HENLEY'S
ABC OF GLIDING
AND
SAILFLYING

Frontispiece.—Illustrations Showing the Two Main Classes of Gliders. That at Top Shows a Primary Glider Launched by Shock Cord. The Bottom View Shows a Bowlus Sailplane, an American Built Soaring Type, in the Air.

HENLEY'S

ABC OF GLIDING AND SAILFLYING

This Treatise Contains a Brief History of Gliding and Soaring with Motorless Airplanes and an Interesting Study of Bird Flight and Its Relation to the Principles Underlying Static and Dynamic Sailflying

Popular German and American Gliders and Soaring Planes Are Described and Illustrated. Structural Elements and Materials of Construction Are Fully Considered and Typical Designs Are Outlined in Detail

The Book Also Contains Practical Instructions for Forming Glider Clubs, Selection of Terrain for Gliding and Methods of Launching and Flying Gliders and Soaring Planes Incidental to the Training of Pilots

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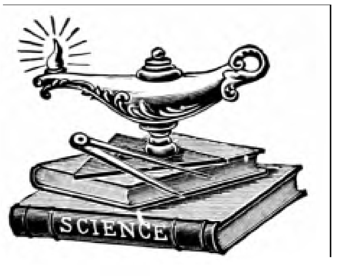

ILLUSTRATED WITH NUMEROUS SPECIALLY MADE DRAWINGS. WRITTEN IN EASILY UNDERSTOOD LANGUAGE

INSTRUCTIONS AND WORKING DRAWINGS ARE INCLUDED FOR BUILDING A MODERN TRAINING TYPE GLIDER

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THIS TREATISE IS RESPECTFULLY

DEDICATED TO

MR. EDWARD S. EVANS, *Honorary President*

OF THE NATIONAL GLIDER ASSOCIATION AND THE MEMBERSHIP OF THAT SOCIETY FOR THEIR UNSELFISH EFFORTS TO PROMOTE AN UNDERSTANDING OF SAFE GLIDING AND SOARING IN AMERICA BY PROVIDING PROPER REGULATION AND PROMOTING THE FORMATION OF PROPERLY ORGANIZED GLIDER CLUBS

PREFACE

The German nation was prevented by the terms of the Versailles treaty from any extensive airplane manufacturing and so the attention of her flying public was diverted to the glider. Progress in the art of gliding has gone rapidly ahead as a result of this enforced limitation. Modern scientific construction and meteorological knowledge have enabled a soaring record of over 14 hours' duration and another when a sailplane attained 2,500 feet altitude above the starting point, to be set in that country.

Gliding and soaring are rapidly acquiring the proportions of a National sport in Germany. Many of her young men have become quite proficient in both these branches of motorless aviation. Gliding is comparatively simple and consists of sailing downhill, using the lift component of the wind resistance offered by the wings of the glider as a means of lessening the pull of gravity; soaring calls for considerably more skill and machines that are much more efficient aërodynamically than gliders. Soaring machines or sailplanes are usually monoplanes with a higher aspect ratio than found in the training planes and are so designed as to possess the highest possible degree of maneuverability consistent with stability.

Great care should be exercised by amateur builders in constructing the wings, and in order to design them correctly a thorough knowledge of aërodynamics is necessary. By far the most important part of motorless aircraft building is the design, construction and bracing of the supporting surfaces, also their attachment to the fuselage. A word of caution must be sounded to any one building a glider from stock plans. Only the best of materials and workmanship is permissible and there can be no compromise with quality in either the constructional details or the faithful working out of the design.

Properly designed and constructed gliders combined with a fair amount of common sense in their use are practically harmless. An occasional stall and crash results at the worse in a severe shaking up and is the cheapest and least dangerous lesson possible on the hazards of losing flying speed in any aircraft. Glider training is a splendid preparatory course for those intending to take flying lessons in full sized motored aircraft. Gliding is cheap. The relatively low cost of gliding compared with powered flight is perhaps its greatest single recommendation.

Gliding may be indulged in at a small fraction of the cost of owning and operating an airplane. And last, but not least, gliding is using the air and becoming familiar with the air as a medium of transportation for human beings. The so-called mystery of flight fades quickly after the fundamentals instilled through gliding have been acquired by the embryo airplane pilot. Here lies its greatest value to aviation. A glider can safely be landed in places that would greatly disturb airplane pilots; in underbrush, in hollows, on steep inclines, or jumping over fences. After having stalled in the air, flying speed may be recovered after a drop of something like 25 feet.

There remains the possibility of fitting the glider with a small auxiliary engine. Thus the glider may take off in the plains and fly to any place, where, upon meeting soaring flight conditions, the engine is shut off and the real sport begins. The auxiliary engine would also help out a glider that drifts away from lifting currents or runs into a calm. All kinds of motorcycle engines have been tried. This brings us out of the realm of the true sailplane or glider, however, and into the field of the "flivver" airplane.

Unfortunately, no present motor seems to meet all the ideal requirements at once, but that will come. When this goal is reached some authorities profess to believe that it will be comparatively easy to build a reliable and fairly foolproof light airplane of high efficiency, and capable of soaring flight, accommodating two people. It will be slow and safe to land, of amazing fuel economy and negligible maintenance cost. There is little doubt that this generation will see and use it and flying should become nearly as popular as motoring now is. A beginner on a training type, motorless glider is not disturbed by the speed, roar, vibration, and fumes of a motor. There is no throttle to regulate. He can concentrate upon maintaining balance, getting "the feel of the air." This saves time later during powered glider or airplane instruction.

