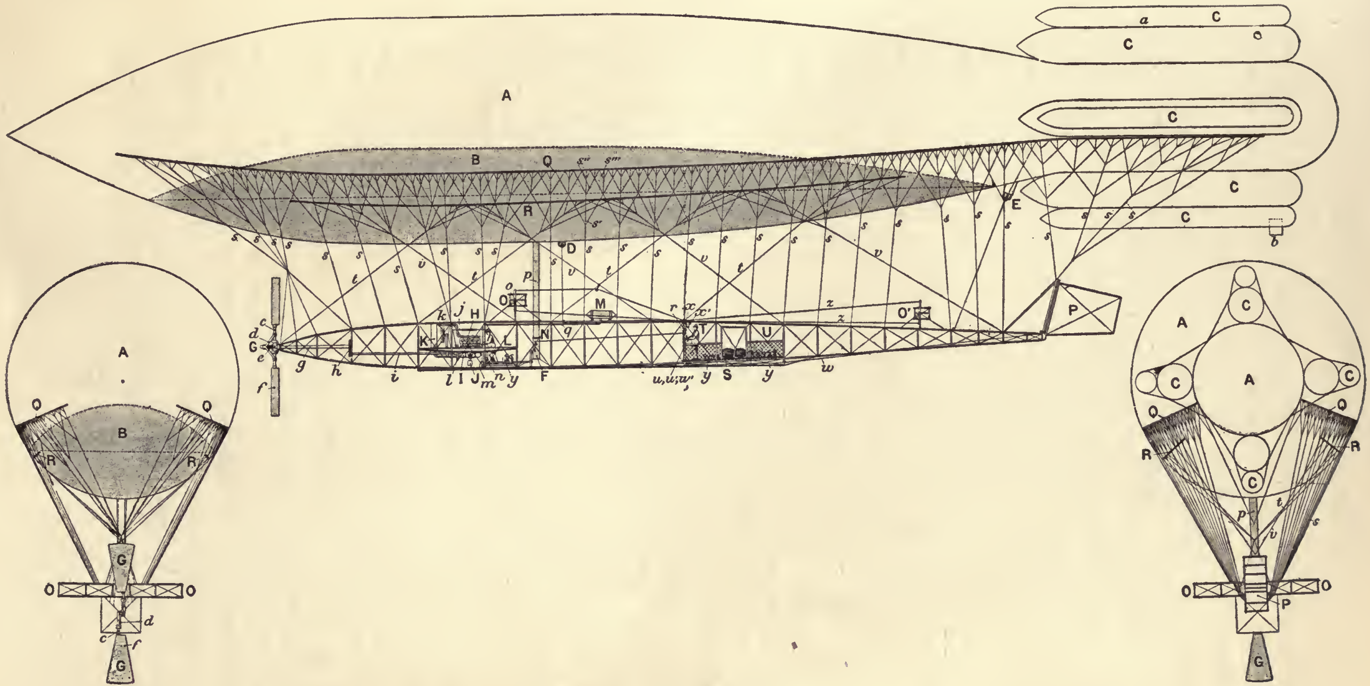


FIG. 21.—*La Ville de Paris.*

blance to her prototype, the *France* of 1884, but differed from that elegant vessel in various important features. Her hull was shaped like a wine bottle with its thickest end, or bow, brought to a sharp projectile point, and its other end furnished, like an arrow, with four fixed guiding surfaces to steady its flight. These guiding surfaces were elongated, finlike, cylindrical sacs, inflated as shown in the illustration. The hull measured 200 feet long, 34½ feet in major diameter, 112,847 cubic feet in volume. Heavy bands of canvas with their edges sewed along the sides of the balloon served as flaps for the attachment of the cords suspending the long car beneath. With this long suspension the weight of the car was more evenly distributed over the envelope than in the Lebaudy balloons. An interesting improvement in this air ship was the stabilizing planes, placed above the car, fore and aft, to lift or depress aëroplanelike, thus enabling the pilot to raise or lower the vessel, also to alter her trim, or to check her pitching. As might be expected, her flight was very steady, but as the motor developed only 70 to 75 horse power, her velocity did not exceed twenty-five miles per hour. In January, 1908, she made a run of 147 miles in seven hours, six minutes, with an average speed of 21 miles an hour. Further details of construction are given in Appendix III.

We now have had examples of the three leading types of motor balloons; the rigid, the semirigid, the flexible. The rigid type, as exemplified in the Schwartz and Zeppelin air ships, is characterized by its solidly trussed hull of invariable size and form to which all other parts are directly attached. The semirigid type, exemplified in the Lebaudy vessels, has a flexible hull, generally of woven fabric, with a trussed floor or platform for its ventral part, from which the car is suspended. The flexible type, as seen in the *Ville de Paris,* the *France,* and its predecessors, consists of a flexible hull entirely devoid of stiffening framework, together with a car, usually quite long, suspended from the bag directly. These are all of the important kinds in use at present. A combination of balloon and aëroplane has been tried by Santos-Dumont, Malecot, and others, but thus far has not resulted in a very successful and distinct type. Of the many powerful, swift, and elegant balloons which sprang into being after the success of the Lebaudy vessels, all could be classified under the above three types. Neither kind proved preëminently the fittest for all service, but the semi-rigid and flexible balloons multiplied most rapidly; partly, no doubt, because of their cheapness and convenience of management. We may review briefly this new crop of air ships, before turning to the novel and huge rigid vessels of Count von Zeppelin.

The *Ville de Paris* was followed, in 1909, by the *Clément-Bayard,* a slightly larger vessel of very similar pattern, constructed for the Russian government for $40,000. It also, like the *Ville de Paris,* was built by the Astra Society. The most striking feature of this new balloon was its curious stern with its bulblike steadying surfaces. These fin surfaces were not flat, as in the *Patrie,* nor cylindrical, as in the *Ville de Paris,* but of pear form, with the blunt ends pointing rearward and inflated like the rest of the hull. Apparently these tail bags were not economical of power, since, as is well known, a pear shape encounters greater resistance when moving sharp end forward than when moving blunt end forward. However this be, the stabilizing force proved very effective. The vessel was driven by a Clément-Bayard motor of 100 horse power actuating a wooden screw placed in front of the long car, as in the *France.* A speed of 30 miles an hour was attainable, and the ship could accommodate eight passengers. On one occasion it made a round trip from Sartrouville, traversing 125 miles at an average speed of 27 miles an hour. It was acquired by the Russian government on August 23, 1909, having on that day completed its third official test, and satisfied the requirement of rising 1,550 meters and voyaging two hours at a height of 1,200 meters. Two notable incidents of that voyage were that the air ship made a new record for altitude, and on landing was caught by a squall which tore it from the hands of thirty men, after which, owing to motor failure, it drifted freely across country, tripped on a willow, and fell into the Seine, whence it was rescued after considerable pains and labor.

Other vessels presently built by the Astra Society may be listed, together with their size in cubic meters, as follows: *Ville de Bordeaux,* 3,300 m^3;[1] *Ville de Nancy,* 3,300 m^3; *Colonel Renard,* 4,000 m^3; *España,* 4,000 m^3; *Clément-Bayard II,* 6,500 m^3; *Transaerienne I,* 6,500 m^3; *Flandre,* 6,500 m^3 (228,579 cubic feet). These were among the most noted air ships produced in France toward the close of the first decade of the twentieth century. On the whole they proved to be swift and stable ships adapted either for military use, or for exhibitions and sport, and even for regular transportation of passengers.

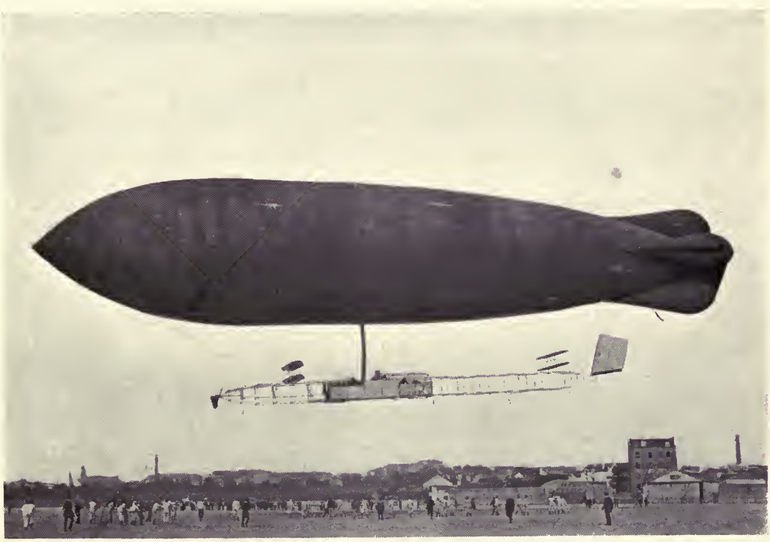
The *Ville de Nancy* was one of the conspicuous dirigibles of the summer of 1909. It was constructed primarily for use at the Exposition at Nancy, and was owned by the Compagnie Générale Transaerienne, an aërial passenger transportation

[1] m^3 signifies cubic meters. One cubic meter equals 35.3166 cubic feet.

PLATE IV.

LA VILLE DE PARIS.

Photo E. Levick, N. Y.



COLONEL RENARD.

Photo E. Levick, N. Y.

society organized at Paris, in March, 1909, with a capital of one million francs. This society planned to inaugurate an aërial line from Paris to Bordeaux, in 1910, equipped with other vessels of the Astra construction, more powerful than the *Ville de Nancy,* and capable of transporting a dozen passengers.

The *Ville de Nancy* was slightly smaller and slightly more powerful than the *Clément-Bayard I,* besides differing in minor details. It measured 55 meters in length, 10 meters in greatest diameter, and cubed 33,000 meters, as against the 35,000 meters of its predecessor. It was driven by a 100-horse-power Bayard-Clément motor actuating a Chauvière screw propeller at the front of the car. The car itself was made of steel tubes covered with fabric, and near the engine with sheet aluminum. The tail bags were an evident improvement on those of the previous air ships, being less blunt at the rear, and therefore less adapted to generate a retarding suction. They were still rather bulbous, however.

This splendid vessel made various interesting voyages during the summer of 1909, the first on June 27th, piloted by Surcouf and Kapferer, directors of the Astra Society. On July 14th, she maneuvered at Longchamps, side by side with the *République,* thus contrasting nicely with the ship designed by Julliot. It was the first time two dirigibles navigated together in regular maneuver. The *Ville de Nancy* was naturally the swifter, having greater power and less bulk than the other. About the middle of July she sailed from Sartrouville to Nancy, where she was to sail about the Exposition grounds and make daily excursions, carrying passengers for 100 francs per trip. These voyages proved very popular, being the first of their kind, and in themselves quite attractive. As the vessel was endowed with excellent stability and had manifested high speed, she was well suited to be the first regular passenger air ship, and the herald of the aërial liners projected to cruise between Paris and Bordeaux.

The *Colonel Renard* was closely patterned after the *Ville de Nancy,* but was larger and more powerful. She measured 212 feet in length, 140,000 cubic feet in volume and carried an engine of 120 horse power, driving a Chauvière propeller. On July 13th she made her first trip, cruising one hour with notable facility, then reëntered the hangar[1] of the Astra Society, at Beauval near Meaux. Thence, on August 23d, she sailed for Rheims to compete in the aëronautical races, arriving after a very successful cruise. On August 29th, she circled the ten kilometer rectangular course at Betheny, near Rheims, five times in 1 hour, 19 minutes, 40 seconds, thus winning the Prix des Aëronats,[2] of 10,000 francs offered for the vessel that should accomplish, in the least time, those five rounds, aggregating 50 kilometers. The showing was not remarkable, but the vessel could sail much faster in a straightaway voyage.

The prize-winning *Renard* was quickly followed by the *España,* a vessel of the same size and pattern, built for the Spanish government by the same capable firm. During October this fine air ship made several trial trips, carrying seven men. On November 2d she made a splendid official test voyage of five hours, sailing from the Astra aërodrome, at Beauval, to Paris and return, a distance of 250 kilometers in 5 hours and 10 minutes, or at the

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[1] Hangar, an airship harbor, or garage.

[2] Aëronat, an airship of the lighter-than-air kind.

average rate of 31 miles an hour for the entire course. On November 5th, she started on a ten-hour voyage, with five men and fuel for fifteen hours; but after five hours, stopped her engine, and came to earth, owing to the bending of the main shaft of the motor.

Besides the great auto balloons designed by Julliot and Surcouf, of which the *République* and *Colonel Renard* are examples, a number of convenient cruisers were brought forth in 1909 by the Zodiac Company. One of the leading spirits in this enterprise was the famous Count de la Vaulx, well known for his auto balloon designs and his long voyages in sphericles. The chief merit of these modest air ships, which ranged in volume from 25,000 cubic feet upwards, was cheapness and facility of demounting and shipment. They were intended to popularize the art among the masses, by giving everyone a chance to make a voyage at no great expense. Besides their applicability to sport, touring, and public uses, some were designed for considerable speed and endurance; which qualities, together with their demountability and partial independence of hangars, were expected to give them military value. They were of the flexible type, so arranged that the various parts were easily detachable, so as to be packed for transportation, by wagon or car. The smaller ones might be called semi-navigables, since they had the organs of a swift motor balloon, but, like the common sphericles, could easily be demounted and hauled home—a likely issue on a day of any considerable wind. The first one cost $5,000, cubed 25,000 feet and, with its 16-horse-power engine, traveled 13 miles per hour. Its hull had the form of a whale with docked and rounded tail. From this body hung an elongated car with a screw at the rear and elevating planes in front. Others of similar make, but larger, followed in rapid order, their common mission being that advocated by Santos-Dumont, in the early part

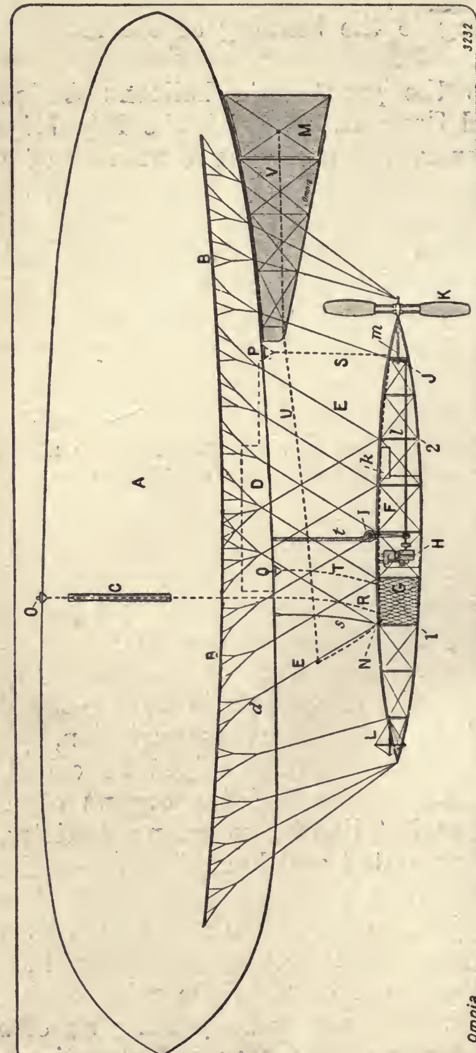
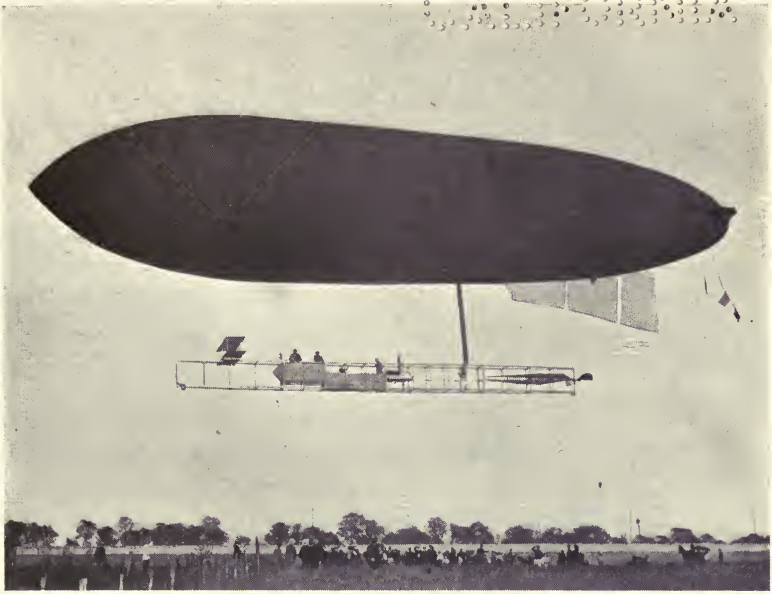
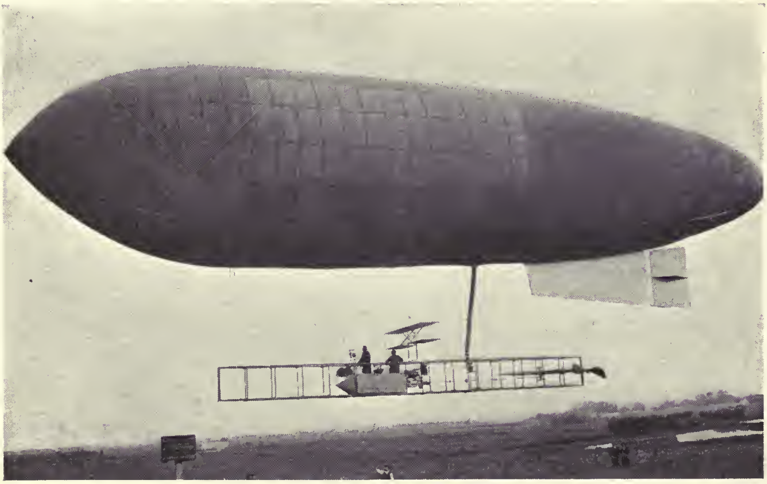


FIG. 22.—*Le Petit Journal*, ZODIAC TYPE.

PLATE V.



ZODIAC III.



ZODIAC IV.

of the decade, when he produced his *Runabout* and *Omnibus*—to give everybody a ride.

The *Zodiac I* was quickly followed by vessels *II* and *III,* cubing respectively 1,200 and 1,400 meters. The *No. II* had a speed of twenty, or more, miles per hour, and carried two passengers when inflated with coal gas, three with hydrogen. The *No. III,* of torpedo form, measured 133 feet long, 28 feet in major diameter, carried four persons, and sailed 25 miles an hour with her 40-horse-power Ballot engine. On August 29th, piloted by Count de la Vaulx, she competed with the *Colonel Renard,* at Rheims, for the *Prix des Aëronats,* making five rounds of the ten kilometer course in one hour and twenty-five minutes, this being at the average speed of 22 miles an hour. On October 30th, again piloted by the same renowned aëronaut, she sailed from Brussels to Anvers, rounded the lofty Cathedral spire, and returned to her aërodrome, traversing a distance of sixty kilometers in one hour and twelve minutes, or with an average speed of 31 miles an hour, a good showing for so small an air ship.

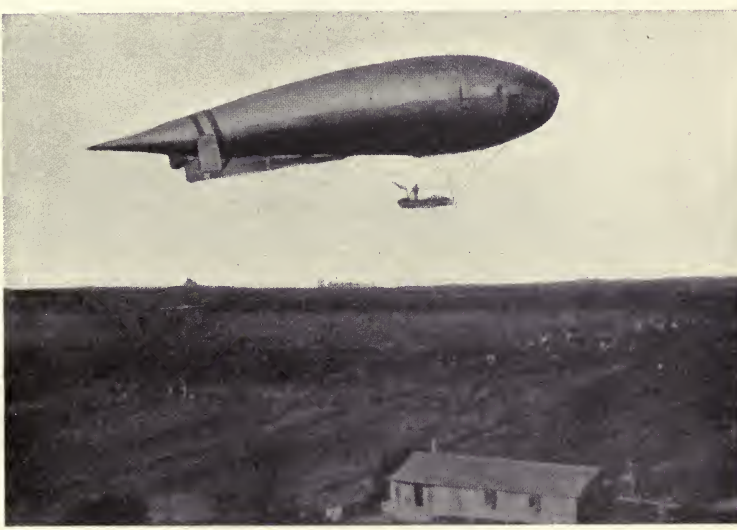
A very handsome dirigible, named the *Belgique,* was constructed early in 1909, by the skillful aëronautical engineer, Louis Godard, of Paris, in collaboration with the prominent Belgian engineer and sportsman, Robert Goldschmidt. It was a flexible balloon of elegant torpedo form, measuring 175 feet long, 30 feet in major diameter, and 106,000 cubic feet in volume. It was propelled by two 60-horse-power Vivinus engines actuating two screws, made of fabric stretched over radial sticks, and placed at either end of the spindle-shaped car. The control was provided for by ample keel surface, an elevating plane in front, and ingeniously designed fins on the rear of the hull to steady the motion. The entire structure showed much originality and skill. When the dirigible was tested near Brussels, on June 28th, it was piloted by Louis Godard, the famous expert in sphericals, accompanied by Goldschmidt. Godard's début in this capacity was reported as excellent.

The Italian government brought forth, in the summer of 1909, a swift and elegant auto balloon showing considerable originality of design. It has a porpoise-shaped hull of 2,500 cubic meters capacity, divided into seven compartments, so as to obviate the accident which wrecked the *République*. An ample keel along the rear bottom, and large aëroplane surfaces at the stern, serve to guide and steady the vessel. Propelled by twin screws well above a short car, she readily attained thirty miles an hour, carrying four persons. On October 31st, starting on her seventeenth voyage, she cruised from the aëronautic park, Vigna de Vale, near Rome, to Naples and back to Rome by ten o'clock at night, having sailed over the edge of the Mediterranean Sea and over the French squadron in the bay, remaining fourteen hours in the air and traversing 520 kilometers, or 323 miles. It was one of the finest voyages of the year. Further details of this Italian military dirigible *No. I bis,* together with illustrations, are given in *Aërophile* for January 15, 1910, together with its prototype the dirigible *No. I,* which maneuvered so successfully in 1908.

England and America all along had pursued an oriental, or semicivilized, policy toward the auto balloon, languidly watching the progress elsewhere, and hoping some time to enjoy the fruition, if not the glory, of the costly and successful experiments made in other countries. In 1909, however, the British government appropriated nearly $400,000 for aëronautics, and the United States House of Representatives voted $500,000, but promptly re-

PLATE VI.

LA BELGIQUE.



ITALIAN MILITARY DIRIGIBLE *NO. I BIS.*

versed its action, and gave nothing, though it may be said that even then there was a growing sentiment in favor of a more liberal policy. The movement to secure the beginning of an aërial fleet in England is summarized in the following paragraph.[1]

"The naval authorities were entrusted with the building of a rigid ship, whilst to the military department was delegated the work of building non-rigid and semi-rigid ships. A national air-ship fund was organized by the *Morning Post* with the object of purchasing a French Lebaudy semi-rigid dirigible which would be presented to the War Office; whilst Mr. Arthur du Cros and other members of the Parliamentary Aërial Committee arranged for a *Clément* non-rigid air ship of new design, to sail from Paris to London, and also to qualify for purchase as a unit of the British aërial fleet."

The non-rigid auto balloon ordered from Clément, and afterwards known as the *Clément-Bayard II,* was the masterpiece of that skilful designer, and occupied his best thought and energy for eighteen months, aided by his devoted and capable engineer, Sabathier. She was completed in the Clément-Bayard factory at Lamotte-Breuil in April, 1910, and during the next five months made thirty-two test ascensions and practice voyages. In particular she took a conspicuous part in the military maneuvers at Picardie during the early half of September, where with wonderful precision and airworthiness she made forced voyages in fair weather and foul, remaining, when so desired, in continuous communication with the land office by means of wireless telegraphy. Finally, on a fair day, September 16th, the tried and perfected vessel was brought forth from her hangar for the long contemplated voyage

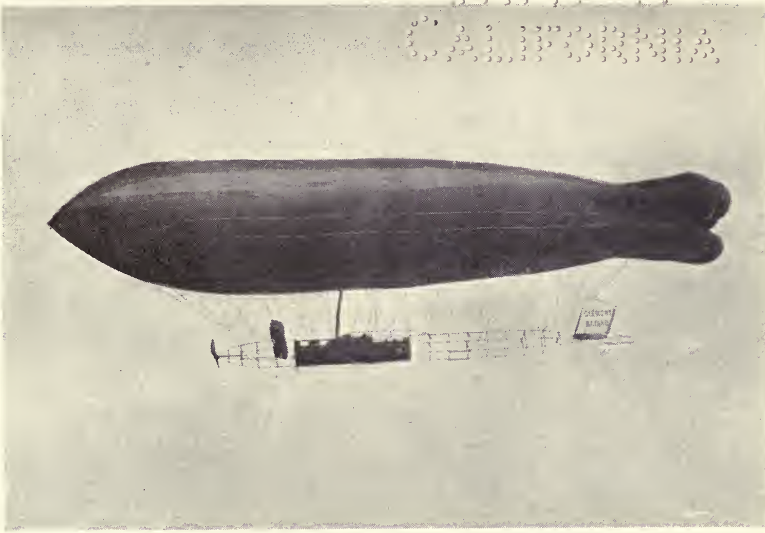
[1] Hearne, *Airships in Peace and War.*

to London, her machinery and rigging in trimmest order, and her car furnished with supplies for twenty hours, or thrice the anticipated time of transit.

The voyage was a glorious achievement for aëronautics, and for the enthusiastic constructor and his devoted aids. Starting at seven o'clock in the morning, with seven men aboard, including happy Clément, Sabathier, and an English delegate, the whale-like cruiser sailed directly to London with admirable regularity, covering the entire distance of 242 miles in six hours, or at the rate of forty miles an hour, which is better time than could be made by land and water. Enthusiastic cheers from the English spectators greeted the arrival of this French dirigible, built for the English government. Then quietly the English soldiers took the vessel in hand, as if performing a familiar duty, and housed her in the *Daily Mail* hangar, at Wormwood Scrubs. Thus simply and without unusual incident terminated the first motor-balloon cruise between the two countries, and one of the finest voyages in the history of aëronautics.

In outward appearance the *Clément-Bayard II* closely resembled her predecessor, except for the absence of empennage on her envelope. In the whalelike elegance of her hull she was, in fact, a reversion to the trim and efficient model of Renard's dirigible of 1884, which in turn was a fair copy of Jullien's model of 1850, all having excellent forms for speed and stability. But the new vessel was of greater size and power than her predecessor. Her net buoyancy was sufficient to carry twenty passengers. Her average speed tested in a round-trip voyage was about 50 kilometers or 31 miles per hour when her two motors developed 200 horse power, and 55 kilometers or 34 miles per hour when

PLATE VII.



CLÉMENT–BAYARD I.
(Courtesy E. L. Jones.)

CLÉMENT–BAYARD II.

Photo E. Levick, N. Y.

the engines developed their maximum effort of 260 horse power. The details of construction were so

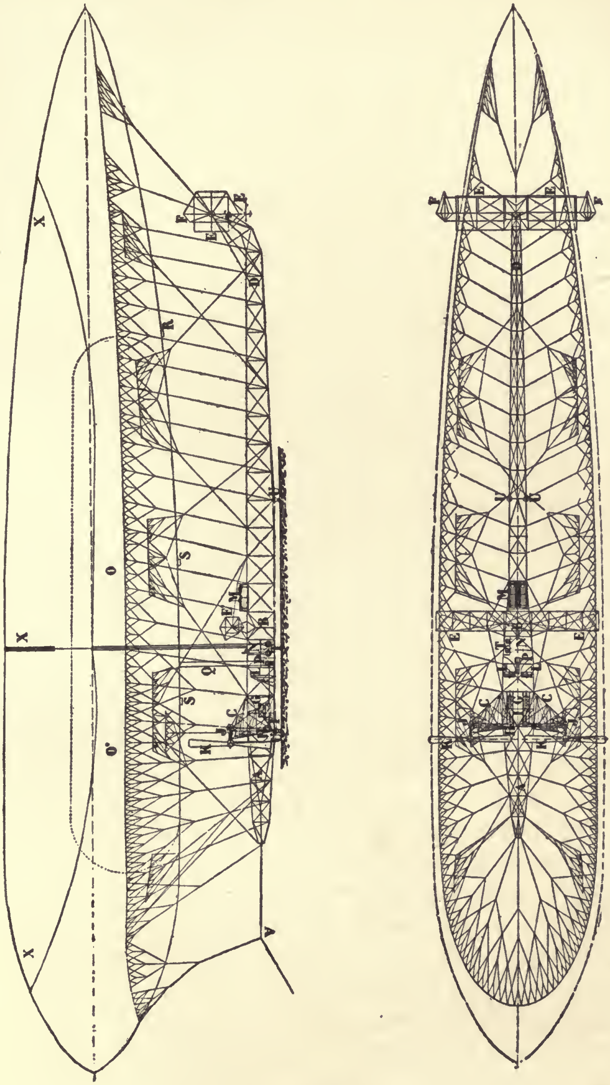


FIG. 23.—*Clément-Bayard II*, 1910.

elaborate and important, and so representative of the best aëronautical workmanship of the time that a full account of their chief features is presented in Appendix III. In passing it may be added that some time before sailing to England the *Clément-Bayard II,* because of her excellent workmanship and maneuvers, received the first prize at the review of dirigibles by the French Minister of War.

The dirigible to be purchased with the money secured by the popular subscription organized by the *Morning Post* was ordered from the Lebaudy factory at Moisson in July, 1909, to be delivered directly through the air to Farnborough before November 6, 1910. This stipulation was severe enough, but furthermore the vessel was to be a considerable departure from any thus far built at that famous factory, and was to be the largest air ship yet constructed in France. As usual the general design of the huge balloon was intrusted to the distinguished aëronautical engineer, Henri Julliot, and this was a certain guarantee of its successful operation.

The general features of this great military dirigible resemble those of her prototype, the *Patrie,* differing chiefly in the shape of her hull and the method of stiffening. The hull itself was more longish than the *Patrie's,* but had the same sharp prow and blunt stern; for a blunt stern offers better support to the empennage planes, though it increases the resistance more than a tapering stern. The trussed framing to stiffen the ship was no longer a platform inserted in the base of the hull, but a long trussed beam of cruciform cross section, made of steel tubing and suspended intermediately between the hull and car.

The hull was of excellent workmanship and bold design. The envelope was of rubberized tissue, measured 338 feet in length, 39.4 feet in diameter and cubed 353,000 feet. Its length was, therefore, 8.5 times its diameter, an extraordinary proportion for a balloon of the flexible type. The hull was pro-

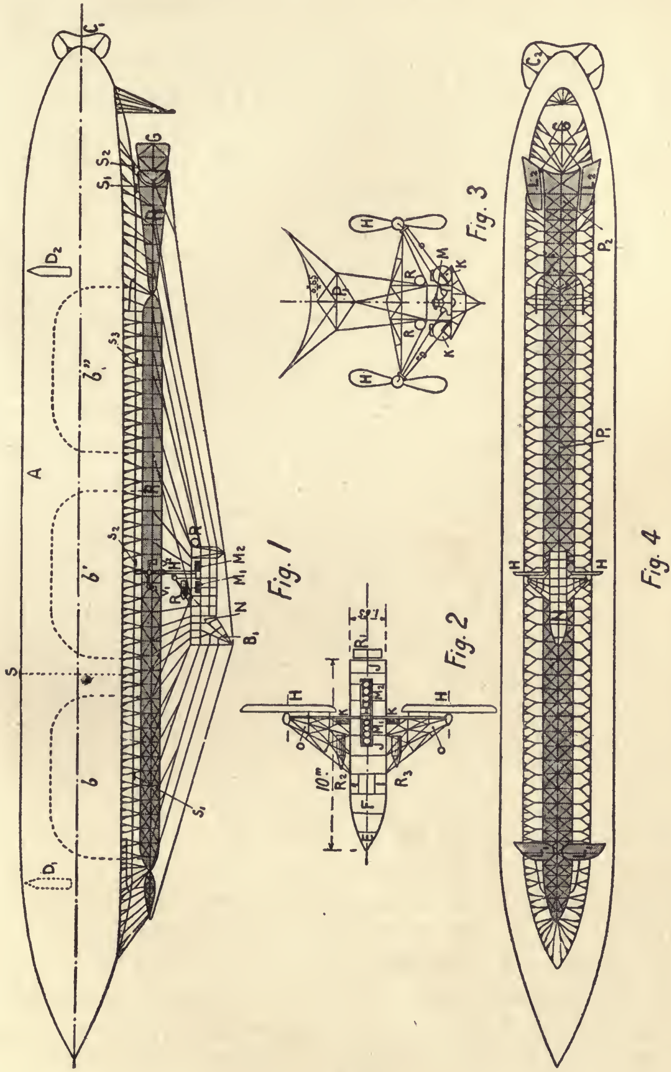


FIG. 24.—MORNING POST DIRIGIBLE, 1910.

vided with three ballonets, two ripping panels, and various valves, as shown in the scale drawing.

The car, made of steel tubing and large enough for twenty persons, carried two Panhard-Levassor motors of 135 horse power each, actuating two Chauvière wooden screws, sixteen feet in diameter, placed on either side, well outward and upward, the transmission gear permitting either engine, or both, to drive the screws at one time. Below the car and well forward was a ground keel, or post, on which the whole vessel could pivot with the wind, when riding at anchor, while a shorter ground post was placed at the rear of the car.

The controlling surfaces were adequate and skillfully arranged. To maintain steadiness and directness of flight, fixed empennage planes, both horizontal and vertical, were provided, some attached to the stern of the hull, others at the rear of the trussed suspension beam. To direct the up and down movement, ailerons placed well to the front and rear of the long framing, were turned about conjunctively in opposite directions, thus causing the vessel to raise or lower her bow. Needless to say, all these navigation appliances worked with ample force and effectiveness from the beginning of the earliest tests.

After four preliminary ascensions the great aïr ship started from Moisson to her destination at Farnborough, having on board Henri Julliot, Louis Capazza, the pilot, Alexander Bannerman, director of the aëronautic military school at Aldershot, and five other men. It was a triumphant and glorious voyage, one of the most splendid in the history of aërostation. Piloted by aid of chart and compass, and by signal fires and captive balloons arranged along her route, the vessel followed a direct course, without check or hindrance, crossing a wide part of the English Channel and arriving before the hangar at Aldershot, where the British soldiers awaited her, and where she was safely landed, having made the whole voyage of 230 miles in 5.5 hours, at a level

FIG. 25.—ROUTE OF BRITISH MILITARY DIRIGIBLES FROM FRANCE TO ENGLAND, 1910.

varying between five hundred and two thousand feet. As shown by the accompanying map, about one third of the route lay over the Channel, or, more accurately, 78 miles, which was traversed in two hours. Thus the whole journey was accomplished at an average speed of nearly forty-two miles an hour, or in less time than it could be effected in any other way than through the air.

The United States War Department, in 1908, started an aërial squadron by purchasing from Thomas S. Baldwin, for $10,000, a tiny air ship of the flexible type, a trifle larger than Santos-Dumont's *Runabout,* but in fact the smallest military dirigible then in existence. It had a rubberized gray silk cylindrical hull slightly tapering toward the rear and terminating in ogival ends, its length being 96 feet, its major diameter 19½ feet. From this was suspended, by means of netting and steel cables, a longish car having at the rear a double rudder working about a vertical hinge, at the front an elevating plane and an 11-foot wooden screw driven by a Curtiss 20-horse-power water-cooled engine. With two men aboard, this vessel readily attained over twenty miles an hour in a straightaway course, and at times more nearly thirty miles an hour. Its total ascensional force was 1,350 pounds, of which 500 were available for men, ballast and supplies.

Santos-Dumont's most strenuous disciples outside of France were found among the German military officers. These advocated and promoted both the semirigid and the flexible types of auto balloon, with such ability as to match the best productions of the foremost French designers. The most successful pioneers of these two types in Germany were respectively, Major von Gross, commander of the balloon battalion at Tegel, near Berlin, and Major Von Parseval of the Bavarian army, and director of the Society for the Study of Motor Air Ships.

Beginning in 1907, a number of Gross auto balloons were built in succession, for the German Aëronautical Battalion, by Master Engineer Basenach, under the supervision of its commander, Major Gross. The first was intended only as a model,

PLATE VIII.

U. S. SIGNAL CORPS DIRIGIBLE I.
(Courtesy U. S. Signal Corps.)

GROSS II.
(Courtesy E. L. Jones.)

though it was large enough for two passengers. It cubed 63,000 feet, but having an engine of hardly more than 20 horse power, was necessarily slow. It was succeeded by the *Gross I,* and others, all having rigid ventral parts, like the *Patrie,* but with hulls of rather better form for speed and bulk combined, having blunter bow and longer stern.

The second Gross air ship, built in 1908, cubed 176,000 feet, and attained a speed of 27 miles per hour, driven by two 75-horse-power Daimler motors. On September 11th of that year, with four persons aboard, she made a round trip from Berlin lasting 13 hours, covering 176 miles, and attaining altitudes up to 4,000 feet. This was one of the finest voyages known at the time. This air ship was purchased by the German government, named *Gross I,* and sent to Metz. A detailed description is given in Appendix III.

The *Gross II,* brought forth in April, 1909, resembled her predecessor in build, but had greater power and speed. Her hull cubed 176,000 cubic feet, had a blunt bow, full body and sharp stern, was provided with horizontal and vertical keels, a sliding weight, and a ballonet at either end. She was propelled by two Körting engines of 75 horse power each, actuating two three-blade propellers. Under the action of her keels and stabilizing planes and rudder, her motion was steady and precise. A special feature of this air ship was the wireless telegraph equipment by which she could send messages in all directions over a range of 300 miles or more. She made many practice voyages during the season of 1909, sometimes alone, again in concert with other auto balloons and with troops. In August she made a fine voyage of sixteen hours, from Tegel to Apolda and return, traversing 470 kilometers.

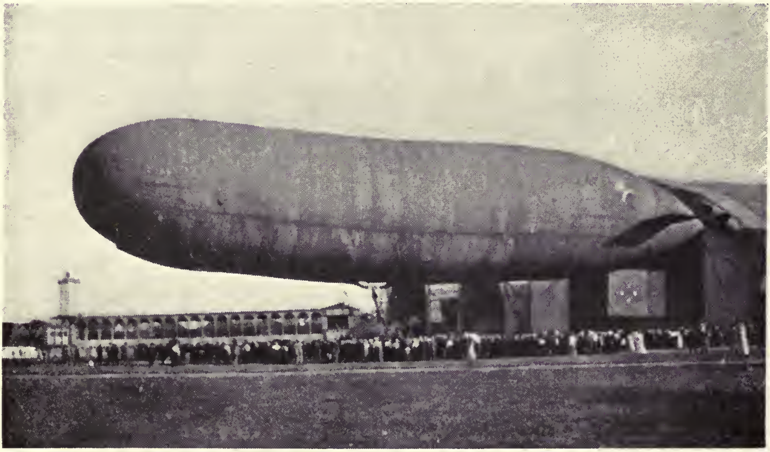
The above described vessel was followed by others, large and small. The *Gross III* measured 70 meters long, cubed 7,500 meters, and was propelled by four Körting motors aggregating 300 horse power. This was a splendid vessel, and one of extraordinary speed.

Various auto balloons of the Parseval type were designed by Major Von Parseval of the Bavarian army, who also was one of the inventors of the kite balloon. Satisfactory experiments with his air ship were made as early as 1906. These formed the basis of larger vessels, subsequently constructed in the same factory of August Riedinger of Augsburg, for the Motor Air Ship Study Society, of which Parseval was general manager. This society, organized practically at the command of the Emperor, purchased the Parseval patents and began the development of auto balloons as a business enterprise, soon furnishing a series of its flexible air ships to the German army.

After the experiments of 1906, the Parseval air ship was enlarged from 2,500 to 2,800 cubic meters, its length becoming 52 meters and its major diameter 8.7 meters. Its hull was of cylindric form, with rounded bow and egg-shaped stern; had two air bags—one fore, the other aft—and at the stern carried two fixed horizontal planes and a vertical rudder. From this envelope the car, made largely of aluminum, was hung by steel cables, and on its bottom had trolley wheels resting on suspension cables joining the front and rear parts of the hull. The vessel was propelled by a 50-horse-power Mercedes motor actuating a four-blade screw propeller 13 feet in diameter, mounted between the car and hull. This screw was made of thin steel tubes covered with shirting. Among the merits of Parseval's air ship may be mentioned its lightness and demountability, and its kite-like effect on the air, got by canting the

PLATE IX.

PARSEVAL I.
(Courtesy W. J. Hammer.)



PARSEVAL II.
(Courtesy E. L. Jones.)

hull while the car, rolling on the suspension cables, allowed the screw mounted above it to thrust horizontally. The canting was effected by giving one ballonet more air than the other, thus causing its end of the hull to sink. The speed was about twenty-five miles per hour.

The second *Parseval* was of greater bulk and power than her predecessor. Her hull which was of cylindric form, with round prow and pointed stern, measured 190 feet long, 30.5 feet in diameter, and 113,000 cubic feet in volume. She resembled her predecessor in the arrangement of the two ballonets, and in the "loose," or trolley, system of suspension of the car. The propeller was a unique patented device of Von Parseval's. It had four cloth blades so weighted with lead as to stand out firmly under centrifugal force, assuming an effective shape for propulsion, though limp and deformed when at rest. Various interesting evolutions were performed by this vessel in the autumn of 1908, including tests imposed by the military authorities, as a condition of purchase by the government, one requirement being a voyage of one hour at an altitude of 1,500 meters; another requirement being a continuous cruise of twelve hours. These tests completed, the Motor-Luftschiff-Studien-Gesellschaft sold its proud ship to the Vaterland for 210,000 marks.

About the same time the War Department purchased the *Gross I,* already described, and Zeppelin's third great ship, naming it *Zeppelin I.* Germany thus began her program of developing a great aërial fleet, by acquiring three powerful and well tried ships, each capable of remaining all day in the air, and having a radius of action of several hundred miles. They were frequently called upon to make test voyages in all kinds of weather, to maneuver with the troops, to pass in review before the Emperor, at times conveying prominent officers and members of the noblest families, including Prince Henry and the Crown Prince, who manifested a fondness for navigating about their newly opened empire of the sky. But sometimes the tests were crucial. On September 11, 1908, both the *Gross* and *Parseval* were summoned to Potsdam by His Majesty. They set forth from their sheds, at Tegel, in face of a strong wind. After journeying some distance they each had to abandon the voyage, the *Gross* returning home, and the *Parseval* falling to the ground owing to an accident.

The third Parseval air ship was brought forth on February 18, 1909, by the Luftfahrzeug-Gesellschaft, an aëronautical firm founded by merging the Motor-Luftschiff-Studien-Gesellschaft with the A. E. G. This vessel closely resembled her predecessor, but possessed greater size, power, and perfection of detail. Her hull at first measured 224 feet long, 47 feet in diameter, and 198,000 cubic feet in volume, but later was enlarged to 235,000 cubic feet by increasing its diameter.

Her car, which could accommodate twelve passengers, was framed of steel tubing covered with canvas, and was divided into two parts, separated by the big gasoline cylinder running athwart ship, the passenger cabin being to the fore, the engine room aft. Here were stationed the two engines, of 120 horse power each, actuating reversible right and left *Parseval* screws 13 feet in diameter, located to the rear, well aloft and outward on either side. In the forepart of the passenger cabin was space for the pilot and his navigating appliances; his chart desk, his valve controls, his statoscope, manometers, etc.

The great ship with her nine tons burden was to have sailed from Bitterfeld to Frankfort, for the Aëronautical Exposition, but owing to excessive gales, she was sent by rail. Once there, she made many excursions, at times carrying passengers at a schedule rate, reported to be 200 marks for a voyage of one to two hours. In October she made an inter-city excursion covering a distance of nearly 500 miles, during which she passed four nights in the open air, finally returning in good form to Frankfort. On October 27th she made a farewell tour about Frankfort, then voyaged along the Main and down the Rhine valley to Cologne, there to participate in the aëronautic military maneuvers, together with the *Parseval I,* the *Gross II* and the *Zeppelin II.* Having passed creditably through these and other operations in the autumn, she was eventually stationed at Tegel, as a part of the national fleet.

The fourth *Parseval,* a smaller vessel, was built for the Deutscher Aëro Club early in 1909. Her hull cubed 113,000 feet, and her framing was made of the strongest materials, carefully hollowed, to eliminate undue weight. At the rear of the car, on either side, were two 100-horse engines, driving two *Parseval* propellers at a common speed, whether both engines were in operation, or only one. In many respects she resembled her immediate predecessors, and her little successor *Parseval V* of 1,200 cubic meters capacity and 30 meters length, built for the Imperial Automobile Club.

The maneuvers at Cologne constituted the first grand demonstration of the new fleet of military dirigibles, and proved a severe test of the powers of the air ships, even when manned by experienced crews and commanded by regular military officers. Two companies of the balloon corps battalion were in attendance. Large provisions of hydrogen loaded on wagons, each carrying 100,000 cubic feet, were kept in readiness to be attached to an express train and rushed at the first alarm to any balloon in need of replenishing. On Sunday, October 31, three of the dirigibles representing each type, *Zeppelin IV, Parseval I, Gross II,* left Cologne together, by official order, and returned after flights of 7, 10 and 11 hours respectively, covering in the aggregate 930 miles. Again, leaving Cologne shortly before noon on November 3d, they went down the Rhine, simulated a concerted attack on the great fortress of Eherenbreitstein, and returned in the evening, each having covered 155 miles. And so on for many days they continued to execute maneuvers under military orders and in severe forced marches.

CHAPTER VI

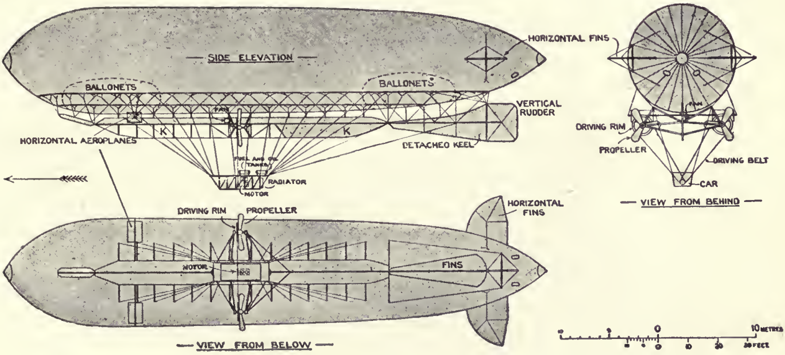
DEVELOPMENT OF RIGID DIRIGIBLES

Count Ferdinand von Zeppelin, the famous cavalry general of Würtemburg, and hero of the Franco-Prussian war, after retiring from the army, organized, in 1898, a limited liability company for the purpose of developing a new type of dirigible which he had long contemplated. It was to be a vessel far larger and swifter than any the world had yet seen. In the summer of 1900, after two years of industrious experimental research and active construction, he brought forth from his floating laboratory on Lake Constance, near Manzell, the first of those wonderful air ships which have aroused such expectation and enthusiasm in Germany. In outward appearance and in its chief features of design it typified the whole series of motor balloons thus far developed and navigated by that illustrious inventor. Many valuable improvements were added, as a result of trial and the advance of the collateral sciences; but the fundamental plans seem to have proved as practical as they were bold and original. One by one were surmounted the greatest obstacles, physical, financial and finally political; for the Prussian Ministry did not favor his project at first, and many aëronautical adepts were adverse to it. Those huge ships faced the fury of many a tempest; their dauntless builder endured the storm of hostile criticism; but in the end, builder and ships alike won the plaudits of a proud empire and of an astonished world.

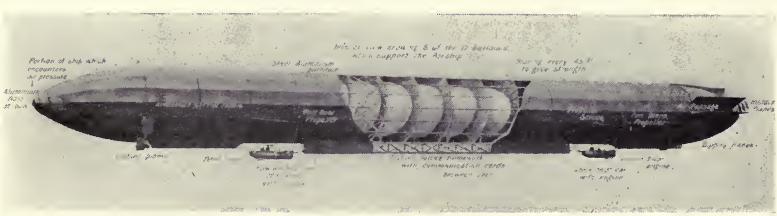
Outwardly a Zeppelin balloon may be described as a long cylinder with ogival ends and a V-shaped keel running the length of its bottom. From afar the cylinder and pointed ends appear circular in cross section, but they are sixteen-sided. About one-third the distance from either end of the great ship a small boat is suspended from the hull so closely that at those places the keel is omitted to make room. These two boats are rigidly connected with the hull and support it when the vessel rests on, or is towed along the water. Within them are the crew and petroleum engines, while above them and outward on each side of the hull, and fastened to it by outriggers, are two pairs of screw propellers, so placed as to exert their united thrust along the line of resistance. In some cases the crew can walk through the V-shaped keel from one boat to another, the passageway being illuminated here and there, by transparent covering, or windows of celluloid, along the sides and floor. Again an observer may climb up through the hull and take observations of the sky from above. Telephones, electric bells, and speaking tubes serve to transmit intelligence from one part of the vessel to another.

The frame of the hull is formed of sixteen longitudinal beams, or girders, of trellised metal work running from prow to stern and riveted at regular intervals to cross bridges of similar trellised metal work, each cross bridge being a sixteen-sided wheel with trellised rims strengthened by radial rods running inward to a central flange of sheet aluminum. Thus the body of the vessel is divided into many compartments, each bounded by two wheels, and the surrounding longitudinal beams. Each compartment contains a hydrogen balloon, or sac, which

PLATE X.



GROSS III.



ZEPPELIN AIRSHIP STRUCTURE.

fairly fills it and exerts a lift against the longitudinal beams and against a netting formed of ramie cords stretched from wheel to wheel, diagonally between beams at their inner corners. Similarly the outward corners of the beams are joined by strong diagonal wires for the purpose of rigidity, and the whole external frame is covered with a heavy fabric which forms the outer skin, or wall of the hull. Between this skin and the hydrogen bags are air spaces, as also between bag and bag. Thus the whole vessel is buoyed up by numerous thin hydrogen sacs, protected by the frame and outer skin from the direct sun, from foul weather, and from external shocks. The gas bags are also separated from each other by the bridge work and flanges of aluminum.

Obviously there is a material advantage in having many gas cells and two propelling plants; for if one fails it may not prevent navigation. The tandem arrangement of bags separated by the wheel-like cross bridges also allows the balloon to rear any amount without material displacement of the gas, or dangerous increase of pressure; for it must be remembered that a single hydrogen sac extending the full length of an up-ended balloon of such length, would have an outward pressure of about thirty pounds per square foot greater at the top than at the bottom. The poise of the vessel is maintained by shifting weights, and also by use of fins, or rudders, when driving through the air; but those arrangements vary in the different machines. So much for the general features of these wonderful ships, of which four were built during the decade from 1898 to 1908, and several more since that period.

The construction and trial of Count Zeppelin's first air ship proved a formidable task, requiring all his resources of money and mechanical skill. As it rivaled in size and fluid displacement a large ocean liner, it could not well be launched and landed, except on the water. It was therefore housed in a wooden shed 472 feet long, floating on 95 pontoons, and so anchored as to swing freely with the wind and assume its direction. This shed, as well as the ship, was very costly, and in an unfortunate hour was torn from its moorings by a tempest, which did other damage entailing great expense and time for repairs. The inventor's resources were becoming strained; for, as reported, the shed cost $50,000, while the first balloon cost more than twice that sum.

Finally, the first launching was officially set for June 30, 1900. The lake was thronged with people massed along the shores, and dotting its surface with every kind of craft, from the fisherman's primitive boat to the handsomest private yacht, or launch. All day the expectant multitude waited, only to learn at dusk, that the inflation was not completed. Next day they tarried again till evening, and merely saw the raft on which the balloon rested, towed out of the floating house. On the third day, July 2d, those who waited were rewarded with an interesting spectacle. The long stiff air ship was drawn forth from its shed, like a ram rod from a gun. Count Zeppelin, with two men, occupied the front boat, while two others took the rear one. After careful adjustment the vessel was liberated, at eight o'clock, rose slowly and advanced over the water, accompanied by the droning of its propellers and the shouts of the delighted spectators, who realized that they might be witnessing the commencement of a new epoch in aërial navigation. But the voyage was not an unqualified success. The controlling mechanism became deranged, the framework was bent, and the propellers could not be worked properly. A gentle wind was blowing and the vessel drifted with it, having an independent speed of only thirteen feet per second, at best. At eight-twenty she reached Immenstadt and landed on the water, having voyaged three and one half miles, and having attained a height of thirteen hundred feet on a part of the journey.

At that date the *Zeppelin I* was by far the largest and most elaborate air ship ever constructed. Her hull measured 416 feet long, 38 feet across, cubed nearly 400,000 feet, weighed 9 tons, and had a displacement of 10 tons. The trellised frame was made of aluminum, and its body comprised seventeen compartments, of which fifteen were 26 feet long, and the other two 13 feet long. The outer cover was of linen treated with pegamoid and tightly stretched. The hydrogen sacs were of thin fabric. The propulsion was effected by two benzine motors, one in either boat, which together developed 32 horse power, each driving, by means of bevel gears and shafting, a pair of four-blade propellers 3.77 feet in diameter, at 1,100 revolutions per minute. Steering sidewise was effected by means of vertical rudders, while the trim was controlled by horizontal rudders at either side of the vessel, as also by means of a sliding weight which could be drawn fore and aft by means of a winch. Naturally some of these details were superseded ere long by better devices suggested by subsequent experience.

On October 17, 1900, *Zeppelin I* made her second voyage, and with much better result. Starting from the same balloon house at Manzell, at four-forty-five, she promptly rose a thousand feet, and maneuvered in a seven-mile wind, steering in great curves at the will of the pilot. At times the speed was nearly twenty miles an hour, as determined by continuous observations of the balloon's position, taken from three points of a triangle, together with the velocity of the wind on its course, duly recorded by an anemometer. Finally a landing on the water was made at six o'clock, without mishap.

This last demonstration left the Count triumphant in other respects, but without sufficient funds to bring his invention into practical use. He must, therefore, look for additional money for the proper continuation of his great work. The financial task thus ensuing occupied much of his time during the next five years, but he finally secured capital enough to continue his experiments and to build a second air ship. This was completed and ready for trial in the latter part of 1905.

Zeppelin II resembled its predecessor in appearance, but embodied many improvements suggested by the former trials. Its hull was 414 feet long, 38 feet in diameter, held 367,000 cubic feet of hydrogen in its sixteen gas bags, and weighed with all appliances and cargo, about nine tons. It was, therefore, about ten per cent smaller than its predecessor; but at the same time it was far better powered than the earlier one, and more effectively controlled. Each boat carried an 85-horse-power Daimler benzine motor, actuating two enlarged propellers. Ample steering surfaces, operated by the helmsman in the front boat, served to turn the great ship about either of three axes and, at the same time, to displace her bodily up and down in the air, either by direct lift or by canting her hull so that her screw thrust and the pressure on her sides would produce the desired translation.

Two trials of Zeppelin's second air ship were made on the Borden-See, one on November 30, 1906, the other on January 17, 1907; but both met with serious accident. In the first trial the balloon was towed by a motor boat some distance, then cut loose in the wind, which was carrying it forward faster than the boat. But it soon became unmanageable and plunged into the water, suffering considerable damage. In the second trial it flew for a short time at a speed of thirty feet per second, when the engines were developing 36 horse power. Some maneuvering was effected in a strong wind, but presently the propellers stopped, the vessel dropped to the shore and was anchored on the ground. During the night it was so badly damaged by the wind that Count Zeppelin ordered it to be taken to pieces to furnish material for further construction.

The loss of two mammoth air ships after such brief trial seemed enough to appall even a sturdy general of the Prussian army; but Count Zeppelin was too resolute to waste time in futile tears and hopeless dejection. Strong natures are usually stimulated by disaster, and aroused to fuller energy, to grimmer determination, if not to desperate hazard. However, not desperation, but buoyant hope and high expectation, based on ample experience, were now his ruling motive. Had not his ship attained thirty feet per second with less than one fourth her motive power? The year began with disaster indeed, but he intended it to terminate in glorious victory. And such, indeed, was the happy issue.

October, 1907, witnessed the launching of *Zeppelin III*. She had the same length as her immediate predecessor, but she was a luckier vessel and better powered. On her official trial she voyaged at the height of half a mile, carrying eleven persons sixty-seven miles in two hours and seventeen minutes, or at more than twenty-nine miles per hour. This was a record velocity exceeding that of the best military balloon in France. At times she attained a velocity of fifty feet per second, thus considerably outspeeding the swiftest ocean liner. Moreover, her stability and steering qualities were excellent. With pardonable elation, therefore, the illustrious inventor could report to the Minister of War the complete success of his experiments. And with good reason the German government now granted financial aid to test more fully the merits of the rigid system of construction.

With this assistance the industrious aëronaut erected a new floating house on the Borden-See at Friedrichshafen, and began the construction of a still larger air ship embodying further improvements in various details. *Zeppelin IV* was 446 feet long, 42.5 in diameter, held 460,000 cubic feet of hydrogen in her sixteen compartments, and had a total buoyancy of sixteen tons. She had a surplus buoyancy of over two tons, carried a crew of 18 men, and had an estimated range of action of eighteen hundred miles. When drawn from her shed in the autumn of 1907, her great buoyant hull resting lightly on the water supported by her two floating cars, she had all the appearance of a royal passenger express ready for important service. In general features the vessel was like her three predecessors, but in the center of the keel, with transparent floors and windowed sides, was a special stateroom designed for passengers only. This seemed very suggestive, if not prophetic, of the future trend of aërial navigation. Moreover, the mechanism of propulsion and control were increased in power and effectiveness. In each boat-like car was a 110-horse-power Daimler benzine engine, actuating a pair of three-blade propellers about 15 feet in diameter. A large vertical rudder, mounted on the extreme end of the stern, and supplemented by a pair of smaller vertical rudders at either side of the stern, served to steer the vessel right and left. For steering up and down, as also for exerting a direct lift up or down, four superposed planes like a Venetian blind were placed at either side of the hull fore and aft, at about the same level as the propellers. In addition the hull was provided, like a feathered arrow, with fixed fin-like planes at the stern, both vertical and horizontal, for securing steadiness of flight.

Several trials of this leviathan were made preliminary to her official government test which, if satisfactory, assured her purchase by the German government for $500,000. At the builder's suggestion this test should include a voyage of 24 hours duration, a safe descent on land or water, an ascent to 4,000 feet, and the fulfillment of various secret requirements. In the autumn of 1907 a successful voyage of eight hours was easily accomplished. In the early part of the next summer, 1908, a series of voyages were made which aroused intense interest throughout the civilized world. On June 13th the great ship, starting from her harbor at Friedrichshafen, sailed over the Alps to Lucerne, steering in among the mountains; here buffeted by eddies, and cross currents, there stemming such stiff head winds that her shadow could hardly creep forward over the ground, again driving through a dark lowering hailstorm which pelted with ominous thunder on her resounding hull; but at length reaching Lucerne safely, then returning in triumph to her harbor at Friedrichshafen. For twelve hours the stanch vessel endured the elements, by no means hospitable, and in that period voyaged 270 miles at an average speed of 22 miles an hour. It was a record journey and a triumph in the art.

The following picturesque account of a flight in Count von Zeppelin's gigantic air ship, written by Emil Sandt, appeared in the *Scientific American Supplement* of August 15, 1908:

"Early in the morning Professor Hergesell, Freiherr von Bassus, Dr. Stalberg, Herr Uhland, and myself set out in Count Zeppelin's launch for the shed in which the great air ship is housed. When we arrived everything was in readiness for us. Count Zeppelin is proud of the fact that his colossal craft can be drawn in and out of the shed with very little help. In seven minutes the huge gas bag had emerged, and a few minutes later we were floating up to the sky. I took my station in the central car or cabin, a comfortable room flooded with the yellow light that filters through the translucent balloon fabric of which the walls, the floor and the ceiling are constituted. Comfortable seats suspended from fine chains provide a seating capacity for a dozen passengers.

"For a great portion of their length the walls are provided with celluloid panes. The floor is also transparent wherever it is not used as a footway. Seated comfortably in the central car, I could look down through my knees and see the green earth, water, people, cities and castles far below. I could also see birds circling around and fluttering anxiously, evidently frightened by the strange giant of the air.

"We crossed over to the Ueberlinger See, traversed the intermediate neck of land, and turned into the valley of the Rhine at Konstanz. Here I left the central car and walked toward the rear car along the keelway, which is flanked with balloon cloth, and which is closed at the end of the keelway by a celluloid door. I opened the door and stepped out on the narrow aluminum gangway, which runs down sharply to the rear car. The gangway has no protecting handrail. It is merely ribbed to give a better foothold. That apparently flimsy structure bridges a chasm of twenty feet between the end of the keelway and the car. From below, the passage from the keelway and the car must seem perilous indeed, but up in the air ship itself no fear is felt. I stood on this narrow bridge and gazed on the landscape. To the north I could see the Hohendtwiel. Behind us lay the Swabian See glistening in the morning's sun. In the southeast I saw Thurgau wrapped in violet light. On the horizon the lofty peak of the Saentis rose broad and jagged, capped with ice and snow. Below us writhed the Rhine. I looked across at the propellers. Count von Zeppelin had signaled full speed ahead. The giant air ship trembled. The propellers seemed like disks, revolving with furious speed and yet as transparent as a locust's wings. They gave out a note like that of a deep organ, so loud that the human voice, even when lifted to a shriek, could hardly be heard.

"I walked down to the rear car to obtain a better view. Here the gigantic craft could be seen in a wonderful perspective. The sensation was strange. The giant ship obediently sank and rose. Obediently moved to the right or to the left, slavishly following the slightest pressure of the human hand. Sometimes its angle was such that the entire fabric seemed inclined like a kite. At times the forward car lay below us; at times we had to look up at it.

"As we neared the splendid falls of the Rhine at Schaffhausen, the Count brought the air ship down, in order to ascertain whether the eddies occasioned by the waterfall would have any effect.

"We turned into the Reusstal, but were buffeted by the wind all the way up the valley. To the south the sharp jutting peak of Mount Pilatus hove in sight. Soon Lucerne appeared, a jewel among cities. The lake itself shimmered brightly where it was struck by the sun; its darker portions lay like an emerald, held in a setting of heliotrope. It was like a melody in colors. Below us in Lucerne itself there was a hubbub and a great jubilation. The streets were crowded with gayly clad people. The roads were a-swarm. Zeppelin guided his air ship down, and allowed it to glide full speed over the city at the height of a church steeple.

"We traveled over the Vierwaldstaetter See, and crossed to Knessnacht, to Zug Lake, and up northward to Zug itself. Then came the most difficult task which Professor Hergesell had assigned to the air ship. The craft was to carry us straight across to Lake Zurich, through a narrow pass where it would be caught in a veritable cyclone. The motors groaned and rattled. The propellers howled a deep groaning song. The air ship did all that it could. The wind was dead against us, traveling with a velocity of nearly thirty-one miles an hour. The Count could easily have arisen and escaped the fury of the blast, but it was his purpose not to avoid obstacles, but to court them. Whenever the great air ship showed signs of swerving, it was brought back to its course. Far below us in the valley the sharply marked shadow of the air ship, crawling slowly from tree to tree, showed us how hard it was struggling. There were minutes when it seemed as if we stood stock still, despite the infernal music of the propellers. Gradually the nose of the craft was thrust forward; once more the air ship mastered the winds. We had forced our way through the pass, and were dashing on at full speed. The vast shadow below us traveled with the velocity of a bird over the mountain, valleys, cliffs and rocky points, over railway embankments and road, over water and land."

Two attempts were made in July, 1908, to complete the government test; but they proved abortive, and in the second one the hull was damaged by the wind pushing it sidewise against the shed, as it was being towed out by motor boat. This accident caused a delay of two weeks, much to the disappointment of the expectant populace. As a consequence Zeppelin resolved to begin the next attempt unheralded. He had the repairs made quickly and all was ready early in August.

On Tuesday, August 4th, at six forty-five in the morning, the great twenty-four hour test for the government began, without previous announcement, but with fairest prospect of success. Sailing from Friedrichshafen, Zeppelin purposed to follow the Rhine as far down as Mayence, then return in a direct line to his starting point. All went splendidly at first. He passed Constance at seven o'clock in the morning, Basle at nine-thirty, Strassburg about noon, then with slower speed passed Mannheim at two-fifty and Darmstadt at four-thirty. At about six o'clock a descent was made at Oppenheim, eleven and a quarter hours after starting. The air ship had voyaged 270 miles at the average speed of 22 miles an hour. A wonderful demonstration it was for the inhabitants of that historic valley, and a glorious tour for the brave old sailor and his crew. Resuming the voyage, Mayence, the turning point, was reached at eleven o'clock at night, and the vessel was headed for home. But now the engines, being overworked, could not maintain the usual speed, which therefore was lowered to twelve miles an hour. Next morning at eight o'clock, after Stuttgart had been passed, a descent had to be made at the village of Echterdingen, to adjust and overhaul the machinery. Ninety-five miles of the return had been made in nine hours.

It was most unfortunate that a landing had to be made without a harbor, particularly as a gale was in pursuit of the vessel. Ere long she was torn from her moorings by a squall, carried into the air, and set on fire, probably by an electric discharge. Immediately the great hull was enveloped in flame and completely destroyed, leaving a tangled network of distorted framing. It was a dismal termination to the greatest motor balloon voyage in the world's history up to that date; for the vessel had been in the air continuously for twenty and three-fourths hours and had traveled 378 miles.

The hardy and venerable hero of so many voyages and long continued experiments quite broke down at the sight of his grandest vessel in ruin. But an unlooked for and a sudden turn of events brought him the greatest triumph in his darkest hour. While the world expressed its grief and sympathy his loyal countrymen hastened to his relief in an admirable burst of enthusiasm. Within twenty-four hours the government had made him a grant of $125,000, and subscriptions offered in all parts of Germany brought the sum to over $500,000. By October, 1908, the total gift amounted to $1,500,000, which was paid to the Zeppelin Air Ship Company, formed for developing and building air ships on a large scale. A tract of 300 acres was secured at Friedrichshafen for an air ship factory. Here was erected the necessary shops, hydrogen plant, balloon harbor, and everything necessary to enable the compainy to construct several mammoth air ships each year. To these new grounds the Count's former interests were gradually conveyed, while his old station, with its air ship dock on Lake Constance, was converted into a military post by the German government.

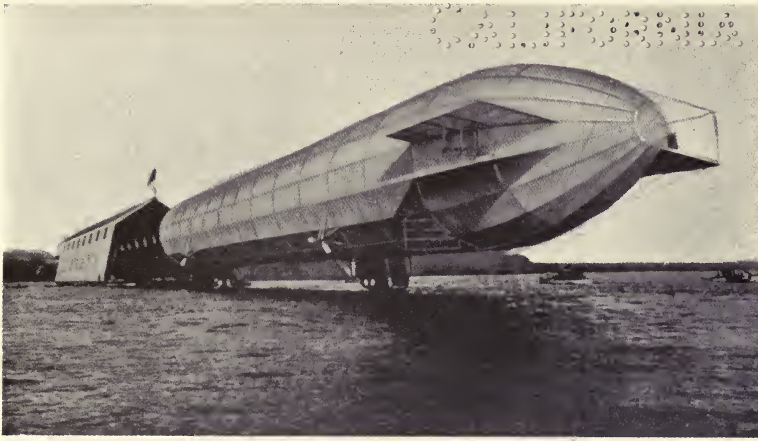
After the destruction of *Zeppelin IV*, its predecessor, the Count's third air ship, was again prepared for service and for new triumphs. Her hull was lengthened by the addition of a cylindrical section having the length of one compartment, or about 26 feet. This alteration gave a considerable increase of net buoyancy with but slight increase of resistance. The dimensions now were: length 446 feet, diameter 38 feet, volume 423,768 cubic feet. The gas was contained in sixteen sacs, twelve in the cylindrical part and two at each end. The ship was propelled by two 85-horse-power engines, supplied with sufficient gasoline for a forty-one hour voyage at 25 miles per hour. The loss of gas by leakage was less by weight than the loss of fuel. The famous old cruiser, thus remodeled, was operated in the autumn of 1908 with her usual precision and grace; thus winning new distinction and renown. On one occasion she had as passengers the Crown Prince and the Kaiser's brother, Prince Henry. The Emperor himself witnessed the demonstration, and decorated the Count, referring to him as "the greatest German of the century." Soon afterward the ship was taken over by the government and assigned to the Prussian Battalion of Aëronauts, being christened *Zeppelin I,* since it was the first vessel of the kind taken into the military service.

Beginning with March 9, 1909, the military *Zeppelin I* was kept in active operation by the officers, and subjected to a wide variety of tests day by day. She was driven through rain and snowstorms, at all elevations up to a mile; she was anchored over land and over water, sometimes exposed for hours to a gale; she was steered in and out of her shed without the aid of her floating raft; she was sent on long trips, landed in the open country, by day and by night, and returned to harbor in safety. On one occasion she carried twenty-six passengers for over an hour and a half; again she made an endurance flight of thirteen hours. These maneuvers exhibited for the first time many capabilities of the ship, which all along had been stoutly affirmed by the inventor, but questioned by his critics.

On April 1, 1909, at four o'clock in the morning, the renowned *Zeppelin I*, with the Count as helmsman, started through the rain and wind on a voyage from Friedrichshafen to Munich, a hundred miles distant. The ship followed the railway as far as Ulm, guided by the station lights, which were kept burning all night to mark the route. As she approached Munich, at the appointed hour of nine next morning, her approach was announced from afar by the droning of her machinery and propellers, whereupon she was welcomed by loud music from many bands and the joyous ringing of all the bells in the city. The Prince Regent of Bavaria and a great throng of applauding citizens awaited her at the Teresenhohe park. Presently the swift cruiser approached, sailing over the steeple tops like a monstrous arrow. She halted before the Regent and dipped her bow three times, in graceful salute. Then she circled widely over the city, intending to land at the Oberwiesenfeld Parade Grounds, where part of the garrison troops were drawn up to receive her. But now, while so near the goal, she found it difficult to stem the increasing gale, and unsafe to land; so, with her bow pointed to the city, and propellers humming furiously, she gradually yielded to the storm, and drifted slowly backward toward the northeast.

The crucial hour had come for this stanch vessel and her audacious captain. They wrestled with the storm bravely and obstinately, but were beaten back steadily, with no port in view. The Count determined to weather the gale till it should spend its fury. He coolly sent an aërogram to Munich, saying that all was well and that he might reach the city late in the day. Observing a suitable place to land, near the village of Loiching, he pointed the prow of his ship downward, approached the earth and cast anchor. As the front car touched the ground it was grasped by the willing hands of thronging peasants and vil-

PLATE XI.



ZEPPELIN DIRIGIBLE RESTING ON THE WATER.

Photo E. Levick, N. Y.

ZEPPELIN DIRIGIBLE OVER ~~ZÜRICH.~~ Strassburg

Photo E. Levick, N. Y.

lagers. Presently the ship was taken in charge by a military relief party which the Count had hailed on the way, at Guendelkoven, and which had hastened to his aid in automobiles. Fifty soldiers, in regular shifts, that night held the bow of the vessel by a short leash. The anchor was firmly fastened, and additional ropes secured the bow to an unwheeled wagon loaded with stones. Thus all night long that mighty hull swayed to and fro in the passing storm, securely as a ship anchored at sea.

Next morning the vessel was well replenished and headed for home, by way of Munich. The return was easy, for the wind had nearly reversed its course. Sailing at 32 miles an hour, with a quartering current, the stormbeaten ship soon reached Munich, where she was hailed with boundless enthusiasm. The Prince Regent entertained the Count during his sojourn of three hours, and decorated him with a gold medal. The ship then sailed for Friedrichshafen, with the full speed of the wind and of her propellers, at one time attaining 68 miles an hour. At nightfall she landed gently on the lake near Manzell, having weathered that tempestuous voyage without serious mishap.

This was a splendid proof of her stanchness; but a few days later she was put through other tests quite as severe, one being a night voyage of thirteen and a third hours, after a day of busy maneuvering. Following this came her still longer voyage, to Metz, where she was stationed as a frontier war vessel, and one of a considerable fleet contemplated by the German government.

In the meantime the energetic Count had started his fifth vessel, or military *Zeppelin II*, which now was nearing completion at the works of the Zeppelin Air Ship Construction Company. Her hull measured 446 feet in length, had a diameter of 42½ feet, and a volume of over half a million cubic feet. It also had a ladder running through one of the compartments to a platform on its top. Her motors of 220 horse power were taken uninjured from the wreck of the old *Zeppelin IV* at Echterdingen.

Without previous notice this new air ship set forth in a rain on the evening of May 29, 1909, headed toward Berlin, having on board the Count and seven other men. The purpose of the voyage was merely to exercise the ship; not to reach any definite goal; but by mistake she was reported on her way to Berlin, so that the Kaiser and his retinue waited some hours in vain to receive her. She voyaged bravely past Nuremberg and Leipsic to Bitterfeld, within 85 miles of the capital; then turned for home, the Count being unaware of the hopes he was disappointing. She returned successfully past Weimar and Stuttgart, then, near Goeppingen, descended on an open plain to take on gasoline from a neighboring petroleum refinery. As they were nearing the ground in a heavy rain, Count Zeppelin, who was acting as pilot, suddenly beheld, just before them, a half dead pear tree, with gaunt bare limbs. He gave a sharp order to starboard the helm; but his aëronaut, worn by too long service, thrust the helm to port, and the ship, impelled by a sudden gust, plunged head on against the tree. Her prow was wrecked, the frame and envelope being wrenched and torn for a distance of 100 feet.

The disaster seemed complete, but the dauntless Count was equal to the emergency. Twenty workmen were summoned from Friedrichshafen, sixty miles away, and sped to the rescue in automobiles. Electric wires from a nearby plant were stretched to furnish light for night repairs. The grounds were guarded by police and troops. The hull was detached from the tree; furnished with a temporary prow of young firs covered with balloon cloth; relieved of the forward motors and other impedimenta; furnished with fresh supplies; and, in exactly 28 hours from the mishap, was ready for the homeward voyage.

Slowly the crippled air ship sailed for Friedrichshafen, followed by the white-haired inventor in an automobile, unmoved and triumphant. A mighty shout ascended from the immense crowd of witnesses who had assembled from many quarters. All Germany was elated and jubilant. The great voyage and the prompt recovery from apparent disaster were a triumph of the whole people, for they had helped their hero to build this ship, and now participated in his victory over the spite of fortune and the elements. The Emperor telegraphed his congratulations, affirming his renewed confidence in the rigid system. Without further difficulty the vessel reached her port at an easy gait of ten miles an hour, thus completing a memorable voyage of seven hundred miles—one of the most glorious in the history of aëronautics.

If the citizens of Berlin were disappointed on this occasion, they had not long to wait for an aërial visit from the wizard of Friedrichshafen. On August 27th, at 4.45 A.M., his crew of five men sailed for Berlin via Nuremberg and Leipsic in his sixth air ship, his latest and largest, hurriedly finished for the Berlin voyage. It cubed 533,000 feet, and was driven by two Daimler engines of 150 nominal horse power each. In the afternoon they reached Nuremberg, circled over the city and landed for the night. Starting at 2.15 next morning they battled their way toward Leipsic against a strong wind, and at 6.45 P.M. landed for the night at Bitterfeld, where they arrived with a broken propeller. Here Count Zeppelin joined them. The next morning, after a good night's rest and some repairs, they started at half past seven, in a dense fog, which, however, soon cleared. Finally they arrived at Berlin at half past twelve o'clock, as the people were returning from church. They circled over the city, to the delight of the multitude of spectators who thronged the house tops, parks, and thoroughfares, finally reaching the parade ground at Tegel. Here, after saluting the Emperor, the happy navigator maneuvered before the imperial tribune, greeted by the thunderous Hoch! Hoch! of a hundred thousand throats, and the ringing of all the church bells of the nation's capital. The venerable Count was graciously received by the Emperor and members of the royal family. After spending the day at Berlin, the crew sailed for Friedrichshafen, about midnight, where, after various accidents and delays, they arrived in safety on September 6th.

In some respects this was Von Zeppelin's crowning voyage of the year, though effected with a hurriedly finished vessel, not yet thoroughly adjusted. In mechanical execution this journey was equaled on many other occasions; for those great air ships were kept in active service and were everywhere hailed with enthusiasm. Both the Emperor and his people were proud to number those grand cruisers among the nation's aërial warships. With general commendation, therefore, was received the announcement that four large *Zeppelins* were ordered for the use of the German navy. And not surprising was the announcement that other inventors were at work on designs for dirigibles of the rigid type. The projects of these new rivals, who began to appear in 1909, are set forth in the following account:[1]

[1] *Over Sea by Air-Ship*, MacMechen and Dienstbach, *The Century*, May, 1910.

"Count Zeppelin, who proved that air ships have a practical future, is no longer undisputed 'king of the air.' His rivals have taken his pattern, and improved it until soon air ships will be able to keep afloat for many days and in that case to cross oceans. A type of this modern ship is the first Schütte leviathan of wood and steel bracing, now nearly finished at Mannheim. It is expected to lift its twenty-four and one-fifth tons one and a quarter miles, because its beam is sixty feet as compared with the forty-four feet of the *Zeppelin II.* The car is one hundred and thirty feet long, with a cabin to accommodate thirty passengers. The new ship displaces nineteen thousand cubic meters, as against fifteen thousand in the *Zeppelin III.* It is expected to carry a cargo of five to six tons supported by ten spherical sustaining chambers, and eight ring-shape reservoir chambers connected by a secret apparatus. These eight reservoirs automatically receive all expanding gas that escapes from the sustaining chambers, thus conserving the entire supporting power. Four motors of combined five hundred and forty horse power will drive the propellers. Expert opinion predicts a speed of thirty-seven to forty-three miles an hour, three miles faster than the *Gross III,* at this writing the fastest air ship in the world. The whole enterprise is backed by Mr. Lanz, a rich manufacturer, who is president of the German Air-Navy League. A wooden-braced ship of equal equipment and size, designed by the Engineer Rettich, is well under way.

"Another rival of the *Zeppelin,* so far only projected, has been designed by the Engineers Radinger and Wagner, and is intended to be an advance in endurance. It should float for fifty days without replenishing gas. It is planned to have a rigid hull of hollow paper tubes and steel bracing and to be thirty per cent lighter than a *Zeppelin* built of aluminum, in any equal size. Drum-shape compartments are to hold the sustaining hydrogen, none of which is to be lost through expansion by the sun, as any surplus will be compressed by automatic pumps into the hollow tubes.[1] Having six thousand meters less displacement than the *Zeppelin III*, it will carry a reserve of seven hundred cubic meters of gas. Thirty-two per cent of its weight-carrying capacity will be given up to passengers, fuel, and baggage. Engines of two hundred and forty-two combined horse power are expected to develop a speed of forty to fifty miles an hour. Larger craft of the same type would, of course, carry much heavier cargoes and have higher speed. This type of ship, soon to be placed in the construction cradle, is expected to cross the ocean easily with fifteen passengers."

In keeping with the lively growth of these great ships was the formation of the German aërial transportation company, with a capital stock of $750,000, reported in *l'Aérophile* for December, 1909. A line of large *Zeppelins* was to connect Baden-Baden, Mannheim, Munich, Leipsic, Cologne, Düsseldorf, Berlin, Dresden, Essen and Frankfort. The first two auto balloons of this line were to be the *Zeppelin IV* and *Zeppelin V*, to be put in commission in the spring of 1910. The *Zeppelin IV* was to cube 706,000 cubic feet, and carry twenty passengers in three cars, each containing a motor. The *Zeppelin V* was to be constructed of a remarkably light rigid allow "electrometal," and was to carry at least thirty passengers. This enterprise certainly formed an appropriate termination to the first decade of practical auto ballooning.

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[1] A mathematical argument against this device is presented in Appendix I.

The projected passenger line of the German Air Ship Society was inaugurated the following summer with serene audacity and fairy-like magnificence. The first ship employed, *Zeppelin VII,* was a huge vessel of unusual power, speed and elegance of appointment. She was 485 feet long by 46 in diameter, cubed 690,000 feet, and carried three engines totaling 420 horse power and competent to drive her 35 miles per hour. Midway beneath her hull and rigidly joined to it, was a passenger car thirty-five feet long, having a vestibule at one end, a lavatory at the other, and five compartments between them, with seats for twenty persons. Beyond the ends of the car were open decks leading to the boats fore and aft containing the machinery.

At three o'clock on the morning of June 22, 1910, with Count Zeppelin in charge, and a dozen passengers aboard, this majestic auto balloon sailed from Friedrichshafen up the Rhine Valley for Düsseldorf, three hundred miles, and after a prosperous voyage of nine hours, made an easy landing. Next morning at eight thirty she voyaged from Düsseldorf to Dortmund, thirty-seven miles north, sailing at a general height of one thousand feet, over some of the finest industrial parts of Germany. Then she returned to Düsseldorf with her delighted passengers who were all enthusiasm for the new mode of travel so auspiciously begun. Of the thirty-two persons aboard, the majority were regular public passengers who had paid fifty dollars each for the trip, several of them tourists from various countries, and ten of them women.

The maiden voyage of this first air liner was a marvel and dream of delight to the fortunate few traveling in such celestial style. The comforts and splendors of the service quite surpassed their expectations. Seated in that fairy car of aluminum framing lined with mahogany and rosewood inlaid with pearl, they looked from spacious windows over the beautiful German landscape gliding beneath them, and enjoyed visions fit for itinerating gods. Along the shining waters of the Rhine, and over its castellated crags, and among its rolling hills terraced with luxuriant vineyards, now lapped in the glory of summer, and above stately cities murmuring with multitudinous life, they sailed in serenest comfort and security, marveling at their own strange career through the sky, and equally regarded with wonder by all the inhabitants below, not to say written and read about by millions in all parts of the civilized world. The delights of land and sea travel were happily mingled, without their inconvenience. Neither dust nor smoke was here, nor rattle of iron rails, nor lurching and rolling from heavy seas. Quite otherwise. The senses were charmed with the fanning of fragrant winds forever and uniformly blowing, with the melodious drone of the swift propeller wheels, with the green glories of the earth and purple splendors of the sky. When the tourist was sated with these he could turn to his book; when tired of his chair he could stroll to and fro in the car on a soft carpet, or along the trellised deck beyond; when his appetite called, he could answer with the choicest food and wine; for every convenience of an ample buffet was available. It was all so enchanting if only practical.

Encouraged by these trials the company announced, and hoped to make, voyages at frequent intervals. But in this they promptly encountered difficulties. On June 28th the *Deutschland* started from Düsseldorf on a four-hour cruise, with nearly a score of passengers, mostly newspaper representatives. But she remained in the air longer than intended. Passing Solingen she tried to reach Eberfeld, but ineffectually; nor could she find a landing place. Toward five o'clock she was caught in a great rising wind and carried one mile aloft like a passive balloon in a vortex or thunderhead. Here much gas was lost by expansion, and presently, as the ship emerged from a snow cloud in the upper vortex, with cooled gas and hull laden with precipitation, she descended at a terrible velocity. With crippled motive power, the vessel could not be supported dynamically by the impact of the air against her sustaining planes and against her canted hull, for lack of forward speed. At length with a terrific crash she struck upon the forest of Teutoberg, 80 miles from Düsseldorf, a great tree trunk piercing the rear boat and projecting among the terrified crew. Here the vessel lodged with her stern and controlling gear badly wrecked, and here she was abandoned by the passengers, with her huge hull resting on the branches forty feet from earth. Ere long she was retrieved by a company of infantry who sawed down the trees, dismantled the ship, and returned the parts on railway trucks to Friedrichshafen, to be used in building another vessel.

Thus in both civil and military aëronautics the pioneers had to endure many losses and grievous hardships; but the direst disasters often mark the way to the greatest victories.

PART II

GROWTH OF AVIATION

CHAPTER VII

MODEL FLYING MACHINES

From time immemorial man has admired the aërial evolutions of wing-gifted creatures, and aspired to imitate them. But which evolutions should he attempt first? Which if any are practicable for the ponderous lord of creation? The question is still pertinent.

Nature in her bounty bewilders us with wondrous models. All about and overhead, with exquisite art, they challenge us to float or fly. Before the flower-bell drifts the ruby-throat, his long bill in the honey-hearted bloom; now bulletlike he leaps through boundless space. Why not adopt that style of locomotion? Call your rainbow equipage to the door, and take the family forth in purple state, to the music of melodious wheels.

If the humming bird will not serve, look above you. There rides the dark-winged master of aërial motion, throned like a god on the impetuous wind. Mark his majestic sweep as all day long, with unbeating pinion, he scours the wide plain and rugged regions of the hills, unwearied, reposeful, deliberate; now skimming the fragrant forest, or meadow; now scaling the precipice, or swinging above the abyss; now soaring cloudward beyond the range of human vision. There is a model for the ambitious and the brave!

Or turn to mid ocean when the hurricane, shearing the tops of the arched billows, scatters them in foam and spray over the watery chaos, and the big ship strains in the storm. See the long-winged albatross, white vision of joy in the darkness, careering all playfully round the imperiled vessel, and above the monstrous waves; wheeling in glad curves, frolicking in the face of the tempest, riding, without toil or trepidation, the rudest[1] winds a thousand miles over the sea. What a jocund pace for man!

Of all the charming modes of flight now possible to us it is certain that our ancestors could copy but one with any hope of success. Minus motive power they could not imitate the direct flight of the homing pigeon, much less the mid-air pause of the bumblebee floating round a daisy. Hence there remained to them only passive flight on nonvibrant wings. The gliding of vultures, of gulls, and of certain quadrupeds and fishes, they could imitate with profit; but when they essayed power flight they invariably and egregiously failed.

The art of aviation presents two main groups of fliers. The first comprises the various man kites, parachutes, gliding machines, soaring machines. These may be called passive flyers, because they carry no motive power, but ride passively on the air by the force of gravity or a towline.

The second group comprises the bird-like flapwing machines, called orthopters by technical people; the screw-lift flyers, called helicopters; the aëroplanes, also called monoplanes, biplanes, triplanes, according to the number of superposed main lifting surfaces; and lastly the gyroplanes, whose sustaining surfaces may turn over and over, like a falling lath, or whirl round and round, like a boomerang. These all may be called dynamic, or power,

[1] It is commonly reported by navigators that the albatross "sports in the tempest" on unbeating pinions; but it may be questioned whether any bird can make headway against the swiftest winds.

flyers. The technical names, however, are not so important, as they are numerous; for the whole aëronautic nomenclature is in a formative, not to say chaotic, state. We may, therefore, like Adam, name the creatures as they pass before us for review or discussion.

Disregarding the crude essays at human flight, recorded in the early literature and history of many peoples, we may notice first the well authenticated sketches of Leonardo da Vinci. His fertile mind

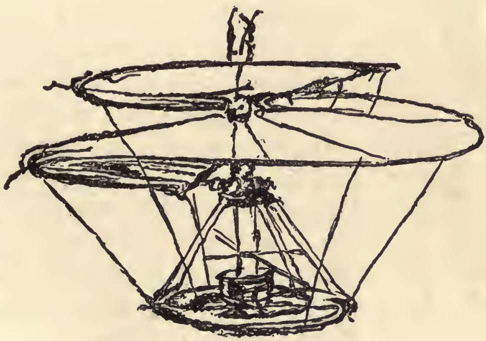


FIG. 26.—DA VINCI'S HELICOPTER.

conceived three distinct devices for carrying a man in the air. But he and his successors for nearly four centuries could do little more than invent. For lack of motive power they could not navigate dynamic flyers, however ingeniously contrived.

Da Vinci's first design, as shown in Fig. 26, provides the operator with two wings to be actuated by the power of both arms and legs, through the agency of very ingenious harness. With this device an acrobat could fly forward and downward, to the delectation of a multitude; but he would have to be caught on something soft to escape injury. Since Leonardo's day the experiment has been tried occasionally, with varied results, sometimes grotesque, sometimes tragic. He doubtless realized the impracticability of an orthopter actuated by human muscle, and yet he has had many followers. The orthopter is still a favorite device cultivated by a few persons who propose to work its wings by means of a gasoline motor. Doubtless the feat is physically possible, and may be accomplished in time.

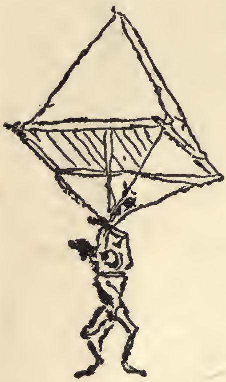


Fig. 27.—Da Vinci's Parachute.

Da Vinci's second flyer was a helicopter, as shown in Fig. 26. An aërial screw 96 feet in diameter was to be turned by a strong and nimble artist who might, by prodigious effort, lift himself for a short time. Though various small paper screws were made to ascend in the air, the larger enterprise was never seriously undertaken. Many subsequent inventors developed the same project; but the fellow turning the screw always found it dreadful toil and a hopelessly futile task. Of late the man-driven helicopter has been abandoned, but the motor-driven one is very much cultivated. Scores of inventors in recent years, aided by light motors, have been trying to screw boldly skyward, and some have succeeded in rising on a helicopter carrying one man.

Da Vinci's third scheme for human flight, as shown in Fig. 27, was a framed sail on which a man could ride downward, if not upward. This device never fails to navigate with its confiding sailor. Sometimes he lands in one posture, again in another; but voyage he must, with the certainty of gravitation. Leonardo is, therefore, the father of the parachute. This, in turn, has had a varied off-spring. The common parachute, the aërial glider, the soaring machine, or passive aëroplane, that rides the wind without motive power and without loss of energy.

The foregoing sketches by the great artist were made toward the year 1500, and there the science stood for nearly three centuries. Much speculation followed, but no substantial progress. Mathematicians proved by figures the inadequacy of the human muscle to achieve human flight. Dreamers demonstrated the same by launching themselves from high places, and breaking their bones on the unfeeling earth, before unpitying crowds. Finally came the balloon, giving a new impetus to an embryo art.

The earliest of Da Vinci's aëronautic ideas to be practically realized was the parachute. The exact date of its first employment is not exactly known. In the year 1617 Fauste Veranzio published in Venice a good technical description of the construction and operation of the parachute, accompanied by a clear illustration, as shown in Fig. 28. But the first authentic account of a parachute descent of a human being is that given by Sebastien Lenormand. This dauntless inventor, on December 26, 1783, descended from the tower of the Montpelier Observatory, holding in either hand an umbrella sixty inches in diameter. A few days later he sent to the Academy of Lyons the following description of his improved parachute, illustrated in Fig. 29:

"I make a circle 14 feet in diameter with a heavy cord; I attach firmly all around, a cone of linen whose height is 6 feet; I double this cone with paper laid on the linen to render it impermeable to air; or better, instead of linen, taffeta covered with gum elastic. I place all about the cone small cords, which are attached below to a wicker frame, and forming with this frame an inverse truncated cone. Upon this frame I place myself. By this means I avoid the ribs and handle of the umbrella, which would add considerable weight. I am sure to risk

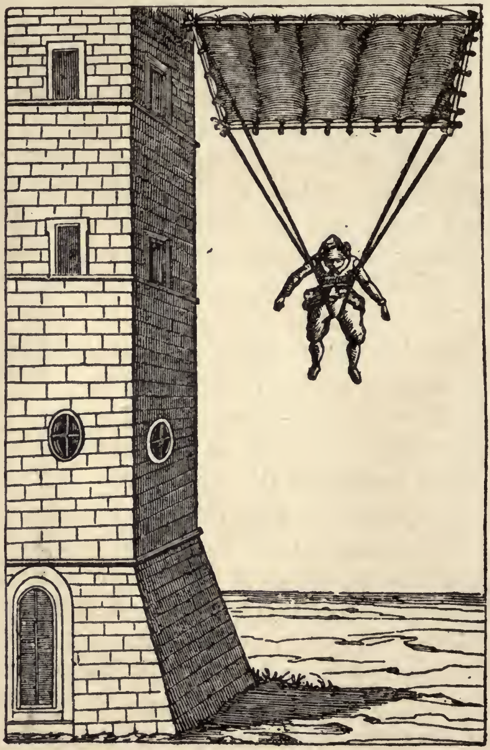


FIG. 28.—VERANZIO'S PARACHUTE.

so little that I offer to make the experiment myself, after once having tried the parachute with different weights to make sure of its solidity."

Previous to Lenormand's experiments, Blanchard, the aëronaut, had dropped small parachutes from his balloon, sometimes carrying animals, but never a human being. For unaccountable reasons the world had to wait fourteen years longer to see a man make the new familiar parachute descent from a balloon. On October 22, 1797, in presence of a large crowd Jacques Garnerin ascended in a closed parachute to a height of 3,000 feet, then cut loose. The people were astonished and appalled; but they soon saw the umbrella-shaped canvas spread open and oscillate in the sky with its human freight. As it was but eight yards in diameter, it descended rapidly and struck the ground with violence, throwing Garnerin from his seat. He escaped with a bruised foot, mounted a horse, and returned to the starting point, where he received a lively ovation.

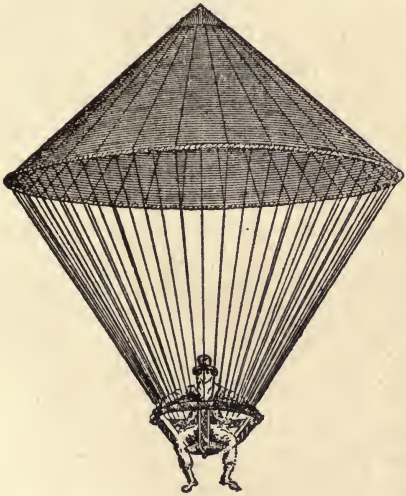


FIG. 29.—LENORMAND'S PARACHUTE, 1784.

After this experiment, parachute descents became popular the world over, and have been repeated up to the present time substantially without change. A slight improvement in the construction was made by cutting away the top of the canvas, thus allowing the air to escape sufficiently to check the oscillations; but no radical change in the design has come into general use. It would seem easy to have transformed the craft into a traveling parachute gliding down the sky like a great bird on outstretched wings. Such a device would enable the aëronaut to sail some miles and direct his course in the air. If fair skill had been acquired it might have hastened the advent of human flight twenty years, so far as it is practicable without the aid of the internal combustion motor. For two decades ago Maxim produced an abundantly powerful steam engine; but could find no one to furnish him a manageable glider on which to mount it. Now, indeed, such gliders are available; but they were developed by aviators, not by balloonists, or parachutists, who should have effected that advance many years ago.

Curiously enough, Nature has furnished a traveling parachute which seems never to have been imitated by man, though not difficult to copy. It is a large two-winged seed, which when dropped in any poise, immediately rights itself, and glides gracefully through the air. The seeds grow on a tree in India, bearing the name *Zanonia Macrocarpa,* and when shaken from its branches look like so many sparrows sailing earthward in wide curves. Artificial gliders of this type are easy to construct, and would make interesting toys. However, if man has not copied such natural models, he has done much better, by making his gliders concave below instead of concave upward, as are the beautiful Indian seeds.

An interesting model of a traveling parachute, quite as efficient as the gauzy-winged seed, is shown in the accompanying figure. It is a sheet of paper twenty inches long by four inches wide, having a quarter inch strip of tin folded in its forward margin, and having its rear margin turned upward slightly, to steer the little craft from a too steep descent. In order to improve the stability of the paper plane, its sides may be bent upward. The model when dropped in any attitude quickly rights itself, and sails down a gently sloping course, the rear margin functioning as a rudder or tail.

One of the earliest trustworthy and scientific accounts of experimentation with an aërial glider was given by Sir George Cayley in *Nicholson's Journal,* in 1809 and 1810. After a careful study of the principles of stability, he, in 1808, constructed a glider spreading 300 square feet of surface and weighing with its load 140 pounds. It had wing surfaces slightly inclined to each other, and a tail inclined enough to determine a gentle downward course. "When any persons," says Cayley, "ran forward in it with his full speed, taking advantage of a gentle breeze in front, it would bear him up so strongly as scarcely to allow him to touch the ground, and would frequently lift him up and carry him several yards together. It was beautiful to see this noble white bird sail majestically from a hill to any given point of the plain below it, with perfect steadiness and safety, according to the set of the rudder, merely by its own weight, descending in an angle of about 18° with the horizon."

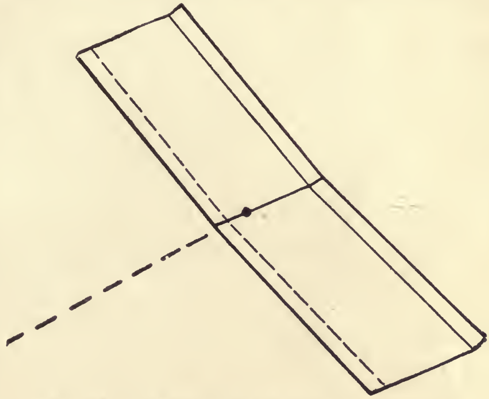


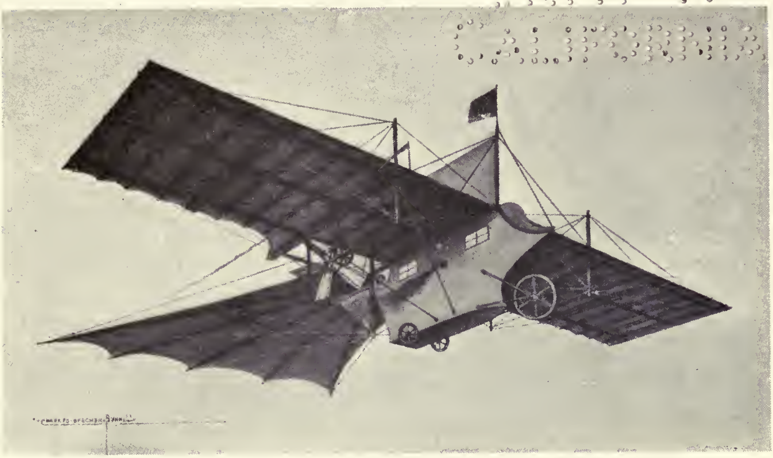
FIG. 30. PAPER TRAVELING PARACHUTE.

Sir George Cayley made a brave start in the science of dynamic flight, marshaling to it all the mechanical resources of his day. He applied the most reliable data of fluid resistance then available. He formulated the laws of equilibrium and control of a flying machine quite as well as any of his successors for two generations. He estimated the propulsive power required to carry a man, and computed the weight of the newly invented Bolton and Watt steam engine capable of supplying that power. He even conceived the idea of burning a gas or inflammable vapor behind a piston, thus anticipating the modern aëronautical motor. But the project as a whole was too formidable at that time for the genius of this one man, or of his generation of colleagues. Sailing flight they could have practiced with profit to the advancement of aviation, but power flight on a practicable scale had to await the long evolution of the internal combustion engine.

The next great advancement in the devices and principles of aviation was made by another Englishman, and a worthy successor to Sir George Cayley. In 1842 Mr. Henson patented the aërial equipage shown in the accompanying illustration. It was what in present-day parlance is called a monoplane, being in fact the first commercially planned aëroplane known to history. As seen at a glance it consisted of a large sustaining surface rigidly trussed and driven through the air by two propellers actuated by a steam engine. It was to be guided up and down by means of a horizontal rudder, and guided to the right and left by means of a vertical rudder, seconded by a keel cloth; both rudders being at the rear of the large plane. The machine was designed to be launched by running down an inclined plane or track. Fuller details of this first patent aëroplane are given in the following official description in the South Kensington Museum of a model aëroplane constructed by Henson and Stringfellow:

"The model consists of an extended surface, or aëroplane, of oiled silk or canvas, stretched upon a bamboo frame made rigid by trussing both above

PLATE XII.



HENSON'S AËROPLANE.

ADER'S AËROPLANE.

Photo E. Levick, N. Y.

and below. A car is attached to the underside of the aëroplane to contain the steam engine, passengers, etc. It has three wheels to run freely upon when it reaches earth. Two propellers, three feet in diameter, are shown with their blades set at 45°. They are operated by endless cords from the engine. Behind these is a fan-shaped tail stretched upon a triangular frame capable of being opened out, closed, or moved up and down by means of cords and pulleys. By this latter arrangement ascent or descent was to be accomplished. A rudder for steering sideways is placed under the tail, and above the main aëroplane a sail was to be stretched between two masts rising from the car, to assist in maintaining the course. When in motion the front edge of the machine was to be raised in order to obtain the required air support. To start the model it was proposed to allow it to run down an incline—e. g., the side of a hill, the propellers being first set in motion. The velocity gained in the descent was expected to sustain it in its further progress, the engine overcoming the head resistance when in full flight. Experiments were eventually made on the Downs near Chard, in Somerset, and the night trials were abandoned, as the silk became saturated from a deposit of dew. After many day trials, down wide inclined rails, the model was found to be deficient in stable equilibrium for open-air experiments, little puffs of wind or ground currents being sufficient to destroy the balance. The actual machine was never constructed, but in 1847–48 F. Stringfellow built a model which is supposed to be the first flying machine to perform a successful flight."

The creation of Henson's flying machine at that early period is one of the most original and fruitful achievements in the century-long development of the modern aëroplane. Barring the torsional wing-tips invented more recently, it hardly differs in principle from the successful monoplane of to-day. The same mode of propulsion, the same mode of sustention, the same mode of launching and lighting, the same mode of steering and control. What has been added since is not so much original invention as perfection of detail through the combined efforts of many designers. After Cayley, Henson, as nearly as any one person was the inventor of the flying machine. He did not bring his conception to practical maturity, nor was that to be expected; but he did lay down the broad lines which have led others to success. His ideas still feature every practical aëroplane, and particularly every successful monoplane. Indeed, it is now possible to construct an aëroplane from Henson's description that will fly, even in breezy weather, with a stability practically as good as that of the early Voisin and Antoinette machines before the use of the aileron or torsional wing was practiced. It is all a question of wise proportioning and sufficient motive power.

So much for Henson's contrivance as an abstract invention. The concrete, full scale machine was to spread 6,000 square feet of surface, weigh 3,000 pounds, and be propelled by a high pressure steam engine of 25 or 30 horse power. The machine was not completed on a large scale, and wisely so; for it was inadequately powered, and, moreover, required many refinements of detail to make it entirely practical. These improvements had to be left to succeeding inventors with accumulated experience and resources.

In 1844 Mr. Henson began the construction of a steam-driven model, in partnership with his friend, Mr. Stringfellow, who designed the motor for it. They experimented together for some weeks with only meager success, but gaining valuable experience.

A model of the Henson-Stringfellow machine is on exhibition at the South Kensington Museum.

In 1846 Stringfellow built a steam model aëroplane about the size of a large soaring bird, and weighing all together, with fuel and water, 6½ pounds. A special feature of this model was that its main surfaces were sloped like the wings of a bird, *slightly concave below and feathered toward the back;* thus making it more efficient and stable in flight. With a

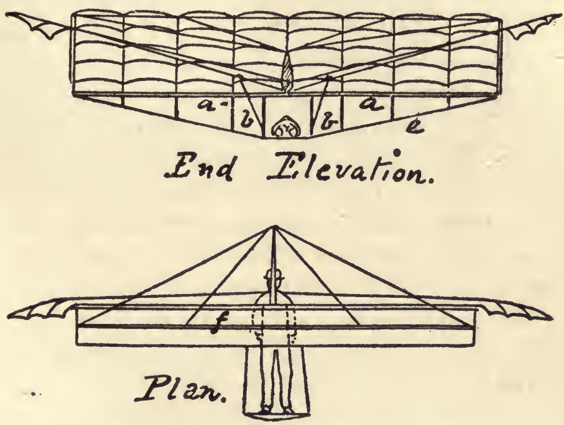


FIG. 31.—WENHAM'S AËROPLANE, 1866.

good head of steam, and propellers whirling, the model ran down a stretched wire, leaped into the air " and darted off in as fair a flight as it was possible to make, to a distance of about 40 yards." Thus the first power-driven aëroplane to fly successfully was the little steam model constructed by Stringfellow in 1846.

In 1866, two decades after the flight of Stringfellow's monoplane, Mr. F. H. Wenham, another Englishman illustrious in the annals of aëronautics, patented the multiplane; that is, an aëroplane comprising two or more superposed surfaces. This proved to be a valuable contribution to the art of aviation, and continues in use at the present time. The device furnished an increase of sustaining surface without enlargement of the ground plan. It moreover lends itself conveniently to a strong and simple trussing of the surfaces. Some designers protest that superposed surfaces blanket one another; but the advantages just named seem amply to compensate for this objectionable feature. If the surfaces be properly spaced, very little interference is found; moreover, any blanketing that may occur diminishes the drift as well as the lift,[1] though not necessarily in the same proportion.

Wenham's aëroplane is illustrated in Fig. 31. The rider lies underneath the multiple wings, so as to diminish the resistance to progression through the air. The apparatus could thus be used as an aërial toboggan for coasting down the atmosphere. To prolong the flights two flappers actuated by a treadle were to be employed, their ends being hinged at a point above the operator's back. Though the device was patented, no very serious efforts were made to operate it practically. Once, indeed, the inventor took his glider to a meadow and mounted it, during a lull in the evening wind, but soon a gust caught him up, carried him some distance from the ground and toppled him over sidewise, breaking some of the surfaces. The machine disclosed some good working principles; but it was inadequately ruddered, and too feebly constructed, to weather the buffets of the prevailing ground currents.

Adopting the scheme of superposed surfaces then recently devised by Wenham, Mr. Stringfellow in 1868 constructed the interesting steam-driven model

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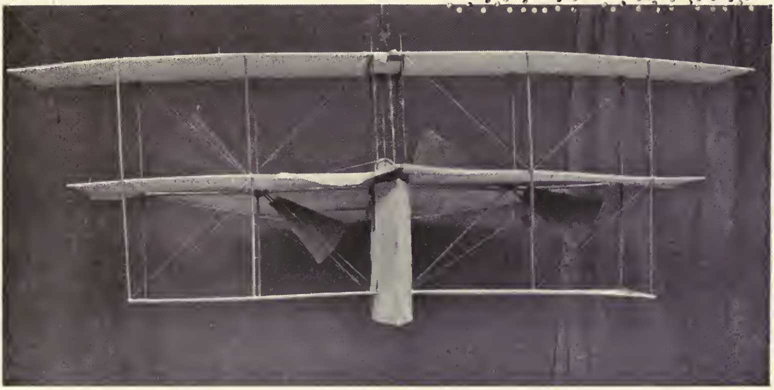
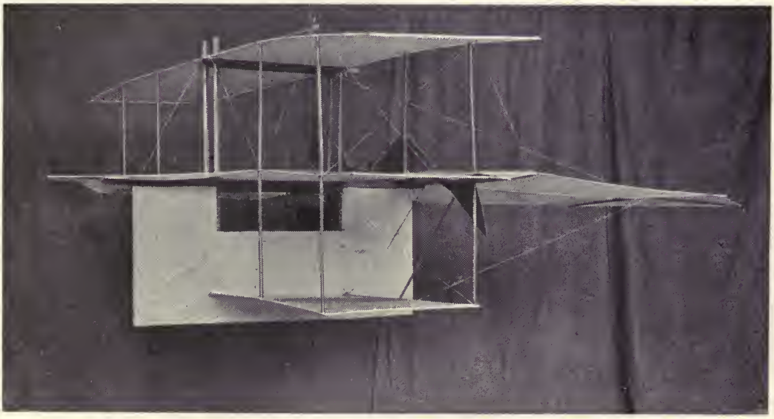
[1] The "drift" and "lift" are the components of surface wind-pressure respectively in the direction of flight and at right angles to it.

PLATE XIII.



STRINGFELLOW'S AËROPLANE (FRONT).
(Courtesy Smithsonian Institution.)



STRINGFELLOW'S AËROPLANE (SIDE).
(Courtesy Smithsonian Institution.)

shown in Plate XIII. This consists essentially of three superposed planes, rigidly connected by rods and diagonal wires, propelled by a pair of screws actuated by a high pressure steam engine, and guided by a tail. The three planes aggregated 21 feet in length and 28 square feet in surface; totaling, with the tail, 36 square feet. The engine was rated at one third of one horse power. Its weight is not known, but may be roughly surmised from the fact that a separate engine exhibited simultaneously by String-

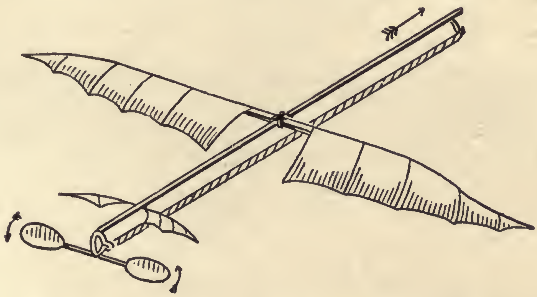


FIG. 32.—PENAUD'S AËROPLANE TOY, 1871.

fellow weighed thirteen pounds per horse power. The model was entered for competition in the London Aëronautical Exhibition of 1868. In actual operation, however, it seems not to have excelled the monoplane of 1846; but still it is of much interest as being the prototype of the multiple-wing aëroplane now in common use. It seems to have been the first aëroplane having two or more sustaining surfaces joined by rods and stayed by diagonal cords after the manner of a Pratt truss. This historic little model was purchased by Professor Langley for the Smithsonian Institution, and is now to be seen suspended from the ceiling of the National Museum, beside Langley's own models and Lilienthal's epoch-making glider.

In 1871 M. A. Penaud produced the interesting toy aëroplane shown in Fig. 32. The model is propelled horizontally forward by a single screw, actuated by twisted rubber, and is fastened, as shown, to the middle of a long stick or backbone. The center of mass of the machine is well to the front, tending to plunge the model earthward like a heavy-headed arrow; but this down-diving is promptly checked by

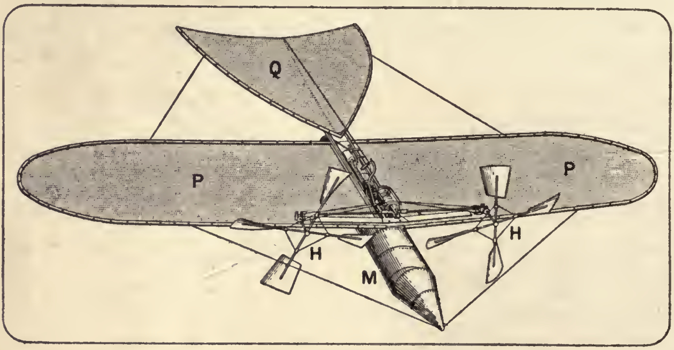


FIG. 33.—TATIN'S AËROPLANE MODEL, 1879.

the tiny rudder which is so inclined as to counteract the diving proclivity. That is to say the rudder dips so as to receive the aërial impact on its upper surface; which impact increases with the speed of flight and causes the bow to rise, until the weight before the wings just balances the impact on the rudder at the rear. The equilibrium is thus automatic, on the principle expounded by Sir George Cayley sixty years earlier. This quaint little bird when liberated in the Garden of the Tuileries flew a distance of 131 feet in eleven seconds, much to the delight of some members of the French Society for Aërial Navigation. It may be added that Penaud, who was a most promising and clever aëronautical inventor, contemplated a twin-screw monoplane large enough to carry two men, but died in his early manhood, before the project could be realized.

In 1879 M. Victor Tatin made some very promising tests with the model shown in Fig. 33, so promising, in fact, as to convince many that human flight was even then practicable. This little flyer was a twin-screw monoplane mounted on wheels, and actuated by an oscillating compressed air engine, the whole machine weighing 3.85 pounds, and supported by a silk plane measuring 16 by 75 inches. The central body of the aëroplane was a thin steel tube three feet long by four inches in diameter containing the compressed air, and weighing only one pound and a half, though strong enough to endure a pressure of twenty atmospheres. When the model was allowed to run round a board walk 46 feet in diameter, tethered to a stake at the center, it quickly acquired a speed of 18 miles an hour, rose in the air, and flew a distance of fifty feet.

A remarkable deduction from the very careful measurements made with this machine was that it carried at the rate of 110 pounds per tow line horse power, when flying at an angle of 8 to 10 degrees. Mr. Tatin concluded: "These experiments seem to demonstrate that there is no impracticability in the construction of a large apparatus for aviation, and that perhaps even now such machines could be practically used in aërial navigation. Such practical experiments being necessarily very costly, I must to my great regret, forego their undertaking, and I shall be satisfied if my own labors shall induce others to take up such an enterprise."

Tatin's faith in the practicability of a large aëroplane was later voiced by Mr. Chanute in his valuable book, *Progress in Flying Machines,* published in 1894, but now unfortunately out of print. Recalling that Maxim had recently produced a large motor weighing complete only ten pounds per horse power, he says: "Aviation seems to be practicably possible, if only the stability can be secured, and an adequate method of alighting be devised." Since the above quoted facts and opinions were published, no competent man well informed in the science of aviation has for one moment doubted the feasibility of human flight.

In 1891, twelve years after Tatin's experiment,

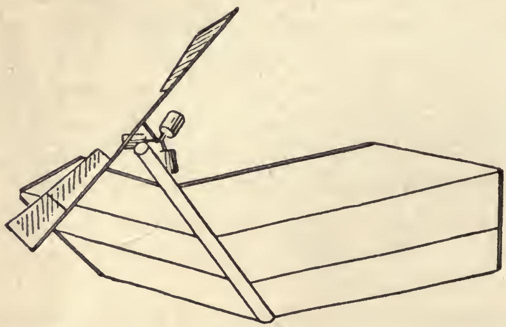


Fig. 34.—Hargrave's Model Screw Monoplane, 1891.

Lawrence Hargrave, of Sidney, Australia, made a similar compressed air monoplane, with a single-screw propeller, but without wheels for launching and lighting. The model, which is shown in Fig. 34, had a wing-spread of 20 square feet, weighed about three pounds, and flew 128 feet in eight seconds. The weight carried was at the rate of 90 pounds per horse power, a very encouraging result. Two years later he described a small steam engine which he had developed, weighing 10.7 pounds per horse power, and capable of driving the model about two miles, though he did not use it for that purpose, being engrossed with other researches.

One interesting outcome of his numerous experiments was the Hargrave Kite, now more familiarly known as the box kite. A good example of his kites is the type shown in Fig. 35. This consists of two arched biplanes mounted tandem on a backbone, or connecting framework. The kite floats steadily, and was thought suitable for the body of a flying machine to be driven by an engine and propeller. Thus meteorology is indebted to aëronautics for its most useful kite.

A very novel and interesting type of aëroplane model was tested by Mr. Horatio Phillips in 1893. After careful preliminary experiments with various

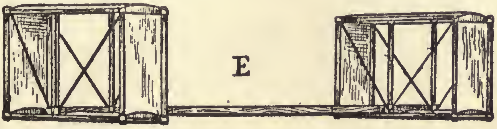


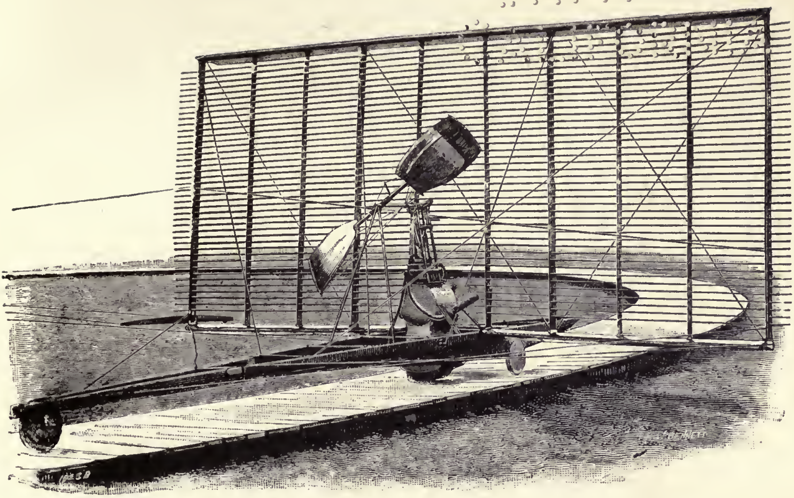
FIG. 35.—HARGRAVE'S KITE.

forms of curved "sustainers," or lifting surfaces, tested in a wind tunnel, to determine which were most suitable wing forms, he finally constructed the flying apparatus shown in Plate XIV. This consisted of a compound aëroplane composed of many superposed narrow curved slats, the whole resembling an open Venetian blind. These curved blades, or sustainers, measured 12 feet long, 1.5 inches wide, 2 inches apart, and were held in a frame sharpened to cleave the air with slight resistance. The entire aëroplane spread 136 square feet of lifting surface, and was mounted on a truck as shown, carrying a steam engine and boiler, to actuate a two blade propeller 6 feet in diameter. The whole apparatus weighed 330 pounds, to which a dead load was usually added, and ran around a circular wooden track 628 feet in circumference, being tethered at the center, as in Tatin's experiment. The apparatus readily lifted itself, when running at a speed of 28 miles an hour, and carried at the rate of 72 pounds per horse power, the added load weighing at times nearly one fourth that of the machine itself. The ultimate purpose of the experiment was to prepare the way for a one-man aëroplane like that shown in the lower part of the figure. This latter model actually carried a man across a field in 1904, but was found defective in longitudinal balance, because perhaps of its inadequate horizontal rudder. Apparently Mr. Phillips had in 1904 a machine capable of well-balanced flight, if he had made the rudders large enough, and provided a mechanism for rotating the slats at either wing end, so as to control the lateral poise, as proposed by the present writer in 1893, for practically that same flier (see page 229).

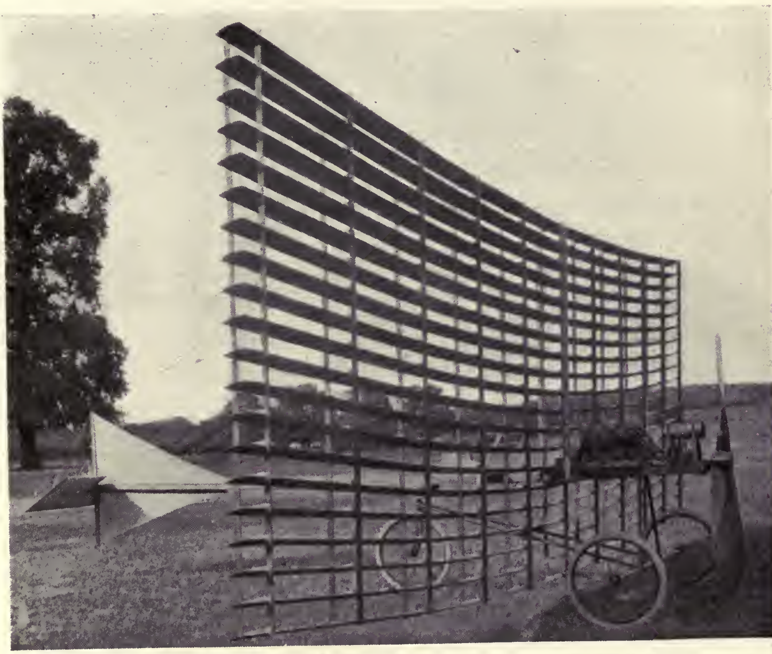
Phillips's aëroplane shows a distinct advance over its predecessors, even Wenham's multiplane, because of the careful curving of the sustainers. Tatin's flat wing machine had, indeed, shown a greater efficiency as a whole, but that was likely due to less proportionate body resistance. To Phillips we owe the introduction of superposed arched surfaces, now so commonly used in mechanical flight. Whether he was wise in using so many narrow wings, instead of a few broad ones, was a question to be answered by precise measurement.

Prof. S. P. Langley, like Mr. Hargrave, made numerous flying models, trying, in turn, the power of twisted rubber, compressed air and steam. He constructed scores of gauzy winged contrivances which flitted about like huge butterflies or birds, till their mission was accomplished—that of illustrating a scientific principle to his inquiring mind. One by one they came into existence, enjoyed an ephemeral life, and then were consigned to the aëronautical attic of the Smithsonian Institution, a storehouse of quaint flying creatures. It was a most interesting

PLATE XIV.



PHILLIPS' TETHERED AËROPLANE.



PHILLIPS' AËROPLANE.

collection which well merited preservation as the "juvenile" creations of an illustrious man. But the first experiments of Langley, like the similar ones of Hargrave, were of value chiefly as training to the inventor himself; they were not important advances in the art of aviation. Such advances were to follow the long preliminary training.

On May 6, 1896, Dr. Langley launched the picturesque steam model, which, to his mind, first proved conclusively the practicability of mechanical flight. It was the crowning success, and, as he thought then, probably the termination of his aëronautic labors. "I have brought to a close," says he, "the portion of the work which seemed to be peculiarly mine—the demonstration of the practicability of mechanical flight—and for the next stage, which is the commercial and practical development of the idea, it is probable that the world may look to others. The world, indeed, will be supine if it does not realize that a new possibility has come to it, and that the great universal highway overhead is now soon to be opened."

As shown in Plate XV, Langley's first successful steam flying machine is a tandem monoplane[1] with twin screws amidships. It measures nearly 13 feet from tip to tip of its wings, about 16 feet along its entire length, and weighs with motor and propellers 30 pounds. The boiler weighs 5 pounds, the engine 26 ounces, and the power developed was between 1 and 1.5 horse power. The model is therefore somewhat larger than a large condor, and very much more powerful.

Being too small to carry a pilot, it was launched

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[1] The tandem monoplane, or two lifting planes arranged in tandem, was invented by D. S. Brown and exhibited to the Aëronautical Society of Great Britain in 1873.

over water, to obviate wreckage on landing. The machine was capable of flying several miles continuously, but in the actual test on the Potomac River the flight was limited, in order to prevent the model passing beyond the shore. The flyer was placed on launching ways on the top of a houseboat, hurled rapidly forward by force of a spring, and liberated in space, with engine and propellers running at full speed. Its subsequent behavior has been graphically described by an eyewitness, Dr. Alexander Graham Bell, in the following passage, published in *Nature,* May 28, 1896:

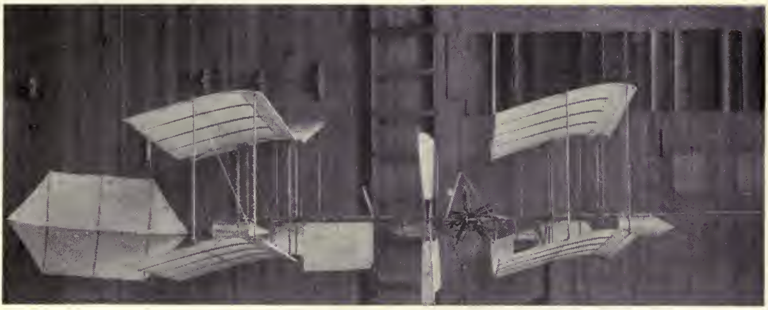
"On the occasion referred to, the aërodrome, at a given signal, started from a platform about 20 feet above the water, and rose at first directly in the face of the wind, moving at all times with remarkable steadiness, and subsequently swung around in large curves of perhaps a hundred yards in diameter, and continuously ascending till its steam was exhausted, when at a lapse of about a minute and a half, and at a height which I judged to be between 80 and 100 feet in the air, the whole ceased turning, and the machine, deprived of the aid of its propellers, to my surprise did not fall, but settled down so softly and gently that it touched the water without the least shock, and was in fact immediately ready for another trial.

"In the second trial, which followed directly, it repeated in nearly every respect the actions of the first, except that the direction of its course was different. It ascended again in the face of the wind, afterward moving steadily and continually in large curves, accompanied with a rising motion and a lateral advance. Its motion was, in fact, so steady that I think a glass of water on its surface would have remained unspilled. When the steam gave out again it repeated for a second time the experience of the first trial when the steam had ceased, and settled

PLATE XV.

LANGLEY'S STEAM MODEL.
(Courtesy Smithsonian Institution.)

LANGLEY'S GASOLENE MODEL.
(Courtesy Smithsonian Institution.)



LANGLEY'S TWO SURFACE GASOLENE MODEL.
(Courtesy Smithsonian Institution.)

gently and easily down. What height it reached at this trial I can not say, as I was not so favorably placed as in the first, but I had occasion to notice that this time its course took it over a wooded promontory, and I was relieved of some apprehension in seeing that it was already so high as to pass the tree tops by 20 or 30 feet. It reached the water in one minute and thirty-one seconds from the time it started, at a measured distance of over 900 feet from the point at which it rose.

"This, however, was by no means the length of its flight. I estimated from the diameter of the curve described, from the number of turns of the propellers, as given by the automatic counter, after due allowance for slip, and from other measures, that the actual length of flight on each occasion was slightly over 3,000 feet. It is at least safe to say that each exceeded half an English mile.

"From the time and distance, it will be noticed that the velocity was between 20 and 25 miles an hour, in a course which was constantly taking it 'up hill.' I may add that on a previous occasion, I have seen a far higher velocity attained by the same aërodrome when its course was horizontal.

"I have no desire to enter into detail further than I have done, but I can not but add that it seems to me that no one who was present on this interesting occasion, could have failed to recognize that the practicability of mechanical flight had been demonstrated."

In passing it may be added that in 1899 this model was again flown successfully, having superposed surfaces; for its inventor all along recognized the structural advantage of the bridge trussing in biplanes. If he preferred the monoplane, or single-tier arrangement, it was because the best flights were obtained with such models.

Many persons now thought that Langley would do well to rest on his laurels, leaving to others the "commercial and practical development" of his ideas. But he had caught the aëronautic fever. Like many another poor son of fancy, he was haunted by magnificent dreams. Now, perhaps, was stirring in his mind that vision of his childhood when he lay on his back in the New England pasture and "watched a hawk soaring far up in the blue, and sailing for a long time without any motion of its wings, as though it needed no work to sustain it, but was kept up there by some miracle." Mr. Andrew D. White declares that Professor Langley was a poet by nature. Whatever the dominant impulse, he followed his "aërodrome" like one possessed. It was the all engrossing pursuit of the latter years of his life, entailing how much vexation, toil and unjust censure!

In 1898 the Board of Ordinance and Fortification, after carefully studying the flights of 1896, appropriated $50,000 to enable Professor Langley to build a one-man flyer. He first tested a gasoline driven aëroplane having one fourth the linear dimensions of the man-carrying one. In external appearance this model resembled the steam "aërodrome," described above, but was considerably larger. It spread 66 square feet of surface, weighed 58 pounds, and developed $2\frac{1}{2}$ to 3 horse power. When ready for the test, August 8, 1903, this beautiful white-winged creature was taken to the middle of the Potomac, 40 miles below Washington, mounted on the launching ways, swiveled into the eye of the wind and shot forth like a stone from a catapult, her engine and propellers humming merrily.

The flight must have been very graceful and dignified, for it elicited commendation even from the squad of reporters present, men who customarily recorded such events with uncontrollable mirth and ridicule. Dr. Langley merely remarks: "This was the first time in history, so far as I know, that a successful flight of a mechanically sustained flying machine was seen in public." It was also the first successful gasoline[1] aëroplane, and the forerunner of the host of flyers presently to spring up in all parts of the world. Its flight though very brief, owing to a surcharge of gasoline, was so satisfactory in all its dynamic features, that it seemed to justify an immediate launching of the one-man machine, with which like maneuvers were anticipated. As will appear in the sequel this prospect of fair sailing was beset with unsuspected shoals.

We have now traced the growth of the aëroplane from its earliest conception to the present time, as exemplified by working models. First came the parachute of Da Vinci and others, whose sole function was to carry a weight softly to earth, with no provision for steadiness of motion, or control of direction. Then, in the beginning of the nineteenth century, arrived the gliders adjusted for steadiness, equilibrium and a predetermined slanting course in the air; beautiful passive birds, actuated by gravity, but riderless and awaiting the advent of artificial motive power. Then suddenly appeared Mr. Henson's wonderful *project;* a large man-carrying aëroplane, provided with a motor, propellers, rudders, wheels for launching and landing—an impossible scheme for that day, but destined to be realized in the course of two generations. Henson's idea was doubtless the most prolific in the history of aviation. After this followed the numerous instructive models, actuated by twisted rubber, steam, gasoline, compressed air—economic

[1] This gasoline aëroplane model was previously tested in private many times, both with single surface wings, and with superposed surfaces.

contrivances for ascertaining the secrets of propulsion, equilibrium and control, of the prospective man-flyer. These may be said to have demonstrated the practicability of man-flight, though many contemporaneous and allied experiments, to be noticed presently, all contributed to the triumphs subsequently achieved by the race of sanguine, daring and tireless inventors.

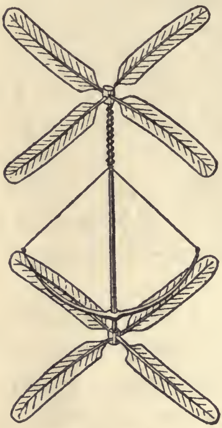


Fig. 36.—Launoy and Bienvenu's Helicopter, 1784.

In this brief outline, the two other main types of flyers, the orthopters and helicopters, have been omitted. The orthopters, or wing flapping machines, have been very numerous, but have not yet approached practical success in use. Though a man-carrying orthopter has not yet been produced, an elegant pigeon-like model operated by rubber has been made by Pichancourt, which flies and balances nicely. The helicopters, or direct-lifting screws, have more than once raised their weight and that of the helicoptrist, or navigator. These latter, therefore, seem to be of sufficient interest to merit a short historical review.

Leonardo da Vinci, the fertile pioneer in aviation, missed one novel device worthy even of his genius. He constructed aërial screws of paper, but he did not endow them with motive force. Such an achievement was in his power, and would have ranked him with Archytas of Tarentum, who 400 B. C. invented the kite, and an artificial dove said to have flown, no one knows how. Having escaped Da Vinci's ingenuity, the power helicopter failed to materialize for three centuries, but finally appeared in France.

In 1784 Launoy and Bienvenu, the first a naturalist, the second a mechanician, exhibited before the French Academy the interesting toy shown in Fig. 36. This was the first power-driven helicopter, and is said to have lifted itself in the air quite readily. As may be observed it consists of two coaxial screws rotating in opposite directions actuated by the power of an elastic stick, like a bow. The screws were each about one foot in diameter and made of four feathers; one screw being fastened to the top of the rotating shaft, the other fastened to the bow, which rotated in the contrary direction. The little model excited much interest, particularly as its inventors expected to build a man-carrying helicopter on the same plan. The larger project was obviously without merit; for no combination of springs can maintain flight for more than a few seconds even on the most favorable scale.

A more powerful toy helicopter was produced by Mr. Horatio Phillips in England in 1842. This was a single aërial screw emitting jets of steam which compelled it to spin, on the principle of a lawn sprinkler, or a Hero engine. The whole apparatus weighed two pounds, and had screw blades inclined 20° to the horizon. The steam was generated by the combustion of charcoal, niter and gypsum, as in the fire extinguisher previously invented by the same ingenious man. The performance of this curious helicopter, is thus described by Mr. Phillips: " All being arranged, the steam was up in a few seconds, then the whole apparatus spun around like a top, and mounted into the air faster than any bird; to what height it ascended I have no means of ascertaining. The distance traveled was across two fields, where, after a long search, I found the machine minus the wings, which had been torn off from contact with the ground."

"The distance traveled was across two fields." For vagueness this surpasses the poet's measure—"as far as oxen draw the plow in a day." It would be most interesting to have an exact description of this classical experiment, when for the first time a flying machine rose in the air propelled by a heat motor. It would be desirable also to know the possibilities of such a helicopter, particularly since Prof. Cleveland Abbe has proposed to employ a like agent

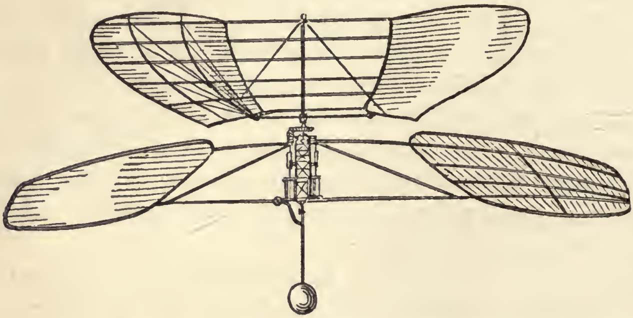


FIG. 37.—FORLANINI'S HELICOPTER, 1878.

to carry meteorological instruments into the higher atmosphere.[1]

A still more ambitious helicopter was that shown in Fig. 37 invented by Professor Forlanini, an Italian Civil Engineer, and launched in 1878. The lower screw was fastened to the frame of a steam engine, the upper screw was attached to the crank shaft. Steam was supplied from the globe shown beneath, which was two thirds filled with water, and well heated over a separate fire just before an ascension. As the globe was merely a reservoir of hot water and steam, carrying neither fuel nor furnace, its power waned rapidly. The best flight lasted about twenty

[1] Abbe, *Helicopters for Aërial Research, Aëronautics,* Feb. 1909.

seconds, attaining a height of 42 feet. The apparatus weighed 77 pounds, spread 21.5 square feet of screw surface, and lifted about 26.4 pounds per horse power.

Many other helicopter models have been tried from time to time, with various sources of power, without, however, yielding any important results beyond those already given. But these were sufficiently encouraging. If a large machine could be made to lift as many pounds per horse power, it would be easy to build one competent to carry a man. That, indeed, has been done on several occasions. Of the various inventors who have built man-lifting helicopters M. Cornu and M. Bréguet, in France, seem to have been first to attain a measure of success. While their machines have raised a passenger directly from the ground, they have not yet maneuvered in horizontal flight with sufficient speed to be of practical service. However, a few helicoptrists in various countries are still industriously at work, and hope eventually to rival the aëroplanists in the mastery of flight. There will doubtless be room in the sky for both. Perhaps also there will be occupation and a mission for both.

CHAPTER VIII

NINETEENTH CENTURY MAN-FLYERS

Having traced the growth of winged models from their earliest beginning to the time when they proved the possibility of mechanical flight, we may now study the evolution of larger machines, designed to carry human beings. Considering first the aëroplane, we may follow the two general methods advocated by various inventors for launching a man safely in the air, both of which led to success. The first of these may be called Henson's method, the second Lilienthal's, coupling them with the names of their distinguished pioneer exponents. Henson in 1842 proposed that the pilot should mount a full-power machine, run along a smooth course, and glide into the air without previous experience in the art of navigating. Lilienthal recommended careful preliminary training on a glider, by which the novice should acquire sufficient skill in parrying the wind to qualify him to manage a dynamic machine, under its more complex conditions of control. Others, more cautious still, contended that automatic equilibrium should be secured before a rider risked his bones on the aërial bronco; while still others thought the uncertain beast should be tethered to some point in the sky, say a balloon or taut wire, or the end of a pole; so that however he bucked, or reared, he should not fall over on his rider.

We have noticed in the first chapter some picturesque man-flights, usually deplorable or tragic;

and always fruitless for lack of scientific method in experimentation and report to the world. There can be no doubt that such flights were accomplished, mainly, of course, by the aid of gravity; but the difficulty is to ascertain the exact nature of any given performance, the specifications of the apparatus, and the principles of equilibrium and control. Gradually, however, the experimenters improved both in the construction of man-carrying devices and in the manner of imparting their results to their colleagues, or successors; and so the flying enterprise began to assume a progressive aspect, attended with that scientific dignity which invests secure and continuous advance in any branch of knowledge. Little of value, however, can be gleaned from any such flights made prior to the middle of the nineteenth century. From that time forward observers and inventors made definite and fairly methodical efforts to develop the art of gliding and soaring in the air, the first fruit of which was to hasten the advent of the modern aëroplane.

A French novelist and aëronautic writer, G. de la Landelle, relates an amazing adventure in the art of soaring, which may have some foundation in fact, though savoring strongly of fiction. An experienced sailor, Captain Le Bris, having observed the albatross soaring without wing-beat, determined to imitate the fascinating flight of that limber-winged spirit of the sea. To such end he built the bird shown in Fig. 38, a ninety-pound albatross, with arched wings fifty feet across and articulated to the boat-like body. In this the brave aviator would stand upright, turn the wings and tail to maintain his balance, and steer grandly through the sky. Placing this long-winged creature across a cart driven by a peasant, he stood erect and headed against a breeze; the wings set low to prevent lifting till an opportune moment, and the bird held down to the car by a rope which the captain could quickly release. When the horse was a-trot, and the wind blowing freshly, Le Bris raised the front edges of the wings. Thereupon the albatross tugged upward, and the mooring rope was slipped, but accidentally whipped around the driver's waist. The horse galloped away with the cart; the bird, with the exultant sailor on its back, soared 300 feet into the air, and incidentally carried up the peasant, dangling at the end of the rope and howling with fright. Noting the distress of his passenger, the kindly captain sailed

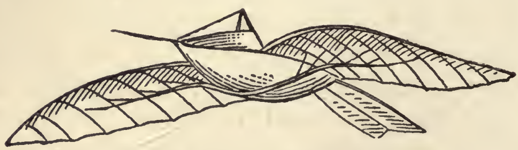


Fig. 38.—Le Bris' Aëroplane, 1855.

close to earth, so that the peasant might disembark and run to his horse, meaning then to hie away for a long cruise in the clouds. But with this change of weight the vessel seemed not to navigate well; so she was brought skimming to land, with no mishap save a slight damage to the advancing wing, which broke as it touched the ground.