In this treatise, some space is devoted to bird flight, especially as related to soaring birds, because much has been learned from observing them and the student of gliding and soaring will find much of interest in studying birds. Space has also been given to the nature and causes of air currents because soaring will be impossible without them. The suggestions for forming a gliding club and the various methods of training pilots and flying gliders should also prove helpful.

The only way to learn to glide is by practice, so any reader with ambitions to become a glider pilot should join a glider club, or purchase a glider of his own and secure actual experience in the air. This book is only intended to be an elementary ground course on Gliders and Sailplanes. One can learn to fly only by flying.

September, 1930 VICTOR W. PAGÉ

ACKNOWLEDGMENT

In compiling this volume, the editor wishes to make acknowledgment to the National Glider Association, Detroit, Michigan; the National Advisory Committee for Aëronautics, Washington, D. C., and various publications and authorities mentioned in the text for valuable illustrative and descriptive material.

Much interesting information relative to German Sailplanes and Sailplane Construction practice was obtained from translations of the writings of Mr. Alfred Gymnich, the well-known German authority on gliding and sailflying, some of which have been published as technical memoranda by the N.A.C.A. Other articles have appeared in *Popular Aviation,* from which excerpts have been taken.

The drawings of the Dickson glider, which are reproduced through the courtesy of *Flight,* a leading British aviation publication, were selected from the number of training glider plans available because of the neat and strong construction outlined therein and also for the reason that all amateur glider constructors exercising reasonable care should produce an airworthy and safe training glider if they follow the instructions given in the working drawings and text.

THE EDITOR

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CHAPTER ONE

HISTORY OF EARLY GLIDER DEVELOPMENT

Some Early Flights—Work of Leonardo da Vinci—Pioneer Glider Pilots —The Chanute Multiplane Glider—Work of the Wright Brothers— Archdeacon's Water Glider—Harth and Messerschmitt—Modern Gliders Are Airworthy Machines—Gliding as a Sport—Suspension Type Glider Obsolete—Gliding Not Dangerous—Gliding Endorsed by Experts—Gliders Must Be Approved—Three Classes of Pilot's Licenses.

Some Early Flights.—About the year 1300 before Christ, an ancient Greek philosopher Dædalus wanted to escape the wrath of Minos, King of Crete. According to legendary lore, he made himself a pair of wings consisting of feathers fastened together with wax; and he made also a pair for his son, Icarus. They both ascended into the air. Dædalus arrived safely in Sicily, having started from Crete. But Icarus, with the usual exuberance of youth, flew too high and approached so near the sun, that the wax in his wings melted; he fell and was drowned in the sea. That incident probably discouraged other would-be flyers from similar lofty aspirations and should be useful even to-day in teaching conservatism in flying because the older and less ambitious pilot did not try any acrobatics or for an altitude record and history records that he reached his goal.

To Archytas, a philosopher and mathematician of Tarentum, who lived about 400 B.C., usually goes credit for the first flying mechanism, a wooden pigeon which according to the ancient record, flew for a distance of 50 feet. The first contrivance to raise a man to the skies is said to have been devised in 200 B.C., when a Chinese general, Han Sin, elevated a man by means of kites to observe movements of the enemy.

Triumph came momentarily to M. Besnier, a French locksmith of 1678, who invented a flying contrivance, with four winglike planes operated by his arms and legs. The wings, which were hinged as in a book, were moved up and down by a motion similar to walking. Besnier began his experiments from chairs and tables, and then from balconies and low roofs. He managed to save his neck throughout these tests which were in the nature of wing-flapping glides, but he could maintain horizontal flight only momentarily, as the physical exertion necessary was beyond the limitations of man.

In 1742, another air-minded French person, the Marquis de Bacqueville, built a gliding machine in which he took off from the window of his mansion, glided over the gardens of the Tuileries, and landed on the top of a washerwoman's barge in the middle of the Seine. There is no record of the nature of his reception by his hostess.

Work of Leonardo da Vinci.—Leonardo da Vinci, an Italian of the Medieval era, who was most versatile and a genius, as he was an artist, writer, sculptor and military engineer, had made engineering drawings and computations showing flying machines very similar to our present-day gliders, as well as sketches of wing-flapping mechanism. His writings, which are still of interest and historical value, were the guide for aëronautical experimenters for several centuries. His manuscripts contain many drawings of birds and designs for flying mechanisms, including a manually operated ornithopter, or wing-flapping machine; an aërial screw (embodying the same principle as the helicopter) and plans for wing operating motions. About 1490, this imaginative inventor worked out the first plans for a man-carrying glider.

He died in 1519 without ever having built the aircraft he had designed, but a quarter-sized model built from the artist's plans by Paul E. Garber, a modern authority on aircraft model making, hangs to-day in the Smithsonian Institution, in Washington, D. C. Birdlike in appearance, the model is supposed to operate by wing-flapping motions. The operator lies prone upon a central beam, his body protruding through a large ring and his head and shoulders through a yoke at the front. His arms pass through small rings, and his feet are placed in stirrups at the rear. By alternately raising and lowering the arms and kicking his feet, a beating motion is imparted to the wings. Short glides might possibly have been made with this machine, but prolonged flight would be impossible, as a human being could not maintain the necessary rapid motions. An interesting feature of da Vinci's design is the dihedral angle of the tail surfaces used to maintain automatic stability—a means employed in connection with the main planes for the same purpose by aircraft of to-day.