Having repaired the great bird's wing, Captain Le Bris next made a launching from the arm of a derrick, 30 feet above the ground, overlooking a quarry 70 feet deep. The attendant swains stood open-mouthed, wondering whether this madman would overleap the clouds, or promptly butt out his brains on a jagged rock. When the wind blowing from the quarry seemed to float him in perfect poise, he tripped the suspension hook, and headed for the precipice on even keel. He was now happily launched, and keen for an aërial journey; but after passing the brink, he seemed to encounter an eddy which tilted his craft forward. The vessel dipped and rose; the captain plied his levers, turning now the tail, now the pinions. He crossed safely over the invisible breakers, and reached the quiet air of the quarry on level wing. But now his forward speed was lost, the great bird sank rapidly and crashed upon the rocky bed below. The wary seaman anticipating a bump, sprang upward to soften his fall; but a lever rebounding from the shock, hit one of his legs and broke it.

Some twelve or thirteen years later, in 1867, Le Bris, aided by a public subscription at Brest, built a second albatross, with which he made a number of small flights, sometimes riding it himself, and sometimes replacing his weight by ballast. On one occasion the loaded bird, held by a light line, rose 150 feet and advanced against the wind. Suddenly the sailors holding the line observed it slacken, and saw with amazement the long-winged creature soar forward 600 feet, as stately and serene as its living prototype. Presently encountering a sheltered and quiet region of air before some rising ground, it settled softly to earth in perfect equipoise. But on a subsequent launching from the same favorable ground, the dumb creature pitched forward and plunged to the earth where it lay shattered and torn in a hopeless tangle. Le Bris looked on the wreck in despair, surveying sadly the remains of his once cherished bird; then sat upon the débris a long time, his head between his hands, his heart broken, his mind tortured with anguish. Impoverished, chagrined, derided, he now must abandon the albatross business. Five years later this intrepid sailor of sea and air was killed by some ruffians, in 1872, while a constable in his native place, and after a period of honorable service to the state in the Franco-Prussian War.

The story is more romantic than instructive, for want of exact data. To give the experiments their proper value to others, fuller details of the mechanism should be furnished, and adequate measurements of the speed and direction of the aërial currents. At one time the sailing was even, at another, rough, though outwardly the conditions appeared the same. Apparently the successful flights occurred when the bird was launched to windward from rising ground, that is, when the current had an upward slant, to exert a propulsive effort. This species of soaring has been observed frequently in Nature, and has been imitated both with models and with man-carrying gliders. Nevertheless Le Bris' experiments were very remarkable for the time, and, if adequately reported, might have proved to be of much interest and value to aëronautical science.

Another Frenchman alert to the glory of aërial motion was L. P. Mouillard, the poet-farmer of Algeria. From boyhood he studied the birds with unabated interest and pleasure. He would journey miles to attend the "morning prayer" of the starlings in the forest of Baba-Ali; noting, just before sunrise, how their melodies suddenly hushed, and the forest seemed to bound upward, and heaven filled with the music of innumerable wings. He would time the shadow of the high bird of passage riding the hurricane from continent to continent. He saw the tyrant eagle fold his wings in mid air and plunge a thousand feet in ferocious swoop after the swift-fleeing duck or rabbit. He loved to watch the great tawny vulture on the mountain top shake the dew from his vast plumes, straddle the morning wind, and all day long, with never a beat of those grand pinions, soar godlike through immensity, the marvel and delight of the nether world. When the electric wind of the desert, blowing from Central Africa, brought the big scavengers and noble birds of prey, he sat on the ground scrutinizing their majestic flight and planning to imitate it. He would lie in ambush where the silent-rowing owl darted at dusk through the timber, fierce and swift as the eagle; a dreadful thing, with its night piercing eyes, its big ears and beak, its horrid talons, its sudden shriek startling the forest with ominous echoes. No feature escaped him, and least of all an aërodynamic one.

For thirty years he continued these studies. He would bring home the birds, lay them on their backs and mark their contour on paper, measure their projected area, weigh and compare them. He formulated curious conclusions about sailors and rowers, the functions of tail and quill feathers, weight and wing-spread, bulk, agglomeration of mass, resistance and velocity. He notes that only massive birds soar well, the broad-winged ones requiring a moderate wind, the narrow-winged ones requiring a gale, and sailing with perfect ease in a tempest; and he concludes that man may imitate both types. His book [1] is replete with charming anecdotes, observations and quaint theories, interesting alike to ornithology and aviation.

But Mouillard did more than theorize; he built soaring machines and soared a little. His third and best glider, illustrated in Fig. 39, was a tailless monoplane made of curved agave sticks screwed to boards, and covered with muslin. The aviator, standing in the open space C, harnessed the plane on with straps looped round his legs and shoulders, and fastened to the points D D. His forearms, passing under straps, rested on the board, enabling

[1] *L'Empire de l'Air.*

him to tilt the whole by shifting his weight. In order to vary the dihedral angle between the wings, they were hinged together and actuated by rods running from the man's feet to the ends of the boards, hardly as far out as the center of wind pressure, thus apparently stressing his legs like a wishbone.

He now sent the home folks away from the farm, buckled on his wings and walked along the prairie road waiting for a breeze. The road was raised five feet above the plain and bordered by ditches ten feet wide. His wings felt light; he ran forward to test

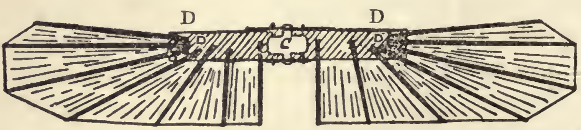


FIG. 39.—MOUILLARD'S AËROPLANE.

their lift, and he thought to amuse himself by jumping the ditch. The result is thus expressed in his own words: [1]

"So I took a good run across the road and jumped at the ditch. But, oh, horrors; once across the ditch my feet did not come down to earth; I was gliding on the air, and making vain efforts to land; for my aëroplane had set out on a cruise. I dangled only one foot from the soil, but, do what I would, I could not reach it, and I was skimming along without the power to stop. At last my feet touched the earth; I fell forward on my hands; broke one of my wings, and all was over; but goodness, how frightened I had been! I was saying to myself that if even a light wind-gust occurred, it would toss me up 30 to 40 feet into the air, and then surely upset me backward, so that I would fall on

[1] *Progress in Flying Machines,* Chanute.

my back. This I knew perfectly, for I understood the defects of my machine. I was poor, and I had not been able to provide myself with a more complete aëroplane. All's well that ends well. I then measured the distance between my toe marks, and found it to be 138 feet.

"Here is the rationale of the thing. In making my jump I acquired a speed of 11 to 14 miles per hour, and just as I crossed the ditch I must have met a puff of rising wind. It probably was traveling some 8 to 11 miles per hour, and the two speeds added together produced enough pressure to carry my weight."

He repaired his wing and repeated the test a few days later. A violent wind gust came; picked him up from the earth, and whelmed him over. In his alarm he allowed his "wish-bone" to spread, and the wings to fold up like those of a butterfly at rest, pinching him between them like a nut in a nutcracker. One wonders whether the overwheeling vultures witnessed this gentleman's flight with any sense of humor.

After mature reflection, Mouillard concluded that he should give his aëroplane a rudder, and flex the wings, in order to insure adequate control. But here he halted, being a poor man unskilled in the art of construction. He had reached the limit of his endowments. He had observed faithfully and described charmingly the wonderful flights of various birds; but he must leave to his technical successors the pleasure of imitating or excelling those extraordinary maneuvers—leave them the pleasure, the sacrifice, the long years of toil and danger, accompanied perhaps by indiscriminate applause or derision.

In the meantime another distinguished disciple of the birds was energetically at work in Germany.

No less ardent than Le Bris, or Mouillard, Otto Lilienthal was far better equipped and circumstanced. He was a graduate of the Potsdam Technical School, and a student for three years in the Berlin Technical Academy. He was engaged in practical construction ten years in various machine shops at Berlin. After 1880 he operated a flourishing machine factory of his own. From boyhood he with his brother Gustavus had carefully studied the flight of birds, and had made numerous experiments in aviation. On moonlight nights in their little home place of Anclam, in Pomerania, the boys would run downhill, flapping their home-made wings, like Dædalus and Icarus, but with no other danger than discovery and teasing by their neighbors. At Potsdam and Berlin they continued to experiment and to construct wings of increasing size and power. Thus Otto Lilienthal reached early manhood thoroughly trained by his long courses in the technical schools and shops, brimming with well pondered ideas, strengthened by continuous observation and experiment, and in financial circumstances which permitted him to devote time and money to the unremunerative pursuit of aviation. To this may be added that his mature years were cast in a time when the allied sciences could aid him far more than they had aided his predecessors of the preceding generation.

After careful research for the most efficient form of alar surface, Lilienthal resolved to imitate the birds. First he would build a pair of arched wings, and learn to coast down the atmosphere, balancing and steering like a stork in the gusty and treacherous current. He would thus acquire the pilot's skill, and ascertain the towline power required to sustain a given weight. Then he would add a suitable propelling mechanism, test it cautiously, and acquire the mastery of dynamic flight. Incidentally, perhaps, he would learn to ride all over creation without motive power; for he was convinced that certain great birds soar without muscular effort, and that man could acquire this delightful art in favorable weather. To strengthen the plausibility of that doctrine, he announced his discovery that the general trend of the wind is three and a half degrees upward, a fact inexplicable and almost incredible to his illustrious confrère of the Smithsonian Institution.[1] Such was Lilienthal's ample program; more, indeed, than he would live to accomplish, though possibly not beyond his power of achievement, if he could have lived to enjoy the hale long years of his illustrious countryman aëronaut, Count Von Zeppelin.

In the year 1891 Lilienthal made his first series of trials in sailing flight. His glider was the bird-shaped apparatus shown in Plate XVI, made of willow wood covered with waxed sheeting. It weighed about 40 pounds, and spread 107 square feet of surface. Taking this in his arms he first ran 24 feet along a raised board and jumped off, gliding through still air. Then, elevating the board to a height of six feet, he repeated the run, jump and glide, always landing very softly. Thus he became "king of the air in calm weather," a title still creditably sustained by his numerous successors of the present day; for as yet no one "mounts the whirlwind and directs the storm."

Next he went to some little mounds in a field beyond Werder, and jumped from these, gradually lengthening his flights till he attained a range of nearly 80 feet. As he was now gliding in light

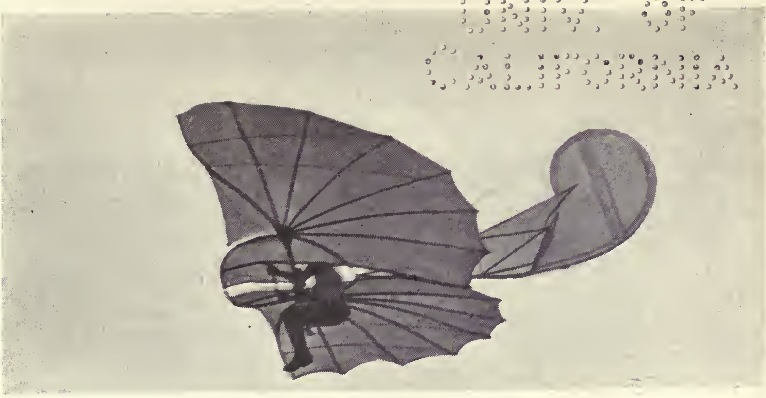
[1] The air rises with increased temperature, hence with increased volume displacement, thus causing the wind in general to have a slightly ascending trend.

winds, he found it necessary to add a vertical rudder, in order to preserve his balance easily, and keep his bow toward the direction of the wind. His complete apparatus was, therefore, a birdlike affair, with two rigid wings and a double tail for steering vertically and horizontally. He found also that he could fly longer and alight more softly when the wind was blowing—an obvious possibility.

Encouraged by this experience Lilienthal explored the country about Berlin for sailing ground where he could make long glides, whatever the direction of the wind. Such a region he found near Rathenow, where the Rhinow hills, covered with grass and heather, slope gently upward from the flat plowland to a height of over 200 feet. This he thought an ideal coasting ground; for he felt the aërial currents very smooth, and he could always select clear land sloping ten to twenty degrees toward the wind. Here in the summer of 1893, with a new and improved glider, he made many flights, finally ranging from 200 to 300 yards, steering up and down, or to right and left at will; sometimes pausing in mid air, and several times returning to the starting point. This was more than coasting; for a mere coaster never maintains, nor returns to, his original level. It was a fair start at true soaring, the ideal locomotion. A glorious sport it was, sailing like an eagle high over the landscape and over the heads of the astonished spectators.

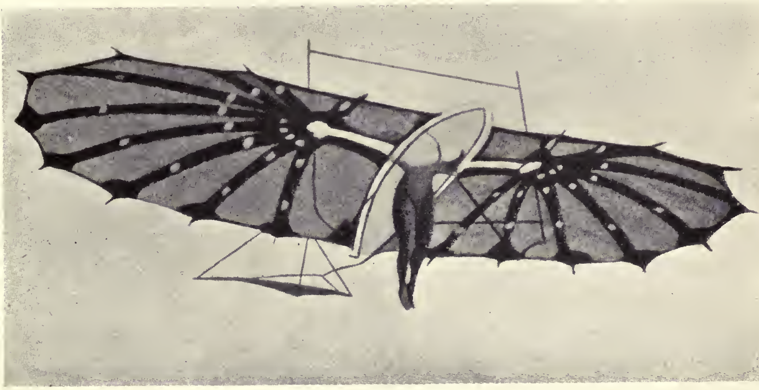
The new machine resembled its predecessors in form and maneuver; but differed in dimensions. It was a birdlike craft with parabolically arched wings and a double tail. It measured 7 meters across, spread 14 square meters of surface, weighed with the rider 200 pounds, and in calm air could sail down a slope of 9°, at a speed of 9 meters per second. This was very efficient sailing, the work of

PLATE XVI.



LILIENTHAL'S MONOPLANE GLIDER.
(Courtesy W. J. Hammer.)

LILIENTHAL'S BIPLANE GLIDER.
(Courtesy W. J. Hammer.)



PILCHER'S MONOPLANE GLIDER.

gravity being hardly two horse power. With the man lying prone, as eventually planned, the economy would be still greater.

The craft was thought also to possess stability; and this it had, in a measure, about those two axes corresponding to the two rudders; but the control about the third axis, effected by dangling the legs to right or left, was extremely crude and primitive. It was in keeping with his adage: "to contrive is nothing; to construct is something; to operate is everything." If he had contrived more intelligently, he would have operated more easily, and avoided those wild and dangerous dancings in space. A more scientific adage would read: "To design effectually is everything, to construct is routine, to operate is play."

The marvel is that Lilienthal, the observant, the technically trained, the practically skilled, should operate for three years, then patent, an aërial glider having two rudders, but lacking the third rudder, or torsional wing, now so commonly used throughout the world. But doubtless he contemplated a device for preserving the lateral balance without shifting his weight; for he acknowledged the economic advantage of lying prone on the machine, and stated that this might be done after some important improvements in the apparatus had been made.

Having executed nearly two thousand flights with his monoplane, Lilienthal in 1895 built a two-surface glider. He found this still easier to control, and now thought he had sufficiently acquired the art of sailing to justify his undertaking the next and more difficult art of imitating the rowing flight of birds. He had constructed a ninety-pound engine, of two and a half horse power, to actuate the wings of his glider; but, before applying this motor, he went to the Rhinow Hills for a little further experience in sailing. Previously he had remained in the air twelve to fifteen seconds; but he wished to exceed this record.

On the 9th of August, 1896, he made a long glide to prove the effectiveness of the horizontal rudder, and then wished to undertake a second flight of the greatest duration feasible. No intimation had he that this sail would prove disastrous. Giving the timepiece to his assistant, he set forth on a level course, but suddenly dipped forward and plunged headlong to earth through a height of fifty feet. He was dragged out from the débris with a broken spine, from which he died the following day.

The machine on which the father of aërial gliding made his last flight is shown in Plate XVI. Of the hazardous nature of its construction Mr. Chanute thus writes: "The two surfaces were kept apart by two struts, or vertical posts, with a few guy wires, but the connecting joints were weak, and there was nothing like trussing. This eventually cost his most useful life. Two weeks before that distressing loss to science, Herr Wilhelm Kress, the distinguished and veteran aviator of Vienna, witnessed a number of glides by Lilienthal with his double-decked apparatus. He noticed that it was much wracked and wabbly, and wrote to me after the accident: 'The connection of the wings and the steering arrangement were very bad and unreliable. I warned Herr Lilienthal very seriously. He promised me that he would soon put it in order, but I fear that he did not attend to it immediately.'"

It will be observed that Lilienthal gave fair attention to the merits of both the monoplane and the biplane, the two familiar types in lively competition at the present hour. The first he found in Nature; the second he could have found in England, as the developments principally of Wenham and of Phillips. His example and prestige did much to promote the biplane; but he seems to have had no very decided preference for either. Though he found his biplane very satisfactory, he thought of returning to the monoplane.

In April, 1896, he wrote: [1] "I am now engaged in constructing an apparatus in which the position of the wings can be changed during flight in such a way that the balancing is not effected by changing the position of the center of gravity of the body. In my opinion this means considerable progress, as it will increase the safety. This will probably cause me to give up again the double sailing surfaces, as it will do away with the necessity which led me to adopt them." He thus seems to have studied the two types impartially, and to have invented a means for balancing the machine without shifting the center of mass.

Lilienthal had given a powerful and permanent impulse to aviation, both by his writings and by his practical experience in the air. He first showed quantitatively the advantage of arched wings, by carefully derived tables of wind pressure; then he mounted the wings himself and taught the world, by bold and frequent flight, the art of aërial gravity sailing. The two remaining achievements, dynamic and soaring flight, he was to undertake as promptly as possible. If his life had been spared, no doubt he would have contributed much to the advancement of these arts, both by example and by direct effort; for he was in the prime of life, full of energy and daring, highly equipped, and ardently devoted to his favorite science. He began his studies in aviation at the age of thirteen and died at the age of forty-eight years.

Among the admirable traits of the father of sail-

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[1] *Aëronautical Annual,* 1897.

ing flight must be mentioned his scientific liberality and *esprit de corps.* Though he patented his invention he did not conceal, or withhold, his discoveries when he could publish them properly. These discoveries were made at a great sacrifice of time and means, and must have appeared to him valuable trade secrets; yet he published all his scientific data, his theories, and observations; he encouraged his confrères in various countries to witness and emulate his experiments, to share intimately his laboriously developed knowledge of aviation, to join hands with him in hastening the advent of practical flight. Such is the *esprit de corps* which has ever prevailed among truly scientific men, as distinguished from the mercenary and commercial; such are the unselfish investigators whom the world delights to honor, both for their genius and for their liberal contributions to the common and permanent possessions of humanity.

Before his death Lilienthal had the pleasure of knowing that competent disciples were emulating him in doctrine and practice. One of the earliest and cleverest of these was Percy S. Pilcher, Assistant Lecturer in Naval Architecture and Marine Engineering at the University of Glasgow. In the summer of 1895 he built the glider shown in Plate XVI. This, like Lilienthal's, was a double-tailed monoplane arched fore and aft; but, better than his for manual control, it was straight from tip to tip, like the designs of Henson, Penaud, and other predecessors. This improvement was introduced to prevent side gusts from rocking the craft so readily as they do the V-shaped gliders. His best sailer, the *Hawk,* shown in the figure, had wings curved one in twenty, about one third from their front edge.[1] Sometimes

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[1] Ella Tidswell, *The Aëronautical Journal,* July, 1909.

he sailed downhill; again he was towed or launched, like a kite, by means of a cord, running through five-fold multiplying gear, and drawn by running boys, or a horse. In both cases he controlled the machine to his own satisfaction, making in 1897 smooth downhill glides of 700 feet length, from an elevation of 70 feet.[1] He had also visited Lilienthal, but only after achieving success at home.

Having acquired some skill in sailing, Mr. Pilcher began work on a power machine. This was to be propelled by a screw actuated by an oil engine, and was to be mounted on wheels backed by stiff springs. Having observed his speed of descent in gliding, he computed that two tow-line horse power would float him and his machine, weighing together 220 pounds. A like result was obtained when he was flown as a kite. He was, therefore, on the straight road to achieving human flight on a screw-propelled, wheel-mounted monoplane. If he had been more cautious he might have been the first person to achieve human flight in a practicable type of dynamic machine; for he seems to have equaled, if not excelled, his German master in aëroplane design. But like the master he provided inadequately for the structural strength of his glider, and braved too far the dangers of gusty weather. One stormy day, September 30, 1899, wishing to please several persons who had come a long distance to see him, he made two trial flights in a gentleman's park near Rugby. The second of these proved fatal. The spectators heard a cracking noise, saw the tail break, and the whole craft plunge headlong to the ground. Poor Pilcher was mortally hurt and died thirty-four hours later, without ever regaining consciousness. He was then in his thirty-third year.

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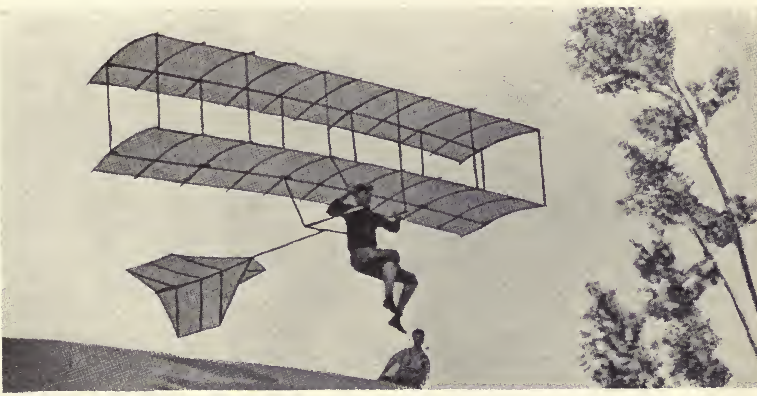
[1] W. J. S. Lockyer, *Nature*, August 12, 1897.

Had this talented young Briton and his German tutor both lived, there would doubtless have been a pleasant race and rivalry between them; for the pupil was forming opinions and plans sufficiently divergent from those of his master and friend. He did not approve Lilienthal's high wings and low center of gravity, nor his V-shape for lateral equilibrium, nor his flapping wing tips for propulsion, nor his method of launching the dynamic machine. Fortunately both published their ideas and experiments, leaving to their successors the task of judging the merits of their designs, and of adding any improvements that might still be required in order to achieve final success.

Contemporary with Pilcher, Mr. Octave Chanute and Mr. A. M. Herring, in America, were emulating the work of Lilienthal. Mr. Chanute was an experienced civil engineer, who had previously written a history of aviation, and experimented with numerous flying models; Mr. Herring, his employee for the time, was a mechanical engineer who had assisted in Langley's experiments, and previously had flown a Lilienthal glider, and had made researches in the science of mechanical flight. On June 22, 1896, accompanied by two assistants, they went into camp among the sand dunes, on the southern shore of Lake Michigan, to study the art of navigating an aëroplane without artificial motive power. Mr. Chanute thought that the maintenance of equilibrium under all circumstances was at that time the most important problem of aviation; and that until automatic stability was secured, it would be premature and dangerous to apply a motor. He wished to evade, for he did not relish, Lilienthal's way of balancing by shifting the body and kicking wildly at the stars. His main purpose, therefore, was to acquire the pilot's science; but secondarily he would

PLATE XVII.

CHANUTE'S FIVE-DECK GLIDER.



HERRING IN CHANUTE BIPLANE.

HERRING'S COMPRESSED-AIR BIPLANE.
(Courtesy Carl Dientsbach.)

learn much about the architecture of gliders, the behavior of air currents, the elements of propulsion and sustentation.

They made some flights with a Lilienthal monoplane; but, finding this unsafe and treacherous, they discarded it in favor of a multiple-wing glider designed by Chanute, which after many empirical modifications in the placement of the sustaining surfaces, assumed the form shown in Plate XVII. This glider resembled the Lilienthal biplane in having the surfaces vertically superposed, the rider below them, and the rudder in the rear; but it was a five-decker whose wings, on either side, could swerve fore and aft, so as to bring the center of lift always over the center of gravity, in order to prevent excessive rearing or plunging. This glider was found very tractable in a twenty-mile wind, and in a thirteen-mile breeze would sail down a slope of one in four.

After further study, the five-decker was replaced by a three-decker; which presently was deprived of its obtrusive and unessential lower surface, thus assuming the familiar form shown in Plate XVII. As will be observed, this was a radically new and elegant design, consisting of two superposed arched surfaces held together by vertical posts and diagonal wires, like a Pratt truss. It was, in fact, the renowned " Chanute glider " which has been copied by so many succeeding designers of biplanes.

The Chanute glider weighed 23 pounds, spread 135 square feet, and readily carried a total weight of 178 pounds at 23 miles an hour. It was provided, as shown, with side planes and a double rudder, and this latter was elastically connected to the main body to insure steadiness of flight, on the principle of the elastic wing margins used by D. S. Brown in 1874. This craft was found easy to manipulate in launching, sailing and landing, a two-inch shift of the pilot's weight equivalencing a five-inch shift on the Lilienthal monoplane. It was steady at a speed of twenty to forty miles an hour through the air, even when the wind was blowing seventeen miles an hour overground. The angle of descent was 7.5° to 11°, depending on the speed and trend of the wind. The work of gravity expended in maintaining steady flight was at the rate of two horse power for the 178 pounds, a good showing with the rider vertical.

Summer passed before Mr. Chanute could perfect the invention for automatic stability by means of swerving wings; but otherwise the gliding experiments were very satisfactory. The strong and simple biplane evolved during those few weeks of fruitful study, though not an original creation, having been foreshadowed theoretically and experimentally, in the work of Wenham,[1] Stringfellow, Lilienthal, Phillips, and Hargrave, was nevertheless an important contribution to the science of aviation, by reason of its strength and simplicity of design, its efficiency, its stability, and, best of all for that day, its record for good flights and safety. All who could appreciate it understood that the addition of a light motor would transform it to a dynamic flyer, navigable at least in mild weather. The most eager, perhaps, was Mr. Herring; for he had not only mastered this glider, but some years previously had flown successfully rubber-driven models very much resembling it in design. These two aviators, therefore, came to a parting of the ways, Chanute still pursuing automatic stability,

[1] Wenham used superposed planes, Stringfellow superposed planes trussed by vertical rods and diagonal wires, Phillips, Lilienthal and Hargrave superposed arched surfaces.

Herring impatiently heading for dynamic flight by the shortest route available. Had they continued together on a practical course, they might, ere the close of the century, have anticipated at least the early flights of the French aviators, if they could have constructed or purchased an adequate motor.

After some further development of the aërial glider to adapt it to power flight, Mr. Herring began the construction of a dynamic aëroplane. He had previously built very light steam and gasoline engines,[1] and deemed the latter best for a perfected flyer, though preferring steam or compressed air in a first experimental test.

When seen by the present writer in October, 1898, at St. Joseph, Mich., Mr. Herring was about to launch himself in the compressed-air driven biplane shown in Plate XVII. It was essentially a powered Chanute-Herring glider, steadied by a double tail, and controlled by shift of the pilot's weight, the tail being elastically attached. The writer then suggested that both a glider and a dynamic aëroplane should be controlled entirely by steering and balancing surfaces, on the principle set forth in his paper of 1893; and, in particular, indicated that the lateral balance should be controlled by changing the inclination of the wings on either side, while the double tail should be used to steer and steady the aëroplane sidewise and vertically; in other words, that a torque about each of the three rectangular axes of the machine should be secured from impactual pressure, thus obviating the need for shifting the pilot's weight. Mr. Herring, while making no objection to this proposal, intimated that he had a device for insuring control without shifting the pilot's weight, but believed the most important ef-

[1] See *Aëronautic Annual*, 1896.

fort for the moment should be to make a short flight with the machine as it stood, for the purpose of enlisting capital, then to add the controlling devices at leisure. He expected to remove the wheels shown in the figure, hold the aëroplane against a stiff breeze from Lake Michigan, start the propellers, strike a soaring attitude, and fly forward for a few seconds against the wind.

The successful accomplishment of such a flight covering an overland distance of seventy-three feet in eight or ten seconds, against a wind of thirty miles an hour, was reported in the Chicago *Evening News,* of November 17th of that year; but the present writer has not been able to ascertain the reporter's name, or that of any other witness to the event, which, if true, is well worthy of verification and detailed record.

In following the votaries of passive flight, as represented by Lilienthal and his school, we have overlooked the great man-carrying bird of Clément Ader, one of the most prominent and successful aviators of that active period. If the reports be true, Ader may justly claim to be the first person to navigate the air in a dynamic flying machine. However, it must be observed that his achievements did not at first arouse in France a great pitch of exultation and enthusiasm. There seemed at the time to be some skepticism as to the practicability of his device. But later cordial reparation was made by placing it on the Stand of Honor at the Aëronautical Salon, held in the Grand Palais, at Paris, in December, 1908.

Clément Ader set out in life with the fixed determination to make a fortune, then to build a practical flying machine. Adopting the profession of electrical engineer, he quickly accumulated enough capital, as he thought, to realize his early ambition. He next visited Africa to study at close range the great soaring birds that Mouillard had described with so much admiration and vivacity. Going to Algeria he disguised himself as an Arab, and, with two Arab guides, journeyed to the interior where he watched the great soaring vultures, which he enticed with bits of meat to perform before him their marvelous maneuvers, wheeling in wide circles, and without wing beat, from earth to sky.

After several years of study of the anatomy and flight of birds, Ader began, at the age of forty-two years, to construct an aëroplane. His first machine was a birdlike monoplane mounted on skids, or wheels, and driven by a 40-horse-power steam engine actuating a screw, placed forward. The total weight was 1,100 pounds, the spread 46 feet, the length 21 feet. The *Eole,* as he called it, received its first open-air test on the morning of October 9, 1890, in the grounds surrounding the Chateau d'Armainvilliers, near Gretz, a portion of the course being so prepared that the trace of the wheels would be visible. When everything was ready for the trial, Ader mounted the machine, in presence of a few friends, ran quickly over the ground, urged by the propeller thrust, then rose into the air and sailed 150 feet. Such is the report of the witnesses to what is claimed as the first flight of a human being in a power-driven flying machine.

Subsequently this bold inventor built *Eole No. 2,* which, by special permission of the War Department, he tested on a prepared track, 2,400 feet long, on the Satory Camp. Over this course he ran his machine several times, and on one occasion flew 300 feet; but on alighting broke one of the wings.

Ader, now having spent one and a half million francs on his experiments, placed the *Eole* on exhibition in order to raise money for their continuation. In this venture also he was successful, being presently subventioned by the French War Department to build an aëroplane for its use. His subsequent labors are concisely set forth in *Automobilia and Flight* for February, 1909, as follows:

"Under these new conditions the workshop in the Rue Pajou was abandoned for larger premises in the Rue Jasmin, where the construction of the *Avion* was commenced in May, 1892, all persons engaged with the construction being under a military vow of secrecy. The motor was built first, and tested before a commission composed of army officers and some of the leading technicians of France. It was found to develop 30 horse power for a total weight of 32 kilogrammes; and even now, though seventeen years old, is regarded as a *chef d'œuvre*. In the spring of 1897 the *Avion* was ready to make flights. Like its predecessors it was modeled on the form of a bat; but, although the wings could not be flapped, they could be folded, and could be advanced or retarded horizontally.

"Everything appearing satisfactory, Ader informed the military commission that he was ready to undergo tests; the committee met at the workshops in the Rue Jasmin on August 18, 1897; were pleased with the machine, and ordered flights to be made immediately at Satory. It was not, however, until October 12th that a flight was attempted on the carefully guarded military ground, and in the presence of General Mesnier. The apparatus covered a distance of 1,600 yards, and although it did not fly, for this distance it is certain that on several occasions it completely left the ground. Ader declared that according to whether the wings were carried forward or to the rear, it was the front or the rear wheels only which left the ground. The pressure in the generator at this moment varied between

3 and 4 atmospheres. On increasing it to 6 or 7 atmospheres none of the wheels touched.

"Satisfied with the results of the test, General Mesnier called the commission together for further trials on the following day, October 14, 1897. Unfortunately it was a rough, squally morning, that would have prevented many a modern aviator from bringing a machine into the open. But as the officers had been brought together specially for this purpose, a flight was attempted.

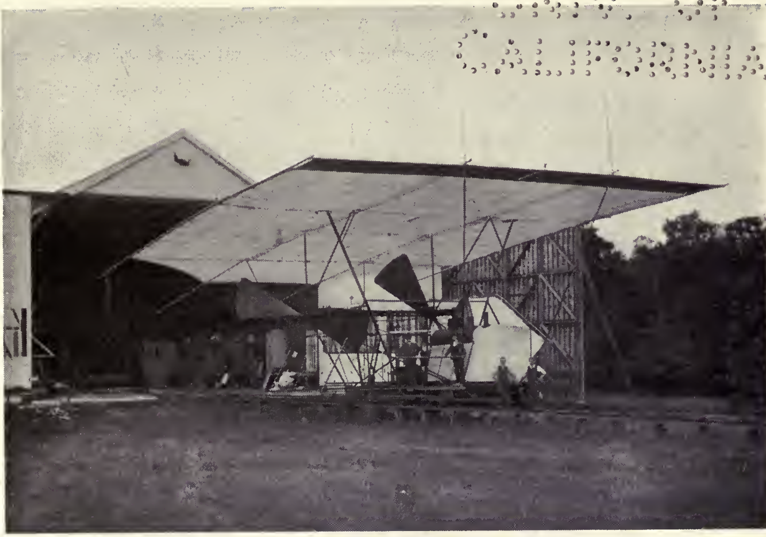
"'After several revolutions of the propellers, and a few yards covered at a moderate speed, we were off at a high rate of travel,' wrote Ader, who was at the wheel on this memorable occasion. 'The pressure was about 7 atmospheres. Almost immediately the vibrations of the rear wheel ceased, and, directly after, those of the front wheels were no longer felt, showing that we had entirely left the ground. Unfortunately the wind had increased in strength, and I had some difficulty in keeping to the line that had been marked out. I increased the pressure to 9 atmospheres, and immediately the speed increased considerably, the vibrations ceased again, showing that we had once more left the ground. Under the influence of the wind the aëroplane had a constant tendency to drift to the right, away from the circular track that had been marked for it. Finally, with the wind broadside on, the machine was in a rather dangerous position, for it was being still more rapidly driven out of its course. I increased the pressure still more and put the rudder hard over to the left, with the result that for a few seconds the machine worked back towards the track and still maintained itself in the air. But it was impossible to struggle against the wind, and finding that the machine was being carried towards some artillery sheds, and somewhat unnerved by the speed at which the ground appeared to be rushing past, I stopped the engine; there was a shock, and I was on the ground.'

"Ader was uninjured, but his machine was rather badly smashed. It had certainly flown, but with such difficulty in the face of the wind that the army commission was evidently little inclined to report favorably upon it. Several weeks passed without any communication being received from the War Department; then it became apparent to Ader that the Government had no longer faith in his invention. This was proved early in the following year by an official communication to the effect that no further funds could be allotted to this work. Discouraged at the abandonment after forty years' labor and the expenditure of about two million francs, Ader commenced the destruction of his machines. The earlier ones were destroyed, but the *Avion,* the one which had appeared before the army commission, was saved and sent to the Museum of the Arts et Métiers in Paris."

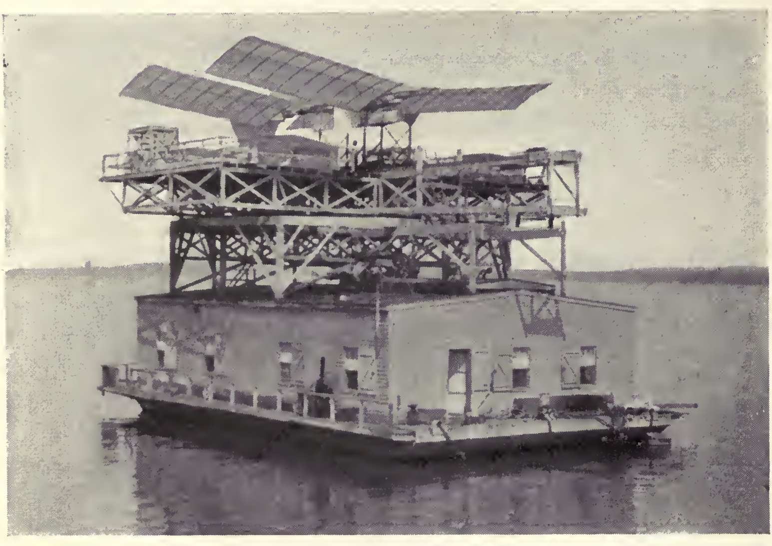
The last aëroplane, or *Avion,* weighed 1,100 pounds, spread 270 square feet, and was driven by a 40-horse-power steam engine actuating twin screws projecting before the bird-shaped flyer. The engine weighed but 7 pounds per horse power—quite a remarkable achievement for that day.

In following the votaries of passive flight, as represented by Lilienthal and his school, we have overlooked the great dynamic aëroplane of Mr. Maxim, one of the most prominent aëroplane builders of that active period. Having in 1889 made elaborate experiments on the atmospheric resistance of sustaining surfaces, and on the thrust of screw propellers, he proceeded to build the gigantic aëroplane shown in Plate XVIII, the greatest flyer thus far known to history. It was a twin-screw multiplane

PLATE XVIII.



MAXIM'S AËROPLANE.
(Courtesy W. J. Hammer.)



LANGLEY'S LARGE AËROPLANE.
(Courtesy Smithsonian Institution.)

mounted on a platform forty feet long by eight feet wide, and having four wheels running along a track eight feet wide and half a mile long. Above the rails of this track were guard rails to prevent the flyer from rising more than three inches during the tests. The whole machine weighed 3.5 tons, spread 5,500 square feet of surface, and, at a speed of 40 miles an hour, lifted more than a ton, in addition to the weight of the three men and 600 pounds of water. Its propelling plant comprised a naphtha tubular boiler, and a compound steam engine of 350 horse power actuating twin screws 17 feet 10 inches in diameter which gave a thrust approximating 2,000 pounds. These screws were made of American yellow pine, covered with canvas and painted, then smoothly sandpapered to reduce the friction; for Maxim, like certain French aviators, erroneously imagined that a polished surface has less air friction than a dead even surface. The framework was composed of seamless steel tubing stayed with steel wire. The aëroplane was to be steered right and left by a rudder, and up and down by horizontal planes, one fore, another aft, and its lateral stability was to be secured by side planes set at a dihedral angle. A meritorious feature for that day were the superposed arched surfaces whose framing was smoothly covered below and above by skillfully stretched fabric, causing the air to flow evenly without wasteful eddies.

Many runs along the track were made to test the working of this great apparatus before trusting it to launch forth in free flight. Dynamometers gave independently the thrust of the screws, and the lift of the wings on the front and rear axles. The ascensional planes for controlling the fore and aft equilibrium were tested during the run, as also the practical operation of the propelling plant. During the trials of 1893 the machine frequently lifted clear of the lower track, and flew forward resting against the guard rails above the wheels. Finally, on a gusty day, the lift against the upper track caused this to give way, whereupon the machine rose into the air with Mr. Maxim and his assistant, then toppled over on the soft earth, suffering some damage to its framework. Here the experiments were discontinued for lack of funds, having indeed demonstrated that a large weight can be carried in dynamic flight, but having proved little as to the feasibility of controlling an aëroplane in launching, in free flight, and in landing.

Compared with the work of his contemporaries this achievement of Mr. Maxim was herculean, both in construction and expenditure, the cost being reported as nearly one hundred thousand dollars. It raised high hopes for aviation. It proved conclusively not only that a flying machine could be made to lift a pilot, but that it could carry hundreds of pounds additional weight. It still holds the world's record for magnitude of machine and cargo. But it had two great defects; it was improperly balanced and it was inadequately powered; for, as Mr. Maxim says, " the quantity of water consumed was so large that the machine could not have remained in the air but a few minutes, even if I had had room to maneuver and learned the knack of balancing in the air." [1] These defects, however, would soon be remedied by the work of others, and particularly by the costly experiments of the automobilists, who were rapidly developing a light gasoline motor suitable for aviation.

The inventors thus far noticed had developed most of the important features of the present-day

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[1] *Aërial Warfare*, Hearne, p. 77.

flying machines, but had not provided adequate mechanism for preserving a steady lateral balance. The present writer had proposed the combination of a double rudder and torsional wings to steer and control a flyer, and had published a paper setting forth its general principle and describing a specific device; but inventors had little need for a third rudder till they encountered the dangers of dynamic flight in gusty weather. The paper referred to was presented to the Third International Conference on Aërial Navigation, in August, 1893, under the title, *Stability of Aëroplanes and Flying Machines*, and was published with the proceedings of the conference.[1] It discusses mainly the question of automatic stability and steadiness; but recommends personal control during the experimental period. It concludes as follows:

"We have been considering the question of automatic stability, in so far as it may be secured in the construction of the craft itself,[2] apart from a pilot, or special equilibrating devices. The application of the latter would give exercise to an infinite amount of ingenuity, and would, perhaps, best be left to the fancy of the individual inventor. One curious design, however, occurs to me, which, since I have not seen it described elsewhere, may be worth a moment's notice.

"Suppose a Phillips's machine (see Plate XIV) to be provided with a double tail, and to have a vertical fin extending longitudinally along its entire length, well above the center of gravity. These would steady its flight and promote stability. *Suppose also that its sustaining slats were pivoted, so that a pilot could at pleasure change their inclina-*

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[1] Published by the *American Engineer and Railway Journal.*

[2] This kind of automatic stability may be called inherent stability.

tion on the right and left side independently. He could then set the engine for a desired speed, sweep forward along the earth with the sustainer slats horizontal, and at will mount into the air, by giving the slats an upward inclination. Once in the air he could raise or lower the machine by slightly changing the angle of the slats; he could wheel to right or left by giving one set of slats a little different slope from the other; he could arrest all pitching, rocking and wheeling by a slight counter movement of the sustainers. It would be necessary, of course, to preserve a rapid forward motion, for it is a peculiarity of the compound aëroplane that, if it comes to a standstill in the air, it will drop plumb down with a frightful plunge until it acquires headway."

The succeeding paragraph disclosed a specific contrivance embodying the principle just given. This showed two levers rotating drum shafts for actuating wires adapted to change the impact angles of the wing surfaces. Accordingly this much of the mechanism of control, together with the broad device of the torsion wings, has been the common property of inventors since the publication of that paper. Furthermore, the combination of torsional wings and a double rudder, either fixed or movable, has been public property since that date.[1]

Little was said about the manner of manipulating the double rudder and torsional wings; for the rules of manipulation would vary in different machines, depending upon structural design and external conditions. For example, if the proposed fin and vertical rudder were ample and suitably placed, the lateral balance could be controlled by merely

[1] Models embodying the above devices had been made and flown by the writer some years previously; but aside from these it is obvious that a Phillips's aëroplane and other kinds can be effectively controlled in flight by the above-proposed three-torque system.

twisting the wings, without touching the vertical rudder; but if the fin and rudder were not adequate, the lateral poise would be controlled by twisting the wings and working the vertical rudder conjunctively. A novice might prefer leaving the rudders fixed and controlling the poise in short flights by twisting the wings by means of a single lever having two independent movements, one to rotate the wings oppositely, the other to rotate them identically.

The principle of control expressed in italics had been set forth also in a preceding paragraph. Having proposed means for securing both stability and steadiness about each of the three axes of an aëroplane, the text continued:

"These ends could probably be attained very well by mounting two compound aëroplanes on a long backbone,[1] somewhat after the manner of the Hargrave cellular kites, and adding a compound rudder to the whole." . . . "*If the inclination of the sustainers, front and back, could be altered independently, it might be feasible for a pilot to preserve the equilibrium of the machine even when its center of gravity was frequently shifted, as by the moving of passengers to and fro.*"[2]

At that date, 1893, an inventor doubtless could have secured a broad claim on a mechanism embodying the torsion-wing-and-double-rudder mechanism of control. But in those days aviation was pursued largely as a liberal study by scientific men who wished to hasten the advent of practical flight, by presenting important physical measurements and principles which could be freely employed by all. Accordingly the three-rudder system of control

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[1] This idea was later materialized in Langley's gasoline biplane.

[2] The means for balancing here suggested in italics was claimed some years later in Mr. Hugo Mattullath's patent application in which the inventor had the assistance of the present writer.

seems not to have been claimed by an inventor much before the close of the nineteenth century. Since then it has been patented in one form or other by many practical aviators, some endeavoring to claim the whole broad contrivance, others claiming more restricted devices.

The static principle of the torsion wing is a familiar one in elementary mechanics. It is this: a torque of given magnitude and direction has the same effect on a rigid body whatever its point of application. The longitudinal torque, or moment, may therefore be exerted by the wings, by suitable rudders, by forward planes, by any auxiliary planes, or fins, however placed or moved for the purpose. Accordingly there seems to be an unlimited variety of concrete patentable devices available to the inventor for securing impactual torque about the longitudinal axis, or either of the other two axes. But in planning such devices it is well to remember that the moment of a couple increases with its arm, so that in a wide aëroplane the wing tips may best furnish the torque; while in a high short-winged machine, vertical planes, fins, or rudders may give the desired longitudinal moment. Obviously such vertical guiding or controlling surfaces may be so placed as to tilt the machine toward the center of curvature of its path, at the same time opposing the centrifugal force, and exerting a torque about the vertical axis tending to steer the flyer along its path.[1]

[1] A nearly equivalent vertical surface was used in Dr. Langley's large "aërodrome." It was a wind-vane rudder placed well below and to the rear of the centroid, to be used in turning corners. The pressure on this rudder would tilt the aëroplane toward the center of curvature of the path, and turn it about the vertical axis, but would conspire with the centrifugal force. If placed above and forward, it would give the desired moments, but oppose the centrifugal force.

The principle of projectile stability is another consideration of some importance in aviation, or more generally in all submerged navigation, whether of air or water. A submerged body has projectile stability if its nose tend always to forerun its centroid, and follow a steady course. A dart is a good example; a fish, a torpedo. Thus if a torpedo-shaped homogeneous solid be hurled in any manner through a fluid, obliquely or even tail foremost, it promptly turns its nose to the front and proceeds steadily along an even course; but if the body has not true dynamical balance, it may oscillate or gyrate, or flit about in the most erratic manner.

Projectile stability in a flyer, as in an arrow, may be attained by playing the centroid in or near the line of forward resistance, and well ahead of the side resistance. The reasons for this are manifest. If, however, this arrangement be neglected, a special damping, or controlling, device is required to preserve headlong and steady motion. In particular, the objections to placing the centroid too low were emphasized in the above quoted paper as follows:

"I have mentioned the advantage of placing the center of mass below the center of surface; this has also its objections. While the stability against inversion is increased, the stability against rocking is sacrificed. The aëroplane so constructed may not easily overturn; but it will sway to and fro with a pendular motion. This, when lateral, is very objectionable, when fore and aft it is fatal to uniform progress, as we shall see in studying the longitudinal stability of flying machines. We shall then see that the center of mass cannot be lowered with impunity."

Of the various flyers and models thus far studied, some manifest fairly good, others very imperfect projectile stability. Many inventors have been more alert to the gravitational stability and safety of the parachute than to the kinetic stability and keen, direct flight of the arrow. Some of the most pretentious machines imitated the thistle down more nearly than the dart or swallow. But the exigencies of actual flight would easily rectify such imperfections of design.

Tractional balance also is a property of some importance in fluid navigation. This requires that the line of propulsive thrust coincide with the line of fluid resistance. It is a property, however, that inventors readily apprehend, and usually provide for.

In general a flyer is subject to four forces: weight, thrust, air pressure and inertia. When these balance about any axis the craft has equilibrium about that axis; when they balance about the three axes the craft is completely balanced, and preserves its orientation in flight. Devices for preserving this complete balance have already been described; as also provision for propulsion and sustentation, launching and landing safely.

Thus at the close of the nineteenth century all the essential principles and contrivances of pioneer flight were worked out, except one—a suitable motor. This was the real problem of the ages. The rest was easy by comparison. A light enduring motor, if available to the old time inventors, would have brought dynamic flight centuries ago. That only could have baffled Da Vinci, Cayley, Henson, Wenham and the long line of pioneer aviators. Eventually, of course, steam engines had come, endowed with ample power; but costly to build and wasteful to operate. The light automobile engine appeared in the latter nineties; promptly thereafter followed the dynamic flyer, the snow-winged herald of the twentieth century.

CHAPTER IX

AËROPLANES OF ADEQUATE STABILITY AND POWER

The dawn of the twentieth century found several votaries contriving aëroplanes for one or more passengers. The epoch of models had virtually closed, bequeathing a rich heritage. The essential elements of aviation, barring the motor, had been clearly worked out. The age of practical flight was at hand. No further need to prove feasible the heavier than air; for that had been done repeatedly. Scientific design and patient trial, not invention and physical research, were now the chief demand. Further research would improve the aëroplane, but not bring it into practical operation. Capital, constructive skill, judgment in adapting principles and devices already known, energy, persistence, caution, imperturbability in danger and derision; these were requisites. Science had led the way, with uplifted torch; let the craftsmen follow her with kit and apron. The aëroplane was sufficiently invented; it now wanted, not fastidious novelty, but concrete and skillful design, careful construction, exercise in the open field.

Of the group of aëroplanists in the beginning of the nineteenth century Mr. Hugo Mattullath, of New York, was one of the most original, daring and resourceful. He had been a successful inventor, manufacturer and business man, accustomed to large enterprises. In the latter nineties, deeming the time opportune for practical aviation, he determined to build a commercial flying machine. He would begin where Maxim had stopped. A larger and swifter craft appeared to him most desirable. In his judgment any clever mechanic could make a one-man flyer. "Take that for granted and waste no time on toys!" Professor Langley's "aërodrome," with every spare ounce filed away, should lift itself, of course. It might navigate a calm; possibly even a zephyr, if no one sneezed; but never could it carry passengers on schedule time. He therefore would jump the little flyers, and build at once a commercial aëroplane strong enough to defy the storm, powerful enough for regular traffic on a business scale. That meant a ship for numerous passengers, equipped to fly fifty miles an hour against the prevailing wind. A glorious project indeed; an enterprise suited to a gentleman of first rate ability.

Mattullath's aim was aërial transportation, not exhibition at county fairs and crowded carnivals. Regular interurban routes were projected, terminating in ample landing floors. Broad-winged aëroplanes, huge catamarans with shining hulls, sumptuously furnished in gold and crimson, should convey happy crews, in all seasons, from metropolis to metroplis. Six great engines and propellers to drive the ship, with abundant reserve power. Melodious strains of music rising incessantly, to soften the thunder of motors and the demoniacal howl of the wind. Then transcontinental voyages, outsailing the nimbus, how lovely to the anointed of fortune! Jocund savannas nestling by the sea, or in the bosom of orchid-crested hills, should welcome to earth the silken sojourners of the north migrating, gay-plumed and potent, to their winter homes in tropic paradise. All the isles of ocean, all the merry mountains, earth, sea and air, one shining empire, blissful and secure as Olympus. Chimborazo, girt with every clime, from torrid base to snowy peak should glow

> With alabaster domes and silver spires,
> And blazing terrace upon terrace high
> Uplifted; here serene pavilions bright,
> In avenues disposed; their towers begirt
> With battlements that on their restless fronts
> Bore stars—illumination of all gems!

Such were his holiday fancies, seldom revealed, even to his associates. The public had no intimate part in his project. A few trusted engineers, eminent in their profession, and a few financiers, formed his advisory board. For two years he worked on the structural elements of the great sails, propellers, and framing of his ship. But unhappily when he was preparing to present his final plans to his council of engineers, before building the large vessel, he was brought suddenly to the close of his career.[1]

Mattullath's proposed air ship consisted of two parallel torpedo-shaped hulls sustained by superposed plane or slightly arched surfaces, and propelled by feathering-paddle disk wheels embedded in the planes; the engines, cargo and passengers to be placed within the hulls.[2] This arrangement would enhance the comfort of the passengers at high speeds, eliminate resistance, distribute the load on the framing, and increase the moment of inertia of the vessel, thereby rendering it less sensitive to side gusts. To improve the projectile stability and steadiness, the centroid was placed as high as practicable. Large steering planes were used fore and aft on both sides of the vessel, whose inclination could be changed independently, to turn the ship about its longitudinal or transverse axis. A vertical rear rudder steered

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[1] He died of apoplexy, January 31, 1902.

[2] The first flights were to be made from the water.

to right or left, in conjunction with the side planes. All the posts were of double wedge shape; all the planes were canvassed above and below to shield the framing, after the style of Maxim. The hulls, the posts, the planes, all parts, were keenly sharpened to economize power. The ship was to run over its smooth launching field till it acquired a rising speed of forty to fifty miles an hour, then continue accelerating up to velocities sufficient for competition with passenger trains in all weather.

While one may easily point out certain questionable features in Mattullath's project, as for example, its odd propellers, one can not so easily estimate its true merits. The torsion wing device for lateral control and steering, which he claimed in his patent application, abandoned after his death, now constitutes a very important feature of every flying machine. His planes for fore and aft control, introduced by Maxim, are also in general use to-day. The principle of load distribution, which he greatly prized for diminishing stress and adding stability, has still to be evaluated by practical test in larger craft than any now in operation. The closed hull, for comfort and economy at high speed, is at present popular with many designers.

One tentative assumption of Mattullath's, made on the authority of Maxim and Langley, was that the friction of the air is a negligible part of the entire resistance encountered by the hull, framing and sail surfaces. Accepting their experimental conclusion, he designed a flyer so sharp and smooth in all its parts as practically to eliminate the pressural, or head resistance. With no skin friction, with scant hull and frame resistance, he could afford[1] to fly at

[1] It can be shown that the angle of flight requiring the least motive power is that which makes the wing resistance, or drift, three fourths of the entire resistance to progression.

a very slight angle, thus minimizing the drift, or wing resistance, while at the same time securing abundant lift by rapidity of flight. He thus arrived, by cold deduction from the data of those prominent experimentalists, at an aëroplane swift as the albatross, and wondrously economical of power. But his financiers were loath to gamble on that assumption. He therefore, at their suggestion, instigated systematic measurements of air friction on smooth surfaces, which demonstrated that in a sharp aëroplane flying at a very slight angle, the skin friction is nearly equal to all the other resistances combined. These results were obtained and published [1] some months after his death. They were unfavorable to his project, and to all projects for attaining high speed through the air by excessive sharpening of the vehicle.

The first dynamic aëroplane of adequate stability and power to carry a man in prolonged flight, was that of Professor Langley. This machine was nearly a duplicate, on a four-fold scale, of the gasoline model previously described, which had flown many times with good inherent equilibrium. There was accordingly every reason to expect that, weighted and launched like the model, it would fly with the same poise and swiftness, even if left to govern itself. Having in addition a living pilot, provided with rudders for steering and balancing, together with adequate fuel for a long journey, it seemed to promise still better results than the model. But an unfortunate accident in the launching so crippled this carefully designed craft that it fell down helpless, without a chance to exhibit its powers of sustentation and balance, even for a moment, in normal flight.

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[1] *Atmospheric Resistance on Even Surfaces*, by A. F. Zahm, *Phil. Soc. Washington.*

The first trial occurred on September 7, 1903, in the middle of the Potomac River at Widewater, Va. The aëroplane was placed on the same catapult, above the boat, that had previously started the models on their smooth and rapid maneuvers. The pilot took his seat, and started the 50-horse-power engine which ran the propellers without appreciable vibration. Tugs and launches were placed along the course where they might be of service. Photographers, on the water and along shore, were ready to furnish important pictorial records of the experiment. The aëroplane was released and sped along the track attaining sufficient headway for normal flight; but at the end of the rails it was jerked violently down at the front, and plunged headlong into the river, sinking beneath the waves. Buoyed up by its floats, it quickly rose to the surface, with its intrepid pilot uninjured, and with little damage to the structure.

As revealed by an examination of the catapult and photographs, the guy post that strengthened the front pair of wings had caught in the launching ways, and bent so much that those wings lost all support. The aëroplane, therefore, had not been set free in the air, but had been wrenched and jerked downward. Thus the launching proved nothing of the propulsive or sailing powers of the machine.

Those who understand the principles of aviation can judge the merit of Langley's "aërodrome"[1] from its mechanical description. As shown in Plate XVIII, it was a tandem monoplane driven by twin screws amidships. The pilot seated in the little boat could control the poise and course by several devices; he could shift his weight longitudinally 4.5 feet, lat-

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[1] The term "aërodrome" is now commonly applied to an aviation field.

erally 2.5 feet; he could elevate and depress the rear double rudder, which when untouched ensured steady longitudinal poise, on the principle introduced by Penaud; he could steer to right and left by turning about its vertical axis, the wind-vane rudder shown below and rearward of the boat. The lines of lift, propeller thrust and forward resistance passed through the centroid, or near it, thus providing for projectile and gravitational stability. In this feature Langley's "aërodrome" far surpassed those of his immediate predecessors, whose machines, by reason of their low centroid, possessed the stability of a pendulum, rather than that of a dart, or swallow. These various devices combined should give the craft better control in free flight than that possessed by any of the models, which had flown successfully many times in moderate weather.

If the projectile and steering qualities of Langley's machine surpassed those of its predecessors, the propelling mechanism was a still greater advance in the art of aviation. The gasoline engine was a marvel of lightness, power, endurance and smoothness of running. It weighed, without accessories, 125 pounds, and developed 52.4 horse power in actual test at a speed of 930 revolutions a minute. With all accessories, including radiator, cooling water, pump, tanks, carburetor, spark coil and batteries, it weighed 200 pounds, or scarcely five pounds per horse power—a great achievement for that time. It could run many hours continuously under full load, consuming about one pound of gasoline per horse power per hour. Its five cylinders, arranged radially round a single crank shaft, were made of steel lined with cast iron, and measured 5 inches in diameter by 5.5 inches in stroke. Its running balance was excellent. By means of bevel gears it drove the twin screws at 700 revolutions per minute, giving a thrust of 480 pounds, the screws being very nearly true helices of unit pitch ratio and 30° width of blade, carefully formed of three radial arms covered with canvas.

The whole machine weighed 830 pounds, including the pilot; spread 1,040 square feet of wing surface; measured 48 feet from tip to tip, and 52 feet from the point of its bowsprit to the end of its tail; soared at a speed of about 33 feet a second and a ten-degree angle of flight, the wings arching one in eighteen at one fourth the distance from their front edge. The double rudder, at the extreme rear, measured 95 square feet in each of its component surfaces.

It is evident from these figures, very kindly furnished by Mr. Manly, the mechanical engineer in charge of the experiments, that such an aëroplane had every equipment needed for a steady flight of many hours in fair weather. A thrust of 490 pounds on well-designed surfaces should easily carry 500 pounds of gasoline in addition to the 830 pounds regular weight of ship and pilot. This would enable the machine to fly practically all day without renewal of supplies. It appears, therefore, that Professor Langley had, in 1903, a dynamic aëroplane quite the peer, in many respects, of the best that were developed during the first decade of aviation, and that a mere accident, which should be expected in such complex experimentation, deprived him of the credit of the first man-flight on an adequately controlled and powered machine. Quite true, he lacked launching wheels; but how easy to add these, since they were proposed many times. He omitted the front steering plane, but had a rear one serving the same purpose. The worst that can be said is that he needed the equivalent of torsion wings for lateral control; but in moderate weather he could have flown successfully without them, as Farman, Delagrange, Paulhan[1] have so fully demonstrated. Besides, Langley had already tested the torsion wing device, and contemplated using it on his large machine.

A second launching was attempted on the Potomac River near Washington, on December 8, 1903. This time the rear guy post was injured, crippling the rear wings, so that the aëroplane pitched up in front and plunged over backward into the water. After some repairs it was stowed away in the Smithsonian Institution, where its frame and engine are still intact, its wings having been injured in the wreck and discarded. The experiments were now abandoned for want of funds to continue them.

Notwithstanding that Professor Langley had contributed much to the science of aërodynamics, by his elaborate researches, and had really developed a machine capable of sustained flight, if properly launched, he was subjected to unmitigated censure and ridicule; for he had incurred the enmity of various journalists and wiseacres, partly by his official secrecy, and partly by that natural reticence which avoids premature publicity in important scientific enterprises. This irresponsible criticism, combined with the cessation of work which should have brought success, profoundly grieved him, and doubtless hastened his death. He had, however, the satisfaction of knowing that a few competent specialists appreciated his labors, and would continue them to abundant fruition. A few days before his death he had the gratification of receiving, from the newly formed Aëro Club of America, the following communication acknowledging the value of his efforts to promote aërial travel.

[1] On August 25, 1909, Louis Paulhan, in the aviation contest at Rheims, flew 82 miles in 2 hours, 43 minutes and 24 seconds, preserving his lateral balance without the aid of torsion-wing mechanism and in a turbulent atmosphere.

RESOLUTIONS OF THE AERO CLUB OF AMERICA

Adopted January 20, 1906.

"*Whereas,* our esteemed colleague, Dr. S. P. Langley, Secretary of the Smithsonian Institution, met with an accident in launching his aërodrome, thereby missing a decisive test of the capabilities of this man-carrying machine, built after his models which flew successfully many times; and whereas, in that difficult experiment, he was entitled to fair judgment and distinguished consideration because of his important achievements in investigating the laws of dynamic flight, and in the construction of successful flying models; therefore be it

"*Resolved,* That the Aëro Club of America, holding in high estimation the contributions of Dr. Langley to the science of aërial locomotion, hereby expresses to him its sincerest appreciation of his labors as a pioneer in this important and complex science; and

"*Be it further resolved,* That a copy of these resolutions be sent to the Board of Regents of the Smithsonian Institution and to Dr. Langley."

This kindly message from America's foremost aëronautic society brought a moment's pleasure to the last hours of the illustrious scientist. "Professor Langley was on his deathbed when these resolutions were brought to his attention, and when asked what should be done with the communication, his pathetic answer was: 'Publish it.' To all who know his extreme aversion to publicity in any form, this reply indicates how keenly he felt the misrepresentation of the press." [1]

[1] *Aërial Locomotion,* A. G. Bell, Washington Academy of Science, March 4, 1907.

Professor Langley's progress with the "aërodrome" was due largely to the skill, energy and devotion of his designer and superintendent of construction, Mr. Charles M. Manly. This talented young graduate in mechanical engineering, of Cornell University, in 1898, went directly from the class room to assume the chief burden of Langley's researches in aërodynamics, and his practical experiments in mechanical flight, remaining till their termination in 1904. He was the confidential secretary and adviser to his chief in that whole enterprise. When in 1900 Dr. Langley stood baffled before the greatest obstacle in aviation, unable to find any manufacturer, in America or Europe, who could furnish a practical engine of the desired power, lightness and durability, Manly came to his rescue with a design which guaranteed success and which resulted in the wonderful gasoline motor built in the Smithsonian shops. Finally when the aëroplane was ready to be launched, it was Manly who bore the long weeks of trial in the malarial region of Widewater, harassed by accidents and foul weather, not to mention the merry agents of the press; and it was he who twice rode the ponderous aërodrome, shot forth in mid air at the imminent risk of his life.

While Langley was building his great tandem monoplane, Wilbur and Orville Wright of Dayton, Ohio, were developing a biplane which was an improvement on the aërial glider of Chanute and Herring. This was to be their preliminary effort toward achieving continuous flight. Their first product, tried at Kitty Hawk, North Carolina, in the summer of 1900, is shown in Plate XIX. The chief points of departure from Chanute and Herring's glider were (1) to place the rider prone on the lower surface, as first proposed and tried by Wenham, forty years previously; (2) to discard the vertical rudder; (3) to place the horizontal rudder forward, as done by Mattulath and Maxim; (4) to control the lateral balance by changing the impact angles of the wings, as recommended by the present writer in 1893. Of these four modifications the first was impractical for general use, though good for soaring and possibly racing; the second was unsatisfactory and later abandoned; the third was effective, and has been accepted by some aviators as an improvement, but rejected by others who prefer the rear[1] horizontal rudder; the fourth proved acceptable to them, as to various other inventors before and after them.

With this glider they made a number of satisfactory flights. The front rudder and the torsional wings proved adequate to control the craft in sailing straight ahead down the Kill Devil sand hills, near Kitty Hawk, N. C. In this, as in all their machines to the present date, sled runners, fixed under the machine, as proposed by Ader and others, were used for launching and landing. With a surface of 165 square feet, they could glide down a slope of 9.5° at a speed of 25 to 30 miles an hour. This showed only a moderate efficiency, but it was a beginning.

The glider used in the summer of 1901 was modeled after that of the previous year, but larger. It was 22 feet wide, 14 feet long, 6 feet high, spread 308 square feet, and weighed 108 pounds. With this a number of glides were made, of various lengths up to 400 feet. At a speed of 24 miles an hour gravity exerted on the aërial coaster $2\frac{1}{2}$ tow line horse power, showing an efficiency nearly equal to that of Pilcher's glider of 1897.

In camp with the Wright brothers in 1901 was Mr. Chanute, the leading aëronautic expert in Amer-

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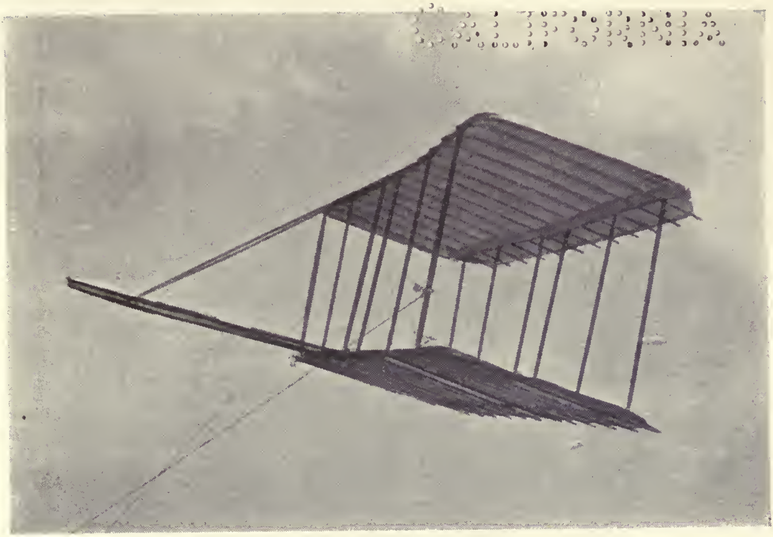
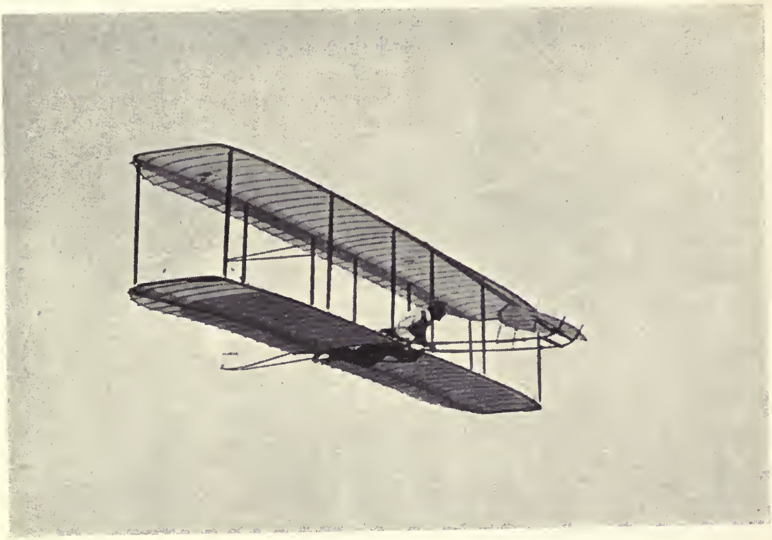
[1] The Wrights in 1910 adopted the rear horizontal and vertical rudder, thus returning to the design of their predecessors.

PLATE XIX.



FIRST WRIGHT GLIDER.



SECOND WRIGHT GLIDER.

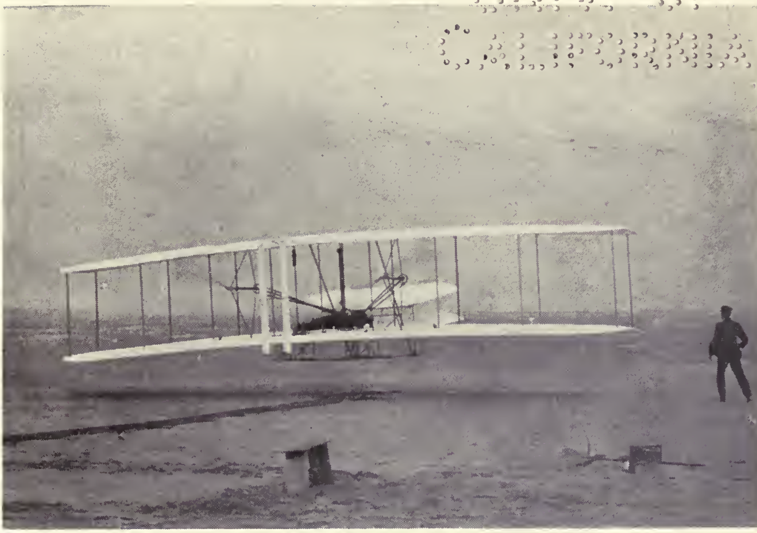
ica. They thus had the advantage of his long experience, both as a student of aviation and a practical experimenter. With them were also two other specialists, Mr. E. C. Huffaker, an experienced aëronautical investigator, who had worked successively with Langley and Chanute; and Dr. G. A. Spratt, who had made some important investigations on the value of curved surfaces and the travel of the center of pressure with the varying angles of flight. The numerous animated conferences with these gentlemen were instructive and profitable. When the season closed the brothers returned home and experimented on curved surfaces to improve the efficiency of their glider.

The 1902 machine, shown in Plate XIX, had two main surfaces, measuring each 32 by 15 feet, and a front rudder measuring 15 square feet. The whole weight was 116 pounds. It will be noted that a vertical rudder was now employed. This was a reversion to the design of Chanute and Herring, but after some experience, the rudder was made adjustable, as in Henson's aëroplane of 1842. Its surface was 12 square feet, but later reduced to six. With this machine they obtained between 700 and 1,000 glides during the season. It showed greater efficiency than its predecessors, its normal angle of descent being estimated at seven degrees or less. This was some improvement over the efficiency of the Chanute-Herring glider, partly due, of course, to placing the rider flat, instead of allowing him the more comfortable erect posture adopted later.

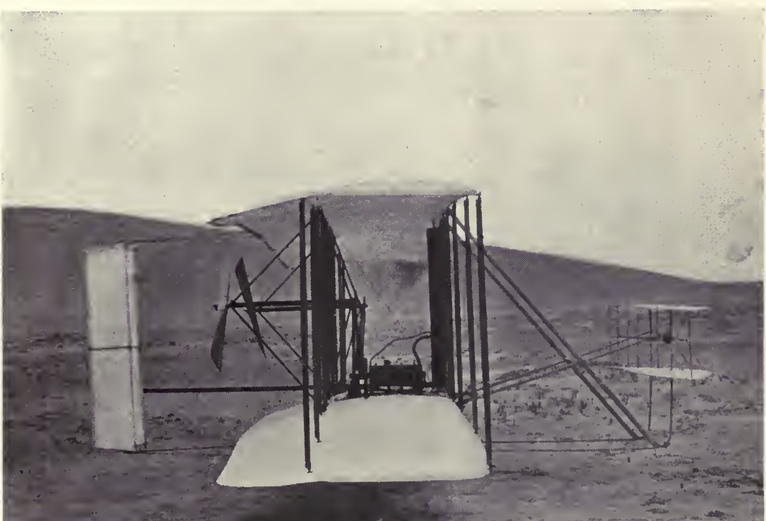
Whatever improvements of efficiency and strength had been made, these were of secondary importance compared with the provisions for projectile stability and manual control. Here at last, after ten years' groping, was an actual glider with sufficiently high centroid to minimize the pendulum effect, and with three rudders to give impactual torque about the three axes. These simple provisions had been previously pointed out in aëronautic writing, and, in the latter nineties, had been embodied in Mattullath's aëroplane, but not tested in the large machine, owing to his death. The wonder is that, of all the practical inventors of aëroplanes, Mr. Mattullath was the only one of that period fully to grasp and adopt these main ideas before starting to build a man-carrying machine. However, it must be added that he had previously made small flying models, which may have suggested the advantage of kinetic stability and the three-torque system of control. If Lilienthal and his disciples, who laid so much stress on gliding experience, had started like Mattullath with three torque-surfaces, they would have missed indeed those acrobatic and picturesque kickings at the sky, but they would have reached the desired goal with less danger, time and expense. They displayed more skill in riding a fractious glider than in designing a tractable one, by providing for impactual torque about each of three axes. Had they started with a good theory of dynamic control, they could have dispensed with coasting entirely, and commenced aviating with short runs over a smooth course followed by cautious leaps in the air, after the style of certain ingenious French aviators. However, the knack of balancing was finally acquired, and thus the glider was ready to receive the propelling mechanism.

In 1903 a 16-horse-power engine and twin-screw propellers were applied to the navigable glider at Kitty Hawk, as shown in Plate XX. The power machine weighed 750 pounds, and was usually started by aid of a tow line and falling weight which helped the craft to acquire headway. After many trials and modifications, the first successful launchings, four in number, were made on December 17th. The

PLATE XX.



FIRST WRIGHT AËROPLANE (REAR).



FIRST WRIGHT AËROPLANE (SIDE).

first flight lasted 12 seconds, the next two a little more, the fourth lasted 59 seconds, covering a distance of 852 feet over the ground in the face of a twenty-mile wind. To the superficial observer these performances did not seem a very remarkable advance on the flights of Ader, but they had in them greater promise and potency of practical flight. They were the first flutterings of a fledgling endowed with the chief essential organs of aërial locomotion—an awkward but healthy creature that had been evolving steadily for several generations. It would grow rapidly, and ere another half decade, increase the 59 seconds to so many minutes.

The experiments were continued during the next two years with increasing success. During the season of 1904, on a field near Dayton, one hundred and five flights were made, some short, others covering the entire circuit of the field no fewer than four times, the two largest measuring each nearly three miles, each accomplished in about five minutes. Various improvements were made in the propelling and steering mechanism, and increased skill in maneuvering was gradually acquired.

In 1905 the flights were resumed with a new machine embodying some changes dictated by experience, particularly in the method of control. Forty-nine landings were made involving seven breakages, but no personal injury. On September 26th a flight of eleven miles was achieved. This was followed, within the next nine days, by flights of twelve, fifteen, twenty-one and twenty-four miles, at a usual speed of 38 miles an hour. After this the field practice ceased for more than two years, and the machine was dismantled to preserve secret its mode of construction till the patents could be disposed of. As these performances and those preceding are of unusual interest, a fuller account is given in Appendix IV.

The Wright brothers now had to assume in aviation the rôle of cautious business men. The gliding experiments had been a scientific recreation, and had been fairly well reported to engineers, except in those details to be covered by patent claims; but the details of the power machine were withheld, or sparingly disclosed. The brothers had sacrificed time and money. They were making aviation a profession. They must, therefore, be repaid. But if they exhibited too promptly their machine and aërodynamic data, they might jeopardize their financial interests by assisting or stimulating rival aviators. On the other hand, by procrastination and concealment they might, in various ways, forfeit priority and scientific credit. Chanute's glider was already familiar in Europe, and it was estimated to have ample efficiency for successful flight with existent motors. Their own published experiments were being studied and repeated. They might, therefore, expect that, at any time, some rash or cunning fellow would bolt into the air and proclaim to all the world that their unpublished devices, if they possessed any novelty, were by no means necessary, as they fancied, to usher in actual dynamic flight. The aëroplane would thus appear to be the sudden outgrowth of fertile and mature conditions, rather than the product of uncommon originality. Scores of aviators would immediately spring into being—chauffeurs, mechanics, sporting gentlemen of every dye. Light motors being now available, any intelligent artisan could power a Hargrave kite, or Chanute glider, and soar aloft. Every odd craft, not too absurdly designed, would navigate, with some showing. Publicity and prize money would develop and perfect the various types with feverish haste. But in 1905 the Wright brothers apprehended no portentous or imminent invasion of the sky. The foreign bogie was five years behind, being unfamiliar with sand hill practice and the torsion wing. They would, therefore, chance the result of withholding their data and concealing their machine. It was a curious situation; Langley and Manly, who produced the first aëroplane endowed with all the essential powers of prolonged flight, were bound to official secrecy; the Wrights, who had a finished machine, tried and fairly ready for public exhibition, were hampered by trade secrecy. These silent leaders in aviation presented a gratifying contrast to the shouting fraternity who, in the daily press, announced impending marvels which never materialized.

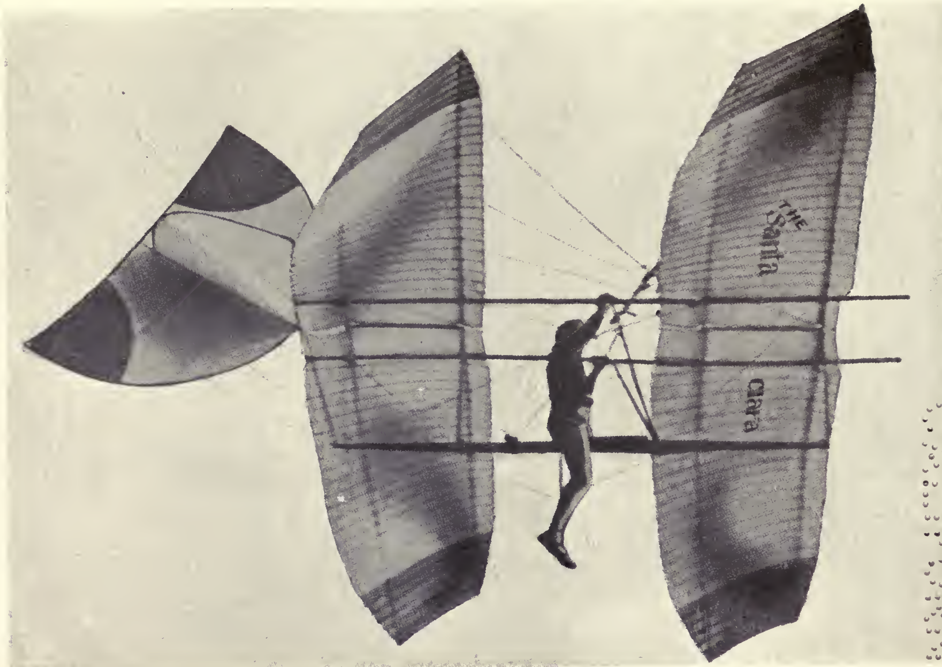
The same year, 1905, which crowned with most success the private flights of the Wright brothers, brought into unusual prominence the quarter century long experiments of Prof. J. J. Montgomery of Santa Clara College, Santa Clara, Cal. He had given much attention to the science of aviation, particularly to passive flight, and had constructed several successful gliders operated by himself or his friends. The most remarkable of these machines was a glider resembling in general appearance Langley's tandem monoplane, but having means for changing the wing curvature during flight, thus varying the lift on such wing, and thereby enabling the operator to control the equilibrium and direction during his glides in the air.

On April 29, 1905, a forty-five pound glider of this pattern bearing an intrepid parachute jumper, Daniel Maloney, was lifted from the college grounds by a hot-air balloon to an elevation of 4,000 feet, then cut loose. "In the course of the descent," writes one of his pupils, "the most extraordinary and complex maneuvers were accomplished—spiral and circling turns being executed with an ease and grace almost beyond description, level travel accomplished with the wind and against it, figure-eight evolutions performed without difficulty, and hair-raising dives were terminated by abrupt checking of the movement by changing the angles of the wing surfaces. At times the speed, as estimated by eye-witnesses, was over sixty-eight miles an hour, and yet after a flight of approximately eight miles in twenty minutes the machine was brought to rest upon a previously designated spot, three-quarters of a mile from where the balloon had been released, so lightly that the aviator was not even jarred, despite the fact that he was compelled to land on his feet, not on a special alighting gear." This daring performance amazed the world, and most of all, the specialists who all along knew such a feat to be practicable. As a further description of Professor Montgomery's wonderful experiments may interest the reader, the following account, written by himself, is inserted from *Aëronautics* for January, 1909:

"When I commenced practical demonstration in my work with aëroplanes I had before me three points. First, equilibrium; second, complete control; and third, long continued or soaring flight. In starting I constructed and tested three sets of models, each in advance of the other in regard to the continuance of their soaring powers, but all equally perfect as to equilibrium and control. These models were tested by dropping them from a cable stretched between two mountain tops, with various loads, adjustments and positions. And it made no difference whether the models were dropped upside down or in any other conceivable position, they always found their equilibrium immediately and glided safely to earth.

"Then I constructed a large machine patterned after the first model, and with the assistance of three cowboy friends personally made a number of flights

PLATE XXI.



MONTGOMERY'S AËROPLANE.

in the steep mountains near San Juan (a hundred miles distant). In making these flights I simply took the aëroplane and made a running jump. These tests were discontinued after I put my foot in a squirrel hole, in landing, and hurt my leg.

"The following year I commenced the work on a larger scale, by engaging aëronauts to ride my aëroplane dropped from balloons. During this work I used five hot-air balloons and one gas balloon, five or six aëroplanes, three riders—Maloney, Wilkie and Defolco—and had sixteen applicants on my list and had a training station to prepare any when I needed them.

"Exhibitions were given in Santa Cruz, San José, Santa Clara, Oakland and Sacramento. The flights that were made, instead of being haphazard affairs, were in the order of safety and development. In the first flight of an aëronaut the aëroplane was so arranged that the rider had little liberty of action, consequently he could make only a limited flight. In some of the first flights, the aëroplane did little more than settle in the air. But as the rider gained experience in each successive flight I changed the adjustments, giving him more liberty of action, so he could obtain longer flights and more varied movements in the flights. But in none of the flights did I have the adjustments so that the riders had full liberty, as I did not consider that they had the requisite knowledge and experience necessary for their safety; and hence, none of my aëroplanes were launched so arranged that the rider could make adjustments necessary for a full flight.

"This line of action caused a good deal of trouble with aëronauts or riders who had unbounded confidence and wanted to make long flights after the first few trials, but I found it necessary as they seemed slow in comprehending the important elements and were too willing to take risks. To give them the full knowledge in these matters I was formulating plans for a large starting station on the Mount Hamilton Range from which I could launch an aëroplane capable of carrying two, one of my aëronauts and myself, so I could teach him by demonstration. But the disasters consequent on the great earthquake, completely stopped all my work on these lines. The flights that were given were only the first of the series with aëroplanes patterned after the first model. There were no aëroplanes constructed according to the two other models, as I had not given the full demonstration of the workings of the first, though some remarkable and startling work was done. On one occasion, Maloney in trying to make a very short turn during rapid flight pressed very hard on the stirrup which gives a screw shape to the wings and made a side somersault. The course of the machine was very much like one turn of a corkscrew. After this movement, the machine continued on its regular course. And afterwards Wilkie, not to be outdone by Maloney, told his friends he would do the same, and in a subsequent flight, made two side somersaults, one in one direction and the other in an opposite, then made a deep dive and a long glide, and when about three hundred feet in the air, brought the aëroplane to a sudden stop and settled to the earth. After these antics, I decreased the extent of the possible change in the form of wing surface so as to allow only straight sailing or only long curves in turning.

" During my work I had a few carping critics that I silenced by this standing offer: If they would deposit a thousand dollars I would cover it on this proposition. I would fasten a 150-pound sack of sand in the rider's seat, make the necessary adjustments, and send up an aëroplane upside down with a balloon, the aëroplane to be liberated by a time fuse. If the aëroplane did not immediately right itself, make a flight, and come safely to the ground, the money was theirs.

"Now a word in regard to the fatal accident.[1] The circumstances are these: The ascension was given to entertain a military company in which were many of Maloney's friends, and he had told them he would give the most sensational flight they ever heard of. As the balloon was rising with the aëroplane, a guy rope dropping switched around the right wing and broke the tower that braced the two rear wings and which also gave control over the tail. We shouted Maloney that the machine was broken but he probably did not hear us, as he was at the same time saying 'Hurrah for Montgomery's air ship,' and as the break was behind him, he may not have detected it. Now did he know of the breakage or not, and if he knew of it did he take a risk so as not to disappoint his friends? At all events, when the machine started on its flight the rear wings commenced to flap (thus indicating they were loose), the machine turned on its back and settled a little faster than a parachute. When we reached Maloney he was unconscious and lived only thirty minutes. The only mark of any kind on him was a scratch from a wire on the side of his neck. The six attending physicians were puzzled at the cause of his death. This is remarkable for a vertical descent of over 2,000 feet."

[1] On July 18, 1905.

CHAPTER X

ADVENT OF PUBLIC FLYING

In 1903, Mr. Ernest Archdeacon stimulated by a conference with Mr. Chanute, at a meeting of the Aëro Club of France, founded a prize of 3,000 francs to be awarded to the first person who should sail or fly 25 meters, with a maximum descent not exceeding one third of the ronge. As yet no one in either hemisphere had flown in a practical machine, but various aviators were industriously pluming their wings. Captain Ferber had been a follower of Lilienthal since 1898, and a pupil of Mr. Chanute since 1891. Dozens of votaries in France, not to mention other countries, had entered, or were about to enter, the aviation field. Archdeacon himself, Voisin, Blériot, Esnault-Pélterie, Vuia, Delagrange, Tatin, Cornu, Bazin, Levavasseur and many others, were stanch apostles of the heavier than air. Many of these were disciples of Lilienthal, but they were destined all to be distanced by an impetuous Hensonite, who could not realize the necessity for spending months, or years, cautiously coasting downhill to acquire the adroitness requisite to speed a flying chariot over the plain.

In 1906, while many aviators in Europe were developing flyers, and cautiously testing them in various ways, by gliding above sand or water, or swinging from a high wire or traveling arm, Señor Alberto Santos-Dumont, of Brazil, brought forth in France the quaint and crude biplane shown in Plate XXII.

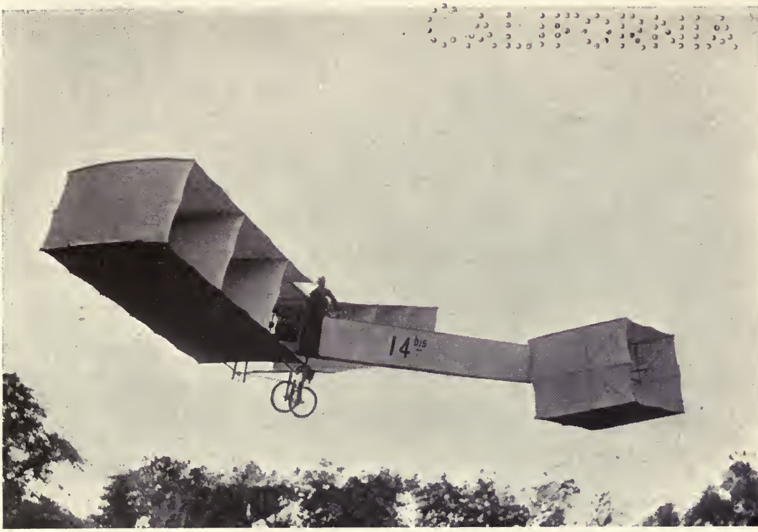
Aërodynamically this was not a great improvement on the aëroplane of Sir George Cayley constructed 98 years earlier; but it had a petrol motor whose power and lightness would have astounded that talented pioneer in aviation. The motor was an eight-cylinder Antoinette, weighing 170 pounds and developing 50 horse power. The screw, formed of two aluminum blades, was of two meters diameter, one meter pitch, mounted on the engine shaft, and, at 1,500 revolutions a minute, gave a thrust of 330 pounds. The total lifting surface of the aëroplane was 650 square feet, and the weight, including pilot, 645 pounds. This bird-shaped craft ran tail foremost through the air, having the screw at the rear, and the rider in a small basket just before the wings. By means of a pilot-wheel and lever, he could operate the "tail," i. e., the front rudder, sidewise and vertically, thus steering the craft in two directions. The lateral balance was preserved automatically by means of the dihedral inclination of the wings, aided sometimes by the rider swaying his weight to right or left.

After some days of preliminary adjustment and trial, Santos-Dumont was ready for a dash in his new aëromobile. On August 22d, 1906, he made a brief tentative flight, the first witnessed in Europe since Ader's surreptitious experiment. On October 23d, he ran this strange machine swiftly over the ground and glided boldly into the air, flying above the excited spectators at a speed of 25 miles an hour, and covering a distance of 200 feet, thus gaining the Archdeacon cup. Again on November 12th, 1906, he made four flights, the last one covering 220 meters in twenty-one seconds, thus gaining the prize of 1,500 francs offered by the Aëro Club of France for the first person who should fly 100 meters. The demonstration was made before the general public and technical witnesses, including an official committee of the Aëro Club of France, who reported that the aëroplane preserved good balance and a true soaring speed independent of the acquired momentum.

Intrinsically the achievements of November 12th were crude and primitive; but in moral effect they were very important. They marked the inception of public aëroplaning before the professional and lay world alike. There was no patent mechanism to conceal, no secret to withhold from rivals, such as had shrouded the work of more circumspect aviators in Europe and America. If Santos-Dumont was not the first to fly, he was the first aëroplane inventor to give his art to the world, and to inaugurate true public flying in presence of technical men, as he had initiated modern motor ballooning. His liberal enthusiasm and that of his colleagues, both aëroplanists and patrons, quickly made France the world's foremost theater of aviation, at least for the moment. The contagion would of course spread swiftly, and involve the entire civilized world.

Santos-Dumont's unconventional dash into the air sounded the knell of Lilienthalism. This slow method served to pass time profitably in the nineties, while the gasoline motor was still developing. But with an *Antoinette* in hand, what live man, particularly what live Frenchman, could tinker long years on the sand hills? Why not mount the craft on little wheels and take a cautious little run; then after some adjustment, make more runs followed by innocuous saltatory flights? This would be so easy, so fascinating, so instructive. How much better than to make two thousand preliminary jumps down the hill slope with the body dangling wildly to keep the balance, then to redesign the entire frame before an engine could be successfully applied! An *An-*

PLATE XXII.



SANTOS–DUMONT'S BIPLANE.

Photo E. Levick, N. Y.

SANTOS–DUMONT'S *DEMOISELLE.*
(Courtesy A. J. Moisant.)

toinette motor, placed on a competently designed Henson aëroplane, would have obviated the whole Lilienthal school. However, they did noble and opportune work, while awaiting the growth of the gasoline engine. This school achieved success by a roundabout method because Henson's method was not available till the present century, for want of a cheap, light motor. When that appeared Lilienthalism quickly subsided. In other words, Lilienthal's method was a passing convenience, never a necessity. It could have been employed very profitably in Cayley's time to develop the art of gliding and soaring; but in the time of Santos-Dumont and his colleagues, flying by Henson's method would have burst upon the world by reason of its superior value and the allied progress, even if the Lilienthal school had never existed. This is illustrated by the fact that Santos-Dumont succeeded without aid from the sand-hill votaries.

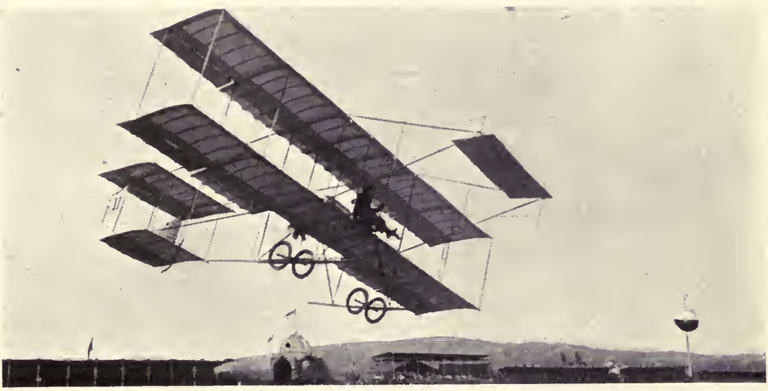
The next daring aëroplanist to arouse the world of aviation was Henri Farman, also a votary of the wheel-mounted flyer. He had been an adept motorist, therefore accustomed to brisk driving. In the summer of 1907 he received from the Voisin brothers the aëroplane illustrated in Plate XXIII. With this he made a number of preliminary flights during the autumn, proving that his aëroplane had suitable stability and motive power. On October 26th, on the government drill grounds at Issy-les-Moulineaux he surpassed Santos-Dumont's record, by flying 771 meters. But this was to him of minor importance; he was preparing to win the Deutsch-Archdeacon prize of 50,000 francs offered for the first person who should fly one kilometer over a returning course. On January 12th, he convoked a committee of the Aëro Club of France to witness a trial on the morrow. Next morning at ten o'clock, the weather being calm and clear, his great machine ran a hundred yards across the course, then rose gracefully into the air, and sailed away for the 500-meter post. Here, making a wide curve, it rounded safely and returned, passing the home line in elegant flight, thus winning the grand prize.

The machine with which Farman achieved his first success, and which broadly resembles his subsequent triumphal flyers, seems to be a cross between a Hargrave kite and a Chanute glider, having a Maxim horizontal steering plane in front. As shown in the figure it was mounted on four bicycle wheels; was steered up and down by the front plane, and sidewise by the box rudder seen in the rear. The rider seated between the large supporting surfaces, and in front of his engine, operated these rudders separately, by pushing or rotating a pilot wheel, and abetted the automatic lateral balance by swaying his body. The machine spread 559 square feet of sustaining surface, weighed 1,100 pounds and carried a 50-horse-power *Antoinette* motor actuating a single two-blade aluminum propeller 6.9 feet in diameter by 3.6 feet pitch, directly connected to the engine shaft. The stability in mild weather was so great that Farman, during his first few weeks' practice, made over 200 flights, measuring in length from 100 to 500 yards, without serious mishap. In gusty weather, however, his machine was defective in steadiness, and unsafe near the ground. This objection was remedied later by adding flexible wing margins for controlling the lateral balance.

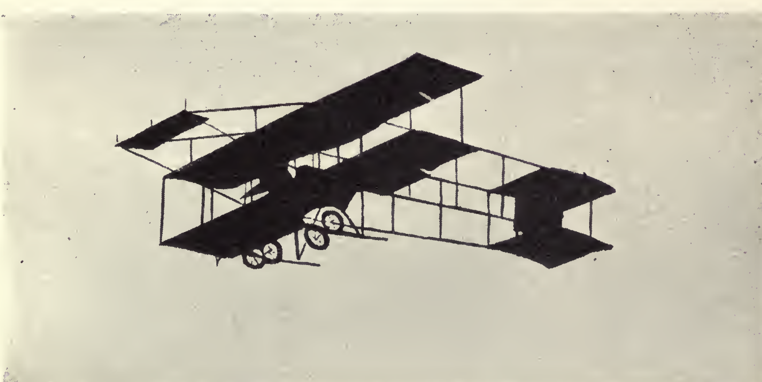
The age of prize flying was thus fairly ushered in by the feeble but very important public demonstrations of Santos-Dumont and Henri Farman. Other public flyers would quickly follow. Delagrange, Blériot, Curtiss would soon become international figures, not to mention numerous more recent avia-

PLATE XXIII.

FARMAN BIPLANE, 1908.
(Courtesy W. J. Hammer.)



FARMAN BIPLANE, 1909.



HARMON IN FARMAN BIPLANE.

tors. They were men of originality, skill and energy, who would shortly be in the front line contesting for world laurels, and winning them gloriously.

Leon Delagrange, the sculptor-inventor, who first had demonstrated the biplane, on March 30, 1907, aspired in 1908 to outfly Farman. He now practiced industriously on the military drill ground at Issy-les-Moulineaux, a large field which the Minister of War permitted the Aëro Club of France to use for such purpose. Here he and Farman, in friendly competition, flew day by day over gradually increasing courses. At times they were joined by other aviators, and thus the drill grounds at Issy became famous as an aviation school.

Farman's new rival made startling progress during those frequent trials of March, 1908. "Just imagine," he says, "that within a week I was able to complete my education as an aviator." On March 17th he made an official flight of 269.6 meters, thus winning a prize of 200 francs offered by the Aëro Club of France for a beginner who should fly over 200 meters. Four days later he engaged in contest with Farman. Two poles were erected 500 meters apart to mark the points about which the men must race. The machines were brought forth from their sheds in the morning, gleaming dimly through a dense fog, and were given some preliminary trials. Then Farman made a flight of 2004.8 meters, going twice around the course in 3 minutes, 31 seconds. He thus trebled his grand prize flight of January. Presently Delagrange took wing and flew 1,500 meters in 2.5 minutes. Having been beaten by Farman, he invited his successful rival to take a seat behind him, and the two sailed away close to the ground, covering a distance of 50 meters. This was the first trip ever made by two men in one flying machine. For the first time also two machines had flown in competition over a considerable course.

Delagrange continued to pursue Farman for the championship. On April 11th, he flew 2,500 meters, and would have exceeded Farman's official record of 2,004 meters, had he not touched the ground. The next day he summoned the official committee of the Aëro Club of France to witness and time his performance. Poles were erected at the corners of a triangle 350, 200, 275 feet apart respectively. Around this course he flew nearly five times, covering a distance of 5,575 meters in 9¼ minutes. Of this range the last 3,925 meters were covered without touching the ground. Thus at last he had outflown Farman and established a new official record, the total distance actually covered being about ten kilometers, or approximately six miles. This ended, at least temporarily, the friendly competition at Issy; for now the aviators separated, Farman going to Belgium, Delagrange to Italy.

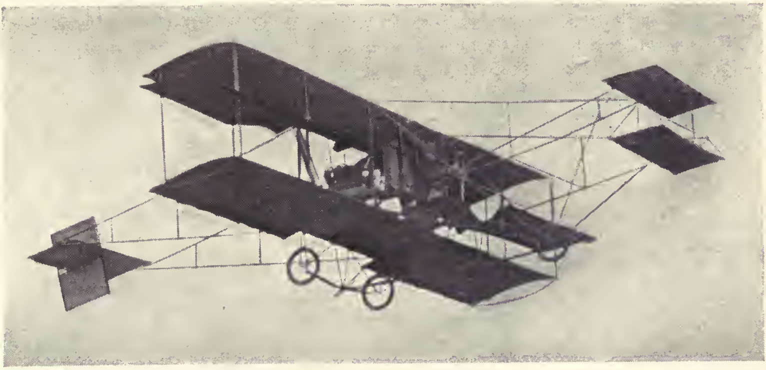
Delagrange's fortune accompanied him abroad. On May 24th, he made some impressive demonstrations on the Place d'Armes at Rome in presence of the Minister of War and thirty thousand people. On May 27th, he flew before the King and Queen of Italy and many other court personages, remaining in the air nine and one half minutes, thus surpassing all previous European records for endurance and distance. But this was only preliminary. On the morning of May 30th, he came forth again on the Place d'Armes, a light breeze blowing. His machine rolled quickly over the ground, then circled gracefully ten times around in the air at a height of four to seven meters, covering an official distance of 12.75 kilometers, and remaining aloft 15 minutes, 26 seconds. On June 22d, at Milan, he flew before 15,000 people in the Place d'Armes, covering seventeen kilometers in 16 minutes, 30 seconds. Finally, on September 6th, at Issy-les-Moulineaux, he flew 29 minutes, 54 seconds, covering 14.8 miles, which proved his crowning effort for the year. As the two flights just mentioned surpassed all previous official ones in duration, it appears that Delagrange raised the world's record four times within five months, increasing his own time from six and a half minutes in April to about thirty minutes in September, or nearly fivefold.

In the meantime, Farman was making rapid progress, gathering prizes and achieving wide renown. On May 30th, at Ghent, Belgium, taking with him M. Archdeacon, he flew 1,241 meters at a height of seven meters. He thus established a new record with two people, and won the 1,200 franc wager made with Santos-Dumont and Archdeacon against M. Charron, who contended that a flying machine would not, within the year, carry two men weighing sixty kilograms each. On June 6th he flew 20 minutes, 20 seconds, covering 19.7 kilometers, thus again increasing the world's record, and winning the Armengaud prize of ten thousand francs for the first aviator to remain aloft fifteen minutes in France. On September 29th and October 2d, at Chalons, he successively increased the world's record, and achieved his best results for the year. The first of these trials lasted 42 minutes, covering 24.5 miles; the second lasted 44.5 minutes, covering 25 miles. This last flight was forty times as long as the one of January, which gave him the grand prize of fifty thousand francs, and is a good index of the wonderful progress in aviation made in France during the year 1908. Between these two performances he, on September 30th, sailed from Chalons to Rheims, a distance of 27 kilometers, in twenty minutes. This flight was made over trees and houses, sometimes at an elevation of 200 feet, and was the first town-to-town flight ever accomplished. The following day he won the 500 franc prize for height, passing over balloons 82 feet from the ground. Such was the lively pace Farman set for the rest of the world.

Mr. Curtiss drifted into the business of building and operating air ships and flying machines by frequent association with inventors, who came to his bicycle works at Hammondsport, N. Y., for assistance in the design and construction of aërial craft. He was particularly sought as a constructor of propelling mechanism, for he had special skill and experience in producing light gasoline engines. As a motor expert he was invited to the laboratory of Dr. Alexander Graham Bell, at Beinn Breagh, near Baddeck, Nova Scotia, in the summer of 1907. Dr. Bell had developed his wonderfully light, strong and stable tetrahedral kites to such an extent that he wished to convert them into "aërodromes" by applying light propelling mechanism. He accordingly invited two young Canadian engineers, F. W. Baldwin and J. A. D. McCurdy, to consult with him regarding the structural details of his proposed flyer, and contracted with Mr. Curtiss to supply the motive power. These gentlemen with Lieutenant T. Selfridge, a guest of Dr. Bell, developed so many independent ideas that Mrs. Bell suggested the advantage of forming themselves into a scientific organization, at the same time offering the capital required for experimentation. Acting on this advice and generous offer, they formed themselves into the now famous Aërial Experiment Association, whose object was the construction of a practical aëroplane, driven through the air by its own motive power, and carrying a man.

PLATE XXIV.

THE *RED WING.*



CURTISS BIPLANE.

CURTISS BIPLANE WITH PONTOONS.

After some preliminary downhill glides[1] and studies with a motorless aëroplane, the association, on March 12, 1908, brought forth their first dynamic machine, the *Red Wing*, shown in Plate XXIV, in order to speed it along the ice of Lake Keuka, near Curtiss's factory; the purpose being, not to fly, but to test the effect of the vertical rudder. To the surprise of the twenty-five onlookers, the machine, after running two hundred feet along the ice, serenely rose into the air and flew 319 feet. "This," says Dr. Bell, "was the first public exhibition of the flight of a heavier-than-air machine in America." It is noteworthy also that this machine was completed and ready for trial in less than seven weeks from the time of starting. Its design, while embodying suggestions from each member of the association, was attributed chiefly to Lieutenant Selfridge, who took the leading part in evolving the plans, and who gave them his final approval, it being the intention of the association to offer each man a chance to produce a flying machine after his own notions, aided by the experience and liberal advice of his fellows.

As the advantage of flying from the ice had been suggested some years before the death of Lilienthal, it seems remarkable that this method did not yield important results earlier in the development of aviation. A smooth ice field is such an ideal place for testing a dynamic aëroplane, that previous gliding experience would seem unnecessary, providing the machines were designed with a fair knowledge of the elementary principles of stability and control. Even glider practice could be effectively conducted over a smooth ice field after momentum had been acquired by aid of gravity, or a tow line. Having sufficient momentum the aviator could test his rud-

[1] These glides were abandoned as too dangerous and roundabout, in favor of direct tentative flights with a motor.

ders cautiously without rising, then, after a little experience, make short glides in the air, and so be prepared to install the motor. Landing or falling on smooth ice at great horizontal speed, from a low elevation, is much less hurtful than tumbling on the ground, as every bold skater knows from experience.

The aëroplane II, designed by Mr. Baldwin, aided by his associates and their combined experience, resembled that of Lieutenant Selfridge in the trussing of its body surfaces, but was mounted on wheels, and provided with torsional wing tips for lateral control. When tested, it was found easy to launch and land, besides responding very promptly to the three-rudder control. In the hands of Mr. Curtiss, on May 22d, this aëroplane, called the *White Wing,* flew 1,017 feet in 19 seconds, and landed smoothly on a plowed field. This at the time was the longest flight ever made by an aviator in his first trip on a heavier-than-air machine.

It was now Mr. Curtiss' turn to be captain of design and construction. Under his supervision aëroplane III, called the *June Bug,* was ushered forth, in the month of honeymoons. It differed from the two preceding in having a box tail; also in having a nainsook cover, instead of the red and white silk that characterized the *Red Wing* and the *White Wing.*

After some practice, this flyer behaved so well that it seemed competent to win the Scientific American Cup offered for a public flight of one kilometer straight away. Accordingly an official trial was arranged with a committee of the Aëro Club of America, for the fourth of July, 1908. It was the first official flight in the western hemisphere, and proved in every way most satisfactory. The machine flew 2,000 yards over an S-shaped course at a speed of 39 miles an hour, displayed admirable control, and had abundant motive power. The performance was an intimation and augury of the victorious flights to come the following year. As the Association now repaired to Dr. Bell's summer home, the Hammondsport experiments terminated for the season.

The year 1908 also brought to happy fruition the long and persistent experiments of Louis Blériot, the most illustrious pioneer and champion of the monoplane. Beginning in 1900, he had tried one type after another, of flying machine, till he became world renowned for his fertility of invention, his daring, his picturesque accidents and hairbreadth escapes. So long as he was not killed he was certain to make progress; for he had every endowment that ensures success. He possessed the energy of early manhood, having been born in 1872; he had the thorough technical training of the Central School of Arts and Manufactures, where he graduated in 1895; he possessed extraordinary talent for invention and constructional detail; he had the prowess, courage and coolness requisite for testing intractable and dangerous flyers; he was in the world's most active center of aviation; he also had sufficient means. If he was late in achieving success, it was because he preferred to develop original ideas, and could not be content with merely copying his predecessors.

Like many other novices in aviation, Blériot began by trying to build a machine with flapping wings that should fly like a bird. This was to be actuated by a carbonic acid motor. In 1904 he abandoned his first machine, of bird type, and turned to aëroplanes, beginning with a biplane of the Farman, or Voisin type. His second machine was built by Gabriel Voisin, one of the most experienced of the pioneer aëroplane manufacturers. This biplane, unprovided with an engine, was mounted on floats, towed along the Seine by a motor boat, and rose from the surface carrying Voisin as pilot. *Blériot III,* composed of elliptical cells, or sustaining surfaces, and powered with two *Antoinette* motors of 25 horse power each, was tested without success on Lake Enghien during the year 1905–6. *Blériot IV* was made of quadrangular cells, and launched at Bagatelle in 1906, carrying a soldier, Peyret; but crashed to earth in its first trial. Finally in 1907, *Blériot V,* mounted by the inventor himself, rose into the air and flew successfully, but was lacking in stability. His sixth aëroplane was of the Langley type, provided with a 24-horse-power motor, then with a 50-horse-power *Antoinette;* but it was unstable fore and aft. One day it traversed 184 meters, then fell from a height of 25 meters and was shattered on the ground. His seventh was one of the swiftest yet constructed, attaining a speed of nearly 80 kilometers an hour, and, in two private trials, covering a distance of 500 meters. Thus seven years had slipped away, leaving Blériot still in the tentative period of his work. But now he was at the threshold of a career of brilliant success, which soon brought him the highest honors at home and throughout the world.

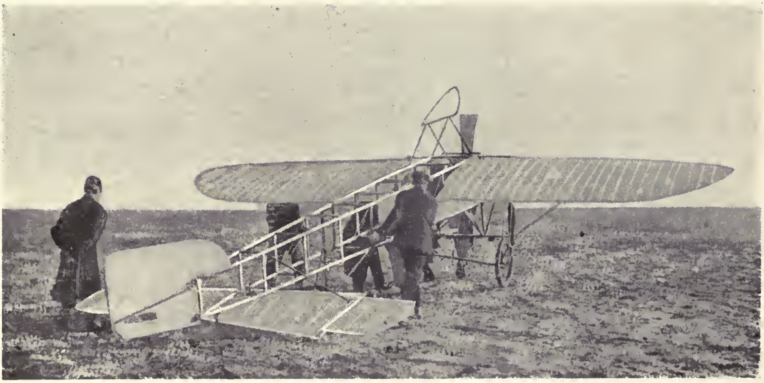
After various minor flights in the spring and summer of 1908, Blériot, on October 31st of that eventful year in aviation, determined to attempt a cross country voyage, as Farman had done the day before. As will be remembered, Farman had flown from Chalons to Rheims, above trees and houses, a distance of nearly 17 miles, thus achieving the first town-to-town flight in history. Blériot would improve that record at once, by flying in a closed circuit embracing several villages.

His renowned cross-country flight was directed from Toury to Artenay, a village nine miles distant. Mounting his aëroplane *VIII ter,* at mid afternoon,

PLATE XXV.

BLÉRIOT FLYING OVER TOURY–ARTENAY CIRCUIT.

BLÉRIOT MONOPLANE *NO. VIII.*



BLÉRIOT MONOPLANE *NO. IX.*

in presence of a large gathering, Blériot followed the course shown in Fig. 40. In the neighborhood

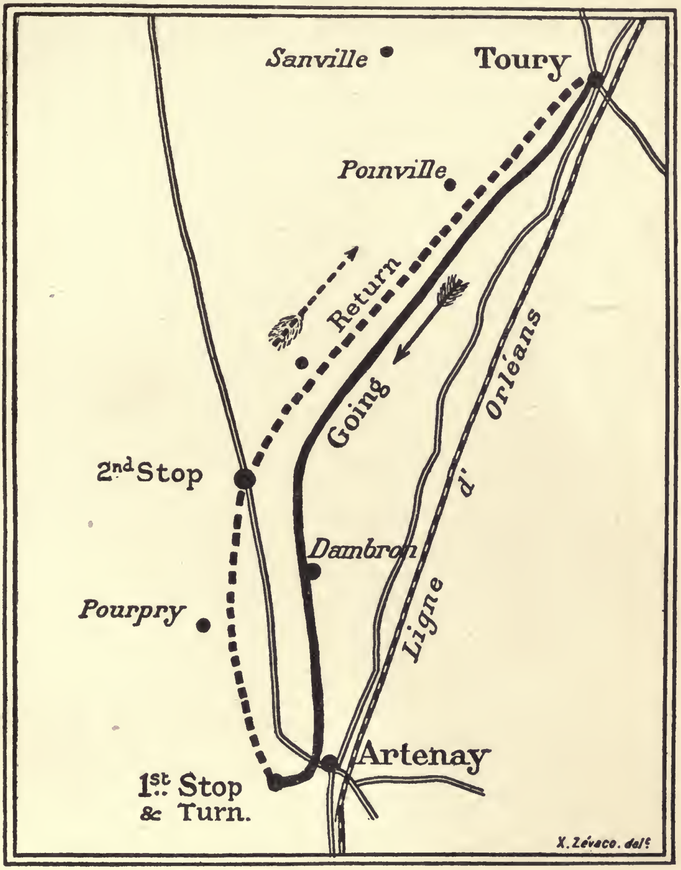


FIG. 40.—BLÉRIOT'S TOURY-ARTENAY AËROPLANE CIRCUIT, 1908.

of Artenay he landed for a few minutes. After some slight repairs to his magneto, he reascended, turned about and headed for home. Half way on his return course he stopped again for a few minutes, at the village of Santilly; then readily reascended and flew to the neighborhood of his starting point. He thus traveled about 17 miles in a closed circuit. This performance, with that of Farman the day before, inaugurated the period of aërial voyages in heavier-than-air machines. It appealed so powerfully to the sentiment of the community that a monument was erected at Toury to commemorate the glorious achievement.

A fair view of the famous monoplane, in its renowned cross-country voyage, is presented in Plate XXV. It consisted of a single sustaining surface firmly attached to a long trussed spine mounted on three wheels, and carrying at its front end the gasoline motor and propeller, at its rear end two of the rudders, the third, or lateral, rudder being placed at the wing terminals. A part of the trussed frame was covered, to minimize the atmospheric resistance against the framing, pilot and engine. The vertical rudder at the rear turned the machine to right or left; the horizontal rear rudder controlled the elevation and pitching of the machine; the torsional wing tips controlled the lateral stability, and could be used to cant the aëroplane or check its listing, as in the Wright and Curtiss machines. The craft exhibited an easy poise in the air, and possessed good equilibrium, owing to its arrowlike structure and its three-rudder system of control. It was a strong rival of the biplanes previously noticed, and a herald of better things to come.

In the meantime the Wright brothers had resumed their field practice. During the month of May, 1908, they tested their famous aëroplane of 1905, provided with increased engine power, and carrying two passengers upright. A few brief flights were made at speeds of 41 to 44 miles an hour, showing that all the mechanism was adequate and effective. But on May 14th a false push on a lever, made by Wilbur Wright, brought the flyer to earth, wrecking it too badly to be repaired in the few days available for experimentation. These flights were but preliminary to the official trials set for the approaching summer; for the brothers had contracted to furnish one machine to the United States Signal Corps, another to a French syndicate.

The Chief Signal Officer of the United States Army in December, 1907, had issued specifications, and invited bids, for a flying machine apparently far in advance of the art. The flyer was to carry two men aggregating 350 pounds, was to remain aloft one hour continuously, and was to maintain an average speed of 40 miles an hour in a cross-country flight to and fro, covering a distance of ten miles. The contractor must instruct two officers to operate the flyer. Furthermore the machine must be capable of flying 125 miles without stopping. The requirements seemed severe, even to those well versed in aviation. Nevertheless two bids were received; one from the Wright brothers for a biplane to cost $25,000, another from Mr. A. M. Herring for a biplane costing $20,000. Both bids were accepted for the summer of 1908; but only the Wright contract was eventually carried out.

About the same time the Dayton inventors had sold their patent rights in France to a syndicate in that country. The contract specified a machine for two passengers, having a speed of 50 kilometers an hour, and a range of 125 miles. Furthermore, the inventors agreed to instruct three pupils to manage the aëroplane. The fulfillment of these two contracts occupied some months, but presented no formidable difficulties. Though neither of the brothers had ever flown an hour, and though both were comparatively unskilled as operators, they had such faith in their invention that they undertook to launch themselves publicly in untried machines, Wilbur Wright in France, Orville in America, at about the same time.

Of these two tests, the one conducted by Orville Wright at Fort Myer, near Washington, was the most successful at first. After a few brief preliminary trips, he suddenly astonished the world by phenomenal flying. On the morning of September 9, 1908, he made a voyage above the drill ground lasting 57 minutes, 31 seconds, and again in the evening another flight lasting one hour and three minutes, this time before a throng of distinguished spectators. Immediately thereafter he took aboard Lieut. Frank P. Lahm for a flight of six minutes' duration. These records were improved day by day, and all things seemed propitious for the official tests of speed and endurance. But on September 17th, while sailing with Lieutenant Selfridge at a height of about 75 feet, a blade of the right-hand propeller struck and loosened a stay wire of the rear rudder. Instantly the wire coiled about the blade, snapping it across the middle. Thereupon the machine became difficult to manage, and plunged headlong to earth, throwing the men with their faces on the bare ground, fatally wounding Lieutenant Selfridge, and seriously injuring Mr. Wright. Lieutenant Selfridge did not recover consciousness, and died within three hours, from wounds on the forehead and concussion of the base of the brain. Mr. Wright suffered a fracture of the left thigh and of two ribs on the right side. The aëroplane was badly shattered in its framing, but the engine was practically intact. This accident terminated the tests for the season; but ere long a date was set for their resumption during the following year.

Wilbur Wright began his demonstration for the French syndicate on the plain of Auvours, ten miles

PLATE XXVI.

WRIGHT BIPLANE OF 1908.

STANDARD WRIGHT BIPLANE OF 1910.

WRIGHT RACING BIPLANE OF 1910.

from Le Mans, France, on August 8, 1908. For some weeks his flights were very brief, owing to the balky condition of his engine; but this difficulty was removed by the middle of September. After the accident to his brother he remained inactive for a few days; then, to reassure his supporters, he raised the world's record by flying a distance of over 52 miles, remaining aloft 1 hour, 31 minutes, 25 seconds. After this he continued at frequent intervals to make long flights, quite usually taking a passenger with him, and on several occasions a lady. His endurance, his altitude, his abandon and perfect control amazed and delighted Europe. Incidentally he won some valuable prizes, beating the French records for duration, distance and elevation. Once he rose to a height of 380 feet. On September 21st, he flew 42 miles in 1 hour and 31 minutes; on October 11th, he carried a passenger an hour and ten minutes; finally on the last day of the year he flew 77 miles in two hours and twenty minutes, thus winning the much coveted Michelin prize of twenty thousand francs for the longest distance flown during the year. It was a triumphal close to the most progressive and eventful year in aviation—the first year of exhibition flying, the inaugural year of a noble art.

Having completed the speed and distance tests at Le Mans by the close of the year 1908, Wilbur Wright went to Pau, in the South of France, for the winter practice with his three pupils, Count de Lambert, Paul Tissandier and Alfred Leblanc. Here on the vast trial grounds at Pont Long, six miles from Pau, he had a commodious hangar with a workshop on one side, and on the other, apartments for the aviator and his mechanics. He arrived with his pupils, on January 14th, and next day was joined by his brother and sister, who had followed him from Paris, Orville being now well recovered from his injuries received at Fort Myer. In a short time the machine was set up, and early in February began its regular service, having a pair of levers for the teacher and another pair for the passenger. The pupils quickly acquired the art of steering, being first allowed to control one lever, with Mr. Wright holding the other; then being entrusted to manage the whole machine, with their tutor as passenger; and finally becoming themselves teachers of the newly acquired art. Only a few hours' practice was needed to attain proficiency, the whole time in the air aggregating hardly half a day for each pupil, though the lessons extended over many days.

A pleasant feature of the sojourn at Pau and Le Mans was the number and character of the visitors, and the boundless enthusiasm displayed toward the new art. Tens of thousands of people from the neighboring places, and tourists from many parts of the earth assembled to see the flights; statesmen, military officers, scientific and parliamentary delegations, representatives of innumerable periodicals. Queen Margherita, having missed a flight on her first visit to Le Mans, came a second time, and remained three hours standing on the field, fascinated by the wonderful aërial equipage. The King of Spain, Alfonso XIII, who visited the aërodrome at Pau, on February 20th, manifested the keenest interest and delight in examining the aëroplane and seeing it fly; first with the pilot alone, then with an extra passenger. He took a seat in the machine beside Mr. Wright, discussed its working, and expressed his deep regret that reasons of state prevented him from making an ascension. A month later the King of England, who was at Biarritz, adjourned to Pau, where he remained to witness two unusually fine flights. He expressed the greatest pleasure in the performance, questioned the brothers about the details of the machine, and complimented them on their achievement.

From Pau, Wilbur Wright went to Italy, about the end of March, to fulfill an engagement to give demonstrations and lessons in the use of the biplane. He was welcomed at Rome by the King of Italy, on April 2d, and later gave a public exhibition of flying, to aid the sufferers in the recent earthquake at Messina. His flights were attended with great enthusiasm, and his lessons in aviation were quickly mastered; his pupil, Lieutenant Calderara, soon making public flights alone. A rare sight it was, this modern winged chariot soaring above the ruins of that ancient campagna, bearing with it a moving-picture camera.

By the end of April Mr. Wright had finished his task in Italy, and was journeying homeward with his sister and brother by way of London, where they enjoyed the hospitalities of the Aëronautical Society of Great Britain; and where, on May 3d, the brothers received the beautiful gold medal of that famous society, the oldest aëronautical organization in the world.

The return to America was primarily for the purpose of completing the official tests at Fort Myer; but incidentally the brothers must find time to receive new honors and ovations. While in the shop at Dayton, working vigorously to complete a new aëroplane for the War Department, in the hope of finishing the demonstrations by June 28th, the limit of their allotted month, they were showered with attentions too numerous for their comfort. They must drop their tools in order to go to Washington to receive the gold medal of the Aëro Club of America from President Taft, at the White House, on June 10th. On June 17th they must witness an elaborate demonstration in their honor at Dayton, where they received a gold medal from the city, another from the State, and another from the Federal Government. Finally late in June, they arrived in Washington with the rehabilitated biplane, to make good their contract with the Signal Corps.

The early tests of this aëroplane were not an unmixed triumph for the Wright brothers and their well-wishers. At first the machine failed to fly completely about the drill ground. It took the air with difficulty, and came to the earth on the first turn. Some lack of adjustment in the frame was suspected. The motor was accused of weakness. The launching weights[1] were too light. The brothers explained that a new flyer is like a new horse; the driver must learn his idiosyncrasies before attempting to show him off to advantage. They intimated also that they would be pleased to have the great throng of prominent people, who flocked daily to the drill ground, kept away until their flying instrument was properly tuned for public performances. They discouraged superfluous attentions. The big legislators who ventured audaciously to peep into the sacred shed containing the marvelous machine, were hailed by the military guard, and unceremoniously marched across the line among the plain people. It was a dreadful shock to these mighty signors, and many a fat lawmaker cursed audibly, vowing never to vote a cent for flying squadrons. But still they haunted the drill ground daily, despite the long journey and the late dinner; for they were fascinated by the untold and unconjecturable possibilities of the new art.

June 28th came quickly, obliging the patient aviators to beg another extension of time. They

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[1] Falling weights pulling a cord that accelerates the aëroplane at starting.

were granted thirty days longer, which seemed to them more than necessary; but in this judgment they were mistaken. One accident after another delayed the consummation of their official task of flying one hour above the field, then five miles across country and return. Finally, on July 27th, Orville Wright, who was making all the flights, took with him Lieut. Frank P. Lahm, and sailed gloriously for one hour, twelve minutes and forty seconds, before ten thousand delighted spectators. It was an ideal summer evening, and all the maneuvers were performed with excellent poise, security and grace. A new world's record was established. Now all the vast throng from the President and his cabinet to the simplest laborer, appreciating the achievement as a triumph for America and for humanity, burst forth into prolonged acclamation and applause.

The cross-country flight was next in order. The course from Fort Myer to Alexandria lay over scattered forests and a deep valley. The flight seemed a difficult and hazardous enterprise; but the brothers, confiding in their machine, seemed to have little apprehension of failure or peril. Indeed, they seemed most concerned about the bonus to be secured by flying at an average rate exceeding the contract speed of 40 miles an hour; for each additional mile an hour would pay them $2,500 above the normal price of the aëroplane. They accordingly declined to fly in any but very calm weather, no matter how vast the gathering of visitors, or how illustrious. They wished, of course, to expedite the final and crucial test; but they could not always have ideal conditions, and would not take undue chances. On the evening after the endurance test the engine balked, owing to the clogging of a rubber pipe from the gasoline tank. Dusk came on, and the disappointed crowd went home to a late dinner.

The Secretary of War, who was present, very kindly granted a third extension of time, covering the rest of the month. Next evening it was a trifle breezy. Wilbur Wright announced that the flight could be made, but that the bonus would be less than on a still evening; he would therefore wait for calmer weather. Twelve thousand people were turned away disappointed. There was muttering among the impatient and warm of blood. It was remarked that the War Department could easily drop these procrastinated experiments and buy a practical aëroplane in the open market for $5,000. But the discommoded officers good-naturedly allowed the thrifty sons of Dayton to have their way in striving for a large bonus, beyond the normal price of $25,000.

On the following evening the weather was clear and fairly still. All was in readiness for the flight to Alexandria and return. Orville Wright, taking with him Lieut. B. D. Foulois, circled the drill ground on easy wing, then sailed directly across country for the captive balloon at Shuter's Hill. In a few moments they vanished beyond the forest, and for a while even the most optimistic were doubtful of their safety. At length they reappeared sailing homeward at very great speed. The machine proudly circled the drill ground amid thunders of applause, and landed softly at the lower end, beyond the shed.

The multitude hastened to congratulate the aviators on their marvelous performance. For everybody it was a scientific and national triumph; for Wilbur Wright it was something more. With pencil and pad he quickly computed the bonus, surrounded by a wall of reporters. "Wise old Wilbur," remarked one, "he knows the worth of coin in a crude republic. While Fame blows her trumpet he counts the solid gain." The figures showed an average speed of 42.6 miles, making the bonus $5,000. The voyage was one of the finest ever executed up to that date; it was a glorious termination to a long and troublesome, but epoch-making demonstration. Now there remained only the task of instructing two officers to fly, and this was leisurely accomplished by Wilbur Wright in October.

As shown in Plate XXVI the Wright aëroplane used at Fort Myer in September, 1908, was a twin screw biplane mounted on skids and having the three-rudder system of control. The rear rudder turned the machine right or left, the front rudder raised or lowered it, the warping of the wings controlled the lateral poise. The turning right or left could be effected on level wing; but the inventors canted the machine sidewise, to obviate skidding, or sidewise gliding of the craft, due to centrifugal force. These three-rudder movements were performed by three separate levers actuating suitable mechanism; but they could be performed easily by a single lever having three separate movements, as preferred by some designers. The aëroplane in launching ran along a monorail, accelerated by a towrope passing over pulleys, and attached to a falling weight comprising nearly a ton of iron. The dimensions of the various parts are given as follows by Major George O. Squier,[1] the officer in charge of the experiments:

"The aëroplane has two superposed main surfaces 6 feet apart with a spread of 40 feet, and a distance of 6½ feet from front to rear. The area of this double supporting surface is about 500 square feet. A horizontal rudder of two superposed plane surfaces about 15 feet long and 3 feet wide is placed in front of the main surfaces. Behind the main

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[1] *Present Status of Military Aëronautics, Journal of the American Society of American Engineers,* December, 1908.

planes is a vertical rudder formed of two surfaces trussed together about 5½ feet long and one foot wide. The motor, which was designed by the Wright brothers, has four cylinders and is water cooled. It develops about 25 horse power at 1,400 r. p. m. There are two wooden propellers 8½ feet in diameter which are designed to run at about 400 r. p. m. The machine is supported on two runners and weighs about 800 pounds."

On the whole the demonstrations at Fort Myer in 1909 did not greatly enhance the prestige of aviation. They were attended by too many delays and accidents, and too much waiting for ideal weather. As a consequence the guardians of the national purse were not clamoring for an aërial flotilla. Some few, no doubt, understood that the aëroplane could brave more than a zephyr with safety; but the general public accepted the demonstrations at their face value. The unthinking multitude did not realize that with sufficient incentive, such as war presents, the Wright brothers could repeat those brilliant flights, of the end of July, under more severe weather conditions. Fortunately, events were transpiring elsewhere which vastly increased the popular fame and valuation of the new art. This refers more particularly to those startling achievements in aviation abroad which were largely stimulated by competition and prizes.

After the Fort Myer flights the Wright brothers separated, Orville going to Germany to represent their interests and give demonstrations; Wilbur exhibiting at the Hudson-Fulton celebration in New York, and teaching the Signal Corps officers to manipulate the newly purchased government aëroplane. As usual, both achieved distinction in their new fields. At Potsdam, on October 2d, Orville Wright, after a ten-minute flight with Crown Prince Frederic

William, ascended alone, mounting steadily in circles for fifteen minutes, and reaching an elevation roughly estimated at 500 meters, after which he descended safely in five minutes. On September 18th, he made a new record at Berlin by carrying a passenger, Captain Englehardt, for 1 hour, 35 minutes and 47 seconds. Wilbur Wright, on September 9th, flew from Governor's Island, in New York harbor, to and around the Statue of Liberty, then returned to the point of departure. On October 4th, starting from the same point, he flew over the waters of New York Bay and above the Hudson River to a point opposite Grant's Tomb, then returned to Governor's Island, covering a distance of about 19½ miles in 33½ minutes. The trip upward was made at an elevation of about 200 feet, through a stratum disturbed by vortices rising from the steamer smokestacks, and eddies caused by the northeast wind blowing over the tall buildings. The return was made at a level of 50 feet on the Jersey side of the river where the air was less turbulent. He intended later in the day to make a long flight, but, owing to the bursting of a cylinder head, he stopped his demonstrations and returned to Washington to finish his instruction of the Signal Corps officers. This was easy routine, and it afforded opportunity to try the effect of transferring one of the forward steering planes to the rear and applying it there as a fixed horizontal tail, as used by Voisin, Curtiss and others. The new arrangement was reported to increase the longitudinal steadiness of the aëroplane, and was used in subsequent Wright aëroplanes.

The brothers now ceased public flying for a while, to attend to the business of manufacturing and selling their craft. They formed an American company, enlarged their facilities for constructing machines, procured grounds for training operators, and prepared generally to fill orders both for aëroplanes and for public exhibitions. Not the least of their labor was to defend their patent claims, which they wished to be interpreted so broadly as practically to exclude all flyers whose lateral poise is controlled by changing the angle of incidence of the wings, or of lateral stabilizing planes. This was not an easy undertaking, since the torsion wing was a well-known device, having been described many times in public print, and having figured in earlier patents and experiments in various countries. To add to the difficulty, their patent claims apply specifically to the warping of normally flat sustaining surfaces, the warping of arched wings having been patented by Prof. J. J. Montgomery, whose invention antedates theirs.[1] However, if they produced no novel and radical invention in aviation, they, like Santos-Dumont in aëronautics, were first to achieve some measure of practical success, by applying a light automobile engine to a familiar machine in which former inventions and ideas were skillfully employed. On this ground of practical success they strove for an interpretation broad enough to establish a monopoly covering even Montgomery's rights, which apparently they were infringing. But when to this end they applied for a preliminary injunction restraining Curtiss from using his system of control, and Paulhan from using Farman's system, they were unable to convince the court of the justice of their petition, and the injunction suit was vacated.

[1] On September 18, 1906, Montgomery received a U. S. patent on an aëroplane having curved wings and three-rudder control, the Wright brothers having on May 22, 1906, received a patent on an aëroplane having normally flat wings and three-rudder control.

CHAPTER XI

STRENUOUS COMPETITIVE FLYING

The cardinal allurements in aviation for 1909 were the prize offered for the first flight across the English Channel, and the prizes to be won at the world's first aviation meet, scheduled for the last week in August of that year, at Rheims, France. The desire to win these honors stimulated to livelier effort the most noted designers and operators of aëroplanes, all of whose machines were represented at the great tournament. It also brought into sudden prominence several new aviators. Young men, little versed in the science or literature of flight, took to wing, and in a few days found themselves world-famous. Aërial chauffeurs, skillful and daring, delighted vast throngs of people, kept the cables warm with news, and incidentally filled their purses with money. Thus the trade of aëroplane jockey was one of the interesting products of this eventful year.

The first half of the aviation season of 1909 brought forth many improvements which seemed to augur well for the public demonstrations to follow. Hubert Latham, with the swallowlike *Antoinette* monoplane, designed by Levavasseur, the inventor of the *Antoinette* motor, began soaring grandly in the sky and into fame. Paul Tissandier, on May 20th at Pau, established a new French record by flying 1 hour and 2 minutes. The Voisin brothers were perfecting in detail their boxlike aëroplanes, noted for inherent stability, and destined to achieve further renown during the summer, under the dexterous hand of intrepid young Paulhan. This new and daring young aviator, after a few practice flights, began making world records. On July 15th, he flew 1 hour, 7 minutes and 19 seconds. On July 18th he made a new world's record for altitude, driving his Voisin aloft 150 meters at Douai. Impatient Roger Sommer, rejecting his own make of biplane, purchased a machine from Farman, and after a little practice, broke the world's record for distance on August 7th, by flying at Chalons, 2 hours, 27 minutes, 15 seconds. Many others were advancing in skill, and would erelong achieve excellent results. Most strenuous of all, perhaps, were Curtiss and Blériot, the champions of high speed, respectively in the biplane and monoplane, and Farman, the winner of large prizes.

In the latter part of April, Henri Farman tested a new biplane of his own design and manufacture, which proved very satisfactory. It resembled his former craft, but was provided with small balancing planes hinged to the rear margins of the wings near their tips. This machine, furthermore, was provided with both landing skids and wheels, the latter yielding to any unusual stress by means of elastic connections, so that the skids took up the shock. With this improved biplane, Farman beat his former records by flying continuously 1 hour, 23 minutes, at Chalons, on July 19th. Four days later he made a new cross-country record by flying from the Chalons parade ground to Suppe, about forty miles, in 1 hour and 5 minutes. These flights were gently suggestive of what might be expected at Rheims the following month.

During the opening period of the 1909 aëroplane season, Glenn H. Curtiss brought forth a new biplane, designed for the Aëronautic Society of New

York, with the coöperation of his new partner, Mr. A. M. Herring, and began active practice for various prizes at home and abroad. After some brief trials at Hammondsport, N. Y., he shipped his aëroplane to Morris Park, in order to participate in the Aëronautic Society's first flight exhibition of the year. On June 26th he flew, but without official witness, far enough to win one of the $250 prizes offered to the Aëro Club of America by its president, Mr. Cortlandt Field Bishop, for the first four persons who should fly one kilometer. He now wished to make an official flight for this prize and also for the Scientific American trophy, a beautiful engraved silver cup—which he had won a year previously for the first public flight of one kilometer, made in America, but which now should go to the person making the longest official flight of the year 1909, not under 25 kilometers. But the Morris Park race track proved unsuitable for such contest, being too restricted. He therefore took his biplane to Mineola, Long Island, where he could practice on a wide plain, and possibly make some new records. Here a triangular course 1.3 miles long was staked off, and some short trial flights were made. Then Mr. C. M. Manly, who was official timekeeper for the Aëro Club of America, was notified that a trial for the prize would be made.

The demonstrations near Mineola were most successful, and proved the beginning of a brilliant summer for Mr. Curtiss. On July 17th he won in quick succession both of the prizes mentioned above. The trial for the smaller prize began at 5.15 in the morning and lasted but 2½ minutes, followed 6 minutes later by the start for the coveted cup. In both cases the machine took the air with ease and grace, after a 200-foot run over the rough marsh land. In the cup trial the first twelve turns, aggregating 25 kilometers, were accomplished in 33½ minutes, but the machine continued for seven more rounds, and finally landed in excellent form, just 52½ minutes after it had crossed the starting line. The actual measured distance flown was 24.7 miles, but the true distance traversed by the machine was probably 30 miles, making the time speed between 30 and 40 miles per hour. This was slow, indeed, but the control was satisfactory. Those who wished for high speed would find it in the new aëroplane which Mr. Curtiss would presently take to Rheims for the speed contest, in which he was to fly as sole champion of the United States.

The type of machine used by Mr. Curtiss in 1909 was a natural outgrowth of his previous ones, but very much perfected in power and finish. It was a biplane mounted on a three-wheeled chassis, two wheels under the main body and one well to the front, so as to prevent toppling forward. It was propelled by a single screw at the rear, directly connected to a water-cooled motor of the Curtiss make. Its flight was controlled by three rudders exerting torque respectively about the three axes of the aëroplane, supplemented by two fixed keels, a vertical one in the front and a horizontal one in the rear. Of the three rudders mentioned, one in the rear turned the craft right and left, like a boat, one in the front raised or lowered her, while the third or lateral rudder, consisting of small horizontally pivoted planes between the wing-ends, and turning oppositely to each other, controlled the lateral poise. These lateral rudders, or winglets, used by Curtiss, Farman and others, are commonly called *ailerons*.

Louis Blériot with his two new machines, his *No. XI* at Douay and his *No. XII* at Issy-les-Moulineaux, practiced nearly every fine day in June and July, making fast progress in the art, and achieving some

PLATE XXVII.

BLÉRIOT XI WITH MOISANT AVIATOR ON MEXICAN BORDER.
(Courtesy A. J. Moisant.)

BLÉRIOT XII.
(Courtesy E. L. Jones.)

notable records. By warping the wings he could keep his balance better than in former years, and dare more severe weather. On June 12th, he made a straightaway flight of 820 feet in his *No. XII*, taking as passengers A. Santos-Dumont and A. Fournier, the entire weight being 1,232 pounds. This was the first flight of three passengers in an aëroplane. On June 25th, despite a strong wind, he circled in his *No. XII* eleven times about the parade ground at Issy-les-Moulineaux in 15½ minutes, maintaining excellent stability. Next day he made 30 circuits in 36 minutes, 55⅗ seconds, stopping finally because of spark failure due to excess of oil. On July 4th, at the aëronautic meet at the Juvisy Aërodrome, for sufferers from the earthquake in the south of France, he flew in his *No. XI* for 50 minutes, 8 seconds, at a height of 50 to 80 feet, finally stopping because of feed trouble in his engine. This flight was his second up to that date. On July 13th, he made a new cross-country record by an early morning flight in his *No. XI* from Etampes to within eight miles of Orleans, stopping some minutes en route, to show the practicability of his monoplane. Thirty-five minutes after landing, his machine was taken apart and shipped back to his factory at Neuilly, near Paris. After this record he received gold medals from the Aëro Club of Great Britain and the Aëro Club of France. He was also awarded the *Prix de Voyage* of 14,000 francs, of which he himself received 5,000 as pilot, 4,000 as constructor, while 3,000 went to the motor manufacturer and 2,000 to the propeller designer.