Pioneer Glider Pilots.—The first successful glider was made in the earlier part of the nineteenth century by an Englishman, Sir George Cayley, and a number of glides were made descending at an angle of about 18 degrees. He made many experiments and made some discoveries in the theory of aërodynamics and the principles of equilibrium and control of a flying machine.

Following these experiments, Captain Lebris, of the French

Army, built a glider modeled after an albatross. (See Fig. 15C, Chapter 3.) He started his apparatus from a moving cart and soared 300 feet in the air against a fresh wind.

The most scientific development in the art of gliding was conducted by Otto Lilienthal and his brother Gustave, Germans, who studied the flight of storks near their home. They built gliding surfaces with means by which they could hold on to them and be carried down from the summit of a high hill. The Lilienthal glider shown at Fig. 1 was modified a number of times and about one hundred flights were made with it before Otto Lilienthal was killed because he did not move his body quickly enough to balance the machine in a gust of wind, and it fell out of control. The death of Lilienthal had a depressing effect upon the development of aviation in Germany, but the foreign countries showed an increase of interest.

The Britisher, Percy S. Pilcher, had experimented already in 1895 with a "suspension" glider of 151 square feet surface area, reaching a maximum flying distance of 394 feet. Due to the many breakdowns of the wings, Pilcher built a stronger glider, having a supporting surface of 172 square feet and weighing 79 pounds. This design was too difficult to handle and a third and lighter glider was constructed with which many successful flights were made. Then Pilcher built a glider in which he placed a 4-horse power benzine motor built by himself, but before he was able to test the glider, he met death by falling during a demonstration flight before a scientific society.

The Chanute Multiplane Glider.—Chanute, a Chicago architect of French parentage, believed that the monoplane type of glider was too unstable and therefore he started very soon to

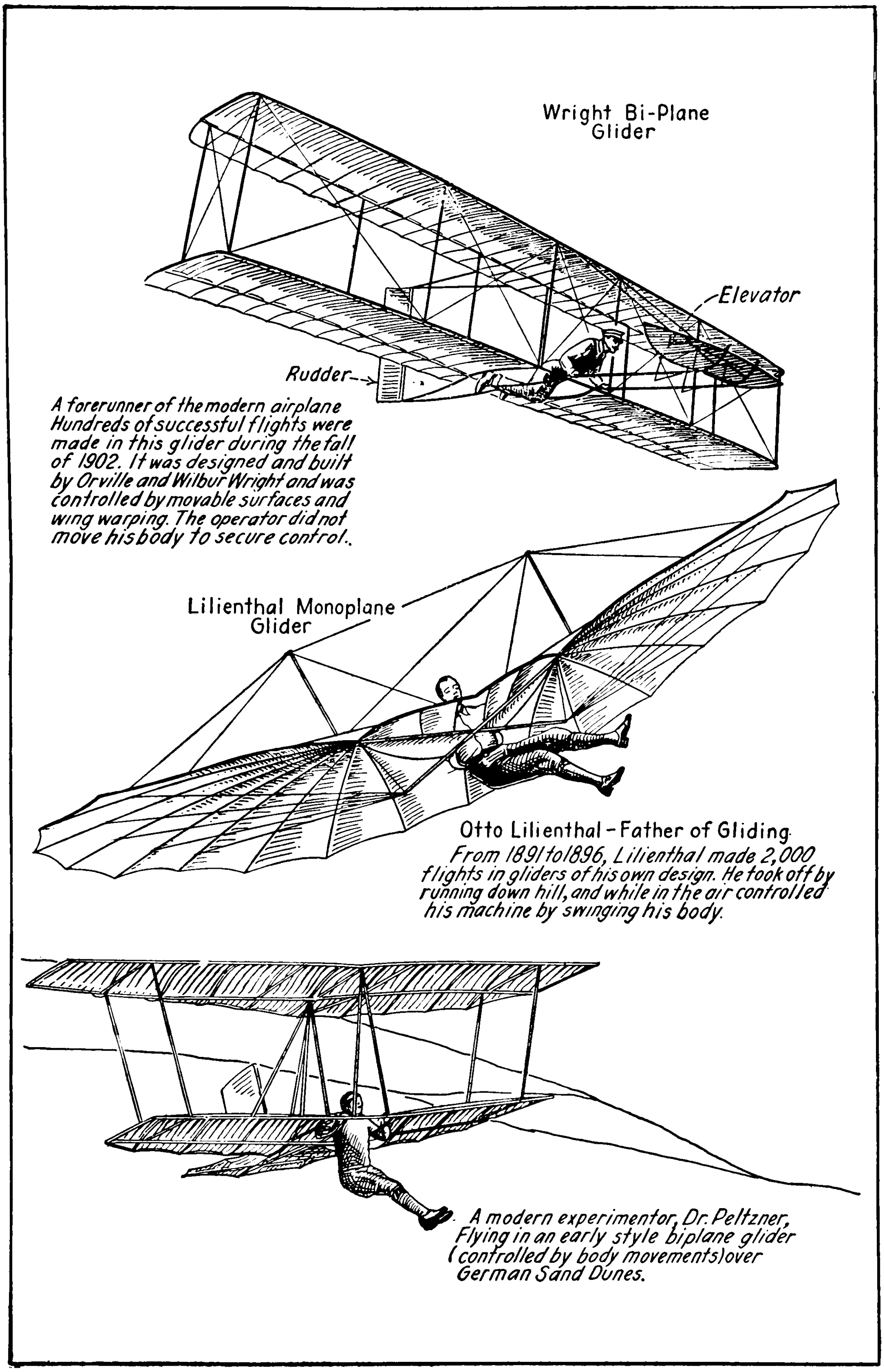


Fig. 1.—The Early Gliders Were of the Suspension Type and Both Monoplanes and Biplanes Were Experimented With. The Wright Biplane Glider Shown at the Top of the Illustration was the Most Successful of the Pioneer Machines and was the Parent of the Modern Airplane.

construct biplane and multiplane gliders. He had been led to this through the kite flying attempts of Hargrave, after whom the box kite was named. Chanute's quadruplane glider, shown at Fig. 2A, having four surfaces, carried a tail of the same width and shape as the wing surfaces. Above the fourth plane was a surface arranged parallel to the direction of flying. The gliding angle of this glider was found to be 12 degrees, which is quite unfavorable. Soon Chanute returned to the biplane with which he obtained better results; the reason for this being probably the fact that the supporting surfaces were arched at the lower side in 1:12 proportion as in the Lilienthal glider. The glider was a "suspension" type and had a net weight of about 22 pounds. Herring, Chanute's assistant, made about 700 flights in it without accident. With a total weight of 179 pounds, the gliding speed was about 33 feet per second and the gliding angle varied between 7 and 10 degrees.

One of the most interesting gliding flights of the time, in the light of Lieutenant Barnaby's recent glider descent from the dirigible Los Angeles, was that of Professor Montgomery, of California. Twenty-five years ago he successfully launched his tandem monoplane glider from a Montgolfier balloon at 2,500 feet altitude and glided safely earthward. But after a series of successful experiments, Montgomery lost his life on July 19, 1905, when the wing of his glider broke during a subsequent attempt to launch it from a balloon.

Work of the Wright Brothers.—It is to the development work of the Wright brothers, Wilbur and Orville, of Dayton, Ohio, that modern aviation progress is due. They were interested students of the work of Lilienthal and Chanute and as they were practical mechanical men with a scientific as well as a literal turn of mind, they evolved certain aërodynamical theories which they proposed to test out with man-carrying gliders. These were of the biplane type and considerable data and experience obtained and published by Chanute were utilized in their designs.

A year later, the brothers launched their second glider, the largest glider that had ever been built up to this time. The new ship had an area of 308 square feet, nearly twice as large as their previous machine. Lilienthal had used an area of 151 square feet, Pilcher 165, and Chanute 134. None of these pioneers would have considered such a large ship safe, but the Wrights had the greatest confidence in the efficiency of their control system. This glider is shown at the top of Fig. 1.

To better study their theories of warping wing control, the brothers took up free gliding. Instead of launching themselves by running downhill as Lilienthal and the others had done, they found they could take off more easily with the help of two assistants who ran at the end of each wing. Lying prone in the glider to cut down head resistance, they found that after a few minutes' practice they were able to coast downhill on the air for distances of 300 feet, and within a few days they could operate safely in winds as high as 27 miles an hour. They made all their launchings into the wind. This glider, which was 14 feet long and 6 feet high, had a 22-foot wing span and weighed 108 pounds. Their method of landing was different from the old way, too. They had planned to swing their body into an upright position upon approaching the ground, and land on their feet, but they discovered it was safer and easier to slide to rest on the skids, keeping the body in the recumbent or flying position. Theirs was