The monoplanes *No. XI* and *No. XII* represented Blériot's most successful types. They bore a family resemblance to his preceding machines, but had a more vigorous lateral control due to warpage of their main surfaces instead of the wing-tips, as of old. Both were provided with a single-screw propeller in front, and both were mounted on three-wheeled chassis with shock absorbers. The larger machine, or *No. XII,* had a wing surface of 337 square feet; the smaller a surface of 151 square feet. The latter, on its historic cross-Channel trip, carried a three-cylinder air-cooled Anzani engine.

Hubert Latham, in his beautiful *Antoinette* monoplane, began to achieve distinction for himself and his admirably designed long-tailed flyer early in the spring, and, ere midsummer, was one of the favorite idols of the thronged aërodromes. He preferred a lofty course; he cut through the sky with the precision and grace of a winged-spear; he fascinated the spectators by the steadiness of his sweep. The French reporters declare they saw him roll and light cigarettes in full flight. Not only did he delight the artist, but he surprised the official measurer. Toward the end of May he established a new monoplane record by a flight lasting 37 minutes and 3 seconds. On the 5th of June he flew continuously 1 hour, 7 minutes and 37 seconds, at a speed of 45 miles an hour. This was done in a wind and heavy rain which drenched and blinded him, finally inducing him to come down. On June 7th he carried a passenger, something new for a monoplane. In July he increased the altitude record by flying 450 feet high. Next day he flew across country from Arras to Douai, 12½ miles, in 20 minutes. Very reasonably, therefore, he announced his intention of sailing for England above the waters of the turbulent strait.

The *Antoinette* monoplane resembled, at a distance, a long-winged fish with its head cut off and replaced by a screw-propeller. It had a skifflike body with the screw in front, followed by the *Antoinette* engine, then by the pilot's seat, the tail part carrying fixed horizontal and vertical fins and mov-

PLATE XXVIII.

ANTOINETTE MONOPLANE OF 1909.
(Courtesy W. J. Hammer.)

ANTOINETTE MONOPLANE OF 1910.

able horizontal and vertical rudders. These rudders together with *ailerons,* or warping wings, controlled the poise in flight. The body was mounted on a light chassis having cushioned wheels, and a landing skid for absorbing shocks. The engine employed no carburetor, and was cooled by water which turned to steam in the engine jackets, condensed in tubes on the side of the prow, then was pumped back to the jackets.

The cross-Channel prize, above mentioned, was a cash sum of one thousand pounds, offered by the *London Daily Mail* for the first successful flight from France to England. Many would fain have it, though the voyage seemed dangerous, if not foolhardy. Of the various aviators who coveted the prize, Latham and Blériot were the most strenuous in competing for it. The bold boy tried first.

Housing his aëroplane on the high cliff facing the Channel near Calais, Latham looked toward England, impatiently waiting for placid weather, and a chance to soar. The venture was hazardous. By some it was deemed rash, owing to the uncertainty of having to alight upon the water, if the motor should fail. But the brave youth was less alarmed than the old aviators, who had no intention of competing with him. So, with a boy's confidence, he brought forth his huge-winged *Antoinette,* on July 19th, skimmed along the ground, soared grandly above the high cliffs, and sped over the waters at a great elevation, as usual in his aërial voyages.

Latham's flight was magnificent, but brief. Owing to spark failure and the stoppage of his motor six miles from the French shore, he settled promptly, but skillfully, down upon the sea. When found by the accompanying torpedo boat destroyer, detailed to follow him from Calais, he was seated on the aëroplane, serenely smoking, buoyed up by the great hollow wings. He was quickly brought to shore, undaunted and eager for another trial; but in the rescue his frail flyer was roughly handled and very much wrecked.

Louis Blériot now hurried to Calais eager to attempt the cross-Channel flight. Placing his little monoplane, *No. XI,* in a tent on a farm near Calais, he waited an opportune moment to sail. On Sunday, July 25th, he was routed from bed very early by his friend, Alfred LeBlanc, and taken forth all reluctant to the field, for preliminary practice before sunrise; for the weather was favorable and he should sail as soon as the sun arose. Though suffering from a foot burned in a recent accident, he discarded his crutches and mounted his winged machine with eager courage, remarking: "If I cannot walk I will show the world that I can fly." For some minutes he circled about the ground where, even at that early hour, many scores of people were assembling. All was now in readiness; the flyer was in excellent trim, the pilot in buoyant spirits, and the torpedo boat destroyer, *Escopette,* well out at sea to escort her swift aërial charge as well as might be.

The moment of departure had come. Blériot, buttoned in his close-fitting suit and hood, sat on his white-winged machine, headed for the cliff, and surrounded by a group of well-wishers. At 4.35 the light-wheeled craft with propeller whirring, sped along the ground, rose gracefully in the air and shot bravely over the precipice, with the hustling aviator on its back. The admiring spectators were wild with excitement and joy. But there was one sad group in Calais that morning. Latham and his watchers, who had been waiting for better weather, rose in time to see his rival on the wing, but too late for pursuit, as the wind had suddenly risen.

The unwary boy remained behind, weeping with disappointment.

Blériot was now soaring high over the sea, faring toward Dover without a guide or a compass. For some time he could observe the *Escopette* following him, her great column of smoke obscuring the new risen sun. Presently both shores vanished, and for ten minutes he could descry neither land nor signal of any kind. He was sailing over the sea at forty miles an hour and drifting with the air he knew not whither; but he allowed his fiery steed to follow its instinct, as a bewildered horseman does sometimes. Along the horizon now appeared the white cliffs of the English shore. He was headed not for Dover but for Deal, carried adrift by the southwest wind. Three boats crossing his course seemed plying for some port on his left, and hailed him with lively greeting. He could not well inquire the way, but he followed the general course of the vessels, soaring high aloft. At length he saw a man on the cliff violently waving the tricolor, and strenuously shouting: "Bravo! Bravo!" He plunged in the direction of the signaler, whom he knew to be his friend M. Montaine. On nearing the earth he was caught in a violent turmoil of air and whirled about. Wishing to land at once, he stopped his power sixty feet aloft, and swooped abruptly down with an awakening thud upon the old English soil, sleeping in the peaceful sunlight of a Sabbath morning.[1]

Blériot's landing was the greatest jolt to British insularity since the birth of steam navigation. Nevertheless it was welcomed with unfeigned delight as emphasizing the triumph of a new art which enriches all people. Shortly afterward was erected

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[1] The daring aviator escaped without a scratch, but his propeller and running gear were damaged slightly.

on the spot a monument in white granite having the plan and size of the renowned *No. XI* monoplane.

Sportsmanlike, Latham wired his congratulations to Blériot, expressing the hope to follow ere long. Two days later he flew across the Channel to within one mile of the English coast, where he had to land in the water again because of motor failure. This time he struck the sea violently and suffered a broken nose. His goggles were shattered and cut his face.

The big competitive flyers of the world now turned toward Betheny Plain near Rheims, where the first International Aviation Meet was to be held August 22–29, 1909. Here was a place to make record flights, to win rich prizes, and to achieve great distinction. A well-designed aërodrome had been prepared for the occasion. In the midst of a broad plain was marked by means of high poles, or pylons, a rectangular course, measuring roughly one by two miles, or more exactly, 1,500 by 3,500 meters. At one end was the judges stand, the grand stand, the café and the aëroplane sheds. The numerous cash prizes offered for speed, for distance, for endurance, for altitude, etc., totaled in value nearly forty thousand dollars. But the most coveted prize of all was the James Gordon Bennett Aviation Cup, together with $5,000 cash, the winner of which should have the honor of placing the next international contest in his own country. This should be awarded to the aviator having the best speed over a two-round, or 20-kilometer course. The next most desired prize was a cash sum of $10,000 for the longest flight. A special charm of the tournament was that each fortunate entrant should meet the distinguished aviators from all localities, and should fly in presence of a world-gathering. Aëroplanes of all the most successful types were there, numbering together thirty-eight machines.

The first day of the great aviation week, Sunday, August 22d, was devoted to elimination trials to determine which aviators should represent France in the race for the Bennett trophy. Of the seventeen entrants in these trials the three who should cover two rounds of the course in the shortest time should be selected as champions, the next six, in order of speed, to act as reserve pilots. But owing to the severe weather of that day, only six of the seventeen entrants succeeded in flying well enough to be admitted in either capacity. Of these six the cup champions were: Blériot, Lefebvre, Lambert and Latham; the reserve champions being in order, Tissandier, Paulhan and Sommer. These men won their places by bold flying in rough conditions; for rain had fallen heavily during the previous night, and the wind was still blowing in swift and gusty current over the sodden field. Indeed, the weather seemed anything but propitious at the opening of that great experimental tournament, on the success of which should be based the estimates and forecast of so many subsequent meets. Swift clouds overhead, and black flags displayed on high masts, indicated that flying would be impossible. A passing storm raged at five o'clock in the afternoon. But toward evening the face of Nature brightened, and with it the hopes of the aviationists. The weather at last became ideal. Nearly all the aëroplanes came forth, and at six o'clock no fewer than seven were on the wing at one time. Some of them were doing most startling feats. Lefebvre would make a threatening swoop at the grand stand, then circle swiftly away. Blériot, in a moment of unsteadiness, charged a wheat stack with his swift monoplane, damaging his sharp-bladed propeller. Count de

Lambert sailed under Paul Tissandier, heedless of the aërial wake beneath. The crowds applauded and cheered every novel and bold maneuver. The closing hour with its sunny calm atmosphere and its vivacious well-pleased populace, presaged greater joys for the morrow. Sir Henry Norman, who was present, declared that those events marked the birth of a new epoch in human development.

Monday, the second day of the meet, dawned fair and calm, with promise of settled weather. It was the last qualifying day for the ten-thousand-dollar long-distance prize, the Grand Prix de la Champagne. No one who had not flown a reasonable space on, or before Monday, could take part in the trials for that coveted honor on Wednesday, Thursday and Friday. The aviators were about early, and many had qualified before evening. Several of the pilots tried for speed records. Blériot, with an 80-horse-power monoplane, made one round of the course in 8 minutes, $42\frac{2}{5}$ seconds. Curtiss, in his 60-horse-power biplane, lowered the time to 8 minutes, $35\frac{3}{5}$ seconds. This was an achievement of the greatest concern, since Curtiss stood alone, as champion of America, against the more experienced flyers of Europe. He thought of nothing, engaged in nothing, except the speed trials, for in these he hoped to win, with his 60-horse flyer, even against renowned Blériot, in his 80-horse machine. Other interesting events were designed solely to entertain or amuse the people. Lefebvre again furnished merriment by sweeping over and under, and around Paulhan, who was flying at an elevation of 25 feet. M. Kapferer had navigated from Meaux, in the dirigible *Colonel Renard*, and sailed about the grounds, with fine effect.

Tuesday should have brought ideal conditions and performances; for it was the day set for the visit of M. Falliéres, President of France. But the morning was dark, with ominous clouds gathering over the aërodrome, and black flags streaming in the strong wind. When the President arrived, though the clock told four, no flying had yet begun. He examined the machines, held an informal reception, and at five took his box in the grand stand. Presently Bunau-Varilla in his Voisin biplane, rocking in the fifteen-mile wind, flew past, waving his hat to the distinguished spectators. After him came dauntless young Paulhan who also passed the President, shortly before the latter, with his party, returned to the railway station. He flew at an elevation of 300 to 500 feet, his Voisin heaving and lurching in the tumultuous wind, like a boat on the breakers. He had no lateral stabilizing plane, so he let his box kite rock. The people were appalled, but what cared he for wind gusts, so far from earth? Let the craft roll and pitch; he was not uneasy. On the return lap he raced and beat a railway train. These were but inklings of what he would do with increased experience. Latham followed presently on his long swift monoplane, to the delight of all who love the graceful in mechanism and motion. Ere long he was chased and overhauled by Blériot, in his cross-Channel flyer. This was exciting, but Blériot produced still greater enthusiasm by beating the speed record, lowering it to 8 minutes, 4⅖ seconds, for one round of the 10-kilometer (6.21 mile) course. The day was ended, and the spectators were charmed again by the spectacular evolutions of Lefebvre, who cavorted in the air before the grand stand, cutting impressive curves and figure "8's."

Wednesday morning, the fourth of the meet, was heavy with black clouds, which presaged unfavorable weather. The winds were light, but still nothing transpired till late in the afternoon to break the monotony of waiting. During this long interval the crowd could amuse itself with gossip, refreshments and music, and with an occasional flight of lesser moment. About four o'clock Paulhan set forth in a six-mile wind to try for the Grand Prix de la Champagne. His lumbering Voisin had a speed of hardly more than thirty miles an hour, but it was driven by a very reliable 50-horse Gnome 7-cylinder motor, whose body spins round a fixed crank, carrying the propeller with it. No one at first expected a very long flight. The wind rose, sometimes exceeding 20 miles an hour, tossing the young pilot terribly, and once throwing him so far within the course that he must turn a complete circle in order to round the corner post, or pylon. But he kept right on, so long as there remained a drop of fuel. He first broke Wilbur Wright's best record, by 23 minutes, then Sommer's recent record, by 6 minutes, finally landing, at half past six o'clock, with a new world's record of 82 miles in 2 hours, 43 minutes and 24⅘ seconds. The people were frantic with excitement; they clapped their hands and waved thousands of handkerchiefs; they rent the air with tremendous applause as he was borne toward the grand stand on the shoulders of his clamorous comrades. Others at the same time had been flying with varied fortune. During Paulhan's long demonstration, Fournier had encountered a miniature whirlwind, turned over in the air, at a great height, and crashed sidewise to the ground, with some injury to his nose, and with much damage to the wings and tail of his machine. Latham, wishing to lower his circuit time, flew thrice around the course, but without improvement. During his flight, a splendid rainbow appeared, which together with the *Antoinette* dragon fly soaring high aloft with Latham on its back, produced an impressive spectacle.

Thursday morning brought fine weather and the promise of an eventful day. As a consequence serious efforts were made to excel all previous records, particularly for speed, duration and distance. In the forenoon Latham flew 43.5 miles in the *Antoinette XIII.* In the afternoon Count de Lambert, in his Wright biplane, flew 72 miles. Blériot entertained the throng by carrying Delagrange as passenger; but while sailing near the ground he encountered some dragoons, turned sidewise to avoid striking them, and plunged into a fence, breaking his propeller. But the great sensation of the day was Latham's afternoon flight for the Grand Prix, in his *Antoinette No. 29.* Starting with plenty of fuel and favorable weather, he rose to a high level and flew till his supply was exhausted, at times encountering rough winds and for a while plowing through a rainstorm. It was the banner flight of the week thus far; for it surpassed all other long ones in distance and speed, though not equaling Paulhan's in endurance. His total range, when compelled to alight through exhaustion of fuel, was 95.88 miles, in 2 hours, 18 minutes, 9$\frac{3}{5}$ seconds. This showed an average speed of 41.63 miles an hour for the whole distance, while the speed for his first round was 44.65 miles an hour. For this great achievement he could thank his 50-horse, 8-cylinder *Antoinette* motor, one of the lightest in existence, for that power.

Friday, August 27th, was the last day allotted for the distance, or Grand Prix contest. After the wonderful new records of Paulhan and Latham, people were marveling what might happen on the final day. Many assumed, of course, that Latham's record of 96 miles would remain unsurpassed. At four-thirty, Latham started on another long flight, in his *Antoinette* monoplane *No. 13,* followed presently by Farman and Sommer in Farman biplanes; these flying six to twelve feet from the ground, with gallant Latham soaring aloft nearly three hundred feet in his swift long-winged fish, and occasionally gaining a lap on them. Sommer stopped after three rounds, because of motor trouble. Latham's fuel gave out after a voyage of 68.35 miles, and he glided to earth. Farman continued to plod along on his slow, low-wandering craft, with little attention. Others were in the air, with biplanes and monoplanes, entertaining the populace—Blériot, Curtiss, Delagrange, Tissandier, Bunau-Varilla—these had the applause. Presently the spectators remembered that ground-skimming Farman had been a very long time on the wing. He now became the center of rapt attention. Slowly he distanced Paulhan's great world's record of Wednesday; slowly he distanced Latham's greater world's record of Thursday; but still he plodded away. The sun sank on his flight; darkness came on the field, so that he vanished from view at the far end of the course. At the close of the nineteenth round he landed in the dark before the grand stand, limp and exhausted, having journeyed 3¼ hours and traversed 118.06 miles. For the second time he had won a $10,000 prize; nineteen months ago by flying 1 kilometer, to-day by flying 190 kilometers. A searchlight was thrown upon him. He was pulled from his machine and carried upon the shoulders of his friends, receiving a prolonged and tremendous ovation.

The seventh morning of the tournament, Saturday, August 28th, came with a beaming smile, promising good flights and a pleasant termination of the glorious cup contest for the highest speed in two rounds of the 10-kilometer course. The air was calm, mild and hazy above the Betheny plain. The flyers were in fine mood for great achievements. The thronging groups of well-dressed men and women awaited further startling events, with varied animation and constant chatter. The day was well diversified with interesting flights; but, of course, not with long ones. The chief interest centered in the leading cup-champions—solitary Yankee Curtiss and great Blériot with his 80-horse monoplane, supported, if need be, by his allies in the contest, Lefebvre and Latham.

Curtiss, shortly after ten o'clock, made a preliminary trial, lowering his best anterior time. With this he was so pleased that he prepared immediately for the one official flight allowed in that contest. He filled his small gasoline tank, replenished his radiator, signed a legal paper certifying this to be his trial for the cup, and at once took wing, circling before the grand stand, then crossing the line at full speed. The biplane pitched perceptibly at its unusual gait, but turned the corner in easy curves, completing the first round in 7.57$\frac{2}{5}$, the second in 7.53$\frac{1}{5}$; the total time being 15 minutes, 50$\frac{3}{5}$ seconds, and showing an average speed of 47.04 miles an hour.

About noon Blériot came forth with his 80-horse monoplane *No. 22,* which was expected to eclipse the Curtiss biplane, but in reality proved exasperatingly slow. At two o'clock he tried another propeller, with little encouragement. An hour later he tried again with a four-blade propeller, but descended before completing the round. After tinkering for an hour, aided by several mechanics, he flew to his shed, shortly before five o'clock. As no start was allowed after five-thirty, he hastened zealously and started his official flight at five-ten. The mighty monoplane cut the air at terrific speed, without pitching, or rolling, and finished the first round in

$7.47\frac{4}{5}$, or $5\frac{3}{5}$ seconds less than Curtiss' best lap. The overjoyed French throng rent the air with frantic bravos! Curtiss and Mr. Bishop were silent, appreciating the skill of that fiery antagonist, with his monster engine. As the steady birdlike craft turned the last pylon, and swept homeward in magnificent career, the timers called out the seconds. The throng listened with abated breath and then with alarm. Blériot had lost speed in the second round. When he crossed the line his total time was $5\frac{3}{5}$ seconds greater than that of his only rival. The conqueror of the Channel, the champion of France, was defeated and the international trophy must go to America, won by a taciturn, calculating Yankee, never before seen in Europe, and hardly known to fame.

Other official flights for the cup during the day were made by Latham and Lefebvre for France, and by Mr. Cockburn, champion for England, the latter bird-man sailing into a stack of wheat in the middle of his first round, then wheeling to earth. Incidentally Henri Farman established a new world's three-man duration distance and speed record by carrying two passengers ten kilometers in 10 minutes 39 seconds. Thus ended the chief day of the tournament, leaving the contestants in the following order of speed: Curtiss, Blériot, Latham, Lefebvre.

Of the other leading prizes, that for the fastest single round was taken by Blériot; that for the fastest three-round flight was won by Curtiss on Sunday, with a record of 23 minutes, 29 seconds for the thirty kilometers; the Altitude Prize was won by Latham, who attained an elevation of 508.5 feet; the Prix des Mecaniciens was won by Bunau-Varilla in a flight of 100 kilometers; the Prix des Aëronats was won, on Sunday, by the large dirigible, the *Colonel Renard,* in a voyage of 50 kilometers, or 31.06 miles, at an average speed of 24.9 miles an hour. Along with the chief prizes, many smaller ones of considerable value were awarded, thus summing up the total of $37,000.

The small band of men who organized the first international aviation meet, with the Marquis de Polignac as president, and the great wine merchants of the Champagne district as their supporters, were now elated and triumphant. They had undertaken a novel and costly sporting enterprise, regarded by many as hazardous, or rash, even though sanctioned by the Aëro Club of France. For an enormous attendance would be required to meet the expense of preparations and prize money. It was doubtful whether the few available aviators could draw large crowds to Betheny for a week, even in ideal weather, and there was risk of sending the critical populace away displeased if abundant flights were not made. The whole event might prove a painful fiasco, if rains and high winds should predominate; for were not aviators notoriously reluctant to fly in rough weather? Vain apprehensions, ignoring the reckless and intrepid daring of the Gallic sportsmen! Nothing short of a week's continual tempest could have kept them down.

The great tournament was a triumph, not only to the courageous promoters, but also to the aviators, the manufacturers, the whole of mankind. It astonished both actors and spectators. It marked a new epoch in the art of aëroplaning. It inaugurated a magical and wholly novel kind of recreation and public amusement that should be demanded at once in all civilized countries. It eradicated, in a measure, the inveterate notion that the aëroplane is essentially a fair-weather machine. With a cheap instrument capable of flying scores of miles in rain and wind,

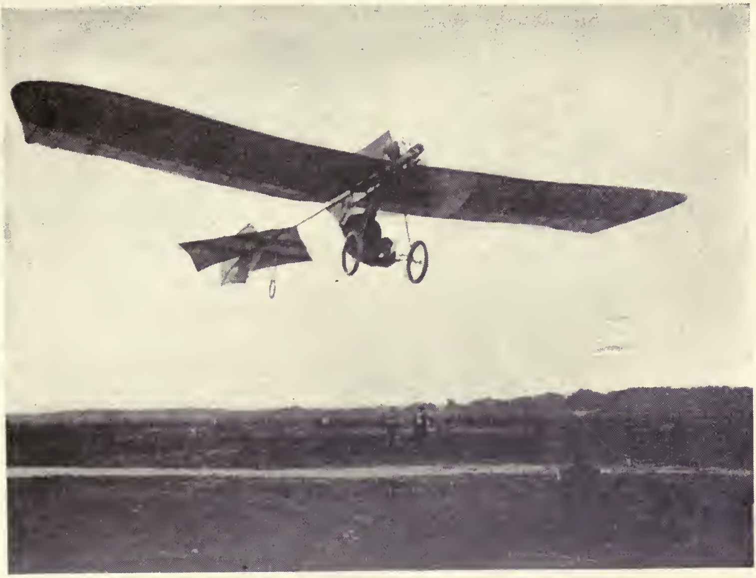
that lofty flying might enable one to pass safely over a city, even with an unreliable motor, since, if the propeller stopped, a glide of many thousands of feet could be made, to choose a landing. Farman's flight was less spectacular, but quite as marvelous. On November 4th, while competing for the Michelin trophy for the longest distance traversed in 1909, he flew continuously for 4 hours, 6 minutes, 25 seconds, voyaging in that time 144 miles, at an average speed of 35.06 miles an hour. This proved to be the record distance-and-endurance flight for the year. Other men spoke of sailing all day in a machine carrying ample gasoline, but failed to make good their words.

Unheralded, but quite astonishing, were the flights of Santos-Dumont in September, 1909. Though conspicuous as a pioneer in aviation, he for a while had been absorbed in other affairs, and had not kept pace with his brother aëroplanists in France, since his bold and brief dashes into the air in the early days of the art. During the season of 1909, however, he developed a surprisingly small and simple monoplane, spreading 102 square feet of wing surface, and weighing in complete running order, 259 pounds. It was driven by a Darrac motor, mounted above the main surface, carrying the propeller directly on its shaft, and having radiator tubes along the inner surface of the main plane. Its triangular trussed frame was wheel-mounted, and tapered rapidly to the rear, terminating in horizontal and vertical rudders. With this tiniest flyer he sailed across country from St. Cyr to Buc, 4¾ miles, in five minutes, at the unprecedented speed of 55 miles an hour, repeating the performance several times, according to report. He also left the ground after a run of 60 feet, in an unofficial trial. Characteristically, he presented to the public the scale drawings of his machine, with all rights to its use.

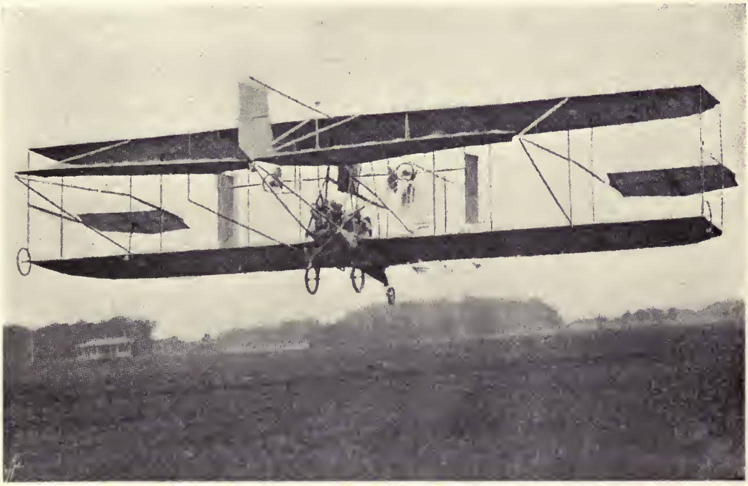
A very original type of monoplane was developed by Robert Esnault-Pélterie, who began experimenting in 1903. As shown in Plate XXIX, its body frame was covered to reduce air-resistance, and was provided with ample keel surface to promote directness and steadiness of flight. The weight was borne on two wheels in tandem, aided by wheels at the wing tips to preserve the lateral balance when the machine was resting. When under way the lateral poise was controlled by wing warping; the motion about the other two axes being controlled by a horizontal and a vertical rudder, the latter being "compensated," that is, having its axis near the center of side pressure, when in action. An air-cooled motor of 30 to 35 horse power with a direct mounted four-blade screw formed the propulsion plant. Though the "R. E. P." aëroplane, as it was commonly called, did not achieve great distinction at first, due, perhaps, to the inventor's being over original, and making all its parts himself, instead of buying some high-class engine and propeller, as other successful aëroplanists had done, still his machine was greatly admired by technicians for its excellent finish and the fastidious, thorough and patient manner in which its young inventor labored to make it perfect, both in design and construction. It was regarded as a future record-breaker, which, indeed, it was destined to become on further improvement.

Although little was accomplished in building aëroplanes in other countries than America and France, up to the beginning of 1909, that year witnessed some good flights in homemade machines in Germany, England and Canada. In November, 1909, Herr Grade, in Germany, made a flight of

PLATE XXX.



GRADE MONOPLANE.
(Courtesy E. L. Jones.)



CODY BIPLANE.

55 minutes in his monoplane. Mr. S. F. Cody, who constructed a biplane for the British army, flew over forty miles across country on September 8th, high above trees and buildings, remaining on the wing for 63 minutes. The machine spanned 52 feet, weighed with the pilot, nearly a ton, and was controlled by front and rear vertical rudders and two lateral rudders, well in front, so geared that if worked oppositely the machine listed, while if worked identically it rose or fell. In Canada Dr. Alexander Graham Bell and his associates continued the experiments, already described, begun in 1908 by the Aërial Experiment Association. In 1909 their fourth machine, the *Silver Dart,* flew many times round a course on the frozen lake, Bras d'Or, traversing, all told, about 1,000 miles in 100 flights.

The last months of this strenuous year, 1909, and of the first decade of dynamic flight, closed without further startling developments. True, some records were made, but they merely pleased, not perturbed the world, now accustomed to marvels. Be it recorded, however, that, with a Voisin biplane, Paulhan, on November 1st, flew 96 miles in 2 hours, 20 minutes, and on November 20th flew 1,960 feet high in a Farman biplane; on December 9th, Maurice Farman, mounted on his own type of biplane, rode through the icy atmosphere from Buc to Chartres, a distance of 40 kilometers, in 50 minutes, the longest town-to-town flight up to that date; and on December 31st he flew from Chartres to Orleans, a distance of 41.6 miles, in forty-six minutes. But several fine achievements which the world anticipated for that year remained unattempted. The great prize flight of 183 miles from London to Manchester was still untried, though several machines and pilots seemed equal to the voyage, and $50,000 would be awarded by Lord Northcliffe to the brave aviator who should accomplish that journey in not more than three stages and within a period of twenty-four hours. Neither had anyone yet flown to an elevation of one kilometer. These tasks were left over as allurements for the succeeding year.

CHAPTER XII

FORCING THE ART

THE decade that inaugurated dynamic man-flight had closed without fully demonstrating the capabilities of such aëroplanes as had been so far developed. No considerable altitude record had as yet been achieved. No very long cross-country flight had yet been attempted, though for many months the New York *World* had offered $10,000 for the first aërial voyage from Albany to New York, and the London *Daily Mail* had long offered $50,000 for a flight from London to Manchester. The uses of the aëroplane for scouting by land and sea had not been tested, much less its probable value in aggressive warfare. Such experiments were for the immediate future, as also the development of specialized types of machines for racing, for climbing, for burden bearing, for distance, for endurance, for landing on water, for rising from water, for protection of passengers from severe weather. To air men and spectators alike the future of the art promised to be quite as captivating as the past.

The first startling achievements to usher in the new decade were the great altitude flights. New world records followed in rapid succession all through the year 1910, with marked persistence and wonderful progress. Levels that had been regarded as the peculiar region of motor balloons were passed one after another, until the aviators vanished beyond the clouds, their limbs palsied with cold, and their aëroplane wings whitened with frost. Though the greatest prizes were not offered for this species of flight, and frequently none at all, it had an abiding fascination for both the flyers and the public. At the same time it proved to be as safe as it was theatrical and popular.

The starter in this exciting race for cloudland was Hubert Latham, already the official holder of the world's altitude record. At Bouy, on January 7th, in presence of official witnesses, he rose in his *Antoinette* monoplane, describing a great upward spiral till his barometer recorded 1,050 meters; then returned to earth with like ease and precision, landing softly near his hangar, before his assistants, transported with enthusiasm. He had touched the goal of Gallic ambition, having driven his aëroplane to the height of one kilometer.

Latham's tenure of the world's altitude record quickly passed to his doughty rival, Louis Paulhan. At Los Angeles, on the twelfth of January, Paulhan, mounted on a Farman biplane, ascended 4,165 feet, as against Latham's record of 3,444 feet. This was a great step upward, due not only to Paulhan's prowess and dexterity, but also to the science and constructive skill of the less spectacular gentlemen in the designing room, workshop and laboratory.

Latham strove again for the world's altitude record and gained it on July 7th at the second Rheims tournament, by driving his *Antoinette* to a height of 4,541 feet.[1] But again his victory was soon eclipsed; for two days later, Walter Brookins at Atlantic City ascended 6,175 feet in a Wright biplane. An American was thus the first to fly above one mile, as a Frenchman had been first to pass the

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[1] This was an official record, but Brookins had flown 4939 feet high, at Indianapolis, on June 17th.

1-kilometer limit. The 2-kilometer and 2-mile elevations were exceeded before the close of the year, as shown by the following table, which also manifests a fair distribution of honors among various nations and types of machines:

Feet	Aviator	Aëroplane	Place	Date
3,445	Latham	Antoinette	Betheny Plain	January 7
4,165	Paulhan	Farman	Los Angeles	January 12
4,541	Latham	Antoinette	Rheims	July 7
6,175	Brookins	Wright	Atlantic City	July 9
6,604	Drexel	Blériot	Lanark, Sc.	August 11
8,271	Morane	Blériot	Havre, France	September 3
8,406	Chavez	Blériot	Issy	September 8
9,104	Wijnmalen	Farman	Mourmelon	October 1
9,714	Johnstone	Wright	Belmont Park	October 31
10,499	Leganeaux	Blériot	Pau	December 9
11,474	[1]Hoxey	Wright	Los Angeles	December 26

Such lofty flights have proved a severe test of both the aëroplane and the pilot. In the lighter atmosphere the engine must turn the propeller at higher speed to secure the same thrust, and the aëroplane must sail faster to support the same weight as at the lower levels. Thus more power is required on high, though the explosive medium, being less dense, is less capable of exerting power. The driver has, therefore, to jockey his machine with assiduous care and alertness, at a time when he is least fitted for exertion, owing to fatigue, cold, and it may be, physical discomfort due to the great change of atmospheric pressure. But still, both aëroplane and pilot are capable of ascending well above any levels thus far attained.

After the triumphant altitude flights of 1910 the aëronautical skeptics could no longer contend that

[1] This record was made with an uncalibrated barograph, and hence was unofficial and unaccepted as a world's record.

the aëroplane was useless in transportation and warfare, because of its inability to fly above high land or the usual range of the guns of battleships and coast fortifications. Most of the important mountain passes lie below 10,000 feet. The safe elevation for motor balloons menaced by terrene guns is taken to be much less than two miles, and in military practice they usually operate below the one-mile level. The aëroplanes, therefore, may not only cross mountain ranges, but may also scrutinize, or grievously molest, land forces, marine squadrons and perhaps even the great gaseous cruisers of the atmosphere, which they can far outspeed, and may even destroy.

The increase in speed of flight during 1910 was also quite remarkable. The official record by which Mr. Curtiss won the Bennett Aviation Contest at Rheims, in 1909, showed a speed of 47.04 miles an hour. Still higher velocities, ranging from 50 to 60 miles an hour, were reported later in that season from England and France. In 1910, however, at the Rheims aviation meet, Morane, with a Blériot monoplane, covered the 20-kilometer course in 12 minutes 45.2 seconds, or at an average speed of 66.2 miles an hour, showing a gain of forty per cent on Mr. Curtiss's speed of the preceding year. Still better was achieved at the international tournament held at Belmont Park in 1910. Le Blanc in a 100-horse Blériot monoplane, especially designed for speed, covered nineteen laps of the 5-kilometer course at an average rate of 61 miles an hour, and his fastest lap at the rate of 71.68 miles an hour, thus exceeding Curtiss's speed of the previous year by fifty per cent. Other spurts during the latter part of 1910 were reported to have attained nearly 80 miles an hour over a closed circuit, though perhaps not a level one. The best results were achieved with machines having high power engines, small surfaces and slight forward resistance.

The advance in long-distance flying in 1910 more than kept pace with the progress in speed. The best achievement at the close of the preceding year had been Farman's flight of 144 miles at an average rate of 35.06 miles an hour in a closed circuit. At the Rheims aviation meet in 1910, Jan Olieslaegers, in a Blériot monoplane, driven by a Gnome engine, covered 244 miles in a rectangular course, at an average speed of 48.31 miles an hour. At Buc, on the 28th of October, an aviator of three months' practice, Maurice Tabuteau, in a Maurice Farman biplane, driven by a Rénault engine, flew over a closed circuit, covering 288.8 miles at an average speed of 47.9 miles an hour. At Pau on December 21st, M. G. Leganeaux, in a Blériot monoplane, flew for the Michelin Cup, covering 516 kilometers or 320.6 miles in six hours and one minute, or at an average speed of 53¼ miles an hour—a splendid showing. Finally, at Buc, on December 30th, Tabuteau, flying for the annual Michelin prize, covered 362.66 miles in a Maurice Farman biplane with an 8-cylinder 60-horse Rénault motor. The average speed in this very long flight was 47.3 miles an hour, or practically the rate by which Curtiss won the international contest of the preceding year. Of course a considerably better showing of both distance and velocity could have been made on a longer course.

The world records for cross-country flying and for endurance and load illustrate both the increasing perfection of the machine and of the pilot's skill and confidence. At Los Angeles, on January 19th, Mr. and Mrs. Paulhan, in a Farman biplane, flew together 21 miles overland from the aviation field to Redondo and Hermosa Beach and return.

On January 31st Van der Born made a world's duration record with a passenger on a Farman biplane, flying 1 hour 48 minutes 50 seconds. On March 5th, Henri Farman, who had previously twice broken the world's duration record for a pilot with two passengers, set a new and astonishing pace at Moumelon, by carrying Mr. Hevardson and Madame Frank in easy flight for 62.5 minutes on his new biplane. In France, on April 3d, Emile Dubonnet on his *Tellier* monoplane flew from Juvisy to La Ferte-Saint Aubin, a distance of 109 kilometers or 70 miles in 1 hour and 50 minutes, thus winning the ten-thousand-franc prize offered by *La Nature* for the first straightaway flight of 100 kilometers to be effected in less than two hours, over a previously indicated course. This fine record voyage was achieved in a machine never before thoroughly tried. At Chalons-sur-Marne, on April 8th, Daniel Kinet, a Belgian, mounted with a passenger on a Farman biplane driven by a 50-horse Gnome engine, broke the world's record for duration and distance for two persons by flying round a closed circuit 2 hours 19¼ minutes, covering a distance of 152 kilometers, or 94 miles. On April 17th, H. Farman, with a passenger in his biplane, voyaged from Etampes to Orleans, 28 miles. Next day, Paulhan, mounting the same machine, flew 108 miles, and the following day 42 miles. This tour established a new cross-country record for total distance, for single stage distance with one passenger, and for duration and single stage distance with two passengers. During the same month Farman made a new record for four passengers by carrying three gentlemen for 1 hour and 4 minutes on his new biplane, spreading 47.6 feet. On June 9th, two French officers, Lieutenant Fequant piloting and Captain Marconnet observing, flew on a Farman biplane from Bouy to Vincennes, 145 kilometers, in two hours and a half, thus breaking the world's cross-country distance and duration record for a pilot with a passenger. On June 13th, Charles K. Hamilton, in a Curtiss biplane, flew from New York to Philadelphia, a distance of 86 miles in 103 minutes, and returned the same day, thus completing 172 miles in one day. This was an exhibition flight made for *The New York Times* and the *Philadelphia Ledger,* for a sum reported to be $10,000. It was a sequel to Glenn H. Curtiss's memorable flight on June 5th, down the Hudson River from Albany to New York, for the New York *World's* $10,000 prize. Hamilton's average speed was 50 miles an hour going and 51 miles returning. On August 29th, at Lille, Louis Bréguet is reported to have carried with him on a biplane of his make, five passengers, who, together with the gasoline, weighed 921 pounds. It may be added that the Bréguet biplane of that date was advertised and guaranteed to carry a cargo, or extra load, of 250 kilograms. It thus appears that by 1910 the aëroplane had grown powerful enough for an aërial cab service, and that it could carry sufficient explosive gelatine to derange a battleship.

The contest for cross-country records continued unabated all that memorable year. During the first three days of September, Jean Bielovucic, a youth of twenty-one, mounted on a new type of Voisin biplane, with but a few days' practice, flew from Paris to Bordeaux, covering 540 kilometers, or 336 miles, in four stages, comprising altogether $6\frac{1}{4}$ hours on the wing. In spite of severe weather, at times, he beat the regular express train and established a new world's record for cross-country straightaway distance flying with stops. On August 17th, Alfred Le Blanc, finished a six-stage tour round a hexagonal circuit northeast of Paris, with the finish at Issy, near Paris, covering a total distance of 785 kilometers, or 440 miles, in 12 hours 56.4 seconds effective time. On September 7th, Weyman flew with a passenger from Paris to Clermont near the Puy de Dome, covering 205 miles in one day, while trying for the Michelin prize of 100,000 francs, for a flight to the Puy de Dome inside of six hours. On December 18th, Thomas Sopwith, competing for the longest flight across the Channel and into Belgium, on a British-built aëroplane, flew from the Isle of Sheppy across the Channel, and landed at Beaumont, Belgium, covering a distance of 174 miles in 3.5 hours. At Buc, on November 27th, Laurens, in a 60-horse R. E. P. monoplane, flew with his wife 53 miles at an average speed of nearly 50 miles an hour. On December 22d, Lieutenant Cammeran, a French army officer, won the L. Weiller prize by flying across country with a passenger, 147 miles in 4 hours and 2 minutes.

These are but a few of the records which serve to illustrate the progress in cross-country flying during that year of strenuous and world-wide popular demonstrations. But the bare numerical statement of facts can give no conception of the delight and exultation aroused in millions of souls who witnessed or learned of these marvelous human achievements. They were the advancing triumph of a proud and fortunate generation, happy in realizing one of the fondest dreams of the ages. Often during one of these cross-country flights the aëroplane was accompanied by a swift railway train whose passengers were delirious with enthusiasm. The entire route was thronged with people assembled from afar. It was a general holiday for all the fortunate cities and villages along the way. Mills and factories blew their whistles and forgot the serious business of life, homes were deserted, schools were dismissed; the whole population for the time congregated in the open; bearded mechanics in their aprons, bare-armed housewives holding their children aloft, girls and boys with wondering eyes, all shouting, waving banners, throwing up hats, and hailing with tumultuous demonstration that strange and huge-winged creature gliding from horizon to horizon with the steadiness, precision and directness of a mighty projectile. But beyond stating the records of this season of aërial wonders, only a passing notice can be given to some of the more conspicuous events.

The most famous overland voyages of the season 1910 began with the race for the London *Daily Mail* prize of $50,000, offered by Lord Northcliffe for the first person who should fly from London to Manchester, 183 miles within twenty-four hours, with not more than two stops. An Englishman, Claude Grahame-White, comparatively new in the pilot's art, was first to undertake that difficult and perilous adventure. Starting from London, without competitor, on April 24th, he flew in his Farman biplane, from London to Rugby, thence to Hademore, about halfway to Manchester, landing at a quarter past nine o'clock at night, after a four-hour trip, and hoping to reach Manchester next day. But during the night his aëroplane, which was left in the open, was damaged by the wind, thus necessitating repairs and a new start. On April 27th, while he was strenuously mending and adjusting his biplane for a new start, Louis Paulhan, who the day previously had arrived from France with a Farman biplane to enter the contest, was also vigorously setting up and adjusting his machine.

At half past five in the afternoon, Paulhan suddenly set out for Manchester. Mr. White, who was much fatigued and expecting to start on the morrow at dawn, after much-needed rest, learned toward six o'clock that his rival was on the wing, and hurriedly sailed from London, hoping by skill and good chance to overtake the flying Frenchman. The race was now the most exciting event in the world. The first flyers of France and England were competing for the greatest prize yet offered in the history of aviation, competing in a most modern and extraordinary race, attended with abundant danger and hardship. The contestants were evenly matched in mechanism and capability, but the Frenchman had gotten the march on the unwary Englishman. Paulhan followed the Northwestern Railway, at times outracing the special pilot train carrying his mechanics and supplies. At ten minutes after eight o'clock, he landed at Lichfield, having covered 115 miles. Mr. White had landed five minutes before eight near Roade, after flying fifty-nine miles.

Next morning, Paulhan sailed away at a quarter past four. Mr. White, hoping to overtake him, had started at dead of night and covered twenty miles before Paulhan had started. It was a heroic effort, but unavailing. At twelve minutes after five, Mr. White landed at Hademoor, having completed two thirds of the entire journey. Twenty-five minutes later Paulhan landed on the outskirts of Manchester, greeted by a thousand persons. He had covered the whole distance in 4.2 hours, and had fulfilled all the essential conditions for winning the great prize.

The next world-famous aëroplane voyage was that of Glenn H. Curtiss for the New York *World's* prize of $10,000 for the first aërial journey from Albany to New York, allowing two stops. Aviators had been yearning for this prize since the previous year, but had been too timidly shying at the dangers of the route. After most careful preparations for this voyage, Curtiss, bearing a letter from the

Mayor of Albany to the Mayor of New York, sailed away at seven o'clock on Sunday morning, May 29th, accompanied by a New York Central special train, bearing his wife and a few friends and newspaper men. He landed an hour for supplies and adjustment at Camelot, 41 miles down the river, and thence flew to Spuyten Duyvil, at the northern extremity of New York, having completed the required distance, 128 miles, in 2 hours and 32 minutes, or at the rate of 50.52 miles per hour along the course. An hour later, he flew down the river to New York Harbor and landed on Governor's Island, where he received a becoming ovation.

Perhaps the most exciting incident of the voyage to Mr. Curtiss was his transit of the Storm King Mountain. As he was flying through the narrow gap at this place he caught the down-rolling air on one side more than on the other, and dropped very suddenly sidewise 30 or 40 feet. By shifting his front control, he quickly gained headway and promptly righted his machine.

Commenting on Mr. Curtiss's average speed of 50 miles an hour and his rugged course, *Aëronautics* makes comparison between his voyage and Paulhan's great prize flight as follows:

"Paulhan took 4 hours 12 minutes elapsed time to cover 183 miles when he won the *London Mail's* $50,000 and made it in two stages of 117 and 66 miles each. The 117 miles were covered in 2.39, a rate of nearly 44 miles per hour. A night's sleep intervened and the remaining 66 miles were covered in 1.23, a rate of nearly 48 miles per hour. The average for the above was 44.37 miles per hour. Paulhan could have landed at almost any time and started again, whereas Curtiss could not have started if he had had to land in the water, and for the whole distance there was scarcely a suitable space for landing on the ground, as for nearly the entire way rocky, wooded hills with precipitous sides line the river."

The most audacious and marvelous aëronautic exploit of the year was the flight of George Chavez across the Alps from Brig to Domodossola, in his attempt to win the prize of 70,000 francs offered by the Italian Aviation Society for the first aëroplane flight from Brig to Milan, a distance of 75 miles. From the nine volunteers for this contest who presented themselves to the committee in charge, five competitors were selected, and these for several days made tentative efforts to scale the lofty pass, but were baffled by the wind or fog. Finally at one-thirty, on September 23d, the conditions being favorable, Chavez rose, from Briegen-Berg, in his white-winged Blériot, spiraled upward 1,000 meters, circling around the vast amphitheater of the mountains, and in nineteen minutes appeared in magnificent career well above the Simplon Pass, probably 7,000 feet above the sea, whence he glided grandly down the Italian slope, parrying the rude cross winds and finally reaching Domodossola, where the enthusiasm was at its climax. Here he expected to land on a level spot to replenish his supplies, thence proceed over the easy remaining two thirds of his journey. But though the perilous pass had been crossed so successfully, disaster appeared in the valley when least expected. As the aëroplane was gliding thirty feet high over the level tract chosen for landing, it met a sudden gust, its wings collapsed, and it fell crashing to earth, pinioning its brave pilot under the débris.

Poor Chavez suffered severe wounds about the face and head, had both legs broken, and for some moments lay unconscious. But he was soon revived by his friends and taken to a hospital, where he died four days later. Thus ended the career of a brave and most promising youth of twenty-three. He had taken his pilot's license only in February, 1910, yet had established a new world's record on September 8th, by driving his Blériot to an elevation of 8,406 feet. He was of Peruvian parentage and born in Paris.

The exact nature of the accident was never ascertained, but it was surmised that the sudden starting of his engine preparatory to landing overstressed some part of the structure already fatigued from hard usage. However this be, the committee recognized that Chavez had with excellent skill covered all the really difficult and dangerous part of this journey. Accordingly they very generously waived the exact letter of the rules, and awarded him one half the prize, though he had completed but one third of the journey.

Quite as dangerous, spectacular and brilliant as the flight across the Alps, though less arduous, was Hubert Latham's aërial voyage over Baltimore. On previous occasions cross-city flights had been made, but never one of such length or one executed under such exacting conditions. At various times aviators had flown above Paris, Rome, Berlin, etc. On October 14th Mr. White had flown across Washington, landing on a narrow street between the White House and War Department; on October 15th Leganeaux had flown above Paris with a passenger; but these were short flights over an uncharted course. Latham's voyage was unique; for he had to follow a long and a prescribed course over the business section and closely built residence portion of the city. This great exploit was an exhibition flight made on the invitation of the *Baltimore Sun* for a sum of $5,000. It was to be made at the time of the Baltimore aviation tournament at Halethorpe, Md., and was calculated to be seen by half a million people; for the whole city was to be notified and would cease its usual activities to witness the rare and hazardous demonstration.

The voyage was triumphant and glorious in every feature. Starting from the aviation ground, seven miles south of Baltimore, about noon on November 7th, Latham drove his beautiful *Antoinette* about the field in an ascending spiral, like some imperial bird taking its bearings; then, chart in hand, deliberately sailed away over his elaborately prescribed journey. This was a figure 8 course with its bottom at the aviation field and its center at the *Sun* Building in the heart of Baltimore, the whole length being 22 miles. As the long-winged bird in majestic poise, with the intrepid rider on its back, approached in the distance, soaring 1,000 feet above the gleaming waters of the Chesapeake, the great bell of the City Hall sounded a mighty peal, and the whole populace responded in tumultuous chorus; whistles, bells and a myriad voices mingling their heartiest welcome to the bravest of aviators. With arrowlike speed and directness he rounded the center of the course at the *Sun* Building, then looped the vast northern half of the city, flying a thousand to three thousand feet high, more easily to parry the surging eddies of the northwest wind; rounded again the center of his course and then returned to the aviation field, where he landed with infinite coolness before the excited throng of applauding spectators, whose acclaim was all too feeble to express their mingled wonder, admiration and delight. The voyage lasted forty-two minutes and fulfilled perfectly every minute requirement, including a short circle and salutation before the home of Mr. Ross Winans, an invalid gentleman who had solicited this unique favor, and rewarded it with a gift of $500. It was the climax of the aviation week at Baltimore.

Among the many brilliant flights of that memorable year of strenuous piloting will long be remembered the voyage of the Hon. C. S. Rolls to Calais and return without landing, and that of Mr. Sopwith, already recounted; the splendid flight of Mr. Clifford B. Harmon in his Farman biplane from Mineola, Long Island, to a small rounded island before his house on the Connecticut shore, for the trophy offered by *Country Life* to the first person who should fly across Long Island Sound; Henri Farman's flight of December 18th, for the Michelin long-distance prize, covering 288 miles, and establishing a new endurance record of 8 hours 23 minutes; Mlle. Helene Durtrieu's flight of December 21st, for the Coupe Femina, covering 103¾ miles in 2 hours and 35 minutes in a Farman biplane. Interesting, too, were the first attempt to fly from Paris to Brussels with a passenger, when Mahieu and Manihé on starting were brought to bay by a vicious dog which violently attacked the propeller and was cut in two; and when Loridan and Fay landed on a tree, from which they descended by a ladder. After this followed the glorious voyage of Henri Wijnmalen, the youthful and many-sided Dutch sport, for the prize of 150,000 francs offered by the Automobile Club of France for the quickest aëroplane trip not exceeding 36 hours, with a passenger from Paris to Brussels and return. This voyage of some 320 miles was valiantly accomplished by Wijnmalen and his companion Dufour, in a day and a half, of 13.2 effective hours, and in weather for the most part windy or tempestuous. Finally to the foregoing list of splendid achievements must be added the glorious voyage of John Moisant, who in August flew with a passenger, by compass, from Paris to London, though he had never been over the route before and had only just learned to use an aëroplane.

The International Aviation Tournament of 1910, held at Belmont Park, Long Island, October 22d to 31st, was the most prominent and eventful meet of the year, and the second of its kind in history, as the meeting of the preceding year at Rheims was the first. The present meet was conducted by the Aëro Corporation, Limited, of New York, under the auspices and official sanction of the Aëro Club of America, representing the Federation Aëronautique Internationale.

This tournament was the annual aërial Olympic contest of the world, and should have been indicative not only of the aviator's skill, but also of the state of national progress in the science and art of aëroplane construction. Unfortunately, however, for the prestige of the most deserving nations, the rules of the International Aëronautic Federation did not confine the contestants to the use of home-built machines, to prevent the glory of winning the international contest from passing to the nation which merely furnished the operator, a person who might be an illiterate jockey, and representative of a country wholly devoid of science. As luck decided, however, the highest honor in 1910 was won by a first-class French machine driven by a first-class English aviator.

In some respects the raw material and working elements of this meet were most satisfactory. The site is near the wealthiest and most populous center in America. The grounds are spacious and level, and provided with all the equipment of a great race course; the transportation facilities by carriage and by rail from the heart of New York are adequate to every requirement. The personnel of the meet comprised the most experienced and most devoted members of the Aëro Club of America, the oldest and strongest aëronautical body in the western world, and the only one representing the International Aëronautic Federation. It is true the season was late and the weather would probably be cold and tempestuous; the management was burdened by a costly license, whether just or unjust, imposed upon it as the price of immunity from patent litigation; the remaining time, after the final placement of the meet, was all too short for the myriad preparations to be made. But whatever the obstacles, physical or financial, the personnel was paramount, and naturally made the huge tournament a glorious triumph. It was the cardinal sporting event of the year.

The status of aviation was well represented in both pilots and machines. Twenty-seven aviators were entered on the program, many of them world famous. Of these Alfred Le Blanc, Hubert Latham, Emile Aubrun were the formidable champions of France in the contest for the James Gordon Bennett aviation trophy; Claude Grahame-White, James Radley, A. Ogilvie represented England; while Walter Brookins, J. A. Drexel, Charles K. Hamilton were enlisted as defenders of the coveted cup and of American prestige. All told, the aviators brought with them nearly two-score machines, ranging in capacity from 30 to 100 horse power. Of these about half were monoplanes and half biplanes, for the most part of French and American manufacture.

The prizes and remuneration awarded to the contestants were on a scale proportionate to their skill and number. All told the winnings aggregated more than $60,000. Further appropriations were made to cover the expenses of the aviators, and a further sum equal to about forty per cent of the winnings was paid for immunity from prosecution for possible infringement of an unlitigated patent. Considering the immense expenditures for buildings, for policing and other incidentals of the meet, it may be readily inferred that there was an ample deficit, and that the air-men as a whole were much better rewarded than some of the sportsmen who gave so much time and labor to the organization of the tournament.

A conspicuous feature of the meet was the display of hardiness and skill of several of the aviators in facing the cold and tempestuous weather. This was particularly characteristic of Latham in his *Antoinette* monoplane, and of Ralph Johnstone and Arch Hoxsey in Wright biplanes. On October 27th Latham flew round the regular course for an hour when it was nearly impossible to turn the pylons against the fierce wind, while Johnstone and Hoxsey performed lofty altitude flights in a powerful gale which carried them backward, sometimes at the rate of 40 miles an hour. As a consequence they landed in the open country, remained overnight and returned next day. Johnstone was carried backward to Holtsville, 55 miles east of the aviation grounds, and Hoxsey was blown to Brentwood, 25 miles away, both landing at dusk in open fields, and both having attained great elevations: Hoxsey, 6,903 feet; Johnstone, 8,471 feet.

An interesting novelty of the aviation week, at least to Americans, were the erratic Demoiselle monoplanes, invented by Santos-Dumont and piloted by Garros and Audemars. These aëroplanes were notable as having the pilot under the sustaining plane, and the engine above with its direct mounted propeller. The lateral stability was enhanced by a low placement of the center of mass, and by a slight dihedral inclination of the wings. Furthermore, as there was not much leverage or surface in the rear double rudder, the flight was more stable than steady, like that of a propelled parachute. In fact, the little monoplanes pitched, rocked, and fluttered about so like huge butterflies as to provoke constant merriment. They gave a faint suggestion of how ludicrous aëroplane clowns could be made by one who has genius for such things.

Barring the stormy voyages above mentioned, the most memorable events of the tournament were the Gordon Bennett speed contest, the Statue of Liberty race and Johnstone's great altitude flight. Of the numerous other performances little need be said, except that they contributed to the general success of an elaborate and most interesting program. They served the daily need of a costly tournament; they delighted vast throngs of spectators whose admission fees helped to promote the aërial sport; but they did not of themselves have more than local interest, or constitute an advance in the records of first-class achievement.

The chief race of the meet, the James Gordon Bennett speed contest, was scheduled for Saturday, October 29th. The prize of $5,000 and the coveted cup were to be awarded to the pilot who should make the best average speed in 20 laps over a 5-kilometer course, aggregating 100 kilometers, or 62.14 miles. The winner should have the distinguished honor of taking to his own country the next annual contest for the precious speed prize.

Grahame-White, England's foremost aviator and strongest hope in the contest, brought forth his untried 100-horse Blériot in the calmest part of the day, and took wing a quarter before nine. He flew with steady poise and swift, well-sustained speed, completing the 100-kilometer distance in 1 hour 1 minute and 4.7 seconds, at an average speed of 61 miles an hour.

Le Blanc, the most likely winner of all, sailed at nine o'clock. He was mounted on a 100-horse Blériot with nearly flat wings, the swiftest monoplane of French manufacture. He was the boldest, sturdiest and most dexterous pilot in a nation of renowned aviators, the winner of unnumbered trophies, the "Vainquer de l'Est." He now flew at unwonted speed, establishing new world records at every round of the course. It seemed evident to the timers that only an accident to this impetuous Frenchman could retrieve the glory of England and save that of America. Suddenly the accident came. In the last lap, when victory seemed assured, the gasoline failed; the monoplane shot downward, knocked off a telegraph pole, and, with broken frame and engine, fell crashing to earth, entangling the brave aviator. Le Blanc was cut and bruised about the forehead, and was taken to the hospital to be bandaged, not seriously injured but in a towering rage, suspecting that some trickery had given him a shortage of fuel. He had lost the day, though his average speed for the whole flight was 67 miles an hour as against Grahame-White's speed of 61 miles.

No well-tried machine was available to defend the American prestige. Curtiss had constructed a new monoplane designed for speed, but though he had brought the cup to America, he was not chosen as one of its three defenders. The little Wright biplane of 61 horse power had flown a few minutes with great velocity, and was looked to with some confidence. Mounted by Walter Brookins, it set out with tremendous speed, but had only well started when the cylinders began to miss fire. Brookins turned toward the infield to land, struck the ground with terrific shock and tumbled violently on the field beside his broken machine. He, too, was taken to the hospital for treatment, but was not seriously injured.

It was now granted that Grahame-White would be the ultimate winner. Other aviators attempted to defeat him, but lacked either the necessary speed or endurance. The cup was accordingly taken from the nations that had done the most to develop the practical art of aëroplaning. Of these two nations, the one most deserving of victory, by virtue of its more careful preparation, was defeated by an extraordinary mishap, when victory was at hand; the other failed perhaps for want of preparation rather than from lack of manipulative or constructive skill.

Of the various highly coveted stakes the largest in monetary value was known as the Thomas F. Ryan Statue of Liberty Prize. This was a cash sum of $10,000, to be awarded to the properly qualified contestant who should fly from the aviation ground to and around the Statue of Liberty in New York Harbor, and return in the shortest time, the air-line distance being 16 miles each way. The prize was founded by Mr. Thomas F. Ryan, whose son, Allan A. Ryan, was Chairman of the Committee on Arrangements of the tournament, and who though suffering with pain and ill-health, labored so indefatigably to insure the success of the event so germain to the aëronautical prestige of his country.

The Statue of Liberty race occurred on Sunday afternoon, October 30th, beginning just after three o'clock. Count De Lesseps in a 50-horse Blériot monoplane led the race, followed three minutes later by Grahame-White. They passed toward the southwest in perfect poise and vanished beyond the horizon unchallenged by an American contestant; for Moisant, the American champion, had shortly before injured his racing monoplane, and the other American racing machines had been damaged the week before, or had not yet been fully tested. But with admirable enterprise, Moisant telephoned Le Blanc, in New York, who was not racing because of the accident to his 100-horse Blériot the day previously, and offered the Frenchman $10,000 for his 50-horse Blériot monoplane. The sale was effected in time for the race that day. But for all that the enterprise seemed futile; for as Moisant was preparing to start, the others were returning, Grahame-White well in the lead, having overtaken De Lesseps. As these two aviators were receiving the applause of innumerable spectators and the felicitations of their friends, audacious Moisant, the impetuous soldier of fortune, and hero of the famous flight by compass from Paris to London, started toward the declining sun, just after four o'clock. He was determined to win by superior skill and daring. His prudent competitors had followed a circuitous southern route interspersed with landing places; but he flew like a maniac straight over the church spires and crowded buildings of Brooklyn, guided to his goal by a compass, rounded the Statue of Liberty at a great altitude and plunged homeward with all possible speed and directness. The megaphone announced his progress, which indicated some hope of victory so little expected and so much desired by the vast throng that stood gazing toward the western sun. In headlong career the swooping monoplane shot by the judges' stand, circled and softly landed on the field, triumphant by 43 seconds over the 100-horse Blériot of Grahame-White. As the intrepid aviator approached the vast and delighted throng of spectators to acknowledge its noisy and tumultuous ovation, he was met by the chiefs of the tournament, draped in an American flag, and paraded before the grand stand, "which shook in its effort to do honor to the little air conqueror." Ultimately, however, the prize was awarded to Count De Lesseps, because Moisant had failed to qualify properly, and Grahame-White had fouled the initial pylon.

The final day of the tournament was made memorable by Johnstone's altitude flight. The best previous record was that of Wijnmalen to an elevation of 9,104 feet, made at Mourmelon, France. Johnstone ascended on a small Wright machine with powerful propellers adapted to rapid climbing, determined not only to surpass Wijnmalen but to exceed, if possible, the ten-thousand-foot level, and win the special prize offered for such achievement. He actually rose to the great elevation of 9,714 feet, but could not develop power enough to continue upward. On his descent he fully exhausted his fuel at 3,000 feet, and thence glided to earth, landing softly, 1 hour and 43 minutes from the time of starting.

Thus the greatest tournament of the year terminated with fine new laurels for the science and art of aviation; for the spectacular pilots and for the unseen men behind them—the scientific men in the laboratories, the designing rooms and the workshops. New standards had been established in speed, in altitude, in prowess and daring. In these elements, the spectators could hardly ask for a better exhibition. What is it to the onlooker to have an aëroplane go higher than the cumuli, since at that level a thousand feet makes no perceptible difference? What more could he wish in dexterity of manipulation and audacity in braving the elements? One thing more, doubtless, and that is, security and precision of flight in stormy weather. When these improvements shall have been effected much will have been added to both the sportive interest and practical utility of the aëroplane.

The most businesslike and crucial flying contest of the year was the famous "Circuit de l'Est," organized by the Paris *Matin*. It was a competitive voyage over an irregular hexagonal course, lying generally northeast of Paris, and having its vertices at various cities to the east and north of the national

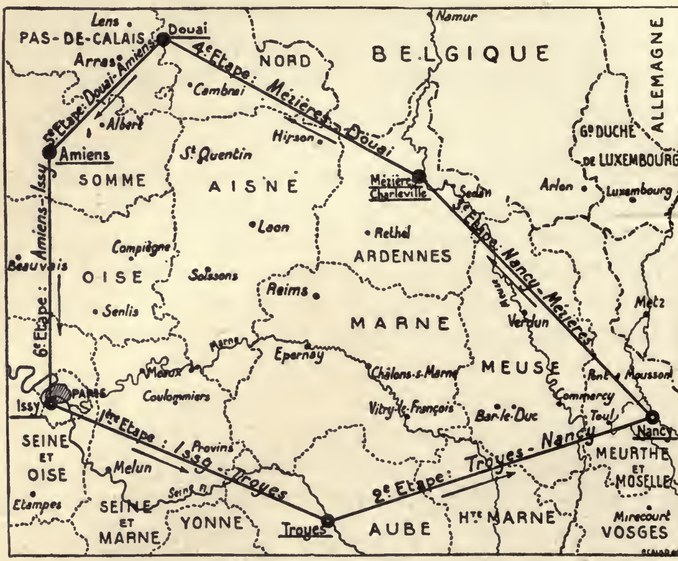


FIG. 41.—MAP OF THE "CIRCUIT DE L'EST."

capital. The main prize offered by the *Matin* was one hundred thousand francs for the first air man to complete the entire course, doing the first side of the hexagon on August 7th, and the succeeding sides in regular order on successive odd days of the month, the place and hour of starting each stage being assigned in advance. Various subsidiary prizes aggregating nearly a hundred thousand francs more, were available for meritorious performances at the various stages and stopping-places along the route.

But there were also penalizations for those contestants who failed to start on schedule time and observe the rules of the course.

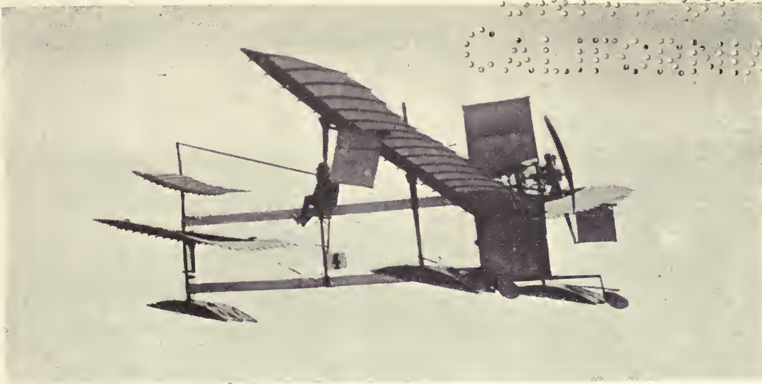
The race began at Issy, near Paris, on August 7th, with eight aviators on the wing—Le Blanc, Aubrun, Leganeaux, Mamet, Lindpainter, Weyman. It terminated August 17th, headed by Alfred Le Blanc on his Blériot, and followed by Emile Aubrun on a Blériot, then by Weyman on a Farman, all three driven by Gnome engines actuating Chauvière propellers. Le Blanc completed the tour of six stages, covering an air-line distance of 488 miles, in 12 hours' effective flying, or at the average rate of 40.6 miles per hour.

This long tour on schedule time over a rough and varied country in face of fog, wind and rain, was a most severe trial of the prowess and endurance of the brave pilots who had the hardiness and pertinacity to complete the voyage. Needless to add that it created unbounded enthusiasm among millions of people who witnessed the event, or read of it, and that the clocklike precision of the "grand raid" inspired new confidence in the practicability of the aëroplane.

A particularly impressive feature of the event was that many of its participants, the aviators, government officers, and members of the controlling committee, assembled at Issy and other posts of duty, not by rail, but by aëroplane, sailing across country from many directions and from great distances. This matter-of-fact procedure led many persons to believe that the period of mere demonstrations had approached its close, and that the epoch of practical utility was at hand; that after marveling so much at the aëroplane, with mingled faith and skepticism, people would next calmly turn it to practical use.

Though the progress in designing and constructing aëroplanes in 1910 did not keep pace with the wonderful advance in new records, still the inventors and manufacturers continued industriously to perfect the details of their best standard machines, and in a few instances to make radical innovations. The perfection in details of construction manifested itself in the public performance of aëroplanes, particularly in their greater reliability and their increased capabilities. The radical innovations were mainly experimental, and not generally exhibited, though none the less important for all that. Chief of these perhaps were the hydro-aëroplane developments of Fabre in France, and of Mr. Glenn H. Curtiss in America, which enabled the aviator to launch into the air directly from the water and to alight safely on the water, thus virtually adding a new and very important domain to the empire of dynamic flight.

Curtiss, in 1909, succeeded in landing his aëroplane safely on the water of Lake Keuka, first with sheet iron cylindrical floats under each wing, and a simple float well to the front of his protruding chassis, then with a hydroplane surface to the front as being more effective than the float. But when he attempted to glide up from the lake with this arrangement, he could not entirely clear the surface, though his aëroplane under the powerful thrust of her aërial screw, very nearly lifted from the water. Then he planned to use hydroplane floats, of hollow wing form, and of such size that they would buoy up the machine when at rest, and during motion would skim over the water like a skipping stone, till the biplane should acquire sufficient speed to rise by the dynamic reaction of the air. In the successful execution of this plan, however, he was anticipated by Fabre, who made the first successful flight from the



FABRE HYDRO-AËROPLANE.

Photo E. Levick, N. Y.

PAULHAN HYDRO-AËROPLANE.

Photo E. Levick, N. Y.

MOISANT METAL MONOPLANE.
(Courtesy A. J. Moisant.)

water, on March 28th, 1910, at Martigues, France. But the Frenchman was not left to bear the palm alone. Early in the year 1911, Mr. Curtiss rose and landed successfully on the water at San Diego Bay, Cal., by means of a single float like a flatboat placed centrally under his biplane, seconded by small auxiliary floats at the wing ends. A full account of these valuable contributions to aviation is given in Appendix V.

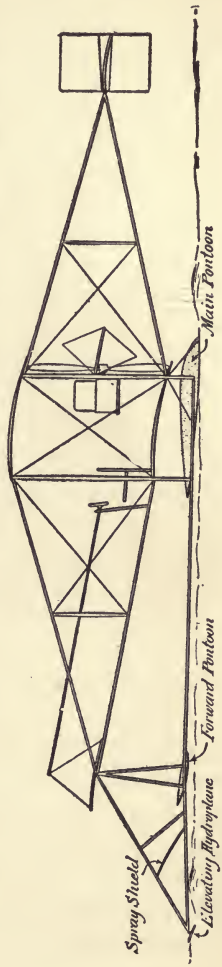


FIG. 42.—DIAGRAM OF CURTISS HYDRO-AËROPLANE. (Scientific American.)

As shown in Plate XXXI, Fabre's hydro-aëroplane was substantially a monoplane mounted on three richochet floats. It was propelled by a screw at the rear, and controlled in flight by the usual three-torque system, in this case consisting of horizontal rudders in front, vertical rudders front and rear, and suitable mechanism for twisting the wings. The floats were hollow to give them static buoyancy; they were curved fore and aft like wings, to give them dynamic lift, both in water and in air; they were elastically constructed with thin veneer bottoms and flexibly attached to the framing, so as to endure the severe buffeting, at high speeds, against the uneven water surface; they were capable of landing the machine safely on a sandy beach or meadow, as well as on the water.

Indeed, a plan was conceived for rising and alighting on land and water indifferently.

The first machine weighed in flight 950 pounds and spread 280 square feet of surface, giving a loading of 3.4 pounds per square foot. It was driven by a 50-horse Gnome engine actuating a Chauvière propeller 7.5 feet in diameter. In the trials of March 28th, the machine cleared the water at a speed of 34 miles per hour, and flew about one-third of a mile, at an elevation of two to three yards; then at the will of the operator it alighted softly on the water.

The structural design of the Fabre monoplane was novel and unique, not to say radical. The wing framing consisted of a single Fabre trussed beam with ribs attached like the quills of a bird, over which was stretched the light sailcloth cover, then laced to the beam. The girder itself was formed of two ash planks eight inches wide by one-fourth inch thick trussed together by flat steel plates zigzagging trelliswise between them. As all parts of the beam cut the air edgewise it offered very little resistance, while at the same time being very strong. The ribs being attached only at one end allowed the sailcloth to be quickly slipped on and off for washing and proper care.

The characteristic features of Fabre's wing construction were adopted by Paulhan in his novel and picturesque biplane shown in Plate XXXI. Trussed beams were used for all parts requiring considerable stiffness, the longitudinal ones being covered with fabric to reduce the resistance. The wings whose solid ribs were fastened only at their front ends were quite elastic, a quality conducive to stability, as long taught by writers [1] on aviation. In addition

[1] The present writer, in his paper quoted on page 229, pointed out the equilibrative and steadying quality of torsionally elastic wings, and

to the front rudder, there was at the rear a horizontal rudder with a vertical one just before it. To reduce the air resistance further the pilot and passenger were to sit tandem in a torpedo-shaped car with the 50-horse Gnome engine and fuel tank back of them. Beneath the longitudinal girders were two Farman skids flanked with the usual wheels, elastically connected. The machine, besides flying well, was readily demountable. The wings could be quickly removed, thus allowing the biplane to enter a door fifteen feet wide. The entire machine could be packed in a case 15½ feet long by 3¼ feet square, the whole case cubing less than six solid yards. Hundreds of them, therefore, could be stowed away in an ocean cruiser.

The flying quality of adequately designed flexible aëroplanes is well illustrated by the swallowlike monoplane shown in Fig. 43. This airy creation of the distinguished Austrian engineer, Igo Etrich, came into public prominence in the spring of 1910, though it had been developing privately for half a decade or more. On May 14th, near Vienna, it carried pilot Illner 84 kilometers in 80 minutes, at an elevation of 300 meters, thus surpassing all previous Austrian records for distance, duration and altitude. Its successor, *Etrich IV,* had wing tips still more turned up, and possessed such stability that during the meet at Johannisthal in October, Illner circled the pylons with his hands off the warping levers. At times he wheeled round curves of only ten meters radius, the whole machine tilted at an alarming angle, yet maintaining its poise with the natural ease and grace of a soaring albatross.

The prominent feature of Etrich's monoplane

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some years previously had proved this by gliding models having sustainers with flexible rear margins.

was the elastic construction of its wings and tail. Across the rigid main bars of each wing were fastened numerous ribs with bamboo terminals, thus making the rear margin and tip of the wing flexible.

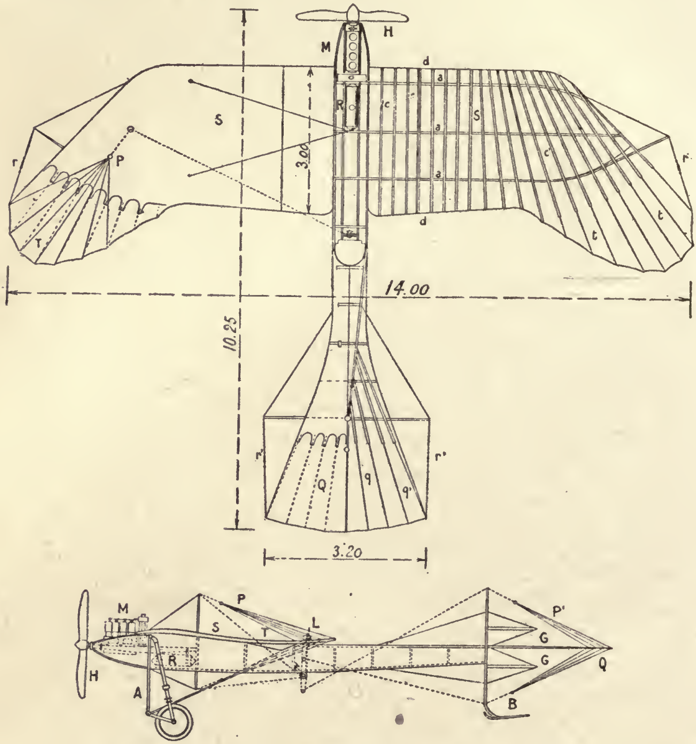

FIG. 43.—THE ETRICH MONOPLANE OF 1910.

Similarly the tail, or horizontal rudder, was framed of bamboo. Hence the pilot, by use of control wires, could flex both the wing margins and the tail up and down at will, to steer the machine, or he could let go the controls and allow the distorted surfaces to spring into their normal positions, and the machine to pursue the even tenor of its way. Moreover, the gusts and whirls in the air, on striking the elastic rear margins of the tail and wings, exert a propulsive effort. Thus could be utilized the wind's energy of turbulence, as indicated by the present writer in 1893, in a paper on "Windgusts and Their Relation to Flight," published in the *Proceedings of the International Conference on Aërial Navigation* of that year. In passing it may be remarked that many other aëroplane designers, notably Bréguet, have emulated Mr. Etrich, though unconsciously perhaps, in providing elastic ribs, hinges or pivots to permit the rear parts of the wings and tails of their machines to yield freely to intentional or unusual impulses, and then spring back to their normal positions.

The carefully elaborated monoplane of Robert Esnault-Pélterie, which had been steadily improving for eight years, had now attained great perfection of finish, and merited prominence in actual flight. As shown in Plate XXIX, it had a general resemblance to the *Antoinette*, though differing throughout in its manifold details. The stream-line body was of steel tubing, braced with wire, and tightly covered with smooth fabric to reduce resistance. A five-cylinder R. E. P. motor in front connected directly with the two-blade propeller. The pilot sat between the wings with the passenger before him at the center of gravity, both having control levers when desired for instruction. The wings could be warped and the rudders, at the end of ample empennage planes, occupied the extreme rear as shown. An elastically cushioned skid between the two freely turning wheels served to absorb the shock of hard landing, though usually not touching the ground. The R. E. P. monoplane of 1910 was a very graceful, swift and strong machine, of marked efficiency.

As always happens in the many-minded development of a complex invention, the general exhibition and use of the aëroplane led toward uniformity of design. This became particularly noticeable during the world-wide demonstrations of 1909 and 1910. Whatever predilection the inventor might have for his own devices, he would rather cast them aside than lose at the tournament and in the market. Without a monopoly of the flying art, he could ill afford to retain too affectionately his own second-rate device in competition with a rival having a more effective one. Accordingly there was a judicious and general adoption of those devices which had proved best in practice, from whatever lowly intellect they had emanated. Thus there was a marked tendency to the general use of starting wheels, landing skids, large warping surfaces, and, in racing machines, to the stream line concentration of the load, and the severe elimination of resistance.

A few examples will illustrate this tendency to choose the most practical devices from the world's general stock. The Wright brothers, who, following Maxim, had been ardent votaries of the forward horizontal rudder, discarded this in 1910 for the elastic rear horizontal rudder introduced by Etrich. At the same time they abandoned the antiquated catapult introduced by Langley, and adopted the combination of wheels and skids introduced by Farman. In their racing machine they no longer placed the aviator beside his engine, presenting a broad front to the wind, but, like Curtiss and foreign designers, they placed the driver and power plant in line, to diminish the atmospheric resistance. These manifold and timely improvements indicate clearly the advantages to mankind of an "open door" in a crescent art.

But if the Wrights adopted the most successful devices of their neighbors, these in turn were not slow to reciprocate that policy. There was ample recognition of the merit of the combination of warping sustainers and double rudder proposed by scientific men before the advent of power aëroplanes, and so admirably employed by the Wrights and Prof. Montgomery in their early coasting flights. The warping wing was quite generally used on monoplanes in 1910; not to mention the *ailerons*, which frequently were an adaptation of the same principle.

As further illustrations, it may be noted that Voisin brothers adopted the Farman *ailerons* and abandoned the cellular type of sustaining surface introduced by Hargrave, finding the vertical surfaces strongly frictional and unnecessary for lateral equilibrium, in presence of the *ailerons*. They also abandoned the forward horizontal rudder, seeing that it could very well be omitted. On the other hand, it must be observed that the Farmans, Sommer and Curtiss still retained the combined fore and aft rudder. Curtiss and Farman also tried their hands at monoplane construction, though without abandoning the biplane. The most famous monoplanists, however, held firmly to their first love. In this they were emulated by many new designers, Nieuport, Hanriot, Déperdussin, etc. These show a marked tendency to employ smoothly covered hulls shaped after the fish or torpedo.

To drive the little aëroplanes so far developed, especially the racers, there was a general preference for a single-screw propeller mounted directly on the engine shaft, though doubtless for machines weighing many tons a multiplicity of such propellers would be used. Theoretically the advantage of twin screws was conceded, but in practice they were employed by very few constructors. The Chauvière wooden propeller was the favorite in France, and was approved by the constructors of propellers elsewhere, at least in its general features. The Voisin firm, indeed, still adhered to the metal propeller, and occasionally some experimentalist employed the more venerable French screw consisting of radial sticks covered with fabric. But the great records in the sporting world were achieved with solid wooden propellers.

A special chapter would be required to describe the various motors, even cursorily. Their relative values, however, may be summarized in the following brief words by Réné Gasnier, in the *Aërophile* for November, 1910:

"Last year we had but few light types; this year there is no dearth of them, and at their head stands that admirable motor *Gnome,* which has enabled aviators to accomplish all their fine performances. At first many persons had no confidence in the future of the rotatory motor. One must bow to the facts; on considering the nature of this motor it is seen to be of an admirable simplicity. It is evidently the typical aviation motor, and an approach toward the veritable rotatory motor which later will be the turbine. Numerous motors of four to eight cylinders are very well spoken of, but none attain the lightness of the *Gnome.* Among the air-cooled motors the *Esnault-Pélterie* is remarkable for the series of trials it has endured, and among water-cooled motors we may cite the splendid performance of the *Antoinette*—2,100 kilometers in one week at the Bordeaux meeting. This would be quite a good run even in an automobile. It is noticeable that the aëroplane motor tends distinctly to differentiate itself from its senior, the automobile motor, and assume a type absolutely adapted to its special work. In addition to the greatest possible lightness, a demand now arises for a slight consumption of fuel, and a range of speed which is indispensable for landing. It is dangerous to descend rapidly with the motor at full speed; on the other hand, in cutting off the ignition to glide down, one risks not being able to restart the motor, if need be, while if the motor relax sufficiently the descent takes place in perfect security. It suffices to speed up at the right moment."

The practical utility of aviation began now to be questioned. The aëroplane had passed the primary epoch of experimental development and was becoming a standard article of manufacture representing a considerable industry. But what was it all worth? Aviators had flown faster than the eagle, higher than the clouds, farther than the common distance from metropolis to metropolis. Schools were licensing new pilots from day to day. But what career had these before them, and what essential function in the affairs of humanity could they perform? Some, indeed, might fit themselves for aërial service in warfare, some for the pleasant profession of amusing and entertaining mankind; but in the serious business of life, what important rôle could the air men hope to play? This was the pertinent inquiry, and it was largely a question of the reliability and economy of the aëroplane. Improvement in these two elements might therefore receive attentive consideration in the immediate future.

The reliability of the aëroplane depends partly on its environment, partly on its plan and structure, partly on the skill of its pilot. The pilot's skill had been admirably developed in the tournaments and public exhibitions. The aërodynamic design conducive to stability and steadiness, the structural design conducive to maximum strength and resiliency, uniformly proportioned to the stress and work of each part of the complex machine; and above all the design of the motor, to ensure it against a thousand foibles—all these could be improved by the patient methods of theoretical and experimental science. The environment could, of course, be chosen. At first only the most favorable regions need be attempted for regular transportation, regions of level plain and farm land, or of lake and river surrounded by country not too rough and precipitous.

The general cost of the aëroplane to mankind depends on its plan and structure, on the methods of manufacture, on the material running expense; but its particular cost to the passenger is determined largely by the cupidity or business acumen of those who furnish the machine and those who operate it. Naturally when the world first awoke in the morning of practical sporting aviation, with a sudden and strong relish for flying, the prices would be fabulous, not to say ridiculous. During that hour no commercial transportation could be contemplated. But without monopoly the prices must quickly abate; for neither the manufacture nor manipulation of the aëroplane demand rare ability or training. The cost of manufacture would promptly be diminished by means of specialized tools and operatives, immediately upon the assurance of large and continuous orders. The cost of pilotage would become insignificant when a single chauffeur could take a dozen passengers on one aëroplane.

So much for the human and external elements in the cost of aviation. The inherent and material cost of the aëroplane could also be reduced, though perhaps less readily. It was unlikely that the machine would be built of much cheaper materials, or made much lighter per pound of cargo. Nor were such improvements of so much importance since they would affect only the first cost of the flyer. But an increase of aërodynamic efficiency in the propeller and aëroplane proper, together with increased thermodynamic efficiency in the motor, would materially lower the current cost of transportation at any given speed. These improvements would require careful research in the laboratory and patient trial in the workshop and field. The refinement and perfection of the aëroplane might therefore be looked for in those communities where men have sufficient foresight, enterprise and liberality to endow research, and to encourage the science and the art of aviation to supplement each other.

PART III

AËRONAUTIC METEOROLOGY

CHAPTER XIII

GENERAL PROPERTIES OF FREE AIR

For aëronautic uses the atmosphere may be regarded as a mixture of two substances, dry air and water. The first remains always in the gaseous state; the second shifts erratically through all possible states. Rain drops freeze or evaporate; sleet, snow, and hail evaporate or melt; the aqueous vapor condenses or congeals. Thus the world is wrapped in a dual sea, one part naturally serene, the other capricious, protean, and turbulent. Dry air, indeed, is a composite of many gases of vast concern in chemistry and biology; but in relation to aëronautics it is practically a single permanent gas. This placid element and its inconstant mate, so curiously mingled, constitute the medium whose flux and vicissitudes the aërial sailor has duly to learn before he can navigate with skill or safety.[1]

But these aërial oceans, the moist and dry, are of very different depth. They commingle only in the lower levels of the atmosphere, whose qualities vary accordingly, both physical and transportational. While the dry air may reach up to more than a hundred miles, substantial enough to singe a meteorite, the sea of aqueous vapor is bounded practically by the shallow region of the visible clouds. Beyond the feather-like cirri, which just overtop the loftiest

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[1] The whole water vapor in the atmosphere of our latitude in summer is equivalent to about one inch of rainfall.

mountain peaks, there is scant, if any, moisture. Never rain, nor cloud is there, nor tempest nor any great perturbation. Beyond the highest excursions of the cirri, at an elevation of some ten miles, stretches the deep ocean of eternal sunshine, of equable and nearly constant temperature. Into that zone of perpetual serenity no tumult of the nether atmosphere can penetrate; against the floor of the isothermal layer the cyclonic currents spread and dissipate. The upper air has, of course, a considerable drift, like a majestic river or stream of the sea, but never turmoil or tempest disturbs its stately march.

In some respects, therefore, that lofty ocean is an ideal one for swift transportation. But at present it is beyond the range of any navigable craft of human invention. Occasionally, indeed, a gauzy balloon from the hand of some inquisitive weather sage penetrates a little way into the exalted deep next the cosmic void, bearing its delicate recorders of heat and pressure; but it wanders alone in a silent and vast solitude outcubing all the habitable space allotted to bird, beast and fish; then at last sinks down to deliver the story of its strange voyage in that lifeless outer sphere. Volcanic and celestial dust may flourish there, tingeing the twilight with rosy flush, but no biologic forms from the teeming underworld may find refuge or sustenance. It is the unconquered domain of who knows what meteoric craft of the future, sweeping the globe from continent to continent, with now unimaginable celerity, grace and precision.

Incidentally and aside from its aëronautic interest, the composition of the atmosphere may be presented in fuller detail, showing the wide variations from level to level, and the manifold complexity of the fluid we daily breathe, not to mention the myriads of motes and germs inhabiting every inch of it. The gaseous components and their distribution are well exhibited in the following table,[1] which represents an average condition:

TABLE I

Percentage Distribution of Gases in the Atmosphere

Height in Kilometers.	Gases.							Total Pressure in Millimeters.
	Argon.	Nitrogen.	Water Vapor.	Oxygen.	Carbon Dioxide.	Hydrogen.	Helium.	
150						99.73	0.27	0.0043
140						99.70	0.30	0.0048
130		0.02				99.64	0.34	0.0054
120		0.10				99.52	0.38	0.0060
110		0.40		0.02		99.16	0.42	0.0067
100		1.63		0.07		97.84	0.46	0.0076
90		6.57		0.32		92.62	0.49	0.0090
80		22.70		1.38		75.47	0.45	0.0123
70	0.02	53.73		4.05		41.95	0.27	0.0248
60	0.04	78.16		7.32		14.33	0.15	0.0810
50	0.08	86.16		10.01		3.72	0.03	0.466
40	0.16	86.51		12.45		0.88		1.65
30	0.22	84.48		15.10		0.20		8.04
20	0.55	81.34		18.05	0.01	0.05		39.6
15	0.74	79.56		19.66	0.02	0.02		88.2
11	0.94	78.02	0.01	20.99	0.03	0.01		168
5	0.94	77.89	0.18	20.95	0.03	0.01		405
0	0.93	77.08	1.20	20.75	0.03	0.01		760

Fixing attention first upon the gases other than water, it will be at once observed from the table that these gases show a very uniform mixture in the moist and turbulent region, while farther aloft the lighter of them tend to predominate in relative proportion. This uniformity of composition at the lower levels, which accords with experience, is due to the constant circulation and turmoil in that region. But for this constant agitation, the uniform-

[1] Computed by W. J. Humphreys for Moore's *Descriptive Meteorology*

ity of mixture could not last. If the atmosphere were perpetually at rest throughout, or moving only in horizontal flow, each constituent gas would assume the same status and distribution as if the others were absent. Each, therefore, obeying Dalton's law of diffusion, would form an atmosphere of itself, independent of the others, and unaffected in density by them. Such a condition is assumed for the higher levels. The percentage distribution in the higher levels is calculated from the known elasticity and density of the gases, assumed as resting in perpetual calm at a constant temperature of .55° C. beyond eleven kilometers, or above the highest ascent of man, and, furthermore, as having at the earth's surface 1.2 per cent moisture and a temperature of 11° C.

But only in the quiescent outersphere can that dynamic gradation be established or perpetuated. Below this lofty region is the sea of water vapor, mingled intimately with the dry air, and churned with it, yet not sharing its uniformity of distribution. Why this rapid diminution of moisture with elevation, as shown in the table? Because throughout the moist region the temperature falls rapidly—about 6° C. per kilometer ascent above the earth—thus chilling and precipitating the vapor, whose pressural resistance to liquefaction diminishes with waning temperature. The explanation is obvious; but why does it not apply as well to the other elements of the atmosphere: why do not the other gases present liquefy with falling temperature as well as the water vapor, which is merely water in the gaseous state? The question cannot be answered very profoundly, but an essential condition of liquefaction of any gas can be stated in learned phraseology, after the preliminary exposition of certain general properties of matter.

We may first set forth those general physical properties, then apply them to answering the above question. Every known substance may exist in either of three states, the solid, liquid or gaseous. For every substance there is a critical temperature above which it can exist only as a gas, and cannot be liquefied by any pressure, but below which a suitable pressure will cause liquefaction. Below its critical temperature a gas is called a vapor, above it a permanent gas. Now in the free atmosphere some of the gases are never below their critical temperatures and, therefore, cannot be liquefied by any pressure, without special cooling; others are sometimes below their critical temperatures and are then capable of liquefaction by sufficient pressure, which however is not always found in free space, but can be supplied by a compression pump; one other gas, that is water vapor, is always below its critical temperature in the free atmosphere, and therefore may always be turned into water by sufficient pressure at its actual atmospheric temperature. Such sufficient pressure in the water vapor actually occurs from time to time in all parts of the atmosphere from the earth's sur-

TABLE II

Critical Temperature and Corresponding Pressure of Liquefaction for the Chief Constituent Gases of the Atmosphere.

Substance	Critical Temperature C.	Critical Pressure Atmospheres.
Dry Air	—140	39
Nitrogen	—146	34
Oxygen	—118	50
Carbonic Acid	— 31	75
Argon	—120	51
Hydrogen	—242	20
Ammonia	130	115
Water	+365	200

face to the highest cirrus region, but more frequently in the nimbus levels, a mile or two above the earth. Thus at all parts of the lower atmosphere liquefaction of aqueous vapor is sometimes observed, either as mist or rain, snow or ice particles, and on the earth as dew or frost. In order to illustrate the above ideas by numerical citation, the accompanying table is given, showing the critical temperature and pressure of the chief gaseous constituents of the atmosphere.

A glance at this table shows that for the pressures and temperatures prevailing in our atmosphere most of the constituents are permanent gases. The conspicuous exception is water which, when in the gaseous state, always exists as a vapor, and never as a permanent gas, since it never even approaches the critical temperature. Fortunately for all life on earth the aqueous vapor condenses at very ordinary temperatures and pressures, else there would be no rainfall for irrigation and drinking. Fortunately also the other gases do not so precipitate, else the world might be flooded with liquid nitrogen and oxygen, entailing who knows what disastrous consequences.

After this digression on the composition of the atmosphere, we may henceforth regard the aërial ocean as a mixture of two substances, dry air and water; the first, a permanent gas; the second, a variable element, existing at times in either the solid, liquid, or vaporous state. For the sake of convenience we may first study the dry atmosphere, then the moist. The dynamic properties of the dry atmosphere may in large measure be deduced by an application of two well-established laws of physics. These will be taken in order.

By careful investigation it has been proved that throughout a considerable range of pressure and temperature the permanent gases very approximately obey the following law; the volume of a permanent gas varies directly as its absolute temperature and inversely as its pressure. In other words the product of its pressure and volume equals the absolute temperature multiplied by a numerical constant. This may be expressed algebraically by the following formula:

$$PV = RT \quad \ldots\ldots\ldots\ldots (1)$$

in which P is the pressure and V the volume of a given portion of gas at the absolute temperature T, and R is a numerical constant for the gas in question.

The value of R in the foregoing equation has been determined experimentally for the component gases of the atmosphere, and for dry air as a whole. For dry air, which, under such conditions as surround the aëronaut, may be treated as a single uniform gas, the equation applied to one kilogram gives $R = PoVo/To = 29.27$, where Po, Vo, To, are respectively the pressure, volume and temperature, in the metric system, of the one kilogram of air under standard conditions; i. e., $Po = 10{,}330$ kilograms per square meter, being the normal atmospheric pressure; $Vo = 1/1.293$ cubic meter, being the volume of one kilogram of dry air at normal pressure and freezing temperature; $To = 273°$ C., being the absolute temperature of freezing. In passing, be it said that the absolute temperature is that measured from the absolute zero, which on the Centigrade scale is 273° below freezing, on the Fahrenheit, 460.6° below freezing.

The second law referred to follows directly from the principle of the permanence of mass. It is a general observation in physics that a given portion of matter is of constant mass, however its pressure, volume, temperature and other conditions may vary. In particular, the mass of a given portion of matter always equals the product of its mean density and volume, since density is defined as the amount of mass in the unit volume. Expressing this physical law, or relation algebraically, gives $\rho V = \text{mass} = \rho o, Vo$, in which ρ, V, are the general symbols for the density and volume of the given portion of matter under any condition, while ρo, Vo, are the specific values of ρ and V observed for some one state and circumstance of the substance in question. In particular, if the mass of air be unity, we may write:

$$\rho V = 1 \dots\dots\dots\dots (2)$$

This relation, together with that expressed in equation (1), will enable us to deduce many of the properties of dry air and of a dry atmosphere.

First let us observe from equation (1) the effect, in turn, of keeping constant one of the quantities P, V, T, while the other two vary. The equation shows that if the temperature of a gas is kept constant the volume is inversely proportional to the temperature. This is called the law of Boyle and Mariotte from its two independent discoverers, of whom Boyle seems to have been the first. As an example of Boyle's law, if any empty glass, or diving bell, be inverted over water, then submerged deeper and deeper, the air within it will shrink with increase of pressure, its volume becoming one half when the pressure is doubled, one third when the pressure is trebled, etc. In particular, if the pressure changes by one unit, the corresponding change of volume is $1/P$ part of that volume. For example, if a captive balloon is anchored in air at constant temperature, while the barometric pressure changes from 30.0 inches to 30.1 inches, the volume of the balloon will contract 1/300 part of itself.

Again equation (1) shows that if the pressure of a gas is kept constant, the volume is proportional to the absolute temperature. This is the law of Charles and Gay Lussac, so called from its discoverers, of whom Charles is thought to have been the first. As an example of this law, if a captive thin rubber balloon is heated, or cooled, its volume will vary directly as its absolute temperature. In particular, if the temperature is changed one degree, the volume changes $1/T$ part of itself. For example, if the temperature of a balloon in air of constant barometric pressure is heated from 300° C. to 301° C., its volume will expand 1/300 part of itself. Historically, be it said, this law of Charles and the law of Boyle were discovered separately, then combined, giving equation (1).

Still a third, though not independent relation may be read from equation (1), thus: when the volume of a gas is kept constant, the pressure is proportional to the absolute temperature. In particular, if the temperature is changed one degree, the pressure varies accordingly by $1/T$ part of itself. For example, if an air tank or gas tank, in a room at 500° F., changes one degree in temperature, its pressure will change 1/500 part.

With minute detail these three conclusions from the general equation (1) have been set forth and illustrated, because of their practical importance. Other valuable results may be obtained by similar reasoning. Thus equation (2) may be read; the volume of a unit mass of any substance is the reciprocal of its density. Hence, if in the three foregoing conclusions, the reciprocal of the density is everywhere written for the volume, three new relations will be obtained which are of frequent practical use. Two of them may be expressed in the following important law; the density of a gas varies directly as its pressure and inversely as its temperature. Useful applications of this law in aëronautics suggest themselves at once.

By means of the various foregoing equations, the value of either one of the four quantities P, V, T, ρ, representing respectively the pressure, volume, absolute temperature, and the density, may be obtained in terms of any two of the others. If then any two of the quantities is observed, the others can be at once computed. If, for example, the pressure and temperature of dry air be observed at any point, its density can be computed from the formulæ, also its volume per kilogram weight, and thence its volume for any other weight. It is important therefore to be able to measure satisfactorily at least two of the four quantities. In usual studies of the atmosphere the pressure and temperature are observed directly. The method and instruments employed for that purpose are too well known to require description here.

In some speculations the pressure and temperature of the atmosphere are assumed, and certain interesting conclusions drawn. For instance, if the temperature is assumed constant throughout a dry atmosphere, the fluid will obey Boyle's law, and it can be easily shown that the height of such a medium is the same whether it comprise much gas or little.[1] Again assuming the temperature and pressure constant, the height of the normal homogeneous atmosphere can be computed by dividing the pressure per square unit by its weight per cubic unit. In this way the height of the normal homogeneous atmosphere has been found to be about five miles. But these are hypothethical cases, of purely theoretic

[1] Ferrel, *Popular Treatise on Winds.*

interest. In practice the temperature may, on the average, be assumed to decrease 6° C. for each kilometer of ascent, and the pressures may then be computed for various elevations by use of Boyle's law, as done for Table I.

This leads us to a study of the gaseous properties of moist air. By moist air is meant a mixture of dry air and aqueous vapor in the form of an invisible elastic gas. The definition does not comprise air containing visible steam, or mist, or cloud, but clear moist air such as one ordinarily breathes. The study of this mixture may be preceded by a brief account of the gaseous properties of the vapor alone.

If water in sufficiently small quantity be introduced in a vacuum bottle at any ordinary temperature, it will promptly evaporate, forming an invisible gas known as aqueous vapor, filling the bottle and exerting a uniform pressure on its walls, except for the minute difference at top and bottom due to gravity. The vapor weighs 0.622 as much as dry air having the same volume, temperature and pressure, or quite accurately $\frac{5}{8}$ as much. It obeys all the laws given above for ordinary gases and dry air. But it has one singularity; at ordinary atmospheric temperatures, it cannot be indefinitely compressed without condensing to a liquid. In this respect it differs from the chief components of the atmosphere, which at ordinary temperatures can endure indefinite pressure without liquefaction. The ammonia and carbon dioxide in the air can, it is true, be condensed by pressure at their usual temperatures, but not by such pressures as occur in the free atmosphere, thus still leaving aqueous vapor the one singular constituent.

Reverting to the behavior of the water in the assumed vacuum bottle at fixed temperature, it may be observed that the pressure of the invisible vapor is directly proportional to the amount of liquid evaporated. In other words, for any fixed temperature the vapor pressure is directly proportional to its density. When this density reaches a certain definite amount, dependent solely upon the temperature, no further evaporation will occur, unless some of the vapor condenses. The pressure of saturation for that temperature has been reached, and any attempt to increase the pressure, by diminishing the volume of the vapor, will cause liquefaction at constant temperature.

If, however, the space is not saturated, the mass of vapor present may be expressed as a percentage of the amount required for saturation at that temperature. This percentage is called the relative humidity. Thus if the relative humidity is seventy per cent, the actual mass of water vapor present at the observed temperature is seventy per cent of the maximum that can exist in the given space, at the given temperature. In other words, the relative humidity is the ratio of the actual to the possible humidity at a given temperature.

In like manner, for any given vapor pressure there is a definite saturation temperature, known as the dew-point. If with constant pressure the vapor is given various temperatures higher than the dew-point, it will remain gaseous and invisible; but if it falls in temperature to the dew-point, liquefaction occurs, and drops of water appear on the inner wall of the vessel. Further cooling will entail still further liquefaction and reduction of pressure; for the lower the temperature the less the possible mass and pressure of saturation. But for all temperatures, down to freezing and considerably below, some vapor exists, and obeys the same laws as at higher temperatures. When, however, saturation occurs below freezing, the vapor may be precipitated as snow instead of water. This is a familiar phenomenon in the free atmosphere.

The actual mass of water vapor present in a cubic unit of space is sometimes called the absolute humidity. A formula giving the absolute humidity f, in kilograms per cubic meter, for any observed temperature t, and vapor pressure e, may be written as follows:

$$f = 0.00106\, e \,/\, (1 + 0.00367\, t)$$

in which e is the vapor pressure in millimeters of mercury, and t is the common Centigrade reading. As an illustration of the actual values of the pressure, temperature and density of saturated water vapor, for various conditions, the following table is presented:

TABLE III

Temperature, Pressure and Density of Aqueous Vapor, in Metric Measures.

Temperature, Centigrade.	Pressure, Millimeters.	Density Kilos. per cubic meter.
—25	0.61	.557
—20	0.94	.892
—15	1.44	1.395
—10	2.15	2.154
— 5	3.16	3.244
0	4.57	4.835
+ 5	6.51	6.761
10	9.14	9.329
15	12.67	12.712
20	17.36	17.117
25	23.52	22.795
30	31.51	30.036
35	41.78	39.183
40	54.87	
45	71.36	

Now by Dalton's law, each gas or vapor in a mixture of several behaves as if it were alone. Thus if the foregoing experiment be conducted in a bottle containing various gases chemically inert to water, the same mass of water will be evaporated, and exert the same uniform pressure, in addition to those exerted by the gases. Now the density of each gas or vapor present, will equal its mass divided by its volume, and the density of the mixture will equal the total mass divided by the volume. Furthermore, it is well known that aqueous vapor is less dense than dry air at the same temperature and pressure. From this it is at once evident that moist air, which is merely a mixture of dry air and aqueous vapor, must be lighter than dry air at the same temperature and pressure. This is true whether the two fluids compared be in closed vessels or in the free atmosphere.

Accordingly in all precise dealing with the free air, whether involving its buoyancy, its resistance, its energy or any other mass function, its density as affected by the humidity must be taken into account. This can be computed from the observed pressure, temperature and relative humidity as revealed by well known instruments, the barometer, thermometer and hygrometer. Thus from the observed temperature and relative humidity, the mass of vapor present per cubic meter is read from Table III, the reader, of course, multiplying the given tabulated mass by the observed percentage of humidity. To this aqueous mass must be added the mass of dry air present. Then the total mass per cubic meter is the density.

Various formulæ are available for computing the density of moist air from the readings of the three instruments mentioned above. Also, tables have been worked out giving the density without further calculation. Moreover, the density of free air may be directly measured, accurately enough for most purposes, by means of a densimeter. A simple formula for finding the density of moist air is as follows:

$$\rho = 0.465\ (b - e)\ /\ T$$

in which b, e, are the pressures in millimeters mercury respectively of the moist air and its vapor, as revealed by the barometer and hygrometer.

In practice no great error will be made in assuming the relative humidity to be fifty per cent. For the moisture content never exceeds five per cent of the mass of the moist air, and hence in assuming a fifty per cent relative humidity, when there is actually a maximum or minimum humidity, the greatest possible error in estimating the moisture content is 2.5 per cent of the mass of moist air. Now if 2.5 per cent of a mass of air be assumed to be aqueous vapor when all is really dry air, or conversely if 2.5 per cent of the whole mass be assumed as dry air when it is really aqueous vapor, an error of much less than 2.5 per cent is made in estimating the true density. No error at all would ensue if both air and vapor were of the same density; but since one is $\frac{5}{8}$ as heavy as the other, the possible error is $\frac{3}{8}$ of 2.5 per cent, or 0.6 per cent. This is a negligible quantity in all mechanical considerations, except where great accuracy is required.

When any gas changes density or volume it also changes temperature, unless there be transfer of heat between it and its environment. When change of volume occurs without such transfer of heat the expansion, or contraction, is called "adiabatic;" when it occurs at constant temperature, the expansion is called "isothermal," the temperature being kept uniform by suitable transfer of heat; when it occurs at constant pressure it is called "isopeistic." In either case work may be done by the enlarging gas, if it press against a moving piston, or yielding envelope of some kind; and conversely work may be spent on the gas in compressing it either isothermally, adiabatically or isopeistically.

If, for example, a balloon rises rapidly its contents will expand adiabatically, pushing the envelope out in all directions against the static pressure of the embracing atmosphere. Thus it will do work and rapidly cool. But if it rapidly sinks, it will contract adiabatically and grow warm, owing to the work done by the surrounding air in compressing it. A like thing occurs when a great volume of air rises or sinks quickly in the free atmosphere. In this case the change of temperature is about 6° C. for each kilometer change of level, so long as the air remains unsaturated. A familiar example of this effect in Nature is manifested when an uprushing column of moist air chills, and precipitates moisture, forming a cloud toward its top. Thus a lone thundercloud in a clear sky may mark the upper part of such a column, or upward vortex in the air. And contrarywise, a descending column may absorb its visible moisture, causing it to become clear aqueous vapor, and thus vanish from view.

CHAPTER XIV

GENERAL DISTRIBUTION OF HEAT AND PRESSURE

Having thus briefly examined the composition and certain gaseous properties of free air, both dry and moist, we may now study the atmosphere as a whole. We wish particularly to know of its distribution of temperature and pressure; of its general and permanent circulation; of its great periodic currents; of its vertical movements, and its minor local winds with their pulsations of velocity and direction. Fortunately much information is available, due both to governmental and private research, though this was collected more for purposes of meteorology than of aërial locomotion. Of late, however, attention has been given to the aëronautic study of the atmosphere, which will, it is hoped, prove valuable to the aërial navigator.

The movements of the atmosphere are due mainly to the sun's heat and to the rotation of the earth. The earth's internal heat and the moon's attraction are other minor agencies, but these may be neglected by comparison. The earth's rotation also would be ineffectual in modifying the aërial movements, except for the coöperation of the sun. Without his influence the atmosphere, always stagnant, would simply rotate with the globe, at constant angular velocity and uniformly graded density at various levels. This evenness of density for any level is broken by the solar radiation increasing the temperature and moisture, otherwise the air would remain practically at a standstill.

Though the moisture by its lesser density causes some lightening of the air at fixed temperature, this at most is hardly one per cent, as already shown, and on the average is much less. Its effect, therefore, is equivalent to less than that caused by a rise of temperature of three degrees. But if percipitation occurs, an enormous amount of stored sunshine, or latent heat, is liberated and applied to warming the associated air. Thus each pound of vapor condensed may, by the release of its thermal store, heat more than a ton of air one degree in temperature, or more than half a ton of air two degrees, etc. The actual number of pounds of air at constant pressure, raised one degree Centigrade by the condensation of one pound of vapor at various temperatures, is given in the following table:

TABLE IV

Temperature of condensation	0°	25°	50°
Pounds of air heated one degree..	2550	2480	2407

The sun then is father of the wind. By uneven heating of the atmosphere it disturbs the uniform density gradation that would otherwise exist. Thus abnormal pressures are generated which disturb the repose of the aërial sea, causing the fluid to flow from regions of excessive to regions of defective pressure. Hence the study of insolation [1] and temperature distribution is fundamental to the science of the winds.

Without detailed study, we may note the aggregate insolation received by the earth, at various lati-

[1] Solar radiation received by the earth.

tudes, and its general effect on terrestrial temperature. The sun emits a nearly constant stream of radiation, from year to year, which plays continuously upon the earth as a whole, with an intensity which varies but slightly from month to month, due to the slightly varying distances of the earth from the sun. Owing to the sun's seasonal wandering across the equator, the insolation at any latitude varies considerably month by month, and the polar regions receive much more light than if no such wandering occurred. The total yearly insolation for every 5° of latitude is shown in the following table from Hann, in which the unit is the amount that the earth would receive in one day at the time of the equinox, if the sun were at its mean distance from the earth:

TABLE V

Annual Amounts of Insolation

Latitude.	Thermal Days.	Difference.	Latitude.	Thermal Days.	Difference.
0°	350.3		50°	239.6	19.1
5°	349.1	1.2	55°	219.4	20.2
10°	345.5	3.6	60°	199.2	20.2
15°	339.4	6.1	65°	180.2	19.0
20°	331.2	8.2	70°	166.2	14.0
25°	320.5	10.7	75°	156.5	9.7
30°	307.9	12.6	80°	150.2	6.3
35°	293.2	14.7	85°	146.5	3.7
40°	276.8	16.4	90°	145.4	1.1
45°	258.7	18.1			

From this it appears that the equator receives nearly 2.5 times as much heat yearly as the poles. Since, moreover, the equator enjoys nearly constant insolation, while the polar regions suffer great variations of heat, with the varying altitude of the sun, the equatorial atmosphere is both much hotter and more equable than the poles, and high latitudes generally. Thus at the equator the frost level stands constantly at 18,000 feet, while in the middle latitudes it varies greatly in height from season to season. If, for example, a circle be drawn to represent the earth, and above it a line to indicate the mean altitude of the frost level in July, the frost line starting at the equator at an elevation of 18,000 feet will decline north and south, finally touching the earth well toward the frigid zones. The levels for other temperatures, above and below freezing, are similarly inclined downward from the equator to north and south. Obviously these isothermal levels vary with the varying season, and at any fixed time differ on different longitudes. On the plane of any given latitude the frost line varies much less in altitude, and so for the other isothermals. This is particularly true at the poles and equator, and everywhere at considerable altitude. If one voyaged around the earth at the equator at an elevation of 5,000 feet, he should find the average temperature about 65° F. In the temperate zone, following a line of latitude at the same height, he should have a lower temperature, but still comparativly equable. The average annual temperature of the earth's entire surface is about 60° F.

In practical meteorology the temperature is observed at many points simultaneously over a wide stretch of the earth's surface. These are then plotted on a weather chart, and through all points of like temperature are drawn lines known as isothermals. These lines not only map the earth's surface into regions of equal temperature, but they also show the direction of fall or rise of temperature, and its space rate of change. This rate is called the "temperature gradient," and when estimated straight across from isothermal to isothermal, that is in the direction of liveliest change of temperature, it is the maximum gradient. Such a map is very useful in forecasting the weather. It is but a particular instance of the more general map conceived by the physicist, exhibiting the thermal condition of the entire atmosphere by means of a series of equal temperature surfaces one above the other. Here, of course, the temperature gradient at any point is the space rate of change of temperature in any direction, being zero along the isothermal surface and greatest normal to it.

The vertical temperature gradient is of particular interest, since it determines the condition of fluid equilibrium at any point in the atmosphere when the level surfaces are isothermal. If, for example, a balanced balloon or portion of air, on starting upward from any level, cools faster than the environing stagnant air, it will become more dense, and cease to ascend, in which case the atmospheric equilibrium is stable. Again, if the ascending gas or air cools more slowly than the surrounding medium, it will become less dense, and so continue to ascend, in which case the atmospheric equilibrium at the point is unstable. Thirdly, if the rate of cooling be identical for the ascending gas and its surrounding medium, the equilibrium is neutral, and the motion will be stopped by friction but unaffected by change of buoyancy, since no such change can occur. Of these three states of equilibrium, the stable is dominant above the cirrus level, while below that level each state may be found, at various times, prevailing at random in all parts of the world, but more generally the stable and neutral states. When the unstable condition occurs at any locality and any level, it is usually followed ere long by a commotion or upheaval in the atmosphere, until the temperature gradient alters to the neutral or stable.

Many observations have been made to determine the variation of temperature along the verticle in various places and in different seasons. From the temperature records obtained in 722 balloon ascensions near Paris, France, the mean fall of temperature per 1000 feet up to 20,000 feet was found to be 2°.4 in winter, 2°.8 in spring, 2°.6 in summer, 2°.5 in autumn and 2°.6 for the year. Near Berlin 3°.1 for the year was found from 75 balloon ascensions, the rate being nearly the same for the halves of the year. Fig. 44 gives the average of 52 winter and 65 summer temperature gradients, taken at about 8 A.M. by means of sounding balloons sent up at Munich, Strassburg, Trappe and Uccle. It will be noted that in both summer and winter the temperature falls rapidly with increase of elevation, up to ten or eleven kilometers, but above twelve remains nearly constant for all altitudes. The difference in temperature summer and winter is interesting, also in its gradual diminution with altitude. Another striking feature is the inversion of gradient shown at twelve kilometers elevation, where the temperature ceases to diminish, and may even increase with altitude. This region is known as the upper inversion level of the atmosphere, as distinguished from other levels at or below three kilometers height, known as lower inversions, where the temperature gradient is sometimes reversed, though not so illustrated in the diagram.

Thus the atmosphere divides into three marked layers. The lower layer, three kilometers deep, is the region of turbulence and storm, the home of heavy rain clouds, lightning, wind gusts and irregular temperatures. The middle layer, some seven kilometers thick, bounded top and bottom by the upper and lower inversion levels, is a clear region of steady-falling temperature, for the most part frigid —a region of far reaching and rapid winds, sweeping eastwardly, except near the equator, and bearing on their backs the frosty cirrus clouds. The upper layer reaching from the cirri to the cosmic void, is always cloudless and very frigid, with temperature

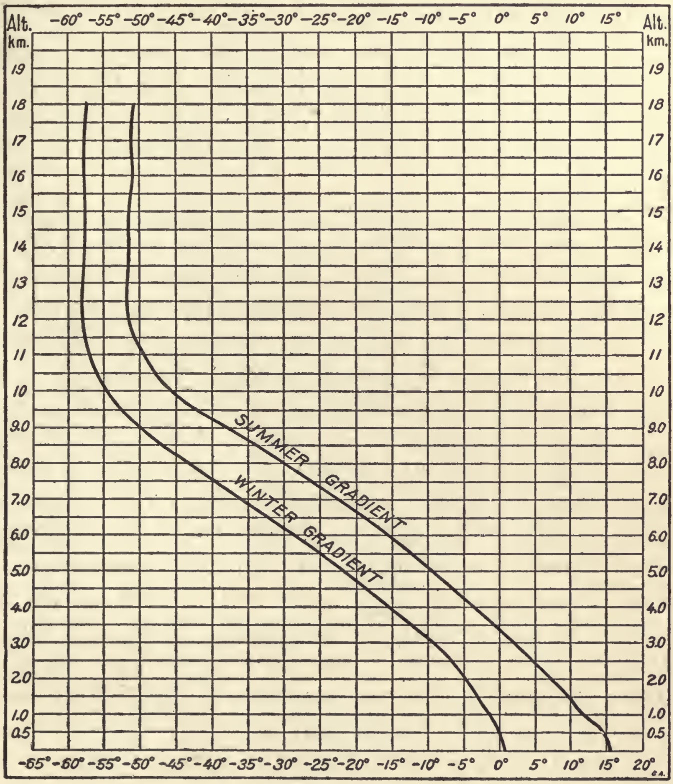

FIG. 44.—SUMMER AND WINTER AVERAGE VERTICAL TEMPERATURE GRADIENTS.

nearly constant, or maybe slightly increasing with elevation.

A striking peculiarity of these three regions is that the lower and middle layers may freely intermingle with each other, but never with the upper, or isothermal layer. Owing to its constant temperature, the upper layer floats on its neighbor like oil on water.[1] If a mass of dry air were forced up into it from below, with the natural cooling due to adiabotic expansion, such mass would be denser than the surrounding medium, and hence would promptly sink back to its initial position. Thus whatever turmoil may vex the middle or lower region, it can at most upheave the floor of the isothermal layer, leaving inviolate the crystal depths of the empyrean.

We may now turn to the distribution of barometric pressure in the atmosphere and the effect of its variation. In general, the distribution is not very uniform, but it can be graphically pictured by drawing a series of surfaces connecting all points of equal pressure. These are called isobaric surfaces. In a stagnant uniformly heated atmosphere, for example, these surfaces would lie one above the other parallel to the ocean face; but where turmoil exists, and irregular temperature distribution, the isobaric surfaces are bent into hills and hollows of varied form. These surfaces not only map the aërial sea into regions of equal pressure, but they also show the direction of fall or rise of pressure, and its space rate of change. This rate is called the "pressure gradient." When estimated straight across from surface to surface, that is, in the direction of the liveliest change of pressure, it is the maximum pressure gradient. Along this normal direction the air tends to flow with an acceleration proportional to the gradient. The velocity thus acquired by any portion of air in being pushed along the line of falling pressure, combined with its velocity due to other causes, gives its true velocity. A most important consideration,

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[1] W. J. Humphreys, *Astro. Phys. Journ.*, January, 1909.

therefore, in a scientific study of the wind is the pressure distribution.

In practical meteorology, observations of the barometric pressure are made simultaneously at many points on the earth's surface, and the readings then plotted on a map, after "reduction to sea level." This reduction is made by adding to each barometric reading the weight of a column of air between the barometer level and the sea level, according to tables prepared for this purpose. Lines called "isobars"[1] are then drawn, at regular intervals, through all points of like sea-level pressure, the indicated change of pressure between consecutive isobars on the U. S. weather map being usually one-tenth of an inch of mercury. These exhibit at once, over the entire field of observation, the horizontal pressure gradient reduced to sea level, and commonly called the "barometric gradient." In meteorology, the pressure normal to the isobar is called the gradient, and is expressed in millimeters of mercury per degree of a great circle. On the same weather chart are mapped the isothermal lines and wind directions for all the stations of the weather service. From these data and the reported moisture conditions, the meteorologist forecasts the probable weather some hours or days in advance.

No perfectly comprehensive formula can be given for the barometric pressure at any place and altitude, but certain general laws may be observed. Where, for example, the speed of the air is increased along any level of an air stream, the pressure is lessened, and conversely. Thus, if the wind blows squarely against the front of an isolated house, the speed will be greatly checked at the center front,

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[1] An isobar is a line of intersection of an isobaric surface with a water level surface at any altitude.

and accelerated at both sides and over the roof, thereby increasing the apparent barometric pressure on the front, and lessening it on the sides and over the top. A similar effect may be observed when the air flows round the hull and framing of air craft.

Again, if the atmosphere over any locality is heated appreciably more than its environment, the heated column tends to expand upward and overflow aloft in all directions toward the cooler neighborhood, thus lessening the pressure throughout the heated column, and increasing the pressure throughout the environing atmosphere laterally. When this effect is marked the plotted isobars often form a series of closed curves about the heated region, manifesting a pressure gradient at the lower levels in all directions toward the heated area. This grouping of the isobars exhibits the familiar low pressure area of the weather map. On the other hand, if any locality be cooled appreciably more than its environment, the cooled column sinks, so that the surrounding warmer air aloft flows in over it, thereby increasing the pressure over the cooled area, and diminishing it throughout the environment. The isobars may then form a series of closed curves about the cooled region, with a pressure gradient along the higher levels in all directions away from the cooled area. Of course, if heat were the only agency disturbing the earth's barometric pressure, there should be a parallelism between the heat and pressure gradients; but, as already noted, the speed or momentum of the aërial currents is also a substantial agency in modifying the pressure lines.

It is well to remember that, while the base of a warm column of air may, due to the overflow aloft, have less pressure than the base of the cool environing column which receives the overflow, the high part of the column may have greater pressure than the equally high part of the cool. For if the columns be initially of the same temperature and pressure, heating one of them uplifts its levels of given pressure above those of its neighbor. When the overflow begins, a partial equalization of pressure levels occurs, but not a complete one so long as the flow has any head.

An interesting hygrometric feature of these highs and lows may here be observed in passing. As already explained, when a column of air ascends it cools by expansion, and tends to precipitate its water content as cloud or rain; and conversely, when the air sinks it heats by compression, thus acquiring greater moisture capacity and tending to clarify. As a consequence, the areas of low pressure and a rising atmosphere are usually marked by clouds and rainfall, while the areas of high pressure and falling atmosphere are marked by clear, or clearing weather. In the low, damp areas, then, the air feels heavy while it is really light; in the high and dry area the air feels light, while it is really dense, and most favorable to air men for carrying heavy loads in their balloons or flyers. Similarly when air flows over a mountain range the ascending stream precipitates moisture, due to cooling by expansion, while the descending stream, on the other side, comes down hot and dry, due to compression.

A characteristic mechanical feature of the high and low pressure areas is the closed circulation between them, involving practically the whole atmosphere below the isothermal layer. If we conceive the entire globe spotted with high and low areas, we may picture the air surging upward in the lows, flowing outward under the isothermal layer, descending in the highs, then flowing outward along the earth's surface toward the lows in a continuous cycle. Thus, chiefly is maintained the vast and multifold circulation of the atmosphere over the entire world.

In general the motion is of a vortical nature, by which is meant that the masses of air as they flow along stream suffer more or less change of orientation in space, the rotation at times being so slight as to be undetectable, and again so marked as to excite wonder, as in the whirlwind. Many of these atmospheric vortices, even though varying in diameter from a few yards to hundreds of miles, resemble in their behavior the gyrating column of water in a common circular basin emptying through an orifice at its bottom. If the water is very still when the drain opens, the column descends with imperceptible, if any, rotation; but if the column has an initial whirl, or angular velocity, this is magnified as the water approaches the axis of the vortex, the tendency of the mass being to preserve its angular momentum, or fly wheel property. A like action obtains in the great atmospheric vortices, though here the motion far from the axis may seem like a straight-blowing wind, rather than part of a vast whirl covering thousands of square miles.

But even if all the air started directly for the axis of the ascending column, like still water in a basin, it would promptly acquire vortex motion, because it flows on the surface of a rotating sphere. The deflection so produced is evidently greatest at the poles, and for other places equals the polar value multiplied by the sine of the latitude. The effect is similar to what occurs when a basin, rotating about a vertical axis and carrying water with the same angular velocity, is opened at the bottom. In this case the water at once begins to gyrate within the basin, as the particles move toward its axis.

With these preliminary generalities we may proceed to study the more prominent movements in the atmosphere.

CHAPTER XV

PERMANENT AND PERIODIC WINDS

THE winds of the world are commonly classified as the permanent, the periodic and the nonperiodic, according to their genesis and character. Their chief features may be briefly outlined.

The most conspicuous and important aërial current on the globe is the permanent double vortex playing between the equator and the poles. The heated air of the equatorial belt, uplifted by expansion, overflows beneath the isothermal layer toward the north and south, thereby increasing the pressure in the higher latitudes sufficiently to generate a surface inflow along the earth, and thus maintaining a perpetual closed circulation which is felt all over the globe. The main features of this motion have been determined mathematically by Ferrel,[1] and summarized as follows:

"In the preceding part of this chapter it has been shown that, if all parts of the atmosphere had the same temperature, there would be a complete calm over all parts of the earth's surface. But that, in consequence of the difference of temperature between the equatorial and polar regions of the globe, and the consequent temperature gradient, there arise pressure gradients and forces which give rise to and maintain a vertical circulation of the atmosphere, with a motion of the air of the upper strata of the

[1] *A Popular Treatise on the Winds.*

atmosphere from the equator toward the poles, and a counter current in the lower part from the poles toward the equator, as represented by the arrows in the following figure, and that this of course requires a gradual settling down of the air from the higher to the lower strata in the middle and higher latitudes and the reverse in the lower latitudes. It has also been shown that in case the earth had no rotation on its axis, this would be exclusively a vertical circulation in the planes of the meridians without any east or west components of motion in any part; but that, in consequence of the deflecting forces arising from the earth's rotation, the atmosphere at the earth's surface has also an east component of motion in the middle and higher latitudes, and the reverse in the lower latitudes, and that the velocities of the east components increase with increase of elevation, so that at great altitudes they become very much greater than those at the earth's surface; while those of the west components decrease with increase of altitude up to a certain altitude, where they vanish and change signs and become east velocities, now increasing with increase of altitude to the top of the atmosphere.

"It has been further shown that the deflecting forces arising from the east components of motion of each hemisphere from the earth's surface to the top of the atmosphere, in the middle and higher latitudes and of the upper part of the atmosphere in the lower latitudes, drives the atmosphere from the polar regions toward the equator, while those arising from the west components of motion in the lower part of the atmosphere in the lower latitudes, having a contrary effect, but small in comparison with the other on account of the weakness of these forces near the equator, tend to drive the air a little from the equator toward the poles. There is, therefore, a depression of the isobaric surfaces at all altitudes in the polar regions, especially in the southern hemisphere, a much smaller depression in the equatorial regions, and a bulging up of the isobaric surfaces in the vicinity of the parallel of 30° in the lower part of the atmosphere, the maximum being nearer the

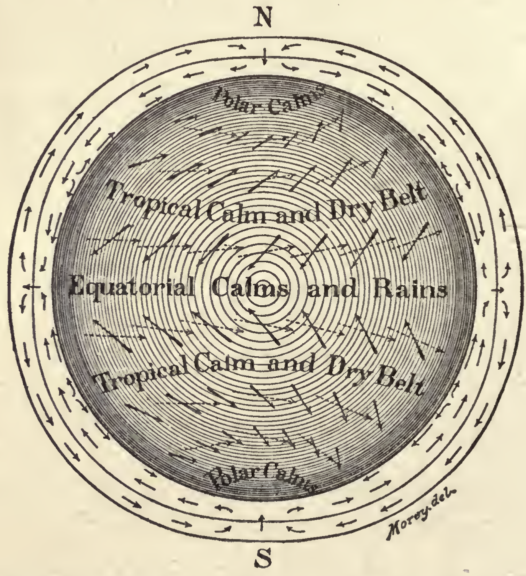

FIG. 45.—GENERAL CIRCULATION OF THE ATMOSPHERE.

equator as the altitude increases, as represented in Fig. 45, but at high altitudes there is a minimum of barometric pressure at the poles and a maximum at the equator.

"In the accompanying figure the solid arrows in the interior part represent the resultant motions of the winds (longer arrows indicating greater velocities), in case of an earth with a homogeneous surface over both hemispheres, in which the motions would be symmetrical in both and the same at all longitudes, and the equatorial and tropical calm belts would be situated at equal distances from each pole. The dotted arrows indicate the strong, almost eastern motion of the air at all latitudes at some high altitude, as that of the cirrus clouds.

"The outline of the outer part of the figure represents an isobaric surface high up where the bulging up near the parallel of 30° disappears and the maximum pressure at the same altitude is transferred to the equator. For lower altitudes the isobaric surfaces have a bulging up at the parallel of 30°, and a slight depression at and near the equator. The arrows in this part represent the polar and equatorial components of motion, the former above and the latter below, except near the earth's surface on the polar sides of the tropical calm-belts, where there is a polar component of motion arising from the air's being pressed out from under the belt of high pressure. This, perhaps, does not extend beyond the polar circles, beyond which there can be little motion in any direction, except from abnormal disturbances.

"For reasons given in § 103, the actual mean position of the equatorial and tropical calm-belts are not precisely as here represented, but are all a little displaced toward the north pole, and the polar depression of the isobaric surfaces is greater in the southern than in the northern hemisphere."

The conclusions from this approximate analysis are in the main supported by observation, except as modified by the heterogeneity of the earth's surface. The sea-level distribution of barometric pressure between the equator and poles, as found by Ross' long series of measurements, manifests a variation of about one inch of mercury, with maxima at about 30° of latitude, north and south, as required by Ferrel's theory. As a further cause of the depression toward the poles, may be mentioned the greater speed of the permanent east wind with the consequent centrifugal lift in the atmosphere.

As to the general easterly direction of the winds at middle and higher latitudes, that is well known from observation of the motion of clouds and of the air near the earth At the cirrus level the velocity in those latitudes is almost exactly eastward. But the flow in longitude, illustrated by the outer arrows in Fig. 45, has not been fully determined by observation. Moreover, as Ferrel himself showed, the unequal heating of continents and oceans sets up gradients in longitude, especially in the northern hemisphere, thus adding considerable disturbance to the general circulation. To this agency must be added also the latitudinal shifting of insolation, due to the annual march of the sun across the equator, entailing an oscillatory seasonal shift of the hot belt, and therefore of the twin-hemispheric cycle of the atmosphere.

Some currents of the general and permanent circulation are sufficiently prominent to have special names, such as the *trade-winds,* the *antitrade-winds,* the *prevailing westerlies,* and, in the lower latitudes, the *calm belts,* where the flow is exceptionally feeble. All these currents have been known to sailors since early times, and have been of considerable importance in marine navigation. Eventually, perhaps, they may be of like importance in aërial navigation.

The trade-winds are mild tropical surface currents of remarkably steady speed and direction. Springing from the high-pressure belts in either hemisphere, at about latitude 30°, they blow toward the equator with increasing westerly trend. As shown in charts 46 and 47 for midwinter and midsummer, the trade winds cover a large portion of the tropical zones in both oceans, and shift slightly in

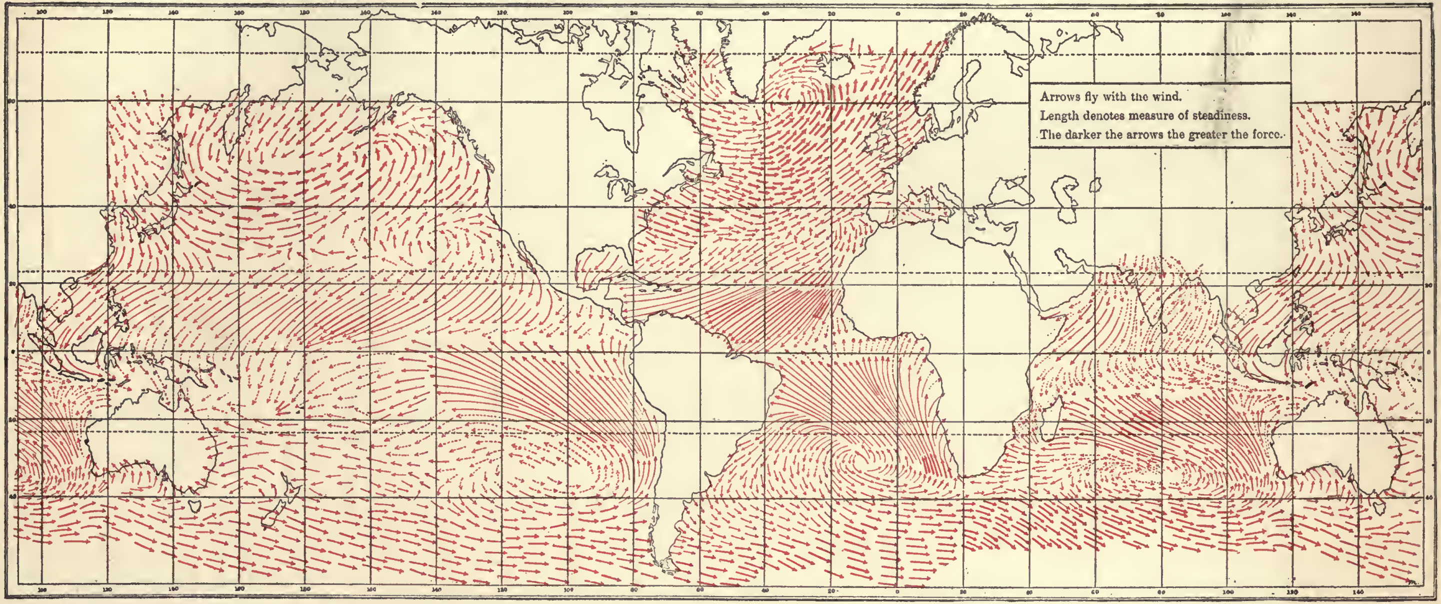

FIG. 46.—NORMAL WIND DIRECTION AND VELOCITY FOR JANUARY AND FEBRUARY. (KÖPPEN.)

latitude with the sun. They are separated at the heat equator by the equatorial calm belts, or doldrums, and are bounded north and south respectively by the calms of Cancer and of Capricorn. Particularly interesting are the trade-winds blowing from Spain to the West Indies, which favored Columbus on his westward voyage, and which certain adventurous Germans have proposed using to duplicate that memorable voyage, in air ships.

The antitrade-winds, or counter trades, are lofty winds blowing over and contrary to the trade winds. As some doubt regarding the direction of these counter trades had existed, an expedition was sent in 1905, by two distinguished meteorologists, Teisserenc de Bort of France, and A. Lawrence Rotch of America, to explore the atmosphere above the tropical Atlantic. Mr. Rotch has summarized their measurements and conclusions as follows:[1]

"Pilot balloons, dispatched from the island of Teneriffe and St. Vincent, were observed with theodolites at the ends of a base-line, and in this way the heights at which the balloons changed direction could be ascertained. Later the balloons were sent up from the yacht itself, which steamed after them, measurements being made of their angular elevation. The observations which are plotted in Fig. 46 prove conclusively the existence of the upper counter-trade. The courses of the balloons are represented as if projected upon the surface of the sea and show that the northeast trade-wind extended only to the height of 3,200 or 4,000 meters, and then gradually turned into a southerly current which, higher up, came from the southwest. The width of the dotted band represents approximately the varying velocity of the trade and counter-trade. Similar

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[1] *The Conquest of the Air.*

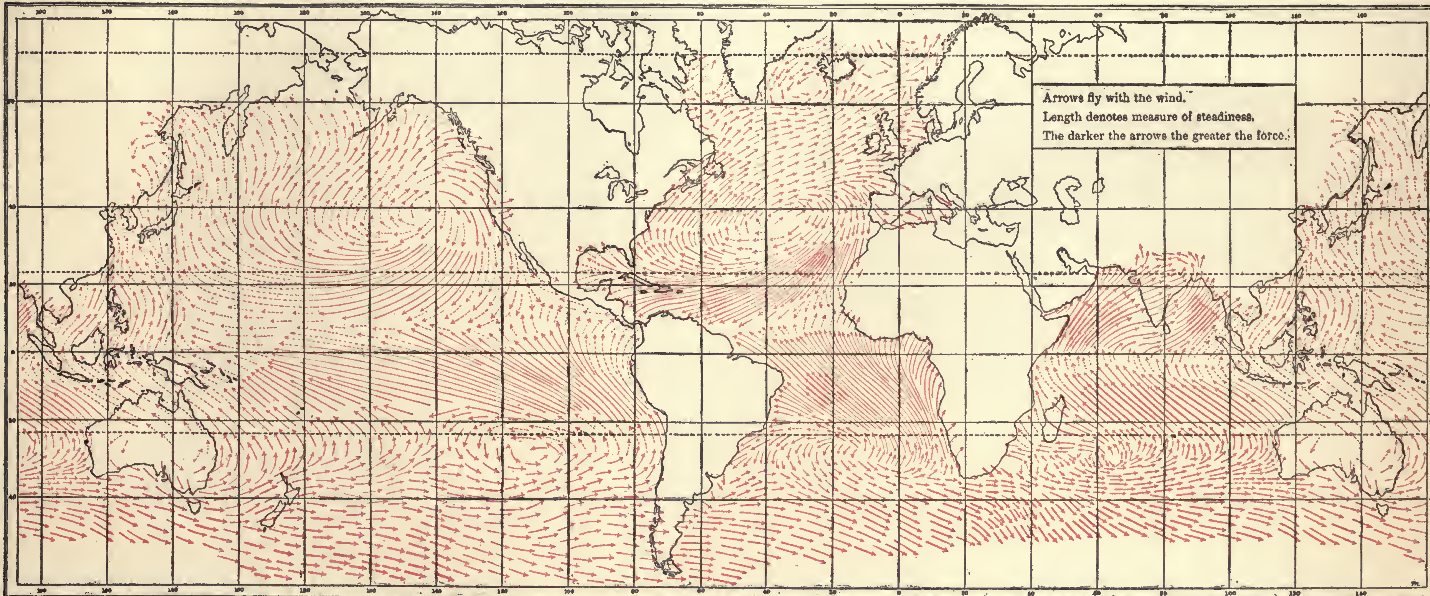

FIG. 47.—NORMAL WIND DIRECTION AND VELOCITY FOR JULY AND AUGUST. (KÖPPEN.)

proofs of the northwest trade-wind, south of the equator were obtained by the same expedition during the following year, but the above suffices to show that it would be possible for an aëronaut in the ordinary balloon to start from the African coast, or from

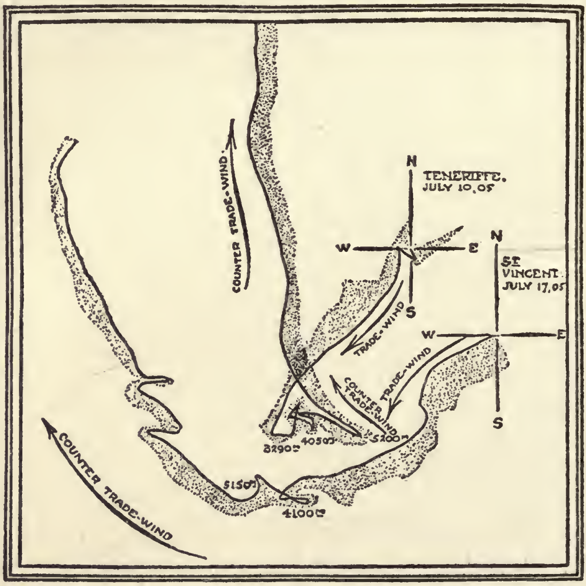

FIG. 48.—TRADE AND COUNTER TRADE-WINDS.

some of the islands in the trade-wind region, and, after drifting towards the southwest, to rise a few miles into the current, which would carry the balloon north and eventually northeast back to land. Nevertheless, it does happen in certain atmospheric situations over the tropical north Atlantic that the winds from the general northwesterly direction prevail up to great heights without any evidence of the return-trade. Near the equator the winds are easterly up to the greatest heights which have been attained."