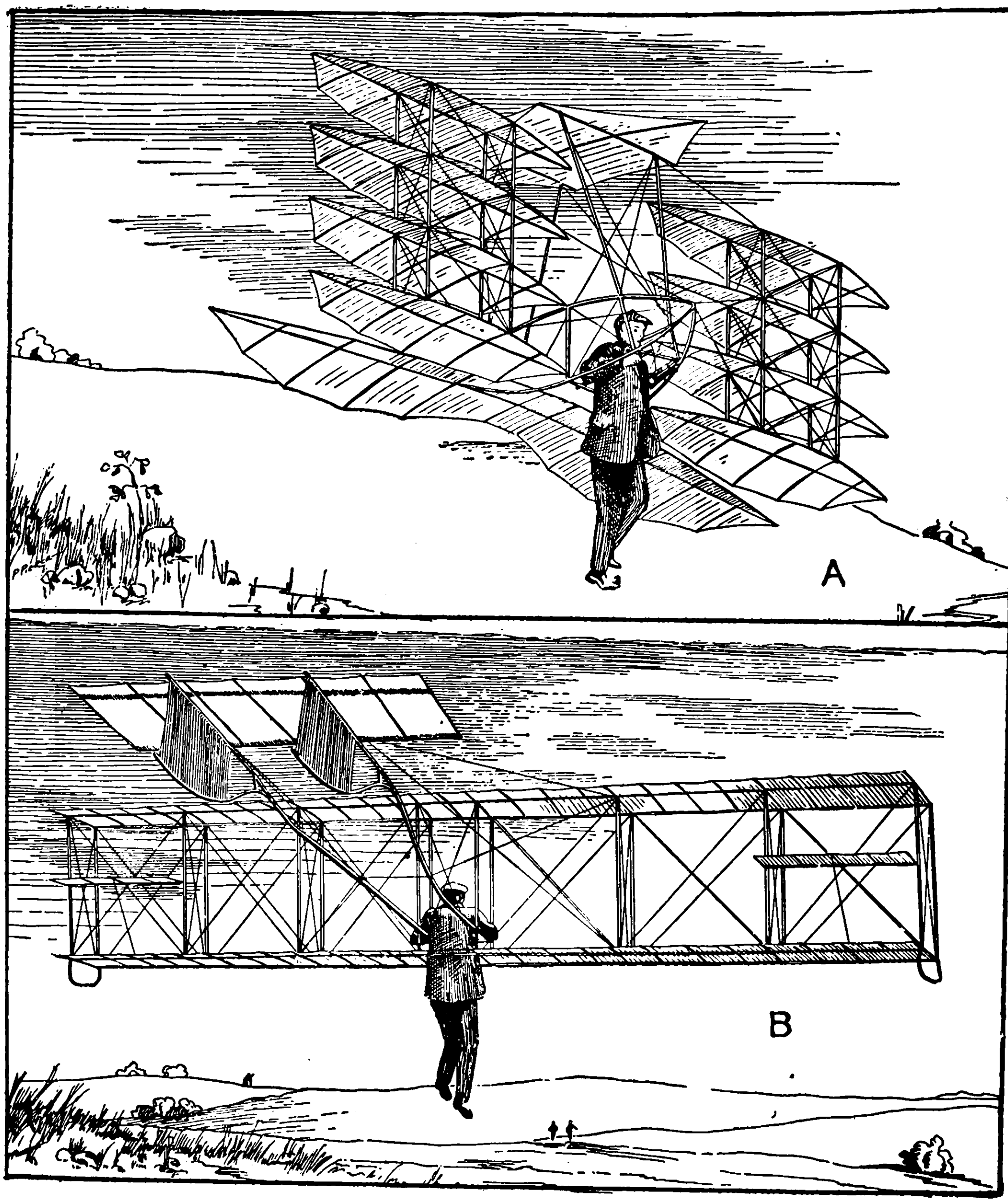


Fig. 2.—Two Types of Gliders or "Suspension" Type Motorless Airplanes that were Experimented with. That at "A" Is a Chanute Multiplane Design; the Other Is a More Modern Biplane Design Constructed by Percy Pierce, Having Ailerons for Securing Lateral Stability and Tail Surfaces for Longitudinal Stability.

the first glider to land on skids or runners in this way.

The third glider, which on September 15 was flown as a kite to test its balance, had narrower wings 5 feet wide, and with 32-foot span. These measurements evolved from scientific calculations gave an aspect ratio of better than 6 to 7, as the span was slightly more than six times the chord or wing width. For greater stability, they added a fixed vane in the rear, which first was of 12 square foot area, and later reduced to six. The front elevator contained 15 square feet. The total weight, unmanned, was 116 pounds.

As in their previous designs, this glider used warped wings to maintain lateral balance. That is, the rear corner of the descending or low wing was twisted down to increase its lift. But, in case the wings were warped excessively, the forward speed was reduced because of augmented drag and the glider turned from its course. To counteract this tendency, the Wrights hinged the rear vane, making it a rudder. This gave their ship three controls to manipulate—the elevator, wing warping and rudder. They found that combining rudder and wing-warping controls simplified the operation as the rudder could be used to correct the swerving tendency due to the warped wing on the low side having more drift or drag than the one on the high side. A glider—perfected at last—was the result of the 1902 experiments. The two men made about one thousand glides at angles of seven degrees or less in this ship. This proved more efficient than the Chanute glider. In it the pilot lay flat instead of sitting upright.

In winds varying from 14 to 36 miles an hour, the Wright brothers made glides lasting as long as 30 seconds and for dis-

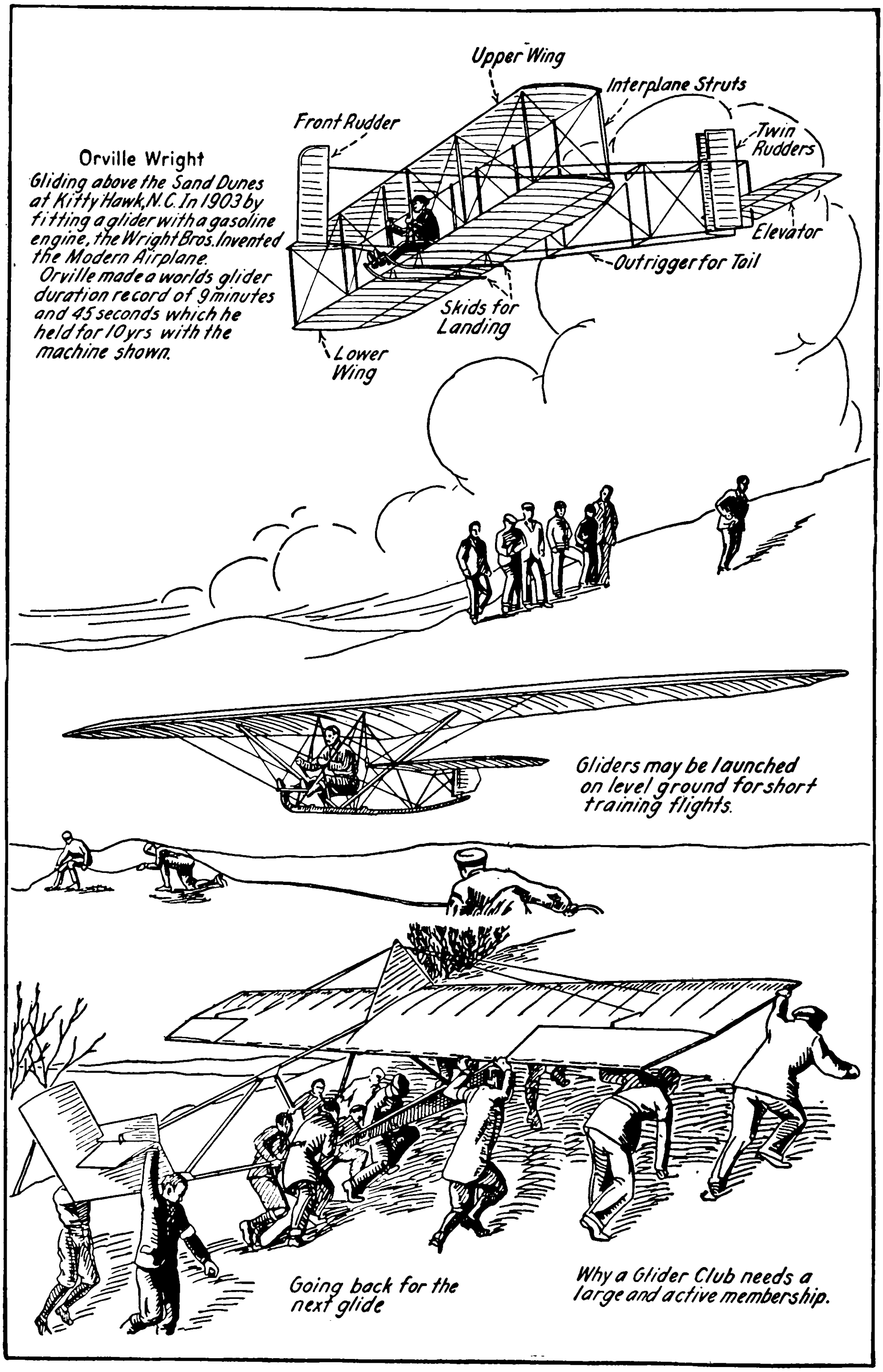


Fig. 3.—An Improved Form of Wright Brothers' Biplane Glider Shown at Top. The Harth and Messerschmitt Monoplane Glider Is Shown Below It. Bottom Illustration Shows One Method of Transporting Training Glider to the Top of a Slope for Another Glide.

tances as great as 622 feet. In the autumn of 1903, the glider stayed aloft for as long as a minute at a time, often soaring practically stationary in the air. At last, the Wright brothers felt they were ready to test their wings in earnest. They had proved their aëronautical theories with motorless ships which actually stayed aloft a short time, supported only by air currents, just as soaring birds were. The soaring trips convinced them that powered flight was possible, and the knowledge gained while actually in the air gave them confidence in their ability to fly. So the Wrights constructed a sturdier glider—one strong enough to hold a power plant, shown at the top of Fig. 3, and fitted it with a light weight automobile type engine of 12 horse power and of their own design and construction. At last they were able to realize the dream which man had aspired to ever since the beginning of thought. They spread their wings on December 17, 1903, and took off, for the first time in history, in the first successful airplane.

Archdeacon's Water Glider.—At the time when the Wright brothers were approaching their flying triumph, others of note were also conducting experimental glider flights. Ernest Archdeacon, of Paris, invented a glider which might be called a godfather to the seaplane. His machine, somewhat like a Hargrave kite, was mounted on two little boatlike pontoons. Archdeacon's glider would lift in the air when towed by a motorboat traveling 22 miles an hour into a 4-mile-an-hour wind. It often fell into the river, because the laws of balance were not known at that time and was finally severely damaged when it turned over completely. In 1904, this Frenchman also made some experimental glides with a plane among the dunes at Berck-sur-Mer.

Harth and Messerschmitt.—Harth and Messerschmitt built their first glider in 1910, and this design was one of the first soaring planes of the high wing monoplane type, in which the wings themselves were movable to vary their angle of incidence. They used a wing profile with a heavier entering edge and controlled their glides by manipulating the wings so the movement of one would compensate the movement of the other. They experimented always above nearly level ground. In 1914 they were able to maintain their glider safely in balance in an air of 49 feet per second velocity. In the year 1916 Harth flew 3½ minutes without losing altitude and that in an air of 26 to 33 feet velocity per second. Then in 1920 Harth flew in the Rhoen at an altitude of 164 feet above his starting place without losing speed in gaining this altitude, and that above a country having a 2- to 5-degree slope. This glider is shown at Fig. 3 below the Wright brothers' glider.