The prevailing westerlies are high-latitude surface winds of the permanent circulation. In the southern hemisphere they are particularly strong and steady owing to the comparatively unbroken stretch of ocean. In the north also they are strong and persistent, but variable in direction because of disturbances by local winds due to unequal heating of tracts of land and sea. These features are well illustrated in charts 47 and 48. Of particular interest in aëronautics is the prevailing wind blowing from the United States to Europe, which has been considered a suitable current for transoceanic balloon voyages.[1]

The periodic winds are those whose gradient alternates annually or daily, due to annual or daily fluctuations of temperature on sloping or on heterogeneous parts of the globe. The annually fluctuating winds due to alternate heating and cooling of continents, or large land areas, bear the general name of monsoon. Among diurnal winds the most prominent are the land-and-sea breezes, and the mountain-and-valley breezes. Both kinds are practically available in aëronautics; the monsoons for long-distance travel, the diurnal winds for local use.

The general motive cause is the same for all periodic winds. When any portion of the earth's surface is periodically more heated above its normal temperature, or average for the year, than the neighboring region, the resulting abnormal temperature gradient causes a periodic surface wind tending toward the excessively heated place, and a counter wind above. That is, the cooler and heavier column of air sinking and uplifting the lighter, results in a lowering of the common center of gravity of the two

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[1] By this current John Wise, in 1870, and Walter Wellman, in 1910, proposed to voyage across the Atlantic; Wise in a free balloon, Wellman in a motor balloon with drag rope. See pp. 74, 75.

columns of air, and thus furnishes the driving power of the wind. For example, an island or a peninsula may be considerably hotter by day and cooler by night than the surrounding water; a continent may be much hotter in summer and much colder in winter than the bordering ocean. Thus during the hot period a moist wind blows landward; during the cold period a dry wind blows seaward. If the land has vast and lofty slopes the uprush of air during the hot period and the downrush during the cool period may be very powerful. The currents so produced by the aggregate of local agencies, including the deviation caused by the earth's rotation, combine with the general circulation of the atmosphere to form the actual wind of the place. Thus the periodic current may conspire with the general circulation, or oppose it; may intensify, weaken or obliterate it; may overmaster, reverse or mask it completely.

Of the various continental monsoons of the globe the most powerful spring from the annual flux and reflux of the atmosphere over the vast declivities and table-lands of Asia. Here the conditions are especially favorable. As the sun approaches Cancer, the burning deserts and high plateaus, combining their force with the draft on the mountain sides, generate a continental uprush that sucks in all the aërial currents of the surrounding seas, hurling them aloft to the isothermal layer whence they radiate as the four winds of heaven; for here at this season the planetary circulation is disrupted, obliterated or reversed, appearing merely as a perturbation of the monsoon at its height. In India the force is particularly effective. Along the north the Himalayas stretch 1,300 miles in latitude, with an average height of 18,000 feet and with sunburned areas on either side. North of this range are the lofty plateaus of Thibet and Cashmere, south of it the desert of Gobi and the borders of the Indian Ocean. Over this watery tract from beyond the equatorial line, from the isles of Oceanica and from the wintry plains of Australia, the air flows in with accumulated strength, sweeping the Bay of Bengal and the Arabian Sea in a continuous gale bearing up the mountain slopes incredible floods of water. Over the Arabian Sea in summer the gale is so steady and swift that no ordinary ship can force a passage from Bombay to the Gulf of Aden. Above the Bay of Bengal the moist south winds, converging between the coast and headlands, pour cloud laden up the Himalayan slopes, precipitating their whole vapor in prodigious torrents seldom seen elsewhere. Khasia at this season sustains a Noachian deluge, the rain at times falling nearly a yard deep in one day and night.[1] Quite appropriately, therefore, the summer monsoon over India, especially its component southwest wind from the Arabian Sea, and southerly wind from the Bengal Bay and farther east, is called the wet monsoon.

The winter monsoon of Asia, is the reverse of the summer one, both in direction of gradient and in physical character. It is a cold flood of air pouring from the frigid table-lands and wintry depths of the desert, down the mountains and valleys in continual overflow on all sides of the continent, and then far out over the sea, where it reascends to complete its long cycle. In its descent all moisture vanishes by heating, and no intensive temperature gradient occurs, as in summer, to accelerate its gently modulated tide. In India the winds from Cashmere and Thibet pour down the Himalayas toward the Arabian Sea a clear current of air which unites with the

[1] It is reported that once during the month of August the rainfall totaled thirty-two feet; and it is believed that the annual fall exceeds fifty feet.

trade-wind, increasing its force, and forming the moderate winter monsoon of that region, or as it is commonly called, from its lack of moisture, the dry monsoon.

The kinematic character, and the extent of both summer and winter currents, are well portrayed in charts 47 and 48 for all the south and southeast of Asia. Across the islands of Japan, it will be observed, the winds blow in opposite directions summer and winter. In Siberia the monsoon winds trend along her great rivers and valleys, generally northward in the winter and the reverse in the summer, combining in both seasons with the prevailing westerlies, due to the rotation of the earth.

All the other continents have their monsoons, though less powerful than those of Asia. In the great desert of Sahara, for example, there is an ascending hot current in the summer, causing a strong indraught from the Atlantic and the Mediterranean; but this is far less intense than if its action were fortified by lofty slopes and table-lands. In winter when the Sahara cools to nearly the oceanic temperature, little monsoon effect is perceptible, and the general circulation continues unperturbed. In Australia the monsoon influence is still feebler, owing to the limited extent of the country and to the general lowness and flatness of the land. Over parts of South America the annual ebb and flow of the atmosphere is considerable, particularly along the northeastern coast, and in the whole Amazon Valley, whose aërial currents in general conspire with the trade-winds, strengthening them materially in the southern summer, though it is less in winter when the continental temperature more nearly approximates that of the ocean. The monsoons of North America have been described in some detail by Ferrel as follows:

"On the continent of North America we have monsoon influences similar to those of Asia, but not nearly so strong, because the extent of the continent, and consequently the annual range of temperature, are not so great. They are, for the most part, not sufficiently strong to completely overcome and reverse the current of the general circulation of the atmosphere, and so to produce a real monsoon, but they cause great differences between the prevailing directions of the winter and summer winds.

"In the summer the whole interior of the continent becomes heated up to a temperature much above that of the oceans on the same latitudes on each side—indeed, above that of the Gulf of Mexico and the Pacific Ocean on its southern and southwestern borders. The consequence is that the air over the interior of the continent becomes more rare than over the oceans, rises up and flows out in all directions above while the barometric pressure is diminished, and the air from all sides, from the Atlantic on the east to Pacific Ocean on the west, the Gulf of Mexico on the south, and the polar sea on the north, flows in below to supply its place. On the east the tendency to flow in is not strong enough to counteract the general easterly motion of the air at the earth's surface in the middle latitudes, and to cause a westerly current, but it simply retards the general easterly current and gives rise to a greater prevalence of easterly winds along the Atlantic sea-coast during the summer season. . . .

"In winter the thermal conditions over the continent are reversed. The interior of the continent is now the coldest part, and it is especially colder than the surrounding oceans at that season. It has also very high plateaus and mountain ranges. The air, therefore, of the lower strata, and especially those next the earth's surface, now tends to flow out in all directions to the warmer oceans and the Gulf of Mexico, and especially to run down the long slope of plateau from the Rocky Mountains into the Mississippi Valley. The effect over the whole of the United States east of the Rocky Mountains is to cause the winds, which otherwise would be westerly and southwesterly, to become generally northwesterly winds, instead of southerly and southwesterly ones, as in summer. There is not a complete monsoon effect, but simply a great change between summer and winter in the prevailing directions of the winds. In Texas, however, and farther east along the northern border of the Gulf, the effect is somewhat that of a complete monsoon. In New England and farther south in the Eastern States the monsoon effect is to cause the prevailing winds to be from some point north of west, instead of south of west as in summer.

"In summer, Central America and Mexico have a much higher temperature than that of the adjacent tropical sea on the southwest, and having high mountain ranges and elevated plateaus, there is consequently a strong tendency to draw in air from the southwest at this season, which not only entirely counteracts the regular trade-winds of these latitudes, but even reverses them and causes southwest winds. The effect is to cause in midsummer a large area here, extending far westward, of calms and irregular and light winds, mostly southwesterly ones, and an apparent widening of the equatorial calm-belt at this season so as to make its northern limit reach up, along the coast, nearly to the parallel of 20°. The effect is similar to that in the Atlantic west of the Gulf of Guinea and Liberia, except that it here appears to be some greater, and causes a true monsoon effect, since during the winter the regular northeasterly trade-winds prevail, but strengthened by the reverse thermal conditions of the winter season. On the eastern side, and over the western end of the Gulf of Mexico, there is a somewhat regular monsoon effect, the prevailing winds being easterly, or blowing toward the land, during the summer, and the reverse in winter.

"Along the west coast of North America in the middle latitudes there is a strong monsoon influence; for the interior of the continent becomes heated in summer to a much higher temperature than that of the southwesterly ocean, and hence a strong current is drawn in from this direction, at right angles to the general trend of the coast which, combining with the general southwesterly winds of these latitudes in the general circulation of the atmosphere, causes the strong and steady westerly and southwesterly winds of this region during the summer. Farther north, up toward Alaska, the summer monsoon effect is combined with the current caused by the deflection of the continent as well as the general easterly current of high latitudes, so that the winds here are generally southerly, but still have somewhat of a monsoon character, being southerly and southwesterly in summer and easterly and southeasterly during the winter.

"Along the northern coast of America, as along that of Siberia, the monsoon tendency is to draw the air from the colder land to the warmer ocean in winter, and the reverse in summer; and these effects, combined with the general easterly motion of the atmosphere in these latitudes, gives rise to prevailing southwesterly winds in winter and northwesterly ones in summer. The winter monsoon influence, however, is small here—much more so than in Siberia, for the ocean contains so many large islands that it has rather a continental than an oceanic winter temperature; and besides, it has not the influence of a warm current—such as the continuation of a part of the Gulf Stream along the northern coast of Europe and Asia."

Similar to the monsoons in essential nature are the diurnal winds of seacoast and mountain side. They begin with the heating of the land in the morning, attain their maximum intensity about mid afternoon, or during the hottest of the day, and finally are reversed at night. Besides being so much briefer than monsoons, they are also in general feebler and less extensive. They may be quite noticeable on calm days, especially in clear weather and in hot climates; but usually they are masked or entirely overwhelmed where other marked currents occur—currents due either to the general circulation or monsoons, or other powerful disturbing agencies.

In land-and-sea breezes, which usually extend not far inland, there is a surface inflow of sea air during the forenoon and early afternoon, balanced by an outflow of warm air above, rising from the heated soil. After sundown this is reversed, the chilled air from inland pouring out to sea, while overhead the warmer sea air is forced landward at a higher level. These currents are strongest where the diurnal range of temperature is greatest and where the local topography is of suitable configuration. Particularly favorable are steeply declining shores, narrow bays and inlets, girded by mountains or lofty hills. During the day heated air ascends such declivities with alacrity, like smoke through an inclined flue, while at night, when cooled by radiation and contact with the soil, it rushes torrentlike down the valleys and hillsides, passing out to sea, often in sudden squalls that embarrass, or endanger, small sailing craft. Circulatory currents like the above have sometimes been used by aëronauts to carry them out to sea and back again to land at a different level.

In like manner the mountain-and-valley winds may be used by the skillful aëronaut. It is well known that these flow up the courses of rivers, cañons and land slopes generally by day, but at night reverse their course and pour down again with considerable force. For this reason experienced hunters place their camp fires below tent in a sloping valley. The strength of the breeze depends, of course, upón the daily range of temperature, and the steepness and expanse of the slope. Such winds are deftly used by the masters of soaring flight, the great robber and scavenger birds, and no doubt may be used by men in motorless aëroplanes, to gain elevation, and journey great distances without expenditure of energy.

CHAPTER XVI

CYCLONES, TORNADOES, WATERSPOUTS

Besides the periodic winds so far treated, there are prominent aërial movements having no regular course or season. These are the nonperiodic winds which so exercise or perplex the weather forecaster and those who confide in him. In general such winds are of a temporary character, arising from an unstable condition of the air in some locality, or from unequal heating, either of which causes may generate, or briefly sustain, an updraught, with its attendant gyration. Owing to the whirling character of such ascending currents, they have received various significant names, such as cyclone, tornado, whirlwind; the three terms applying to vortices in decreasing order of magnitude. Each in turn may be treated briefly.

The cyclone is a temporary large gyratory wind. It may last a few hours or a few days. It may measure fifty to a hundred miles across, or it may measure more than a thousand miles. On the weather map it is in general marked by a group of closed isobars, showing a considerable pressure gradient toward a small internal area where the pressure is a minimum. To an observer looking about the earth's surface and lower levels of the atmosphere, the cyclone appears merely as an ordinary wind, accompanied perhaps by rain or snow. It is not a swiftly rotating narrow column, or cone of air, like a tornado or whirlwind, full of gyrating dust and débris.

The motive power of a cyclone, though in general due to the buoyancy of heated air, may spring from more than one set of conditions. Notice has already been taken of vortices due to a hot column of air at lower barometric pressure than its lateral environment. Take another case. If a dry atmosphere is of uniform temperature and pressure at various levels, but has a vertical temperature gradient a little greater than the normal cooling of an ascending gas, a portion of air started upward in any casual way becomes warmer than its lateral environment, and hence continues to rise until the unstable condition due to abnormal temperature gradient ceases. Again, while the surface stratum is in stable equilibrium, it may happen that the second mile of air is abnormally hot, and the third mile abnormally cold, and thus a vortex may occur in mid air, without disturbing the face of the earth.

Whatever be the initial atmospheric condition causing the vertical uprush, the nature of the resulting circulation is in general that of the cyclone, illustrated, in part, by the whirling vortex of water in a basin. As the current ascends, an indraught occurs in all the lower regions of air, and an outflow in all directions above, sometimes at the height of a mile or two, again in all the region next to the isothermal layer. As the earth has at all places above the equator a component of rotation about the vertical line, it follows that in northern latitudes all the air flowing toward the vortex is in a whirl opposite in motion to the hands of a watch lying face upward, and all the outflowing air above has a like angular motion, but gradually diminishing until it is reversed. At the lower portion of the vortex the air whirls inward and upward with increasing velocity, while above, it whirls outward and upward, with waning velocity, thus moving in a double-spiral path shaped like a cord wound on an hourglass. In the constricted part, or neutral plane of the vortex, the air moves neither outward nor inward, but spirals straight upward. To match the upflow, and complete the closed circulation, there must be a downflow on the exterior of the cyclone, and since the whirl is reversed in direction, this outer mass of downflowing reverse-whirling air embracing the cyclone is called the anticyclone.

Between the inner and outer vortex the air is comparatively calm and the pressure is a maximum, with steepest gradient toward the center of the cyclone. Also the air is calm just at the axis of the vortex, while for some distance away its speed increases as the radius of its whirl, so that the central mass rotates practically as a solid column, thus still further lowering the pressure near the axis. This solidly rotating central column of air is sometimes called the core of the vortex.

High above the center of the cyclone, where perhaps the air is sucked downward, clarified by compression, then whirled outward, the sky is usually clear, or thinly fogged, while without this central patch are heavy clouds. The obscure or clear central part is called the "eye [1] of the storm." Through this the cirrus clouds may sometimes be seen high above, either stationary or radiating away, if the vortex extends so high. Sailors on the deck of a vessel passing through a cyclone have often noticed the eye of the storm overhead, perhaps ten or twelve degrees in diameter, and with special clearness in

[1] The "eye" is most noticeable at sea, where the cyclones are more symmetrical, and particularly in lower latitudes, where they are more concentrated.

the tropics. To the white, feathery cirrus clouds, scurrying away radially from the top of the vortex, they have given the name "plumes of the storm," or "mares' tails." In sailing their vessel through the center of a cyclone, they have observed the circulatory motion of the winds and clouds, and frequently have found the deck covered or surrounded with cyclone sweepings, such as land and water birds, insects, butterflies, etc., brought into the quiet core of the vortex from the incurving winds beyond. Further details of the motion in a cyclone vortex are given as follows by Ferrel, §178:

"In Fig. 49 is given a graphic representation of the resultant motions and of the barometric pressures for both the surface of the earth and for some level high up in the atmosphere and above the neutral plane, where the motions in the vertical circulation are outward from the center. The solid circles represent isobars at the earth's surface and the solid arrows the directions, and in some measure, by their different lengths, the relative velocities of the wind. The heavy circle represents the circle of greatest barometric pressure at the earth's surface, say 765 mm., while the pressure of the outer border is 760 mm., and the dividing line between the cyclone and the anticyclonic gyrations. Within this limit the pressure diminishes to the center, and the gyrations are cyclonic, and the direction of the resultant of motion inclines in toward the center, but beyond that limit the gyrations are anticyclonic, and the direction of resultant motion inclines toward the outer border of these gyrations. The heavy dotted circle represents the circle of maximum pressure at some high level, and is much nearer the center than that at the earth's surface. It is also the dividing line between the cyclonic and anticyclonic gyrations at that level. The dotted arrows indicate the directions and in some measure the relative velocities, of the wind at this level. The arrows in the cyclonic part represent the direction of the wind as declining outward, because the plane here considered is supposed

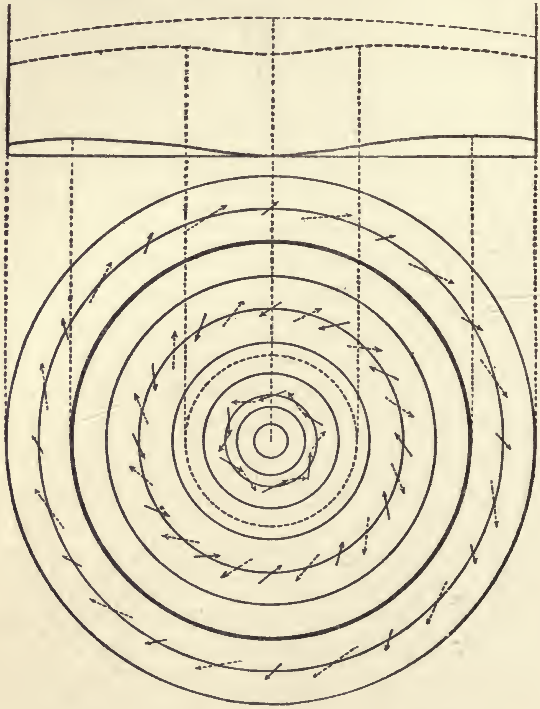

FIG. 49.—VELOCITY DIAGRAM IN HORIZONTAL SECTION OF A CYCLONE.

to be above the neutral plane, where the radial component of motion is outward, but for any level below the neutral plane the inclination is still inward. The arrows are shorter above in the cyclonic part and longer in the anticyclonic part than they are at the earth's surface, since the cyclonic gyratory velocities decrease and the anticyclonic increase with increase of altitude.

"The upper part of the figure is a representation of a vertical section of the air, very much exaggerated in altitude, in which the solid curved line represents a section of an isobaric surface near the earth's surface, say of 740 mm. barometric pressure. The lowest part corresponds with the center of the cyclone and the highest part with the heavy circle in the lower part of the figure, and the steepest gradients with the longest solid arrows, since the greater the gyratory velocities at the earth's surface the greater the gradients, though they are not strictly proportional. The second dotted curved line from the top represents a section of the isobaric surface of high altitudes, in which the highest parts correspond with the heavy dotted circle below, since the highest pressure at all altitudes is very nearly where the cyclonic gyrations vanish and change to the anti-cyclonic. The depression here is smaller because the cyclonic area is smaller, and the gyratory velocities less, than at the earth's surface. The upper dotted line belongs to an isobaric surface still higher, where the gyrations are supposed to be all anti-cyclonic, and here, consequently, the greatest pressure is in the center, as indicated by the curved line.

"As the interior of the whole cyclonic system is warmer than the exterior, and consequently the air less dense, the distances between the isobaric surfaces are necessarily greater in the interior than the exterior part, and so, however much the isobaric surface at or near the earth's surface may be depressed by the cyclone gyration there, at a considerable altitude, if the temperature difference is great enough, it must become convex instead of concave.

"The track of any given particle of air in a cyclone, resulting from the vertical and gyratory circulation, is that of a large converging and ascending spiral in the lower part, but of a diverging and ascending spiral in the upper strata of the atmosphere, and the nearer the earth's surface the more nearly horizontal is the motion, since the vertical component gradually decreases and vanishes at the surface.

"The whole energy of the system by which the inertia of the air and the frictional resistance are overcome and the motions maintained, is in the greater interior temperature and the temperature gradients, by which the circulation is maintained. This being kept up, the deflections and gyrations are merely the result of the modifying influence of the earth's rotation, which is not a real force, since it does not give rise to kinetic energy, but merely to changes of direction.

"It must be borne in mind that the preceding is a representation of the motions and pressures of a cyclone resulting from perfectly regular conditions, in an atmosphere otherwise undisturbed, and having a uniform temperature, except so far as it is affected by the temperature disturbance arising from the cyclonic conditions. Accordingly results so regular are not to be found in Nature, but generally only rough approximations to them.

"Since the wind inclines less and less toward the center of the cyclone below the neutral plane and declines from the center above it, the upper currents above this plane in a cyclone are always from a direction, in the northern hemisphere, a little to the right of that of the lower currents, when not affected by abnormal circumstances."

Observation of cyclones in Nature very well confirms the leading features set forth on theoretical grounds. If the vortex pass centrally over an observatory there is noted first a high barometer and calm air, attended perhaps by scurrying cirrus clouds; next a rapidly falling pressure and increasing wind, with dark clouds and precipitation, commonly accompanied by thunder and lightning; then the hushing of the storm to a dead calm, and low barometer and thinning or clearing of the clouds overhead; then a rising barometer with renewed winds in the reverse direction, and finally subsiding winds, rising barometer and clearing weather. These phenomena are the more definitely presented if the whirl is strong while its travel along the earth is slow. But owing to their progressive easterly motions, cyclones in the north have their moist hot southern masses elevated, chilled and precipitated on their eastern fronts and beyond, while their rear experiences the opposite action and is called the clearing side. Conversely in the tropics the westerly moving cyclones have cloudy and wet rears, because the easterly drift on high carries the precipitating masses toward the rear. The general hygrometric appearance of a centrally passing cyclone in middle latitude is thus described by Ferrel, §207:

"In the regular progression of a cyclone in the middle latitudes somewhat centrally over a place, the cloud and rain area of the front part, extending far toward the east, first passes over, occupying a half-day, or a day and more, and then the front part of the ring of dense cloud with a heavy shower of rainfall. After this there are indications of a clearing up, and even the sun may break through the cloud for an hour or two; but presently there is an apparent gathering and thickening of the cloud and a second shower. This is at the time of the passage of the rear side of the ring of denser cloud. After this there is the final clearing up."

Except for special conditions, cyclones are never stationary, but drift along with the general march of the atmosphere, like dimpling eddies in a stately flowing river. In general, therefore, their trend is westward in lower latitudes, eastward in middle and higher latitudes, with a pace slow or swift according to the prevailing current. Notably also they have a poleward trend. Thus, if the path extends from tropic to temperate clime, it is frequently concave toward the east and sensibly parabolic in form. This is markedly true of those swift-whirling, small cyclones called hurricanes,[1] and particularly those vigorous ones blowing past the West Indies and the Philippines, and those that vex the Indian Ocean.

As to the speed of travel of cyclones, that may be judged, at least for northern latitudes, from the accompanying table, taken from Loomis,[2] and showing the average monthly rate of progression in miles per hour, of cyclone centers over the United States, the Atlantic Ocean and Europe. In general, beyond the tropics tall cyclones travel faster than short ones, owing to the faster drift of the higher strata.

Month.	United States.	Atlantic Ocean Middle Latitudes.	Europe.
January	33.8	17.4	17.4
February	34.2	19.5	18.0
March	31.5	19.7	17.5
April	27.5	19.4	16.2
May	25.5	16.6	14.7
June	24.4	17.5	15.8
July	24.6	15.8	14.2
August	22.6	16.3	14.0
September	24.7	17.2	17.3
October	27.6	18.7	19.0
November	29.9	20.0	18.6
December	33.4	18.3	17.9
Year	28.4	18.0	16.7

To find the actual speed of the wind at a place, of course, the linear velocities of whirl and of translation must be combined; or, vice versa, if one of these

[1] The destructive one that visited Galveston in 1900 is a well-known example.

[2] *Contributions to Meteorology.*

be known it can be graphically subtracted from the observed wind velocity to find the other. This combination of two wind components to find their resultant, or, vice versa, can easily be done by laying off on paper, arrows of suitable length and direction to represent the two known velocities, placing the head of one arrow to the tail of the other, then completing the triangle, and taking its third side to represent the required wind velocity, in magnitude and direction. Obviously if the cyclone moves eastward, whirling oppositely to the hands of a watch, the swiftest wind is on its right side, which consequently is known as the dangerous side. In the northern hemisphere, therefore, the rule for dodging a great whirlwind is to run north, if that be practicable.

Stationary cyclones occur under favorable conditions. At least that name has been applied to columns of hot air streaming up from a fixed base, more or less circular. Every island in the ocean generates such a vortex on a clear, hot summer day, since its temperature far exceeds that of the surrounding water. All day long this uprush continues whatever be the humidity. And if the soil slopes upward steeply, the vortex is so much the stronger, particularly if the island be in a calm region. Above such a tract the gulls and vultures, and possibly even man, might soar all day without motive power. This condition and its interesting possibility deserve investigation.

Cyclones may occur at any season, but in general they are most abundant when the greatest temperature disturbances occur. The relative frequency of tropical cyclones for various localities and for the twelve months of the year is seen in the following table[1]:

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[1] Dr. W. Dauberck, *Met. Zeitschrift*, April, 1866.

The Yearly Periods of Cyclone Frequency in Several Seas

	Arabian Sea.	Bay of Bengal.	S. Indian Ocean.	Java Sea.	China Sea.	Havana.
No. of years...	234	139	40	..	85	363
No. of cyclones	70	115	53	12	214	355
Authority.	Chambers.	Blanford.	Piddington Thom and Reid.	Piddington and Thom.	Schuck.	Poey.
Jan..........	6	2	17	25	2	1
Feb..........	4	0	25	42	0	2
Mar..........	3	2	19	8	2	3
April..........	13	8	15	8	2	3
May..........	18	16	7	0	5	1
June..........	29	9	0	0	5	3
July..........	3	3	0	0	10	12
Aug..........	3	4	0	0	19	27
Sept..........	4	5	2	0	27	23
Oct..........	6	27	2	0	16	17
Nov..........	14	16	7	0	8	5
Dec..........	3	8	6	17	3	2

The tornado is a slender cyclone or hurricane. It is usually but a few yards or rods in diameter, and seldom exceeds one mile across its active column, whereas a cyclone may cover an area of any size from fifty to one or two thousand miles in diameter. Moreover, the cyclone requires for its inception an extensive pressure gradient marked by closed isobars, and once generated may last several days. A tornado per contra may spring into action where the lateral pressure is uniform, spend its force in a few moments, and leave a uniform barometric field in its wake. In shape the tornado is usually of greater height than width. The cyclone is far-flung laterally, but in height may not exceed the narrow tornado, since both must terminate beneath the isothermal layer, and commonly do not extend so high. Both vortices are caused by the ascensional force of hot air. In both the air spirals in and upward at the bottom, out and upward at the top, constantly cooling by expansion, and finally descends on the outside to complete the closed circulation. In general the tornado is the more violent and destructive, though limited to a brief and narrow path. More aptly, perhaps, the tornado may be called a slender hurricane of brief duration; both of them being small cyclones, or aërial vortices, of minor size and concentrated intensity. The relation of the tornado and cyclone has been defined as follows, by Professor Moore:

"The cyclone is a horizontally revolving disk of air of probably 1,000 miles in diameter, while the tornado is a revolving mass of air of only about 1,000 yards in diameter, and is simply an incident of the cyclone, nearly always occurring in its southeast quadrant. The cyclone may cause moderate or high winds through a vast expanse of territory, while the tornado, with a vortical motion almost unmeasurable, always leaves a trail of destruction in an area infinitesimal in comparison with the area covered by the cyclone."

Two initial conditions seem essential to the genesis of a substantial tornado. In the first place, the atmosphere of its immediate locality must have appreciable gyration. Of course, in all extra equatorial regions the air has some incipient whirl due to the earth's rotation, and this whirl is magnified as the fluid is sucked into the vortex. But the magnification may be slight owing to the brief lateral displacement of the air feeding the tornado. If, however, the fluid be drawn from a considerable distance, and have from local conditions some additional whirl superadded to that due to the earth's rotation, the gyratory flow in the medium near the vortical axis may be very swift. On the other hand, the additional whirl, due to local conditions, may tend to neutralize that due to the earth's component, thereby leaving a very feeble gyration, if any. But in general the rotation of tornadoes is observed to be in the direction of the earth's component; to the left north of the equator, to the right south of it. This observation is doubtless the more striking because when the accidental local spin conspires with the permanent terrestrial one, the resultant whirl is intensified, while in the opposite case it is so enfeebled as to attract scant, if any attention.

In the second place, the genesis of a tornado requires unstable equilibrium in the local atmosphere. This instability, as in cyclones, may arise from abnormal temperature gradation. Thus, if along any vertical the temperature falls more than six degrees Centigrade for one thousand meters ascent, a mass of air started upward will continue to rise, since it cools less rapidly than the environing medium. In this way there will ensue a continuous uprush of air so long as the unstable state endures; and the action may be very vigorous if a large stratum of air is greatly heated before it disrupts into the cold upper layers. In general, the loftier the tornado the more violent it is, just as the taller flue generates the stronger draft with the same temperature gradient.

Dynamically, the tornado may be treated as a rotating pillar of air in which each mass of fluid fairly retains its angular momentum. This means that for any mass of the whirling air the radius of its path, multiplied by its circular speed, remains a constant product; in other words, the velocity of whirl varies inversely as the radius. Accordingly, the circular velocity is exceedingly rapid where the radius is very small. Now, when any mass runs round a circle its centrifugal force is known to be directly as the square of the speed of its centroid and inversely as the radius. But by the above assumption the speed itself is inversely as the radius. Hence, the centrifugal force varies inversely as the cube of the radius of the inflowing mass of air. This centrifugal force, acting on the inner layers of air of the rotating column, must be supported by the pressure against them exerted by the outer layers as they pass inward. Thus there is a strong barometric gradient from the remote still air toward the swiftly whirling parts of the vortex.

It follows from the above argument that inside a tornado the barometric pressure may be much below the normal; and it is easy to see that if a barometer, starting from some point on the tornado base, be moved vertically upward it must show a declining pressure, but if moved upward and outward it may be made to show a constant pressure all the way to the upper portion of the vortex. The instrument would thus travel along an isobaric, bell-shaped surface opening upward. On a series, therefore, of concentric circles on the base of a tornado, we may erect a family of coaxial bell-shaped surfaces to mark the points of equal pressure, and thus map out the isobars of the vortex. Inside these coaxial surfaces reaching to earth, others of still lower pressure may be drawn tapering downward to a rounded point and terminating at various places on the axis. In an actual tornado one of these infinitely numerous funnel-shaped isobaric surfaces may become distinctly outlined and visible, if the air has sufficient moisture to start precipitation when it reaches a surface of suitably low pressure. This quite usually occurs in Nature, the funnel sometimes reaching to earth, sometimes only part way, according to the pressure at which precipitation begins, this pressure depending, of course, on the percentage of humidity of the uprushing air.

The form of the funnel-like cloud ere it reaches the earth is interesting. Being an isobaric surface, it would support in static equilibrium a free particle resting on it and sharing its rotatory motion. The lower rounded part of the funnel is parabolic, the upper outer part hyperbolic; the two together delineating the well-known Rankine double vortex of hydrodynamics. Students of hydrostatics know that when a glass of water is spun round its axis at a fixed velocity, the dimple observed is of parabolic form, and if frozen will sustain in repose a small shot resting on its surface and whirling with it. Similarly the lower part of the funnel is parabolic because in it the air rotates, as one solid body, while the broader part of the funnel is hyperbolic because in it the air has a speed inversely proportional to its radius of motion.

If everywhere in a tornado the circular velocity of the inflowing air were inversely proportional to the radius, as above assumed, the speed near the axis would be indefinitely great. This cannot be admitted. Practically, the inflow ceases when the centrifugal force of the gyrating stratum equals the pressure urging it toward the axis. Within this stratum is a column of air rotating everywhere with constant angular velocity about the vortical axis, and thus having quite calm air at its center. Outside this solidly rotating core the air spirals radially inward and upward. Some idea of the stream lines in such spiral flow may be obtained from Fig. 50 if a rapid circular motion be added to the inward and upward velocity represented by the arrows.

In the foregoing discussion no account of friction was taken. Near the earth's surface this dampens the whirl and centrifugal force, so that the air flows more directly into the vortex, while farther aloft the centrifugal force near the axis so effectually checks the inflow as to allow the central core of air to rush up nearly unimpeded, as in a walled flue, taking its draught mostly from the lower part. As a consequence, the upward speed of the heated air in the tornado tube may be enormous, supporting in its stream objects of considerable mass.

The true horizontal speed anywhere in a tornado is compounded of the velocities of gyration and of translation, as in the cyclone. Hence the advancing side may be considerably the swifter and more destructive, particularly more destructive since the impact of air increases as the square of the velocity. If the vortex were stationary it would be equally dangerous on all sides, standing erect and symmetrical; but it drifts with the whole mass of air, sometimes quite swiftly and often with varying speed of travel at different levels; thus, in its slenderest forms, appearing bent and not infrequently twisted, as it advances writhing serpentlike through the sky. Furthermore, the intensity of whirl may fluctuate momentarily, with consequent shifting of the isobaric surface, including that one whose form is visible by reason of incipient condensation; and thus the funnel-like misty tongue appears to dart earthward as a foggy downshoot from the cloud above, whereas its parts are really rushing upward at all times very swiftly, whether visible or not. This agile protrusion of the nimbus, now a tongue, now a dark and mighty tower, is the strenuous part of the storm, the abominated "twister" which the Kansan farmer sedulously shuns, or peeps at from a hole in the ground. Unwelcome, indeed, are its visitations,

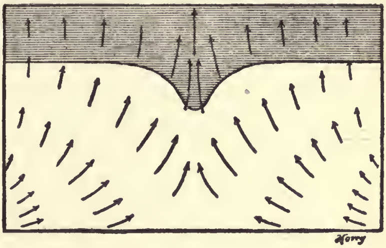

FIG. 50.—FUNNEL-LIKE CLOUD SOMETIMES OBSERVED IN A TORNADO.

when, with mickle and multitudinous roar, it claps his house in sudden darkness, hurls it aloft and sows its sacred relics over all the adjoining township, "that with the hurly-burly hell itself awakes."

Theory, as well as experience, accredits the tornado with vast energy and power. For, suppose a surface stratum of air one mile in area and one thousand feet thick to increase in absolute temperature one per cent, thus uplifting the superincumbent atmosphere ten feet. The total energy stored in this way equals the weight lifted multiplied by its upward displacement. The weight is a ton per square foot and the displacement is ten feet; hence the stored energy is ten-foot tons per square foot of the heated tract, or about 280,000,000 foot tons for the square mile of heated air. This is equivalent to the work of one million horses for over a quarter of an hour. A goodly percentage of this stored work may be converted into kinetic energy in the active part of the dry tornado. It is the energy of a vast reservoir suddenly gushing through a tall penstock. It is a colossal upward cataract, an aërial Niagara, a Johnstown flood suddenly liberated and quickly spent.

A vortex of that description possesses enormous devastating power, for it is endowed with four destructive elements: rapid onset for razing, violent spin for distorting, swift uprush for lifting, low pressure for disrupting. These four grim powers may operate at once and in accord. When, for example, they assault a house, the horizontal blasts push and wrench it on the foundation, the cellar air suddenly expanding puffs it aloft, the internal air bursts its walls or windows, the uprush carries its members on high and scatters them wantonly to the four winds. These powers are abundantly attested by authentic reports from many localities.

When the tornado appears as a misty column it is familiarly called a "waterspout," particularly if it appears over a sea or lake. As already explained, the visible and cloudy portion of the column is due to condensation of the aqueous vapor in the air, as it rushes expanding and cooling into the low pressure part of the vortex. From the lashed and rippling sea surface, where it upcones into the base of the spout, some water is carried aloft as spray

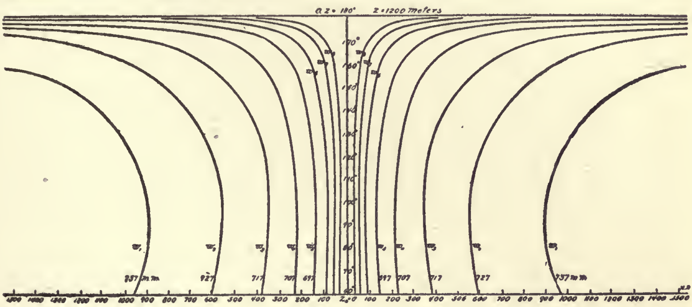

FIG. 51.—VERTICAL SECTION OF THE ST. LOUIS, MO., TORNADO OF MAY 27, 1896, SHOWING THE VORTEX TUBES IN A THEORETICAL, TRUNCATED, DUMBBELL-SHAPED VORTEX.

mingling with the mist of the chilled vapor, but not necessarily in very large proportion, and never rising in solid body to the cloud, as popularly supposed. On the contrary, waterspouts, however massive and formidable looking, are very tenuous, and may occur on land or water indifferently. Doubtless they are better defined, more regular and more familiar over water, and hence their name; but essentially they are vapor spouts, though mingled at times with dust or spray. Owing to rapid precipitation of the uprushing aqueous vapor, there may be heavy rainfall on all sides of the waterspout, so that at sea it may be difficult for the observer to ascertain how much of the downpour is salt water and how much is fresh.

On land the downpour is sometimes mingled with débris, and even with live fish and frogs caught up from neighboring bodies of water. Copious hail also may fall with the rain, if the vortex be a lofty one.

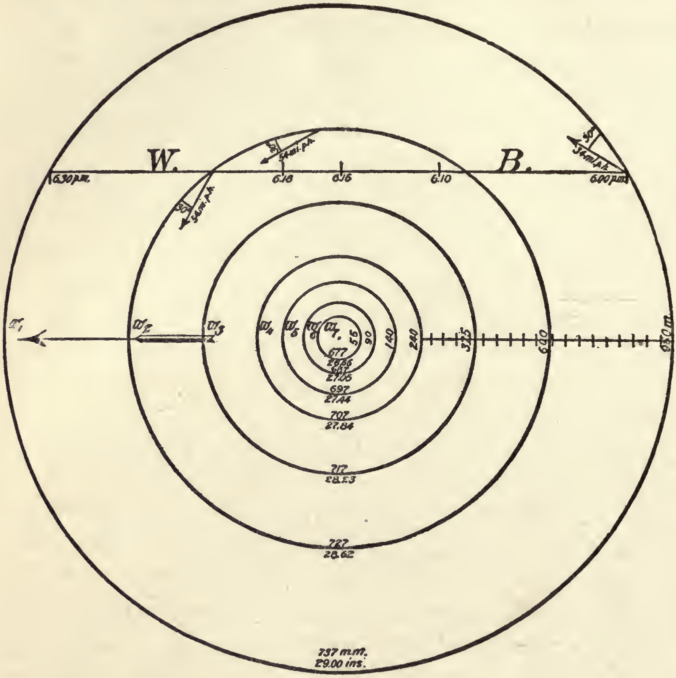

FIG. 52.—HORIZONTAL SECTION OF ST. LOUIS TORNADO OF MAY 27, 1896.

The following description and analysis of a representative spout is due to Professor Bigelow of the U. S. Weather Bureau:[1]

"The tornado may be illustrated by the St. Louis storm of May 27, 1896. It is a truncated dumbbell vortex cut off at the ground on the plane where the inflowing angle is about 30°. This vortex is much

[1] Moore's *Meteorology*, p. 164.

smaller than the hurricane, although of the same type. It is about 1,200 meters high and about 2,000 meters in diameter on the surface. The vortex tubes are shown in Figs. 51 and 52. In these figures can be seen the vortex tubes, geometrically spaced, through each of which the same amount of air rises. The rotating velocity is greatest about 300 meters above the ground, but the dimensions are such as to produce enormous velocities in the lower levels. The radius in the outer tube is taken to be 960 meters, and the inner tube 55 meters. The radial inward velocity on the outer tube is — 8 meters per second; on the outer tube the tangential velocity is 13 meters per second, and on the inner 224 meters per second; on the outer tube the vertical velocity is 0.27, and on the inner tube it is 80 meters per second. On the outer tube the total velocity is 15 meters per second, and on the inner tube 270 meters per second. The volume of air ascending in each tube is 774,500 cubic meters per second. On account of the distortion of the theoretical vortex, due to the cutting of the lower portion by the truncated plane, and to the progressive motion of the whole system that constitutes the tornado, there is difficulty in computing the pressure to fit these observed velocities and radii.

"Tornadoes occur in the southern and southeastern quadrants of areas of low pressure, along the borders of the cold and the warm masses which entered into the structure of the cyclone. When a cold mass is superposed upon a warm mass, as was the case at St. Louis, a tornado will occur if the difference in specific gravity be sufficient to inaugurate a violent mixing, and the rotation be about a vertical axis, instead of about a horizontal axis, as in the case of thunderstorms."

The size and form of waterspouts alter greatly with the state of the atmosphere. As Ferrel observes, they may vary "from that of a cloud brought down over a large area of the earth's surface in a tornado where the air is nearly saturated with vapor and the general base of the clouds very low, somewhat as represented in Fig. 53, to that which occurs when the air is very dry, and when the tornadic action is barely able to bring the cloud down from a great height into a slender spout of small diameter, somewhat as represented in Fig. 54. Horner says that their diameters range from 2 to 200 feet, and their heights from 30 to 1,500 feet. Dr. Reye states that their diameters on land, at base, are sometimes more than 1,000 feet. Oersted puts the usual height of waterspouts from 1,500 feet to 2,000 feet, but states that in some rare cases they cannot be much less than 5,000 or 6,000 feet. On the 14th of August, 1847, Professor Loomis observed a waterspout on Lake Erie, the height of which, by a rough estimate, was a half mile, and the diameter about 10 rods at the base and 20 rods above.

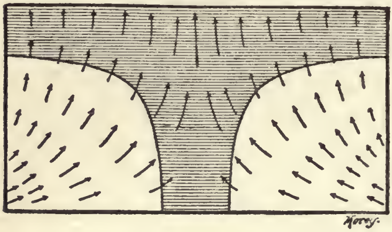

Fig. 53.—Vertical Section of Short Tornado.

"Judge Williams, in speaking of the tornado of Lee's Summit, where he saw it, says: 'It seemed to be about the size of a man's body where it touched the clouds above, and then tapered down to the size of a mere rod.'"

When the tornado vortex is so tall and strong as to carry raindrops up to freezing strata it is commonly known as a hailstorm. The congealing occurs usually in those isobaric surfaces which dip down in the center of the vortex, but reach only part way to the earth. As indicated in Fig. 55, the clear aqueous vapor near the earth is condensed to cloud on crossing an isobaric surface of sufficiently low pressure and temperature; then it proceeds as mingled cloud and rain till it crosses the freezing isobar into the region of snow and hail formation; thence finally curves outwardly to stiller air and descends as a cloud of mingled vapor, rain and frozen parts. Of this frozen shower one part may come to earth as hail or rain, the snow and sleet melting on the way; while another part may be redrawn into the swift uprush, and carried aloft till its frozen drops, or pellets, have grown so large by accretion as to plunge to earth by sheer bulk, even though they must traverse a furious ascending wind.

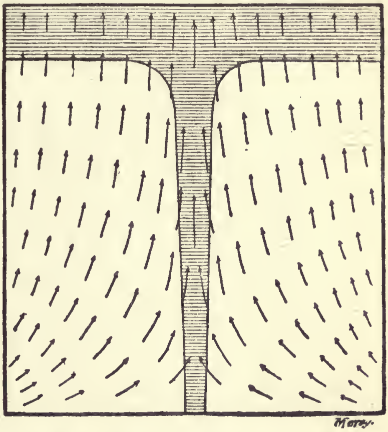

FIG. 54.—VERTICAL SECTION OF A TALL TORNADO.

A good illustration from Nature of this cycle in the center of a hailstorm is presented in the following by Mr. John Wise, America's adventurous pioneer balloonist:

"This storm originated over the town of Carlisle, Pa., on the 17th of June, 1843. I entered it just as it was forming. The nucleus cloud was just spreading out as I entered the vortex unsuspectingly. I was hurled into it so quickly that I had no opportunity of viewing the surroundings outside, and must therefore confine this relation to its internal action. On entering it the motions of the air swung the balloon to and fro and around in a circle, and a dismal, howling noise accompanied the unpleasant and sickening motion, and in a few minutes thereafter was heard the falling of heavy rain below, resembling in sound a cataract. The color of the cloud internally was of a milky hue, somewhat like a dense body of steam in the open air, and the cold was so sharp that my beard became bushy with hoar frost. As there were no electric explosions in this storm during my incarceration, it might have been borne comfortably enough but for the seasickness occasioned by the agitated air-storm. Still, I could hear and see, and even smell, everything close by and around. Little pellets of snow (with an icy nucleus when broken) were pattering profusely around me in promiscuous and confused disorder, and slight blasts of wind seemed occasionally to penetrate this cloud laterally, notwithstanding there was an upmoving column of wind all the while. This upmoving stream would carry the balloon up to a point in the upper clouds, where its force was expended by the outspreading of its vapor, whence the balloon would be thrown outward, fall down some distance, then be drawn into the vortex, again be carried upward to perform the same revolution, until I had gone through the cold furnace seven or eight times; and all this time the smell of sulphur, or what is now termed ozone, was perceptible, and I was sweating profusely from some cause unknown to me, unless it was from undue excitement. The last time of descent in this cloud brought the balloon through its base, where, instead of pellets of snow, there was encountered a drenching rain, with which I came into a clear field, and the storm passed on."

As might be expected the hailstones vary much in form, size and quantity. If by chance any stones become slightly flattened they ride level in the ascending current, and hence by aggelation grow most rapidly on the periphery which is a line of diminished pressure. At times they are more or less oval, and again they appear as fragments of considerable masses of ice, broken perhaps by collision in

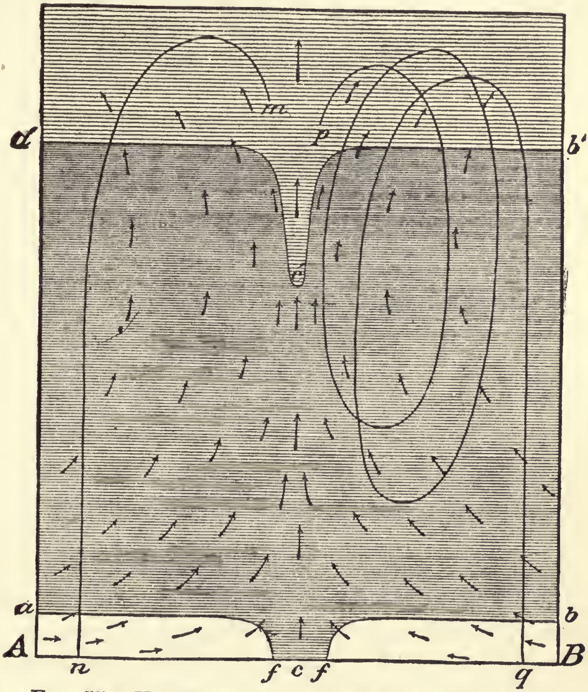

FIG. 55.—VERTICAL SECTION OF A HAIL TORNADO.

the violent parts of the tornado tube. Their great variety in shape and bulk may be appreciated from the following extracts taken from the records of the Signal Service:

In *Professional Paper of the Signal Service No. 4,* describing the tornadoes of May 29th and 30th, 1879, in Kansas, Nebraska, Missouri, and Iowa, this passage occurs relative to a tornado at Delphos, Mo.:

"On the farm of Mr. Peter Bock, in the adjoining township of Fountain, about 4 miles W. of the storm's centre, and during the hailstorm that preceded the tornado, masses of ice fell as large as a man's head, breaking in pieces as they struck the earth. One measured 13 inches in circumference, another 15, and a hole made by one that fell near the place of Mr. J. H. Kams measured 7 inches across one way and 8 the other. This immense fragment of aërial ice broke into small pieces, so that its exact size could not be determined."

The following description is given of the tornado that visited Lincoln County, Neb., at that time:

"At first the hailstones were about the size of marbles, but they rapidly increased in diameter until they were as large as hens' eggs and very uniform in shape. After the precipitation had continued about fifteen minutes, the wind ceased and the small hail nearly stopped, when there commenced to fall perpendicularly large bodies of frozen snow and ice, some round and smooth and as large as a pint bowl, others inclined to be flat, with scalloped edges, and others resembled rough sea-shells. One of the latter, after being exposed an hour to the sun, measured fourteen inches in circumference."

The following was reported by the Signal Service observer at Fort Elliott, Tex., 1888:

"A thunder-storm began at 4.10 P.M. and ended at 7.40 P.M., moving from southwest to northwest. Hail began at 5.18 P.M. and ended at 5.26 P.M., the hailstones being spheroidal in shape and about two inches in diameter; formation, solid snow. The 'break' (hills) at the foot of the plains several miles northwest of station were absolutely white with hailstones for three hours after the storm. This was observed by everybody at the station; on the morning of the 26th I walked down to the Sweetwater Creek, three fourths of a mile distant, and saw great banks of hailstones which had been washed down during the night. The bottoms along the Sweetwater were literally covered with banks of hailstones from six to eight feet in depth. It was estimated that there was enough hail to cover ten acres to a depth of six feet. The hailstones killed five horses which were out on the prairie on a ranch six miles north of station. The Sweetwater Creek was higher than ever known before, the freshet destroying nearly the entire post garden. The high water is supposed to have been caused by a 'cloud-burst' at or near the foot of the plains, where the Sweetwater has its source; there was only 0.36 inch of rainfall at the station. On Sunday, May 27th, hailstones were collected on the banks of the Sweetwater, which had been washed down and lay in drifts 6 feet deep, actual measurement by the observer."

When, after imprisonment and long sustention in a powerful tornadic vortex, the accumulated rain or hail finally breaks through and pours down to earth, in solid cataract, the phenomenon is commonly called a cloud-burst. The foregoing example is a partial illustration. The following is quoted from Espy, describing a cloud-burst near Hollidaysburg, Penn., in which the water seems to have poured down nearly in a solid stream:

"On examining the northern side of this ridge, large masses of gravel and rocks and trees and earth, to the number of 22, were found lying at the base on the plain below, having been washed down from the side of the ridge by running water. The places from which these masses started could easily be seen from the base, being only about 30 yards up the side. On going to the head of these washes they were found to be nearly round basins from 1 to 6 feet deep, without any drains leading into them from above. The old leaves of last year's growth, and other light materials, were lying undisturbed above, within an inch of the rim of these basins, which were generally cut down nearly perpendicularly on the upper side, and washed out clean on the lower. The greater part of these basins were nearly of the same diameter, about 20 feet, and the trees that stood in their places were all washed out. Those below the basin were generally standing, and showed by the leaves and grass drifted on their upper side how high the water was in running down the side of the ridge; on some it was as high as three feet. It probably, however, dashed up on the trees above its general level."

Dry whirlwinds of moderate size, but sometimes of considerable violence, frequently occur in clear weather when the percentage of humidity is small and when the vertical temperature gradient is unusually pronounced. In this case there may be strong agitation of the air, rendered visible at the earth's surface by light débris on land, or boiling of the water at sea; but the main body of the tube is invisible and free from mist except high up where precipitation begins, capped by a growing patch of white cloud in a clear sky, and which may gradually broaden and condense sufficiently to cause a shower of rain. On land the dry whirlwind may be delineated as a tall column, by whirling dust or sand. In this case, if the gyration is violent, the central core may appear clean and clear owing to the centrifugal force which keeps the grains out where they are balanced by the pressure of the inrushing air. In such vortices the sand spout may appear to be hollow as in the case of waterspouts whose interior cores are free from cloud or condensed vapor. On the other hand, myriads of mild transparent whirlwinds unmarked, except by down or humanly invisible dust, or dim aërial refractions, may frisk and play in the boundless sky unnoticed by the blunt eyes of men, yet constantly engaged in generating or marshaling the clouds and in buoying upward the ponderous eagles, the vultures and the whole brood of passive flyers whom we have not yet learned to emulate. Thus when we remember that an upward trend of air of scarcely one yard per second, and too feeble to support a falling hair, is yet sufficient to carry the condor and albatross without wing beat, it seems important to explore these minor vortices and to ascertain their availability and practical usefulness for human soaring.

CHAPTER XVII

THUNDERSTORMS, WIND GUSTS

Still another interesting kind of aërial disturbance is the familiar heat thunderstorm. This is not synonymous with those electrified tornadoes and cyclones which are accompanied by thunder and lightning, sometimes of great violence. Most tornadoes are thunderstorms, but not vice versa. The thunderstorm is not essentially a vortex, but rather a wind squall marked by sudden changes of temperature and pressure, bearing with it massive clouds fraught with rain, or hail, and disruptive electric charges flashing frequently to earth, or from point to point in the sky. Its approach is usually announced by rumbling thunder and heavy black clouds along the horizon. Its duration is brief, varying from a few minutes to an hour or two. Further characteristics are thus expressed by Moore:

"On land, thunderstorms occur most frequently at specific hours of the day or night, such as 3 to 5 in the afternoon or 9 to 10 in the evening and sometimes even at 2 or 3 A.M., but no such diurnal period is observed in midocean. The phenomena usually occur in a pretty regular order of succession. After several hours of fair weather, with gentle winds, there comes a calm; the cumulus clouds grow larger, the lower stratum of clouds is seen to be moving rapidly; gusts of wind start up with clouds of dust, rain is seen to be falling at a distance; the movement of rain and dust shows that the wind is blowing out from this rain cloud near the ground no matter which way the rainy region is advancing; a few large drops fall from slight clouds and then suddenly the heavy rain begins. Lightning that may have occurred during the preceding few minutes becomes more frequent and more severe as the rain increases. After the maximum severity of rain and wind, the lightning also diminishes or entirely ceases, and we are soon able to say that the storm has passed by. If we watch its retreat from us in the afternoon we shall see the rear of a great cumulus on which the sun is shining, but through whose dark-blue curtain of cloud and rain nothing save occasional lightning is visible. After the storm has passed, the lower atmosphere soon becomes appreciably cooler and drier, the sky is nearly clear of clouds, and the wind has shifted to some other point of the compass than that which prevailed before the storm."

The genesis of thunderstorms is varied and manifold. In one simple type, a large tract of heated air in the unstable state and with a high percentage of humidity swells upward at the center, the ascending moist air forming, at the precipitation altitude, a growing cloud which may become very broad, dark and bulky, drifting along over the earth with the prevailing current. Eventually rain begins to form, or may be hail or snow, if the heated column reaches to a great height. The falling shower cools the air from the cloud down to the earth, increasing its density and materially weighting it with the descending liquid or solid particles. The showery column then sinks, especially along its inner part where it is maturest, thus causing an outrush of cool air along the earth, the immediate forerunner and herald of the rain. This outrushing current pushes upward the environing clear moist air, thus forming new margins of massive cumuli around the older nimbus widening within, showering, cooling and sinking. Thus the rain area is broadened and propagated, sometimes with nearly equal speed in all directions, but generally fastest in the direction of the most unstable condition, or of the then prevailing drift of the atmosphere. Indeed, the forward cloud ranks may far outspeed the wind, seeming by their imperious bluster and gigantic gloom to commandeer new recruits, as if by magic, out of the clear sky. Before this solemn mustering and turbulent front of the storm the black vapors suddenly startled into visible shape, rush buoyantly upward in ragged shreds, like smoke from unseen fires, and quickly blend with the general array of compact cloud expanding across the sky. Again, several thunderstorms, merged like a mountain range in solid phalanx, may sweep abreast over a continent, with long horizontal[1] roll, ever rising in front and upheaving the sultry air, thus replenishing perpetually the ponderous cumuli which form the vanguard of this far-flung and titanic march of the clouds. Such a storm is usually powerful and persistent, commonly enduring until the sun's decline and the shades of night have cooled the lower air, and thus allayed the commotion by enfeebling the forces that favor its progress.

The speed of rise of the air beneath the base of the thunderhead is a question of some interest in aëronautics. If the ascent be so much as a foot or two per second, one may expect the vultures to prefer soaring beneath the thundercloud during its formative period. Here also the aëroplanist might attempt a record flight, if the cloud were high enough to be out of his way. But if he ventured to penetrate the base of the thunderhead, he might find

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[1] Von Bezold, on the *Thermodynamics of the Atmosphere.*

the turmoil too irregular and strenuous for his comfort.

Of like interest is the long aërial swell that leads the advancing storm. When will aviators make this the theater of their adventurous frolic, careering playfully before the brow of the tempest and the harmless rage of the lightning, gay-winged heralds of the coming tumult, sailing perhaps with slackened motive power, yet swift and secure as the storm-riding petrels at sea?

Besides the winds and aërial currents commonly studied by meteorologists, are the minor disturbances which affect more particularly the wayfarers of the sky, whether birds or men. The atmosphere quite usually is vexed with invisible turmoils; most sensible, indeed, over rough territory, but conspicuous also above the smooth terrene, and at all elevations from earth to the highest cloudland. Before sunrise, and generally in weather uniformly overcast, these miscellaneous and nondescript movements of the air are least active, for any given speed of the general drift of the atmosphere; but when the sun shines and the soil is nonuniformly heated, the disturbances become most pronounced. A whole troop of playful zephyrs rise and set with the sun, in addition to the diurnal winds already studied. Over the dusty plain they reveal their presence and shape in those coiling columns that constitute the safety vents of the atmosphere, and obviate the disruptive violence of the uprush that would occur should a considerable region of surface air become excessively heated. Over the city, particularly in winter, the local turmoils of the atmospheric surf are revealed in the play of a thousand smoky columns, and better still, when it snows, by the incessant swell and veering of the flaky flood whose surges and eddies bewilder the vision by their complexity. Over the water the clouds of fog and steaming vapor are the best index of the local zephyrs, where, it must be remembered, the rising and veering of the vapor wreaths accompany like motions in the atmosphere. Over the forest, field and meadow the interminable wandering of thistle down and gauzy shreds of vegetation, now fast, now slow, now high aloft, then sheer earthward, indicate what erratic and perpetual motions prevail throughout the open country even on the stillest days. In the deep bosom of the atmosphere, the parallel ranks of the cirri all across the sky mark the crests of undulations quite as regular and tumultuous as the billows of a wind-swept sea; while the fierce seething and upsurging of the separate cumuli manifest the operation of vortices of prodigious energy. These visible billows and whirlwinds suggest an infinitude of transparent ones hardly less powerful, at the various levels unmarked by clouds. For wherever two streams of abnormally graded densities neighbor each other, a readjustment may occur agitating the entire region with a host of pulsations, squalls, cataracts and fountains which the bird and navigator must parry with proportionate care and skill.

And it is because of the amazing resistance of these wandering zephyrs, waves and eddies that they demand the attention of aëronauts; nay, more, it is because of the substantial labor they can perform when adroitly encountered and duly employed. For the simplest elements of aërodynamic science make clear that a rising zephyr hardly strong enough to support a falling leaf is adequate to sustain the heaviest soaring birds and aëroplanes gliding swiftly through it. In fact, the sailors of fast air ships feel a heavy impulse and distinct shock in plowing those mild cross winds which, to the fixed observer, seem not like blasts, but rather as gentle swells or harmless currents. These, therefore, have been made the subject of investigation by various students of aëronautics.

The first incentive to the instrumental study of the fluctuations of the wind in speed and direction seems to have been the hope to furnish a quantitative basis for various theories of soaring flight. Pénaud,[1] in 1875, had explained this phenomenon by postulating an upward current. Lord Rayleigh,[2] in 1883, had made the more general assumption of a wind having either a variable speed or a variable direction as a necessary and sufficient condition for such flight. Marey,[3] in 1889, and Langley,[4] in 1893, gave elementary qualitative explanations of soaring in a horizontal wind of variable velocity, though neither adduced concrete data to prove that the feat could be performed in an actual wind. Each and all of those theories may be sound enough in the abstract, but to show that they represent realities of art or Nature they should be applied to a concrete instance of soaring of a machine or a bird of known resistance, in a wind of known variability.

To such end the writer in 1892 devised an anemograph for recording simultaneously the speed of the wind and its horizontal and vertical components of direction, while Dr. Langley devised a very light and delicate cup anemometer for recording the variations of wind speed in a horizontal plane, but not the changes of direction. Both instruments were set up in January, 1893, and both investigations were published with the *Proceedings of the International Conference on Aërial Navigation* of that

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[1] Chanute, *Aeronautical Annual*, 1897, p. 101.

[2] *Nature*, April 5, 1883.

[3] *Vol des Oiseaux.*

[4] *Internal Work of the Wind.*

year; but neither investigation was pushed far enough to prove conclusively the possibility of a particular bird or model soaring in the particular

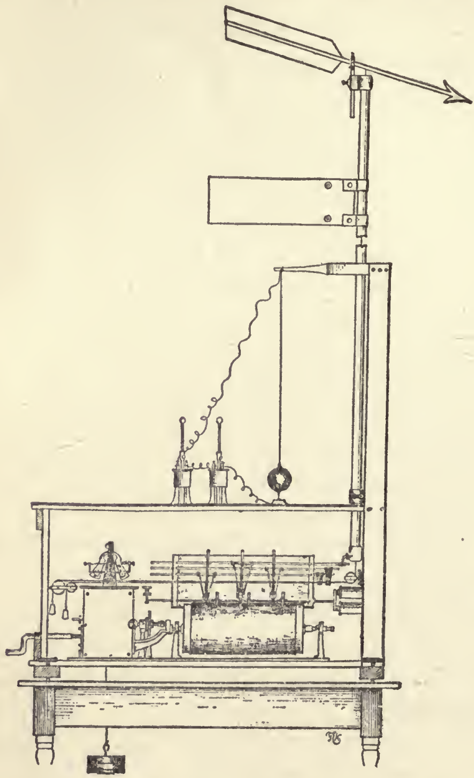

FIG. 56.—UNIVERSAL ANEMOGRAPH. (The vanes are high above the point indicated by the break in the vertical pipe.)

wind recorded. The two together did, however, reveal quite astonishing fluctuations of the wind in both speed and direction, results that have since received ample exemplification in the more extended records of other observers.

Fig. 56 shows the recording anemometer for speed and double direction constructed by the writer in 1892. A large weather vane was firmly strapped to a vertical pipe which turned freely on ball bearings and, by means of a small crank actuating a chronograph pencil, recorded its fluctuations on a long sheet of paper winding on the drum from a roll behind. On top of the pipe and about fifteen feet from the ground, was mounted a carefully balanced horizontal vane, from which a fine steel wire ran down the axis of the pipe to a fixed pulley, thence to a second recording pencil. A third pencil recorded the beats of a pendulum, thus standardizing the speed of the paper. A fourth pencil, not shown, was designed to record the turns of an anemometer mounted near the top of the pipe. The records of the wind speed thus secured are omitted for lack of standardization, as the experiments were prematurely terminated.

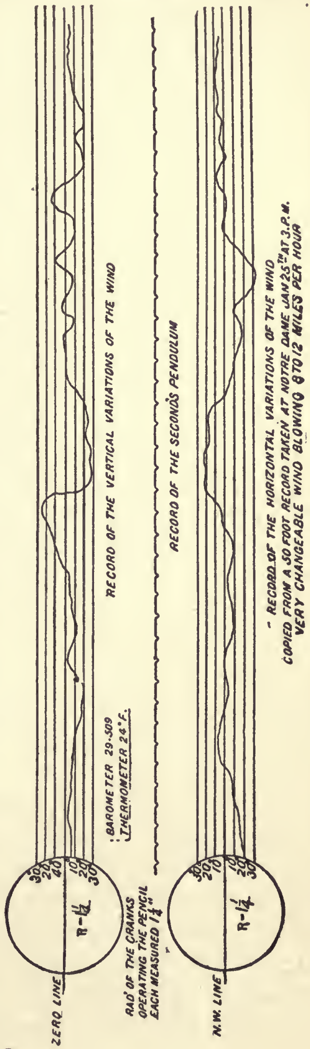

Fig. 57.—Records of Wind Variation in Horizontal and Vertical Direction.

Typical records of the wind direction are shown in Fig. 57 in which the circles represent the paths swept by the wind-vane cranks that operated the corresponding pencils. Both vanes, as shown by their diagrams, veered quite frequently ten degrees in a short interval of time, and not seldom twenty to thirty degrees. Frequently, also, it was observed, in scanning the various records, that a rise or lull in the wind speed was accompanied by a corresponding variation in direction; but the observations were not sufficiently numerous and extended to establish this phenomenon as a general occurrence. But as it can be shown theoretically that a horizontal stream of air of constant cross section and uniform velocity at each section, can not greatly fluctuate in velocity from point to point, without more pronounced changes of density than the barometer records, it naturally follows that the stream must broaden where the air speed lags, and narrow where it accelerates; in other words, it follows that there must be some change in direction. The records were taken in the middle of a clear open space of two hundred acres at Notre Dame University on a sunless day in January, 1893, when the temperature was 24° F., and the wind eight to twelve miles per hour. Their application to the theory of soaring need not be considered here.

Further studies of the wind pulsations were made by use of a toy balloon attached to a long thread. The first trials are thus recounted in the paper above cited:

"After some preliminary tests from the top of the Physical Laboratory of the Johns Hopkins University, during the Easter vacation of 1893, I ascended the Washington Monument at Baltimore, where I paid out the exploring line at a height of 200 feet. The wind was blowing toward the southeast at the speed of 25 to 35 miles per hour, and the sky, which had remained clear till 3 o'clock, was rapidly darkening, with indications of approaching rain. The balloon, when let forth, immediately fell to a depth of 30 or 40 feet, being caught in the eddy of the monument, then presently encountering the unbiased current, sailed in it toward the southeast, approximately level with the spool end of the thread. After the balloon had drawn out 100 feet of thread I checked it to observe the behavior of this much of the exploring line. The balloon rose and fell with the tossing of the wind, but did not flutter like a flag, as it would do if formed of irregular outline. Neither did the thread flutter, nor do I believe there is ever a tendency in a line greatly to flutter in a current as does a flag or sail. Presently I paid out 300 feet of the exploring line, whereupon the waves in the thread became quite remarkable. The thread then, as a rule, was never approximately straight. Sometimes it was blown into the form of a helix of enormous pitch; at other times into the form of a wavy figure lying nearly in a single vertical plane; and again, the entire exploring line should veer through an angle of 40° to 60°, either vertically or horizontally. The balloon, of course, seldom remained quiet for more than a few seconds at a time, but tossed about on the great billows like a ship in a storm. Quite usually the billows could be seen running along the line from the spool to the balloon, and, as a rule, several different billows occupied the string at one time.

"The observations just delineated, however curious they may be, afford no adequate conception of the behavior of the air currents over an open plane, nor at a great height above the earth, because the Washington Monument at Baltimore stands but 100 feet above the surrounding buildings, which undoubtedly send disturbances to a greater height than 200 feet. To supplement these explorations, therefore, I determined to have them repeated from the top of the Washington Monument at Washington and the Eiffel Tower at Paris."

Some months later in the year, the experiment was repeated at the top of the Washington Monument in Washington, at a height of five hundred feet. The balloon, with a stone attached, was paid out from the north window of the monument till it reached the ground. Then the stone was removed by an assistant who drew the balloon well away from the huge eddy of the great shaft, and let it fly toward the east, drawing the thread after it like a mariner's log in the wake of a ship. When six hundred feet of the thread had been let out, it was observed to veer in all directions under the varying surges of the wind. These variations seemed larger than could be expected from the wake of the shaft alone near its summit, where it measures about thirty feet in thickness.