Modern Gliders Are Airworthy Machines.—From the first crude gliders of Otto Lilienthal, the German; Octave Chanute, the Franco-American of Chicago, and the Wright brothers, to the latest German and American motorless machines, is a far step. The early gliders, frail structures of bamboo and fabric, built sometimes like a giant box kite and again, as in Lilienthal's model, like an enormous bat, would do just one thing—glide down the wind from some height, and, if the pilot was lucky, land him safely at the bottom.

The latest machines are more than gliders, for they not only glide but some of them soar, and therein lies the secret of their ability to remain aloft for many hours, make long journeys across country and climb, as Ferdinand Schulz did near Marienburg, to a height of more than half a mile. On that occasion Schulz picked a favorable air current, rode it up to a height of 2,566 feet above the earth, and continued to float about up there for more than four hours. Not long ago, Lieutenant Dinort spent 14 hours and 44 minutes in the air one day, soaring around in a motorless plane. He took off from a sand dune at Rossitten, near Koenigsberg, soared up on an ascending column of warm air, which was climbing above the heavy cold currents off the sea, and continued to soar and glide and dip through the day and into the night.

Gliding as a Sport.—Gliding is a sport comparatively new to America, but in spite of its recent introduction into the country it has already created sufficient interest to warrant the establishment of a glider school on Cape Cod, Massachusetts. Capable instructors were brought over from Germany, and other schools will be opened as interest in gliding continues to grow. Many glider clubs are being formed throughout Europe and the United States and the new sport is receiving attention all over the civilized world. Gliding is a fascinating sport. Whether one is a beginner and is getting his first thrill at "the stick" on a ten-second "hop" downhill or whether one is able to follow Peter Hesselbach on long flights such as he made during the summer of 1929 on Cape Cod, it is beyond the writer's ability to state in cold print the thrill of the experience. There is no noise of motor or propeller. The ship swings through the air with a gentle swish and the German pilots engaged in seeking new endurance records have been known to swing down over the crowd and ask for the correct time. While Hesselbach was flying off Cape Cod, eight to ten sea gulls came in from the