Such qualitative observations, though interesting and suggestive, are not wholly satisfactory. The same may be said of the study of air currents by aid of smoke from tall chimneys. The eddy about such columns may extend to a considerable height above them, and the wake is farreaching. The experiments would therefore best be made from high openwork towers above plane country or a broad sheet of water.

A better method perhaps would be to liberate a pilot balloon, or discharge a bomb giving a bright compact cloud, and to trace its path by means of two cameras, as it floats from point to point in the aërial current. The instruments, if suitably stationed, would give the continuous space history of the floating object; that is, its actual path and the speed at each part thereof, or, in other words, the magnitude and direction of the velocity at each point. But, of course, this method would not reveal the wind's history at any given fixed point, as recorded by the anemograph above described.

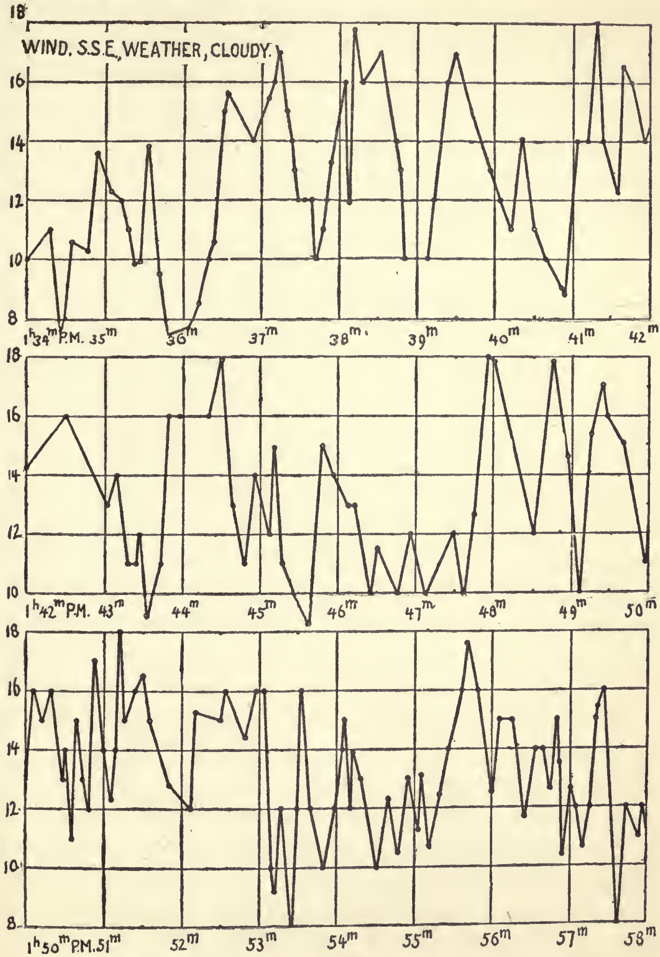

FIG. 58.—RECORDS OF WIND SPEED OBTAINED BY LANGLEY.

Fig. 58 is a typical wind-speed record obtained by Langley in January, 1893, by means of a very light cup anemometer mounted eleven feet above the north tower of the Smithsonian Institution, and 153 feet from the ground. The abscissæ represent time in minutes, the ordinates wind speed in miles per hour. The records were taken in cloudy weather and in a south-southeast wind. Other records were taken during the month of February, showing like deviations from the mean, though at times more pronounced; for Dr. Langley noted that "the higher the absolute velocity of the wind, the greater the relative fluctuations which occur in it."

It will be observed from this record that, when the average speed was about twelve miles an hour, the extreme fluctuation was rarely one third greater or less than that, and on the average varied hardly one sixth. It must be further added that the air on approaching the anemometer had traversed a mile of the lower residential section of the city, then crossed the body of the Smithsonian building, which itself is half as high as the tower. It should be expected, therefore, that this wind was, other things equal, naturally more turbulent than if flowing in from a level plain. This surmise is justified by the more extensive records of wind speeds shown in meteorological records taken respectively in clear and in obstructed places. On the other hand, even in level places where no obstruction is visible for several miles, the wind, though it may be steady at one time, can at another time be gustier than that shown in Langley's record, according to the state of the weather; for the gusts are not all due to neighboring obstacles, but may be transmitted from afar, even from the depths of the atmosphere.

Assuming the wind speed at any instant to vary by one sixth of the mean, its impactual pressure will then vary by thirty-six per cent of the pressure of the mean wind, remembering that the pressure varies as the square of the speed. This fluctuation of the impactual pressure tallies fairly well with that found by Professor Marvin at the top of Mount Washington, in 1890, by means of a pressure plate.[1] He found the variation to be approximately thirty-five per cent of the mean pressure. Professor Hazen, however, reports but little variation in the wind speed in the free atmosphere well above the earth. In several balloon ascensions he suspended from the basket a lead weight by means of a cord to which was looped the thread of a toy balloon. He found that the little balloon sometimes moved ahead if the weight sometimes followed it, but that in general the relative motion was very feeble, thus indicating that the fluctuations of the velocity in the depth of the atmosphere at those times were very slight.[2] However this be for such distances from the earth and its protuberances, the fluctuations of wind speed found at meteorological stations sufficiently resemble those reported by Dr. Langley. As corroborative evidence, the reader may be referred to the wind records published in the *Interim Report* for 1909, of the British Advisory Committee for Aëronautics.

Without the material evidence of commotion in the atmosphere, a moment's reflection will make clear that such turmoil must exist, even over a vast, smooth plain, especially in bright weather, and more particularly over bare ground in dry weather. For it is well known that clear, dry air transmits radiation with very slight absorption, when the sun is well toward the zenith, and hence that the temperature in the depth of the atmosphere is but little changed from moment to moment, due to the passage of sunlight. At the earth's surface, however, the air by

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[1] *Engineering News*, December 13, 1890.

[2] *Meteorological Journal*, November, 1891.

contact with heating or cooling soil may change temperature rapidly. The direct sunlight falling perpendicularly upon a perfectly absorbent material transmits nearly two calories of heat per minute to each square centimeter of the receiving surface. It would, therefore, under favorable circumstances, elevate by nearly two degrees C. per minute a layer of water one centimeter deep, or a layer of air something over a hundred feet thick, if all the heat falling on the assumed surface were communicated to the neighboring air stratum. In practice, a large percentage of the incident sunlight is reflected and radiated by the soil, into sidereal space without heating the air. But every one per cent of it caught up by the air in contact with the earth is sufficient to heat a layer roughly one foot thick one degree per minute. Hence, unless the heated air streamed upward continually, the layer next the earth would quickly be raised to a very abnormal temperature, which would result in a violent uprush. The gradual ascension of the surface air may take place in large or small columns, or in both kinds at once. In either case, the composition of the ascensional motion with the general movement of the wind due to barometric gradient must cause gustiness and marked irregularity of speed and direction.

Various causes have been assigned for the gustiness of the winds. Ferrel and many other writers assume that the air, especially near the earth, is full of small vortices rotating about axes of various inclination. These whirls, on passing squarely across a weather vane, cause it to point one way for a moment, then presently the opposite way, while if they cross obliquely they cause a like sudden veering of the vane, but less extensive.

Helmholtz has proved that in the atmosphere strata of different densities come at regular intervals to be contiguous one above the other, and thus to beget conditions favorable to the formation of aërial waves, sometimes so large as to set the lower regions of air into violent commotion and thereby generate the so-called gusty weather. He has summarized as follows some of the important conclusions of his dynamic analysis.[1]

"As soon as a lighter fluid lies above a denser one with well-defined boundary, then evidently the conditions exist at this boundary for the origin and regular propagation of waves, such as we are familiar with on the surface of water. This case of waves, as ordinarily observed on the boundary surfaces between water and air, is only to be distinguished from the system of waves that may exist between different strata of air, in that in the former the difference of density of the two fluids is much greater than in the latter case. It appeared to me of interest to investigate what other differences result from this in the phenomena of air waves and water waves.

"It appears to me not doubtful that such systems of waves occur with remarkable frequency at the bounding surfaces of strata of air of different densities, even although in most cases they remain invisible to us. Evidently we see them only when the lower stratum is so nearly saturated with aqueous vapor that the summit of the wave, within which the pressure is less, begins to form a haze. Then there appear streaky, parallel trains of clouds of very different breadths, occasionally stretching over the broad surface of the sky in regular patterns. Moreover, it seems to me probable that this, which we thus observe under special conditions that have rather the character of exceptional cases, is present

[1] On *Atmospheric Movements* (Abbe's translation).

in innumerable other cases when we do not see it.

"The calculations performed by me show, further, that for the observed velocities of the wind there may be formed in the atmosphere not only small waves, but also those whose wave lengths are many kilometers which, when they approach the earth's surface to within an altitude of one or several kilometers, set the lower strata of air into violent motion and must bring about the so-called gusty weather. The peculiarity of such weather (as I look at it) consists in this, that gusts of wind often accompanied by rain are repeated at the same place, many times a day, at nearly equal intervals and nearly uniform order of succession."

Commandant Le Clement de Saint-Marcq has drawn some interesting conclusions from the hypothesis that an ordinary wind consists of a uniform current on which is superposed periodic motions in the wind's main direction and also at right angles thereto. But he has not established his hypothesis by adequate observations. He assumes the pulsations to be simple harmonic motions, which of course they would be if they were plane compressional waves; but at the same time he shows that the fluctuations are too large to be compressional waves, with the concurrent slight variations of the barometric pressure.

It is still a question whether the pulsations of the natural wind be harmonic. If so, the speed records should be sine curves, and the to and fro acceleration of any mass of moving air should be variable for any given pulsation. But the few records available show in many parts a constant acceleration of the wind speed throughout a particular swell or lull of velocity, indicating that the pulsations are not generally simple harmonic ones.

In scanning the wind-speed records published by Langley, so many instances of uniform wind acceleration are noticed that one naturally inquires whether the rate of gain of velocity be sufficient to sustain in soaring flight an aëroplane or bird held to the wind solely by its inertia, as Langley believed to be possible. The total forward resistance of a well-formed aërial glider, or bird, may be taken as one eighth of its weight; hence, if poised stationary in its normal attitude of flight, it will just be sustained by a direct head wind having a horizontal acceleration of one eighth that of gravity, or four feet per second. Now, the most favorable parts of the record here shown (Fig. 58) exhibit nowhere an acceleration so great as four feet per second, and on the average far less than that, as may be proved by scaling the diagram. Hence, the wind here recorded was wholly inadequate to support by its pulsative force either bird or man. But as this record is a fair representative of all those published by Dr. Langley, it follows that such pulsations can at best merely aid in soaring when happily and adroitly encountered; but that they cannot fully sustain soaring at any level, much less during ascensional flight to great altitudes, or migrational flight to vast distances. It still remains, therefore, to ascertain what kind of aërial currents are adequate to sustain those marvelous feats of soaring on passive pinions which for ages have been the delight and wonder of all keen observers, and which are of such enduring interest to mankind. This investigation, however, appertains more particularly to the science of applied aërodynamics.

APPENDICES

APPENDIX I

STRESS IN A VACUUM BALLOON [1]

By A. F. Zahm

As inventors frequently propose the construction of a vacuum balloon, to secure buoyancy without the use of gas, it may be desirable to estimate the strength of material required to resist crushing, say in a spherical balloon.

The unit stress in the wall of a thin, hollow, spherical balloon subject to uniform hydrostatic pressure, which is prevented from buckling, is given by equating the total stress on a diametral section of the shell to the total hydrostatic pressure across a diametral section of the sphere, thus:

$$2\,\pi\,r\,t\,S = \pi\,p\,r^2$$

in which S may be the stress in pounds per square inch, p the resultant hydrostatic pressure in pounds per square inch, r the radius of the sphere, t the wall thickness.

The greatest allowable mass of the shell is found by equating it to the mass of the displaced air, thus:

$$4\,\pi\,r^2\,t\,\varsigma_1 = 4\,\pi\,r^3\,\varsigma_2/3$$

in which ς_1 is the density of the wall material, ς_2 the density of the atmosphere outside.

[1] From *Scientific American*, March 13, 1909, by permission of Munn & Co.

Now, assuming $p = 15$, $\varsigma_1/\varsigma_2 = 6{,}000$, for steel and air, the equations give:

$$S = 3p\,\varsigma_1/\,2\varsigma_2 = 45 \times 6{,}000/2 = 135{,}000 \text{ pounds}$$

per square inch as the stress in a steel vacuum balloon.

For aluminum ς_1 is less, but the permissible value of S is also less in about the same proportion.

The last equation shows that for a given material and atmospheric environment, the stress in the shell or wall of the spherical balloon is independent of the radius of the surface. It is also well known that the stress is less for the sphere than for any other surface. Hence, no surface can be constructed in which S will be less than $3p\,\varsigma_1/2\,\varsigma_2$. The argument is easily seen to apply to a partial vacuum balloon, since a balloon of one nth vacuum will float a cover of but one nth the mass and strength.

The above result was obtained on the assumption that the shell was prevented from buckling. As a matter of fact, it would buckle long before the crushing stress could be attained. We must conclude, therefore, that while a vacuum balloon has alluring features, the materials of engineering are not strong enough to favor such a structure. Perhaps it is nearer the truth to say that such a project is visionary, with the materials now available.

A like argument applies to the balloon reservoir in which it has been proposed to compress the surplus gas taken from a balloon hull on expansion of its contents by change of level or temperature. If a given mass of gas obeying Boyle's law be pumped into a receiver of given shape and mass, the resultant stress in the receiver wall will be independent of the size. Hence the material of the proposed reservoir, if expanded to the size of the hull itself, will weigh the same, and suffer the same increment of unit stress, for a given mass increment of gas. Hence, instead of pumping the above-mentioned gas surplus from the hull into the reservoir, this latter may be discarded and its mass of material spread over the hull itself. This argument applies only if the shapes of hull and reservoir be equally effective, as, for example, if both be cylindrical.

APPENDIX II

AËRONAUTIC LETTERS OF BENJAMIN FRANKLIN

PASSY, Aug. 30, 1783.

ON Wednesday, the 27th instant, the new aërostatic Experiment, invented by Messrs. Montgolfier of Annonay, was repeated by M. Charles, Professor of experimental Philosophy at Paris.

A hollow Globe 12 feet Diameter was formed of what is called in England Oiled Silk, here Taffetas gommé, the Silk being impregnated with a Solution of Gum elastic in Linseed Oil, as he said. The Parts were sewed together while wet with the Gum, and some of it was afterwards passed over the Seam, to render it as tight as possible.

It was afterwards filled with inflammable Air that is produced by pouring Oil of Vitriol upon Filings of Iron, when it was found to have a tendency upwards so strong as to be capable of lifting a Weight of 39 Pounds, exclusive of its own Weight which was 25 lbs and the Weight of the Air contain'd.

It was brought early in the morning to the Champ de Mars, a Field in which Reviews are sometimes made, lying between the military School and the River. There it was held down by a Cord till 5 in the afternoon, when it was to let loose. Care was taken before the Hour to replace what Portion had been lost, of the inflammable Air, or of its Force, by injecting more.

It is supposed that not less than 50,000 People were assembled to see the Experiment, The Champ de Mars being surrounded by multitudes, and vast Numbers on the opposite Side of the River.

At 5 O'clock Notice was given to the Spectators by the Firing of two Cannon, that the Cord was about to be cut. And presently the Globe was seen to rise, and that as fast as a Body of 12 feet Diameter, with a force only of 39 Pounds, could be suppos'd to remove the resisting Air out of its Way. There was some Wind, but not very strong. A little Rain had wet it, so that it shone, and made an agreeable appearance. It diminished in Apparent Magnitude as it rose, till it enter'd the Clouds, when it seem'd to me scarce bigger than an Orange, and soon after became invisible, the Clouds concealing it.

The multitude separated, all well satisfied and delighted with the Success of the Experiment, and amusing one another with discourses of the various uses it may possibly be apply'd to, among which many were very extravagant. But possibly it may pave the Way to some Discoveries in Natural Philosophy of which at present we have no conception.

A Note secur'd from the Weather had been affix'd to the Globe, signifying the Time & Place of its Departure, and praying those who might happen to find it, to send an account of its state to certain Persons at Paris. No News was learned of it till the next Day, when information was received that it fell a little after 6 o'clock, at Gonesse, a Place about four Leagues Distance, and that it was rent open, and some say had ice in it. It is suppos'd to have burst by the Elasticity of the contain'd Air when no longer compress'd by so heavy an Atmosphere.

One of 38 feet Diameter is preparing by Mr. Montgolfier himself, at the Expence of the Academy, which is to go up in a few days. I am told it is constructed of Linen & Paper, and is to be filled with different Air, not yet made public, but cheaper than that produc'd by the Oil of Vitriol, of which 200 Paris Pints were consum'd in filling the other.

It is said that for some Days after its being fill'd the Ball was found to lose an eighth Part of its Force of Levity in 24 Hours; Whether this was from Imperfection in the Tightness of the Ball, or a Change in the Nature of the Air, Experiments may easily discover. . . .

M. Montgolfier's Air to fill the Globe has hitherto been kept secret; some suppose it to be only common Air heated by passing thro' the Flame of burning Straw, and thereby extreamly rarefied. If so, its Levity will soon be deminish'd by Condensation, when it comes into the cooler Region above. . . .

P. S. I just now learned that some observers say, the Ball was 150 Seconds in rising, from the cutting of the Cord till hid in the Clouds; that its height was then about 500 Toises, but, being moved out of the Perpendicular by the Wind, it had made a Slant so as to form a Triangle, whose base on the Earth was about 200 Toises. It is said the Country People who saw it fall were frightened, conceiv'd from its bounding a little, when it touched the Ground, that there was some living Animal in it, and attack'd with Stones and Knives, so that it was much mangled; but it is now brought to Town and will be repair'd.

The great one of M. Montgolfier is to go up, as is said, from Versailles, in about 8 or 10 days. It is not a Globe but of a different Form, more convenient for penetrating the Air.

It contains 50,000 cubic Feet, and is supposed to have Force of Levity equal to 1,500 pounds weight. A Philosopher here, M. Pilatre du Rozier, has seriously apply'd to the Academy for leave to go up with it, in order to make some experiments. He was complimented on his Zeal and Courage for the Promotion of Science, but advis'd to wait till the management of these Balls was made by Experience more certain & safe. They say the filling of it in Montgolfier's Way will not cost more than half a Crown. One is talk'd of to be 110 feet Diameter. Several gentlemen have ordered small ones to be made for their Amusement. One has ordered four of 15 feet Diameter each; I know not with what Purpose; but such is the present Enthusiasm for promoting and improving this Discovery, that probably we shall soon make considerable Progress in the art of constructing and using the Machines.

Among the Pleasanteries Conversation produces on this subject, some suppose Flying to be now invented, and that since Men may be supported in the Air, nothing is wanted but some light handy instrument to give and direct Motion. Some think Progressive Motion on the Earth may be advanc'd by it, and that a Running Footman or a Horse slung and suspended under such a Globe so as to have no more of Weight pressing the Earth with their Feet, then Perhaps 8 or 10 pounds, might with a fair Wind run in a straight Line across Countries as fast as that Wind, and over Hedges, Ditches & even Waters. It has been even fancied that in time People will keep such Globes anchored in the Air, to which by Pullies they may draw up Game to be preserved in the Cool & Water to be frozen when Ice is wanted. And that to get Money, it will be contriv'd to give People an extensive View of the Country, by running them up in an Elbow Chair a Mile high for a Guinea, &c., &c.

B. Franklin.

PASSY, Nov. 22d, 1783.

. . . Enclosed is a copy of the Proces verbal taken of the Experiment yesterday in the Garden of the Queen's Palace la Muette, where the Dauphin now resides, which being near my House I was present. This Paper was drawn up hastily, and may in some Places appear to you obscure; therefore I shall add a few explanatory Observations.

This Balloon was larger than that which went up from Versailles and carried the Sheep, &c. Its bottom was open, and in the middle of the Opening was fixed a kind of Basket Grate, in which Faggots and Sheaves of Straw were burnt. The Air rarefied in passing thro' this Flame rose in the Balloon, swell'd out its sides, and Fill'd it.

The Persons who were plac'd in the Gallery made of Wicker, and attached to the Outside near the Bottom, had each of them a Port thro' which they could pass Sheaves of Straw into the Grate to keep up the Flame, & thereby keep the Balloon full. When it went over our Heads, we could see the Fire which was very considerable. As the Flame slackens, the rarefied Air cools and condenses, the Bulk of the Balloon diminishes and it begins to descend. If those in the Gallery see it likely to descend in an improper Place, they can by throwing on more Straw, & renewing the Flame, make it rise again, and the Wind carries it farther.

One of these courageous Philosophers, the Marquis d'Arlandes, did me the honour to call upon me in the Evening after the Experiment, with Mr. Montgolfier, the very ingenious Inventor. I was happy to see him safe. He informed me that they lit gently, without the least Shock, and the Balloon was very little damaged.

This method of filling the Balloon with hot Air is cheap and expeditious, and it is supposed may be sufficient for certain purposes, such as elevating an Engineer to take a view of an Enemy's Army, Works, &c., conveying Intelligence into, or out of a besieged Town, giving Signals to distant places, or the like.

The other method of filling a Balloon with permanently elastic inflammable Air, and then closing it is a tedious Operation, and very expensive; Yet we are to have one of that kind sent up in a few days. It is a Globe of 26 feet diameter. The Gores that compose it are red and white Silk, so that it makes a beautiful appearance. A very handsome triumphal Car will be suspended to it, in which Messrs. Roberts, two Brothers, very ingenious Men, who have made it in concert with Mr. Charles, propose to go up. There is room in this Car for a little Table to be placed between them, on which they can write and keep their journal, that is, take Notes of everything they observe, the State of their Thermometer, Barometer, Hygrometer, &c., which they will have more leisure to do than the others, having no fire to take care of. They say they have a contrivance which will enable them to descend at Pleasure. I know not what it is. But the Expence of this machine, Filling included, will exceed, it is said, 10,000 Livres.

This Balloon of only 26 feet diameter, being filled with Air ten times lighter than common Air, will carry up a greater Weight than the other, which tho' vastly bigger, was filled with an Air that could scarcely be more than twice as light. Thus the great Bulk of one of these Machines, with the short duration of its Power, & the great Expence of filling the other will prevent the Inventions being of so much Use as some may expect, till Chemistry can invent a cheaper light Air producible with more Expedition.

But the Emulation between the two Parties running high, the Improvement in the Construction and Management of the Balloons had already made a rapid Progress; and one cannot say how far it may go. A few Months since the idea of Witches riding thro' the Air upon a Broomstick, and that of Philosophers upon a Bag of Smoke, would have appeared equally impossible and ridiculous.

These Machines must always be subject to be driven by the Winds. Perhaps Mechanic Art may find easy means to give them progressive Motion in a Calm, and to slant them a little in the Wind.

I am sorry this Experiment is totally neglected in England, where mechanic Genius is so strong. I wish I could see the same Emulation between the two Nations as I see between the two Parties here. Your Philosophy seems to be too bashful. In this Country we are not so much afraid of being laught at. If we do a foolish thing, we are the first to laugh at it ourselves, and are almost as much pleased with a Bon-Mot or a Chanson, that ridicules well the Disappointment of a Project, as we might have been with its Success. It does not seem to me a good reason to decline prosecuting a new Experiment which apparently increases the power of a Man over Matter, till we can see to what use that power can be applied. When we have learnt to manage it, we may hope some time or other to find Uses for it, as men have done for Magnetism and Electricity, of which the first Experiments were mere Matters of Amusement.

This Experience is by no means a trifling one. It may be attended with important Consequences that no one can foresee. We should not suffer Pride to prevent our progress in Science.

Beings of a Rank and Nature far superior to ours have not disdained to amuse themselves with making and launching Balloons, otherwise we should never have enjoyed the Light of those glorious objects that rule our Day & Night, nor have had the Pleasure of riding round the Sun ourselves upon the Balloon we now inhabit.

B. Franklin.

Passy, Dec. 1, 1783.

In mine of yesterday I promised to give you an account of Messrs. Charles & Roberts' Experiment, which was to have been made this Day, and at which I intended to be present. Being a little indispos'd, & the Air cool, and the Ground damp, I declin'd going into the Garden of the Tuilleries where the Balloon was plac'd, not knowing how long I might be oblig'd to wait there before it was ready to depart; and chose to stay in my Carriage near the Statue of Louis XV, from whence I could well see it rise, & have an extensive View of the Region of Air thro' which, as the Wind sat, it was likely to pass. The Morning was foggy, but about one o'clock the Air became tolerably clear; to the great satisfaction of spectators, who were infinite. Notice having been given of the intended Experiment several days before in the Papers, so that all Paris was out, either about the Tuilleries, on the Quays & Bridges, in the Fields, the Streets, at the Windows, or on the Tops of Houses, besides the inhabitants of all the Towns & Villages of the Environs. Never before was a philosophical Experiment so magnificently attended. Some Guns were fired to give Notice that the departure of the great Balloon was near, and a small one was discharg'd which went to an amazing height, there being but little Wind to make it deviate from its perpendicular Course, and at length the Sight of it was lost. Means were used, I am told, to prevent the great Balloon's rising so high as might endanger its Bursting. Several Bags of Sand were taken on board before the Cord that held it down was cut, and the whole Weight being then too much to be lifted, such a Quantity was discharg'd as to permit its Rising slowly. Thus it would sooner arrive at that Region where it would be in equilibrio with the surrounding Air, and by discharging more Sand afterwards, it might go higher if desired. Between One & Two o'Clock, all Eyes were gratified with seeing it rise majestically from among the Trees and ascend gradually above the Buildings, a most beautiful Spectacle! When it was about 200 feet high, the brave Adventurers held out and wav'd a little white Pennant, on both sides their Car, to salute the Spectators, who return'd loud Claps of Applause. The Wind was very little, so that the Object, tho' moving to the Northward, continued long in View; and it was a great while before the admiring People began to disperse. The persons embark'd were Mr. Charles, Professor of Experimental Philosophy, & zealous Promotor of that Science; and one of the Messieurs Robert, the very ingenious Constructors of the Machine. When it arrived at its height, which I suppose might be 3 or 400 Toises, it appeared to have only horizontal Motion. I had a Pocket Glass, with which I follow'd it, till I lost Sight first of the Men, then of the Car, and when I last saw the Balloon, it appear'd no bigger than a Walnut. I write this at 7 in the evening. What became of them is not yet known here. I hope they descended by Day-light, so as to see and avoid falling among Trees or on Houses, and that the Experiment was completed without any mischievous Accident, which the Novelty of it & the want of Experience might well occasion. I am the more anxious for the Event, because I am not well informed of the Means provided for letting themselves gently down, and the Loss of these very ingenious Men would not only be a Discouragement to the Progress of the Art, but be a sensible Loss to Science and Society.

Tuesday Morning, December 2,—I am reliev'd from my Anxiety by hearing that the Adventurers descended well near l'Isle Adam, before Sunset. This Place is near 7 Leagues from Paris. Had the Wind blown fresh, they might have gone much farther.

P. S. Tuesday Evening . . . I hear farther that the Travellers had perfect Command of the Carriage, descending as they pleas'd by letting some of the inflammable Air escape, and rising again by discharging some Sand; that they descended over a Field so low as to talk with Labourers in passing and mounted again to pass a Hill. The little Balloon falling at Vincennes shows that mounting higher it met with a Current of Air in a contrary Direction; an Observation that may be of use to future aërial Voyagers.

B. Franklin.

APPENDIX III

SUCCESSFUL MILITARY DIRIGIBLE BALLOONS

France

The Clément-Bayard II [1]

The *Clément-Bayard II* may be classed among the airships usually called "flexible." The shape of its hull is preserved not by any rigid framing, but by internal gas pressure maintained by ballonets fed by ventilating fans. Moreover, the suspension which binds envelope and car together as one solid is composed wholly of flexible elements, without any rigid intermediary structure.

The general plan, then, of the craft comprises three prominent features, well marked and distinct in character:

(*a*) The fish-shaped envelope with major section well forward, a form favorable to both speed and stability.

(*b*) The trussed girderlike car whose length allows the load to be distributed over the hull, thus preserving its nicety of outline. The most minute and technical and mechanical details were studied for eighteen months by M. Clément and his devoted collaborator, the engineer Sabathier. The girder car, as will be seen presently, is particularly well designed to serve as car, sustainer and stiffener. No stabilizing device is attached to the envelope; all are

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[1] For a fuller account of this fine airship see H. Peltier's article in *L'Aérophile*, December 1, 1910.

fixed to the car, on which is mounted also the complete propulsion plant.

(*c*) The suspension which binds the buoyant envelope to the car serves no other purpose. Note also the ingenious arrangement of two motors and two propellers, forming two independent systems, yet unitable under certain conditions. The placement of the propellers, rudders and stabilizing surfaces well above the bottom of the car, insures them against dangerous contact on landing, or while maneuvering near the ground.

The envelope is of rubberized Continental cloth. Its volume is 7,000 cubic meters, length 76.5 meters and major diameter 13.22 meters, or an elongation of 5.76 diameters. Inside the gas envelope is an air bag of 2,200 cubic meters. It is divided into two compartments, Q and Q', which can be filled with air together or separately through the air duct, Q, joined to a blower, P, run by the two motors, or by hand when so desired. The balloon proper comprises two gas valves, R. Each compartment of the ballonet has one air valve, S. The valves of the type Clément-Bayard-Chauvière are automatic. Their construction is so perfect that for the first time in France, at least on a balloon of so large bulk, the blower runs continuously in constant communication with the ballonet, the pressure in the envelope remaining invariable, due to the regular play of the valves, which yield at the pressure for which they are set. They may also be worked by hand from the pilot's bridge in case of emergency. The envelope has on its upper side three ripping seams, one in the middle, the others toward either end. These rip panels can be worked together or separately, and permit the rapid deflation of the balloon.

The long car is attached to the hull by hempen duck feet fastened to a bolt rope running along the envelope below the equator; these duck feet terminate below in steel suspension cables fixed to the car. Below the principal bolt rope are others to which are fastened the duck feet of the oblique cords, which assure the perfect solidarity of the envelope and car. The steel cable sustainers have an ingenious patented regulating windlass. The girder car consists of a latticed girder, built of steel tubes united with cast-iron joints and steel-tie wires. Its whole length is 45 meters, of which 14.5 meters constitute the car proper. It is divided into segments which are easily demountable, thus rendering it easily transportable by truck or railway. The forward segment, *A,* tapers toward the front to a sharp point and is of triangular cross-section. The mid segment, *B,* constituting the car, has a quadrangular section of variable size. The rear segment, *D,* is of triangular section, diminishing progressively toward the rear, which rises to a sort of tail supporting the empennage and the direction rudders. The entire girder car when resting on the ground is supported by two pneumatic shock absorbers, *U, U,* projecting from its floor.

The car proper comprises three parts: in front, the motor and machine room, 2.5 meters wide; in the middle, the elevated bridge, *N*, for the pilot and his aide; in the rear, the passenger cabin, 8 meters long, 1.3 meters wide and 2 meters high for the observers and wireless telegraphy plant. The two reservoirs of essence, *M*, *m*, are placed above the passenger about the center of pressure. The blower *P,* for the ballonets, and the guide ropes *T,* are placed above the pilot's bridge.

In the motor room are symmetrically arranged two Bayard-Clément engines, *G G,* separated enough to allow free passage between them. Each motor is elastically supported to obviate vibrations, and connects with the transmission shaft by a variable speed gear. The engines can be run separately or together by a connecting sprocket chain, and develop 100 to 130 horse-power each. The cooling of each motor is effected by an aluminum radiator, *L L,* of large surface.

The Chauvière propellers, *K K,* six feet in diameter, are driven by shafting and gear wheels at a normal speed of 250 rotations per minute. A special recording device serves to show their thrust at each instant, as also the torque of the motors.

The pilot, standing on the bridge where he enjoys a clear view, has immediate charge of the vessel's movements. Before him are the various controls which he must operate, and the divers indicators which he must consult. These are the direction wheel, the manometers, the aneroid and registering barometers, the clinometer, the blower control to regulate the amount and distribution of pressure, the elevating-rudder wheel, the spark control, the ripping cord, the release string of the guide-rope, and the system of transmitting orders to the mechanicians whereby he can control the engines and the blowers which furnish air to the radiator and ballonet.

The direction and poise of the vessel in flight are controlled by the rudders and empennage at the rear, and its altitude from minute to minute is governed by the elevating biplane E', of 30 square meters above the car in the mid region of the vessel.

The *Patrie* [1]

The *Patrie,* the third of its type, was first operated in 1906. The gas bag of the first balloon was built by Surcouf at Billancourt, Paris. The mechan-

[1] This description and the following are from *Present Status of Military Aëronautics,* by Major G. O. Squier.

ical part was built at the Lebaudy Sugar Refinery. Since then the gas bags have been built at the Lebaudy balloon shed at Moisson, near Paris, under the direction of their aëronaut, Juchmes. The gas bag of the *Patrie* was 197 feet long with a maximum diameter of 33 feet, 9 inches, situated about $\frac{2}{5}$ of the length from the front; volume 111,250 cubic feet; length approximately six diameters. This relation, together with the cigar shape, is in accordance with the plans of Colonel Renard's dirigible, built and operated in France in 1884; the same general shape and proportions being found in the Ville de Paris.

The first Lebaudy was pointed at the rear, which is generally admitted to be the proper shape for the least resistance, but to maintain stability it was found necessary to put a horizontal and vertical plane there, so that it had to be made an ellipsoid of revolution to give attachment for these planes.

The ballonet for air had a capacity of 22,958 cubic feet or about $\frac{1}{5}$ of the total volume. This is calculated to permit reaching a height of about one mile and to be able to return to the earth, keeping the gas bag always rigid. To descend from a height of one mile, gas would be released by the valve, then air pumped into the ballonet to keep the gas bag rigid, these two operations being carried on alternately. On reaching the ground from the height of one mile, the air would be at the middle of the lower part of the gas bag and would not entirely fill the ballonet. To prevent the air from rolling from one end to the other when the air ship pitches, thus producing instability, the ballonet was divided into three compartments by impermeable cloth partitions. Numerous small holes were pierced in these partitions, through which the air finally reached the two end compartments.

In September, 1907, the *Patrie* was enlarged by

17,660 cubic feet by the addition of a cylindrical section at the maximum diameter, increasing the length but not the maximum diameter.

The Gas Bag.—The gas bag is cut in panels; the material is a rubber cloth made by the Continental Tire Company at Hanover, Germany. It consists of four layers arranged as follows:

	Weight oz. per square yard.
a. Outer layer of cotton cloth covered with lead chromate..	2.5
b. Layer of vulcanized rubber	2.5
c. Layer of cotton cloth	2.5
d. Inner layer of vulcanized rubber	2.21
Total weight	9.71

A strip of this cloth one foot wide tears at a tension of about 934 pounds. A pressure of about one inch of water can be maintained in the gas bag without danger. The lead chromate on the outside is to prevent the entrance of the actinic rays of the sun, which would cause the rubber to deteriorate. The heavy layer of rubber is to prevent the leaking of the gas. The inner layer of rubber is merely to prevent deterioration of the cloth by impurities in the gas. This material has the warp of the two layers of cotton cloth running in the same direction and is called straight thread. The material in the ballonet weighs only about $7\frac{3}{4}$ ounces per square yard, and has a strength of about 336 pounds per running foot. When the *Patrie* was enlarged in September, 1907, the specifications of the material allowed a maximum weight of 10 ounces per square yard, a minimum strength of 907 pounds per running foot, and a loss of 5.1 cubic inches of hydrogen per square yard in twenty-four hours at a pressure of 1.18 inches of water. Bands of cloth are pasted over the seams inside and out with a solution of rubber to prevent leaking through the stitches.

Suspension.—One of the characteristics of the *Patrie* is the "short" suspension. The weight of the car is distributed over only about 70 feet of the length of the gas bag. To do this, an elliptical-shaped frame of nickel-steel tubes is attached to the bottom of the gas bag; steel cables run from this down to the car. A small hemp net is attached to the gas bag by means of short wooden cross-pieces, or toggles, which are let into holes in a strong canvas band which is sewed directly on the gas bag. The metal frame, or platform, is attached to this net by means of toggles, so that it can be quickly removed in dismounting the air ship for transportation. The frame can also be taken apart, 28 steel cables about 0.2 inches in diameter run from the frame down to the car, and are arranged in triangles. Due to the impossibility of deforming a triangle, rigidity is maintained between the car and gas bag.

The objection to the "short" suspension of the *Patrie* is the deformation of the gas bag. A distinct curve can be seen in the middle.

The Car.—The car is made of nickel-steel tubes (12 per cent nickel). This metal gives the greatest strength for minimum weight. The car is boat-shaped, about 16 feet long, about 5 feet wide and 2½ feet high. About 11 feet separate the car from the gas bag. To prevent any chance of the fire from the engine communicating with the hydrogen, the steel framework under the gas bag is covered with a noncombustible material.

The pilot stands at the front of the car, the engine is in the middle, the engineer at the rear. Provision is made for mounting a telephotographic apparatus, and for a 100-candle-power acetylene search-light. A strong pyramidal structure of steel is built under the car, pointing downward. In landing the point comes to the ground first and this protects the car, and especially the propellers, from being damaged. The car is covered to reduce air resistance. It is so low, however, that part of the equipment and most of the bodies of those inside are exposed, so that the total resistance of the car is large.

The Motor.—The first Lebaudy had a 40-horse-power Daimler-Mercedes benzine motor. The *Patrie* was driven by a 60 to 70-horse-power 4-cylinder Panhard and Levassor benzine motor, making 1,000 r. p. m.

The Propellers.—There are two steel propellers 8½ feet in diameter (two blades each) placed at each side of the engine, this giving the shortest and most economical transmission. To avoid any tendency to twist the car, the propellers turn in opposite directions. They are "high speed," making 1,000 to 1,200 r. p. m.

The gasoline tank is placed under the car inside the pyramidal frame. The gasoline is forced up to the motor by air compression. The exhaust is under the rear of the car pointing down and is covered with a metal gauze to prevent flames coming out. The fan which drives the air into the ballonet is run by the motor, but a dynamo is also provided so that the fan can always be kept running even if the motor stops. This is very essential as the pressure must be maintained inside the gas bag so that the latter will remain rigid and keep its form. There are five valves in all, part automatic and part both automatic and also controlled from the car with cords. The valves in the ballonet open automatically at less pressure than the gas valves, so that when the gas expands all the air is driven out of the ballonet before there is any loss of gas. The ballonet valves open at a pressure of about 0.78 inches of water, the gas valves at about 2 inches.

Stability.—Vertical stability is maintained by means of fixed horizontal planes. One having a surface of 150 square feet is attached at the rear of the gas bag and due to its distance from the center of gravity is very efficient. The elliptical frame attached under the gas bag has an area of 1,055 square feet, but due to its proximity to the center of gravity, has little effect on the stability. Just behind the elliptical frame is an arrangement similar to the feathering of an arrow. It consists of a horizontal plane of 150 square feet, and a vertical plane of 113 square feet. To maintain horizontal stability, that is, to enable the air ship to move forward in a straight line without veering to the sides, fixed vertical planes are used. One runs from the center to the rear of the elliptical frame and has an area of 108 square feet.

In addition to the vertical surface of 113 square feet at the rear of the elliptical frame, there is a fixed plane of 150 square feet at the rear of the gas bag. To fasten the two perpendicular planes at the rear of this gas bag, cloth flaps are sewed directly on the gas bag. Nickel-steel tubes are placed in the flaps, which are then laced over the tubes. With these tubes as a base, a light tube and wire framework is attached and waterproof cloth laced on this framework. Additional braces run from one surface to the other and from each surface to the gas bag. The rudder is at the rear under the gas bag. It has about 150 square feet and is balanced.

A movable horizontal plane near the center of gravity, above the car, is used to produce rising or descending motion, or to prevent an involuntary rising or falling of the air ship due to expansion or contraction of the gas or to other causes. After the adoption of this movable horizontal plane, the loss of gas and ballast was reduced to a minimum. Ballast is carried in 10- and 20-pound sandbags. A pipe runs through the bottom of the car from which the ballast is thrown.

There are two long guide-ropes, one attached at the front of the elliptical frame and the other on the car. On landing, the one in front is seized first so as to hold the air ship with the head to the wind. The motor may then be stopped and the descent made by pulling down on both guide-ropes. A heavy rope 22 feet long, weighing 110 pounds, is attached at the end of a 164-foot guide-rope. This can be dropped out on landing to prevent coming to the ground too rapidly. The equipment of the car includes a " siren " speaking trumpet, carrier pigeons, iron pins and a rope for anchoring the air ship, reserve supply of fuel and water, and fire extinguisher.

After being enlarged in September, 1907, the *Patrie* made a number of long trips at an altitude of 2,500 to 3,000 feet. In November, 1907, she went from Paris to Verdun, near the German frontier, a distance of about 175 miles, in about 7 hours, carrying four persons. This trip was made in a light wind blowing from the northeast. Her course was east, so that the wind was unfavorable. On Friday, November 20, 1907, during a flight near Verdun, the motor stopped due to difficulty with the carburetor. The air ship drifted with the wind to a village about 10 miles away, where she was safely landed. The carburetor was repaired on the 20th. Soon after, a strong wind came up and tore loose some of the iron pickets with which it was anchored. This allowed the air ship to swing broadside to the wind; it then tilted over on the side far enough to let some of the ballast bags fall out. The 150 or 200 soldiers who were holding the ropes were pulled along the ground until directed by the officer in charge to let go. After being released, it rose and was carried by the wind across the north of France, the English

Channel and into the north of Ireland. It struck the earth there, breaking off one of the propellers, and then drifted to sea.

The *République*

This is the latest of the French military dirigible balloons, and differs but slightly from its predecessor, the *Patrie*. The volume has been increased by about 2,000 cubic feet. The length has been reduced to 200 feet and the maximum diameter increased to 35½ feet. The shape of the gas bag accounts for the 2,000 additional cubic feet of volume. The motor and propeller are as in the *Patrie*. The total lifting capacity is 9,000 pounds, of which 2,700 pounds are available for passengers, fuel, ballast, instruments, etc. Its best performance was a 125-mile flight made in 6½ hours against an unfavorable wind.

The material for the gas bag of the new air ship was furnished by the Continental Tire Company. It is made up as follows:

	Weight oz. per square yard.
Outer yellow cotton layer	3.25
Layer of vulcanized rubber	3.25
Layer of cotton cloth	3.25
Inner layer of rubber	0.73
Total weight	10.48

It is interesting to note the changes which this type has undergone since the first one was built. The *Jaune*, constructed in 1902–3, was pointed at the rear and had no stability plane there; later it was rounded off at the rear and a fixed horizontal plane attached. Finally a fixed vertical plane was added. The gas bag has been increased in capacity from 80,670 cubic feet to about 131,000 cubic feet. The manufacturers have been able to increase the strength of the material of which the gas bag is made, without materially increasing the weight. The rudder has been altered somewhat in form. It was first pivoted on its front edge, but later on a vertical axis, somewhat to the rear of this edge. With the increase in size, has come an increase in carrying capacity and, consequently, a greater speed and more widely extended field of action.

Ville de Paris

This air ship was constructed for Mr. Deutsch de la Meurthe, of Paris, who has done a great deal to encourage aërial navigation. The first *Ville de Paris* was built in 1902, on plans drawn by Tatin, a French aëronautical engineer. It was not a success. Its successor was built in 1906, on plans of Surcouf, an aëronautical engineer and balloon builder. The gas bag was built at his works in Billancourt, the mechanical part at the Voisin shop, also in Billancourt. The plans are based on those of Colonel Renard's air ship, the *France,* built in 1884, and the *Ville de Paris* resembles the older air ship in many particulars. In September, 1907, Mr. Deutsch offered the use of his air ship to the French Government. The offer was accepted, but delivery was not to be made except in case of war or emergency. When the *Patrie* was lost in November, 1907, the military authorities immediately took over the Deutsch air ship.

Gas Bag.—The gas bag is 200 feet long for a maximum diameter of 34½ feet, giving a length of about 6 diameters, as in the *France* and the *Patrie.* Volume, 112,847 cubic feet; maximum diameter at about ⅜ of the distance from the front, approximately, as in the *Patrie.* The middle section is cylindrical with conical sections in front and rear. At the extreme rear is a cylindrical section with eight smaller cylinders attached to it. The ballonet has a volume of 21,192 cubic feet or about $\frac{1}{5}$ of the volume, the same proportion found in the *Patrie*. The ballonet is divided into three compartments from front to rear. The division walls are of permeable cloth, and are not fastened to the bottom so that when the middle compartment fills with air, and the ballonet rises, the division walls are lifted up from the bottom of the gas bag, and there is free communication between the three compartments. The gas bag is made up of a series of strips of perpendicular to a meridian line. These strips run around the bag, their ends meeting on the under meridian. This is known as the "barchistode" method of cutting out the material, and has the advantage of bringing the seams parallel to the line of greatest tension. They are therefore more likely to remain tight and not allow the escape of gas. The disadvantage lies in the fact that there is a loss of $33\frac{1}{3}$ per cent of material in cutting. The material was furnished by the Continental Tire Company, and has approximately the same tensile strength and weight as that used in the *Patrie*. It differs from the other in one important feature—it is diagonal thread, that is, the warp of the outer layer of cotton cloth makes an angle of 45 degrees with the warp of the inner layer of cotton cloth. The result is to localize a rip or tear in the material. A tear in the straight thread material will continue along the warp, or the weave, until it reaches a seam.

Valves.—There are five in all, made of steel, about fourteen inches in diameter; one on the top connected to the car by a cord, operated by hand only; two near the rear underneath. These are automatic but can be operated by hand from the car. Two ballonet valves directly under the middle are automatic and are also operated from the car by hand. The ballonet valves open automatically at a pressure of $\frac{2}{3}$ inches of water; the gas valves open at a higher pressure.

Suspension.—This air ship has the "long" suspension. That is, the weight is distributed along practically the entire length of the gas bag. A doubled band of heavy canvas is sewn with six rows of stitches along the side of the gas bag. Hemp ropes running into steel cables transmit most of the weight of the car to these two canvas bands and thus to the gas bag. On both sides and below these first bands are two more. Lines run from these to points half way between the gas bag and the car, then radiate from these points to different points of attachment on the car. This gives the triangular or nondeformable system of suspension, which is necessary in order to have the car and gas bag rigidly attached to each other. With this "long" suspension, the *Ville de Paris* does not have the deformation so noticeable in the gas bag of the *Patrie.*

The Car.—This is in the form of a trestle. It is built of wood with aluminum joints and 0.12 inch wire tension members. It is 115 feet long, nearly 7 feet high at the middle and a little over $5\frac{1}{2}$ feet wide at the middle. It weighs 660 pounds and is considered unnecessarily large and heavy. The engine and engineer are well to the front, the aëronaut with steering wheels is about at the center of gravity.

Motor.—The motor is a 70 to 75-horse-power *Argus,* and is exceptionally heavy.

Propeller.—The propeller is placed at the front end of the car. It thus has the advantage of working in undisturbed air; the disadvantage is the long transmission and difficulty in attaching the propeller rigidly. It has two blades and is 19.68 feet long with a pitch of 26.24 feet. The blades are of cedar with a steel arm. The propeller makes a maximum of 250 turns per minute when the engine is making 900 revolutions. Its great diameter and width compensate for its small speed.

Stability.—This is maintained entirely by the cylinders at the rear. Counting the larger one to which the smaller ones are attached, there are five, arranged side by side corresponding to the horizontal planes of the *Patrie,* and five vertical ones corresponding to the *Patrie's* vertical planes. The volume of the small cylinders is so calculated that the gas in them is just sufficient to lift their weight, so they neither increase nor decrease the ascensional force of the whole. The horizontal projection of these cylinders is 1,076 square feet. The center of this projection is 72 feet from the center of gravity of the gas. The great objection to this method of obtaining stability, is the air resistance due to these cylinders, and consequent loss of speed. The stability of the *Ville de Paris* in a vertical plane is said to be superior to that of the *Patrie,* due to the fact that the stability planes of the latter do not always remain rigid. The independent velocity of the *Ville de Paris* probably never exceeded 25 miles an hour.

The Rudder.—The rudder has a double surface of 150 square feet placed at the rear end of the car, 72 feet from the center of gravity. It is not balanced, but is inclined slightly to the rear so that its weight would make it point directly to the rear if the steering gear should break. Two pairs of movable horizontal planes, one at the rear of the car having 43 square feet, and one at the center of gravity (as on the *Patrie*) having 86 square feet, serve to drive the air ship up or down without losing gas or ballast.

Guide-Ropes.—A 400-foot guide-rope is attached at the front end of the car. A 230-foot guide-rope is attached to the car at the center of gravity.

About thirty men are required to maneuver the *Ville de Paris* on the ground. The pilot has three steering wheels, one for the rudder and two for the movable horizontal planes. The instruments used are an aneroid barometer, a registering barometer giving heights up to 1,600 feet, and an ordinary dynamometer, which can be connected either with the gas bag or ballonet by turning a valve. A double column of water is also connected to the tube to act as a check on the dynamometer. Due to the vibration of the car caused by the motor, these instruments are suspended by rubber attachments. Even with this arrangement, it is necessary to steady the aneroid barometer with the hand in order to read it. The vibration prevents the use of the statoscope.

Germany

Three different types of air ships are being developed in Germany. The *Gross* is the design of Major Von Gross, who commands the Balloon Battalion at Tegel near Berlin. The *Parseval* is being developed by Major Von Parseval, a retired German officer, and the *Zeppelin* is the design of Count Zeppelin, also a retired officer of the German Army.

The *Gross*

The first air ship of this type made its first ascension on July 23, 1907. The mechanical part was built at Siemen's Electrical Works in Berlin; the gas bag by the Riedinger firm in Augsburg.

Gas Bag.—The gas bag is made of rubber cloth furnished by the Continental Tire Company similar to that used in the *Ville de Paris.* It is diagonal-thread, but there is no inner layer of rubber, as they do not fear damage from impurities in the hydrogen gas. Length, 131¼ feet; maximum diameter about 39⅓ feet; volume, 63,576 cubic feet; the elongation is about 3⅓. The form is cylindrical with spherical cones at the ends, the whole being symmetrical.

Suspension.—The suspension is practically the same as that of the *Patrie.* A steel and aluminum frame is attached to the lower part of the gas bag, and the car is suspended on this by steel cables. The objection to this system is even more apparent in the *Gross* than in the *Patrie.* A marked dip along the upper meridian of the gas bag shows plainly the deformation.

The Car.—The car is boat-shaped like that of the *Patrie.* It is suspended thirteen feet below the gas bag.

Motor.—The motor is a 20- to 24-horse-power, 4-cylinder Daimler-Mercedes.

Propellers.—There are two propellers $8\frac{3}{10}$ foot in diameter, each having two blades. They are placed one on each side, but well up under the gas bag near the center of resistance. The transmission is by belt. The propellers make 800 r. p. m.

Stability.—The same system, with planes, is used in the *Gross* as in the *Patrie,* but it is not nearly so well developed. At the rear of the rigid frame, attached to the gas bag, are two fixed horizontal planes, one on each side. A fixed vertical plane runs down from between these horizontal planes, and is terminated at the rear by the rudder. A fixed horizontal plane is attached on the rear of the bags as in the *Patrie.* The method of attachment is the same, but the plane is put on before inflation in the *Gross* air ship, afterwards in the *Patrie.* The stability of the *Gross* air ship in a vertical plane is reported to be very good, but it is said to veer considerably in attempting to steer a straight course.

The many points of resemblance between this dirigible and the Lebaudy type are worthy of notice. The suspension or means of maintaining stability, and the disposition for driving are in general the same. As first built, the *Gross* had a volume of 14,128 cubic feet less than at present, and there was no horizontal plane at the rear of the gas bag. Its maximum speed is probably fifteen miles per hour. As a result of his experiments of 1907, Major Von Gross has this year produced a perfected air ship, built on the same lines as his first, but with greatly increased volume and dimensions. The latest one has a volume of 176,000 cubic feet, is driven by two 75-horse-power Daimler motors, and has a speed of 27 miles per hour.

On September 11th of this year, the *Gross* air ship left Berlin at 10.25 P.M., carrying four passengers, and returned the next day at 11.30 A.M., having covered 176 miles in the period of a little over 13 hours. This is the longest trip, both in point of time and distance, ever made by any air ship returning to the starting point.

The *Parseval*

The *Parseval* air ship is owned and controlled by the Society for the Study of Motor Balloons. This organization, composed of capitalists, was formed practically at the command of the emperor, who is very much interested in aërial navigation. The society has a capital of 1,000,000 marks, owns the *Parseval* patents and is ready to construct air ships of the *Von Parseval* type. The present air ship was constructed by the Riedinger firm at Augsburg, and is operated from the balloon house of this society at Tegel, adjoining the military balloon house.

The gas bag is similar in construction to that of the *Drachen* balloon, used by the army for captive work. Volume, 113,000 cubic feet; length, 190 feet; maximum diameter, $30\frac{1}{2}$ feet. It is cylindrical in shape, rounded at the front and pointed at the rear. The material was furnished by the Continental Tire Company. It is diagonal-thread, weighing about $11\frac{3}{10}$ ounces per square yard and having a strength of about 940 pounds per running foot. Its inner surface is covered with a layer of rubber.

Ballonets.—There are two ballonets, one at each end, each having a capacity of 10,596 cubic feet. The material in the ballonet weighs about $8\frac{1}{4}$ ounces per square yard, the cotton layers being lighter than in the material for the gas bag. Air is pumped into the rear ballonet before leaving the ground, so that the air ship operates with the front end inclined upward. The air striking underneath exerts an upward pressure, as on an aëroplane, and thus adds to its lifting capacity. Air is pumped into the ballonets from a fan operated by the motor. A complex valve, just under the middle of the gas bag, enables the engineer to drive air into either, or both ballonets. The valves also act automatically and release air from the ballonets at a pressure of about 0.9 inches of water.

In the middle of the top of the gas bag is a valve for releasing the gas. It can be operated from the car, and open automatically at a pressure of about 2 inches of water. Near the two ends and on opposite sides are two rip strips controlled from the car by the cords.

Suspension.—The suspension is one of the characteristics of the air ships, and is protected by patents. The car has four trolleys, two on each side, which run on two steel cables. The car can run backwards and forwards on these cables, thus changing its position with relation to the gas bag. This is called "loose" suspension. Its object is to allow the car to take up, automatically, variations in thrust due to the motor, and variations in resistance due to the air. Ramifications of hemp rope from these steel cables are sewed onto a canvas strip, which in turn is sewed onto the gas bag. This part of the suspension is the same as in the *Drachen* balloon. The weight is distributed over the entire length of the gas bag.

The Car.—The car is 16.4 feet long and is built of steel tubes and wire. It is large enough to hold the motor and three men, though four or five may be taken.

Motor.—The motor is a 110-horse-power Daimler-Mercedes. Sufficient gasoline is carried for a run of twelve hours.

Propeller.—The propeller, like the suspension, is peculiar to this air ship and is protected by patents. It has four cloth blades which hang limp when not turning. When the motor is running, these blades, which are carefully weighed with lead at certain points, assume the proper position due to the various forces acting. The diameter is 13¾ feet. The propeller is placed above the rear of the car near the center of resistance. Shaft transmission is used. The propeller makes 500 r. p. m. to 1,000 of the motor. There is a space of 6½ feet from the propeller blades to the gas bag, the bottom of the car being about 30 feet from the gas bag. This propeller has the advantage of being very light. Its position, so far from the engine, necessarily incurs a great loss of power in transmission.

The steering wheel at the front of the car has a spring device for locking it in any position.

The 1908 model No. 1 of this air ship was constructed for the purpose of selling it to the government. Among other requirements is a 12-hour flight without landing, and a sufficient speed to maneuver against a 22-mile wind. A third and larger air ship of this type is now under construction.

United States

Signal Corps Dirigible No. 1

Due to the lack of funds, the United States Government has not been able to undertake the construction of an air ship sufficiently large and powerful to compete with those of European nations. However, specifications were sent out last January for an air ship not over 120 feet long and capable of making 20 miles per hour. Contract was awarded to Capt. Thomas S. Baldwin, who delivered an air ship last August to the Signal Corps, the description of which follows:

Gas Bag.—The gas bag is spindle shaped, 96 feet long, maximum diameter, 19 feet 6 inches, with a volume of 20,000 cubic feet. A ballonet for air is provided inside the gas bag, and has a volume of 2,800 cubic feet. The material for the gas bag is made of two layers of Japanese silk, with a layer of vulcanized rubber between.

Car.—The car is made of spruce, and is 66 feet long, 2½ feet wide and 2½ feet high.

Motor.—The motor is a 20-horse-power water-cooled Curtiss make.

Propeller.—The propeller is at the front end of the car, and is connected to the engine by a steel shaft. It is built of spruce, has a diameter of 10 feet, 8 inches, with a pitch of 11 feet, and turns at the rate of 450 r. p. m. A fixed vertical surface is provided at the rear end of the car to minimize veering, and a horizontal surface attached to the vertical rudder at the rear tends to minimize pitching. A double horizontal surface controlled by a lever and attached to the car in front of the engine, serves to control the vertical motion and also to minimize pitching.

The position of the car very near to the gas bag, is one of the features of the Government dirigible. This reduces the length and consequently the resistance of the suspension, and places the propeller thrust near the center of resistance.

The total lifting power of the air ship is 1,350 pounds of which 500 pounds are available for passengers, ballast, fuel, etc. At its official trials a speed of 19.61 miles per hour was attained over a measured course and an endurance run lasting two hours, during which seventy per cent of the maximum speed was maintained.

Dirigible No. 1, as this air ship has been named, has already served a very important purpose in initiating officers of the Signal Corps in the construction and operation of a dirigible balloon. With the experience now acquired, the United States Government is in a position to proceed with the construction and operation of an air ship worthy of comparison with any now in existence, but any efforts in this direction must await the action of Congress in providing the necessary funds.

APPENDIX IV

THE RELATIONS OF WEIGHT, SPEED AND POWER OF FLYERS [1]

By Wilbur and Orville Wright

THE flyer of 1903 carried a four-cylinder gasoline motor of four-inch bore and four-inch stroke. Complete with magneto, radiators, tanks, water, fuel, etc., the motor weighed a little over 200 pounds, and at 1,200 revolutions per minute developed 16 horse power for the first 15 seconds after starting. After a minute or two the power did not exceed 13 or 14 horse power. At 1,020 revolutions per minute—the speed of the motor in the flights at Kitty Hawk on the 17th of December, 1903—it developed about 12 horse power.

The flyer of 1904 was equipped with a motor similar to the first, but of $\frac{1}{8}$-inch larger bore. This engine at 1,500 revolutions per minute developed 24 horse power for the first 15 seconds, but only 16 to 17 horse power after a few minutes run. Complete with water, fuel and other accessories, it weighed 240 pounds.

The same engine with a few modifications in the oiling device and the carburetor, was used in all the flights of 1905. A test of its power made soon after the flights of October, 1905, revealed a gain of 3 horse power over tests made just before mounting

[1] From *Navigating the Air*, by permission of Doubleday, Page & Co.

it on the flyer in 1904. This gain is attributed to the increased smoothness of the cylinders and pistons produced by wear. The small output of these engines was due to lack of experience in building gasoline motors.

During the past year further improvements have been made, and our latest engines of four-inch bore and four-inch stroke produce about 25 horse power continuously. The improvement in the reliability of the motor has been even more marked, so that now flights of long distances can be attempted without danger of failure on account of the stopping of the motor.

A comparison of the flyers of 1903, 1904 and 1905 show some interesting facts. The flyer of 1903 weighed, complete with operator, 745 pounds. Its longest flight was of 59 seconds duration, with a speed of 30 miles an hour and an expenditure of 12 horse power. The flyer of 1904 weighed about 900 pounds, including a load of 70 pounds in iron bars. A speed of more than 34 miles an hour was maintained for a distance of three miles with an expenditure of 17 horse power. The flyer of 1905 weighed, including load, 925 pounds. With an expenditure of 19 to 20 horse power it traveled over 24 miles at a speed of more than 38 miles an hour. The flights of 1904 and 1905 would have been slightly faster had they been made in a straight line, as were those of 1903.

In 1903, 62 pounds per horse power were carried at a speed of 30 miles an hour; in 1904, 53 pounds, at 34 miles an hour; and in 1905, 46 pounds at 38 miles an hour. It will be noted that the weight carried per horse power is almost exactly in inverse ratio to the speed, as theory demands—the higher the speed, the smaller the weight carried per horse power.

Since flyers can be built with approximately the same dynamic efficiency for all speeds up to 60 miles an hour, a flyer designed to carry a total weight of 745 pounds at 20 miles an hour would require only 8 horse power or two thirds of the power necessary for 30 miles an hour. At 60 miles 24 horse power would be necessary—twice that required to carry the same weight at 30 miles an hour. At 120 miles an hour 60 to 75 horse power would probably be necessary, and the weight carried per horse power would be only 10 or 12 pounds. At such high speed the resistance of the operator's body and the engine is a formidable factor, consuming 64 times as much horse power as at 30 miles an hour. At speeds below 60 miles an hour this resistance is almost negligible.

It is evident that the limits of speed have not as yet been closely approached in the flyers already built, and that in the matter of distance, the possibilities are even more encouraging. Even in the existing state of the art it is easy to design a practical and durable flyer that will carry an operator and supplies of fuel for a flight of over 500 miles at a speed of 50 miles an hour.

APPENDIX V

CURTISS'S EXPERIMENTS IN RISING FROM THE WATER[1]

During the past two years Glenn H. Curtiss, who, more than any other experimenter, has been given to developing the aëroplane for various uses, has experimented with floats for his biplane that would enable it to rise from the surface of the water. Something over a year ago he succeeded in developing a speed of about twenty miles an hour on the water, but this was insufficient to rise from the surface.

At the beginning of the new year Mr. Curtiss moved to the Pacific Coast and set about endeavoring to develop suitable floats which would make it possible for his machine to rise from the surface of the water. These experiments have been carried on at San Diego, where Mr. Curtiss is instructing several naval and military officers in the art of flying.

In his first experiments on the Pacific Coast Mr. Curtiss followed the successful experiments of this sort made by M. Henri Fabre at Marseilles, France, about a year ago, as far as the design of his floats was concerned. He constructed one large float six feet wide, five feet from front to rear, and one foot thick at its central point, and placed this under the center of the machine. The bottom of this float was

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[1] From *Scientific American* of March 4, 1911, by permission of Munn & Co.

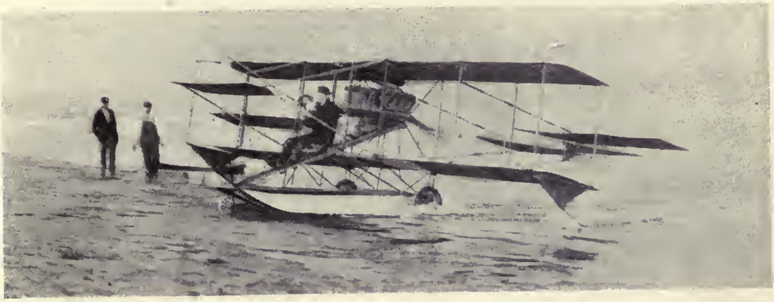
perfectly flat and arranged at an incline of ten or twelve degrees. Some distance forward of the main float, at about the position of the front wheel in the land machine, another float six feet wide, by one foot from front to rear, and six inches deep, was placed; while at the extreme front end of the machine, on a special outrigger, was mounted a small elevating hydroplane six feet wide by eight inches in a fore-and-aft direction, and one and one-half inches thick. This hydroplane was fixed at an angle of about twenty-five degrees and was intended to lift the front part of the machine. A spray shield was fitted back of it, as shown in the diagram, page 333.

The first experiments were made with these new floats on January 26th last; and although they made a considerable disturbance in the water, especially at low speed, the aviator was enabled to get up a speed on the surface of about forty-five miles an hour. He found that at as low a rate as ten miles the hydroplanes (which normally were submerged) rose to the surface, while as the speed increased only the rear edges of the two main planes were required to support the machine. The aëroplane readily attained sufficient speed to rise in the air, for as the speed increased and the floats emerged from the water, the head resistance of the floats diminished and there was only the skin friction of the water on a few inches of the rear edge of these floats, plus the air resistance, to be overcome.

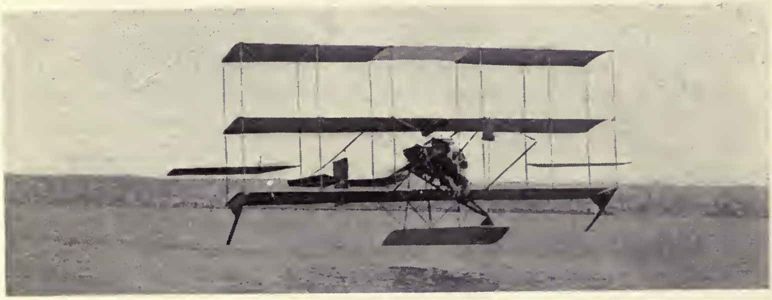
At the first try-out, while traveling over the water at high speed, Mr. Curtiss found himself suddenly nearing the shore, and to avoid running aground he turned his horizontal rudder sharply upward, with the result that the machine rose from the water with perfect ease. He soon alighted again, and in the second flight he made a circle and remained in the air a minute and twenty-one seconds.

PLATE XXXII.

CURTISS STARTING FROM THE WATER.



CURTISS BIPLANE FOR LAND AND WATER.



CURTISS TRIPLANE RISEN FROM THE WATER.

Two other experimental flights were made the first day, and on January 27th he made a three-and-one-half-minute flight and stated, upon alighting, that he found no difficulty in remaining aloft as long as he pleased. The machine showed a speed of fifty miles an hour in the air as against forty-five miles an hour when skimming over the surface of the water.

Not satisfied with the several floats with which he had attained his first success in rising from the water, Mr. Curtiss immediately constructed a single float twelve feet long by two feet in width and twelve inches deep. This float is built of wood and resembles a flat-bottomed boat or scow, the top being covered with canvas to keep the water from getting in. Three feet from the front end the bottom is curved upward forming a bow the full width of the float, while at the same distance from the rear the float slants downward in a similar manner.

This single float is placed under the aëroplane in such a position that the main weight of the machine and aviator is slightly to the rear of the center of the float, which causes the latter to incline upward slightly and thus gives the necessary angle for hydroplaning on the surface of the water. The weight of this new float is but fifty pounds, or less than half as much as that of the two floats that were used before.

The paint was barely dry on the new float before Mr. Curtiss had it fitted to his machine and gave it a trial. This was done on February 1st and the trial was thoroughly successful. The machine ran over the surface of the water with very much less disturbance than before and rose in the air readily. A glance at the photographs showing the new and the old floats in action will give one an excellent idea of the much less commotion caused by the single scow-shaped float. Besides being much more compact and creating less disturbance, this float or scow can be used for carryng articles or a passenger.

In order to keep the aëroplane from tilting to one side or the other, an inclined stick four feet long and three inches wide, to which is attached on its upper side an inflated rubber tube, is fastened to the front edge of the lower plane at each end. By the use of these props the aëroplane does not tip readily when skimming along the surface, even though the scow-shaped float used is but two feet in width.

After meeting with success with his new float, Mr. Curtiss, on February 17th, made more flights with the motor and propeller placed at the front of his biplane and with his seat placed at the rear of the main planes. The chief of these flights was one which he made from North Island, where he is experimenting, over San Diego harbor to the cruiser *Pennsylvania*. He alighted upon the surface close beside the cruiser and his aëroplane was hauled up beside the warship and placed on her deck.

After a short visit on the cruiser the aviator was again lowered to the surface in his machine. A sailor started the engine, and Mr. Curtiss flew back to his starting point in short order. The naval authorities were greatly pleased with his demonstration and it is probable that the Navy Department will purchase one of these machines in the near future and continue the instruction of its officers.

After increasing the surface of his biplane Mr. Curtiss, on February 24th, took up one of his naval pupils, Lieutenant T. G. Ellyson, as a passenger. He made a flight of one and one-half miles, rising to a height of one hundred feet and flying as slowly as twenty-five miles an hour, or as fast as fifty miles an hour, at will. Lieutenant Ellyson was seated on the pontoon below the aëroplane. He could look down in the water and see bottom at a depth of twenty-five feet, and he believes submarines can be easily located by flying over the water. The slow speed at which it is possible to fly will make the biplane especially useful for bomb dropping. As we go to press Mr. Curtiss is about to try his machine fitted with wheels and floats as well.

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