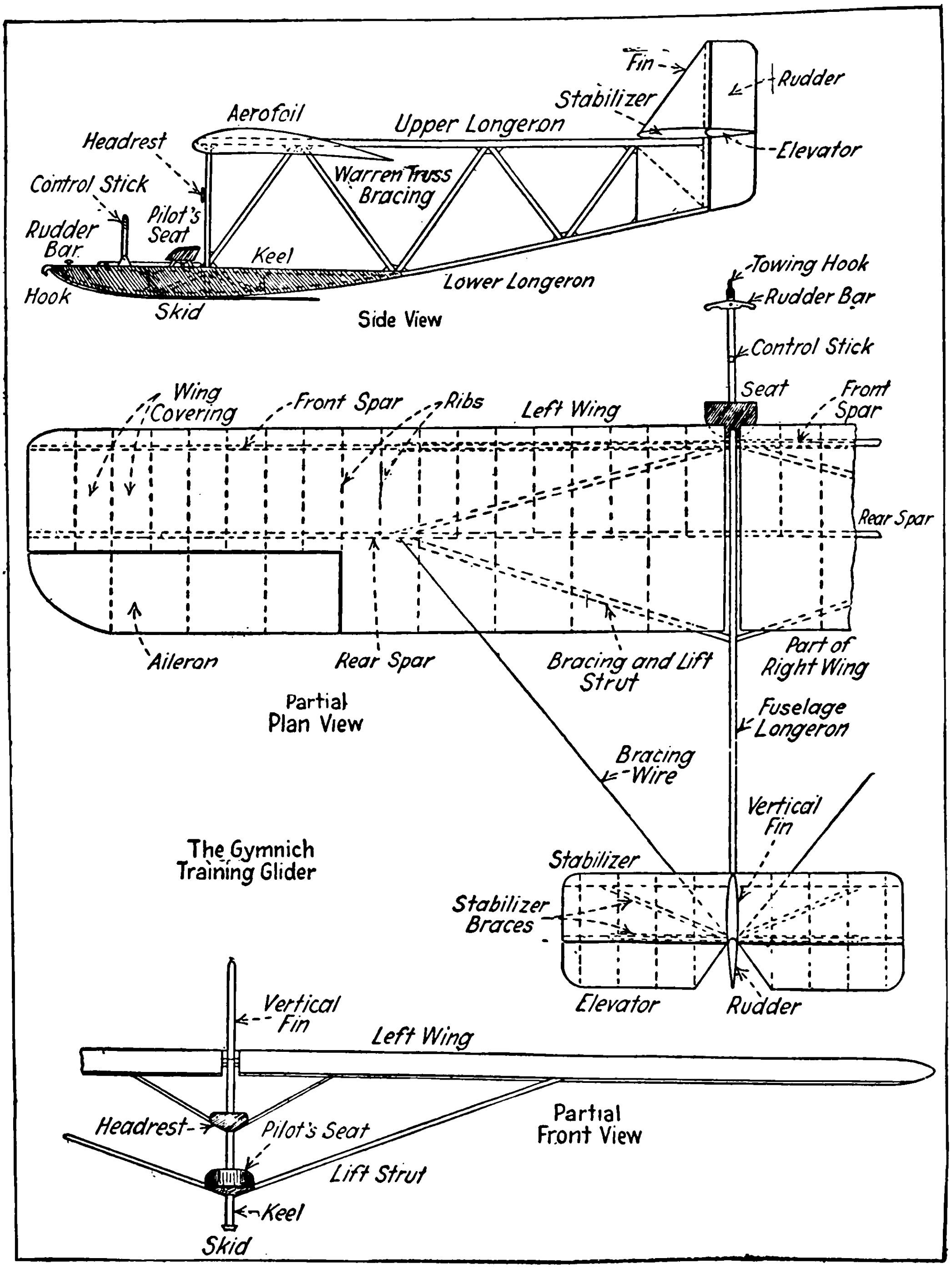


Fig. 4.—Outline Drawings Showing Full Side and Partial Plan and Front Views of Typical Training Type Glider, Depicting Important and Principal Parts and Their Relation to Each Other.

ocean and flew with him in formation, trying to discover what new form of bird he was.

Suspension Type Glider Obsolete.—All of the early glider experiments, which led eventually to the perfection of the motor-driven airplane, consisted in straight glides, never exceeding more than a few hundred feet in length. The glider pilot, taking off with a short run from a hilltop, would rise a few feet in the air at most and glide to the ground again at the foot of the rise. The descent was usually made with his body hanging below the framework so that, by throwing his weight from side to side, he could keep his balance, as the shifting center of gravity thus produced formed the only control. This method of control was so tricky that it ended many flights in disaster, and caused the death of Lilienthal and Pilcher. The new motorless soaring airplanes are entirely different. Sitting in a comfortable cockpit, the pilot operates rudder, tail flippers and ailerons through the same sort of controls as used in a motor-driven plane. The usual method of taking off is to be launched or catapulted into the air at the end of a rubber rope, just as a captive kite is launched into the wind by a boy. The training type of glider shown at Fig. 4 is simple in construction and cannot soar because its weight and air resistance will not permit it to.

The Darmstadt sailplane flown recently at Cape Cod, Massachusetts, by Peter Hesselbach, established a record for gliding in the United States which was broken by Harley Bowlus by a soaring flight of over 9 hours in a Bowlus soaring plane, and later by Barlow with 15 hours and 13 minutes to his credit. Mr. Hesselbach had remained aloft for 4 hours and 5 minutes in this sail flyer, which is a replica of the soaring plane in which

Ferdinand Schulz established a world's record of 14 hours and 23 minutes' duration in the air. Mr. Orville Wright established the previous American record when he remained 9 minutes 45 seconds standing virtually still, in the ascending air currents blowing up the sand dunes at Kitty Hawk on the coast of North Carolina, over eleven years ago.

Gliding Not Dangerous.—Contrary to the popular notion fostered by the deaths of pioneer experiments with "suspension" gliders, gliding is not dangerous. There have been only a few deaths from accidents to gliders and these deaths were the results of unfortunate accidents to men who insisted on trying something new in contrast with proven theories and ideas.

It is generally believed that as long as a pilot keeps his glider balanced he is comparatively safe, but that if a gust of wind should tip one wing considerably higher than the other the machine would be thrown out of balance and immediately crash to the earth. That was the cause of the fatal accident to Lilienthal, the builder of the first successful glider. The present-day gliders, however, are not dependent upon the bodily movements of the pilot for their balance and the early types are not looked upon with favor, by the United States Department of Commerce aëronautical experts. The modern forms are easily and positively controlled and are so aërodynamically correct in their design as to have great inherent stability, and even when put into the stalling position by inexperienced pilots show such little tendency to spin that they are easily righted.

Gliding Endorsed By Experts.—The veteran glider pilot Dr. Wolfgang Klemperer, now of Akron, Ohio, but one of the early

German glider enthusiasts and holder of a number of records, writes:

"It is an unrivaled sport. I am unable to describe by words the sublime pleasure one experiences in gliding over hills and valleys, silently, like the eagle, cruising or hovering, rising or descending at will. The ample controllability makes you feel like them, master of the air. The constant alertness watching for favorable air currents and studying their relation to the varied scenery below provides thrill and challenge. A few weeks in a glider camp is outdoor life in the word's fullest meaning. Soaring flight requires also a certain amount of scientific training, engineering sense and physical skill. Thus it most perfectly blends all the elements requisite for a recreational and educational sport such as the rising generation so appreciates."

Some of the most expert of the fliers of motored airplanes are becoming very enthusiastic about gliding and sailflying or soaring. Colonel Charles Lindbergh is quoted as saying:

"Gliding not only offers a flying medium of safety because of a landing speed of ten miles an hour, but it is much cheaper to learn to pilot a glider than a powered plane. The principle of flight is the same in glider and power planes, with standard airplane controls in both. A glider student learns the feel of a ship, how it banks, turns, and lands and he does it at a ridiculously low price as compared with power plane instruction.

"There is a thrill, too, to gliding. It is a superlative sport which appeals to Americans, young and old. A few can band together and buy a good glider. I see a great future for gliding in America. It will sweep the country during 1930 and I expect to see a million glider pilots within three years."

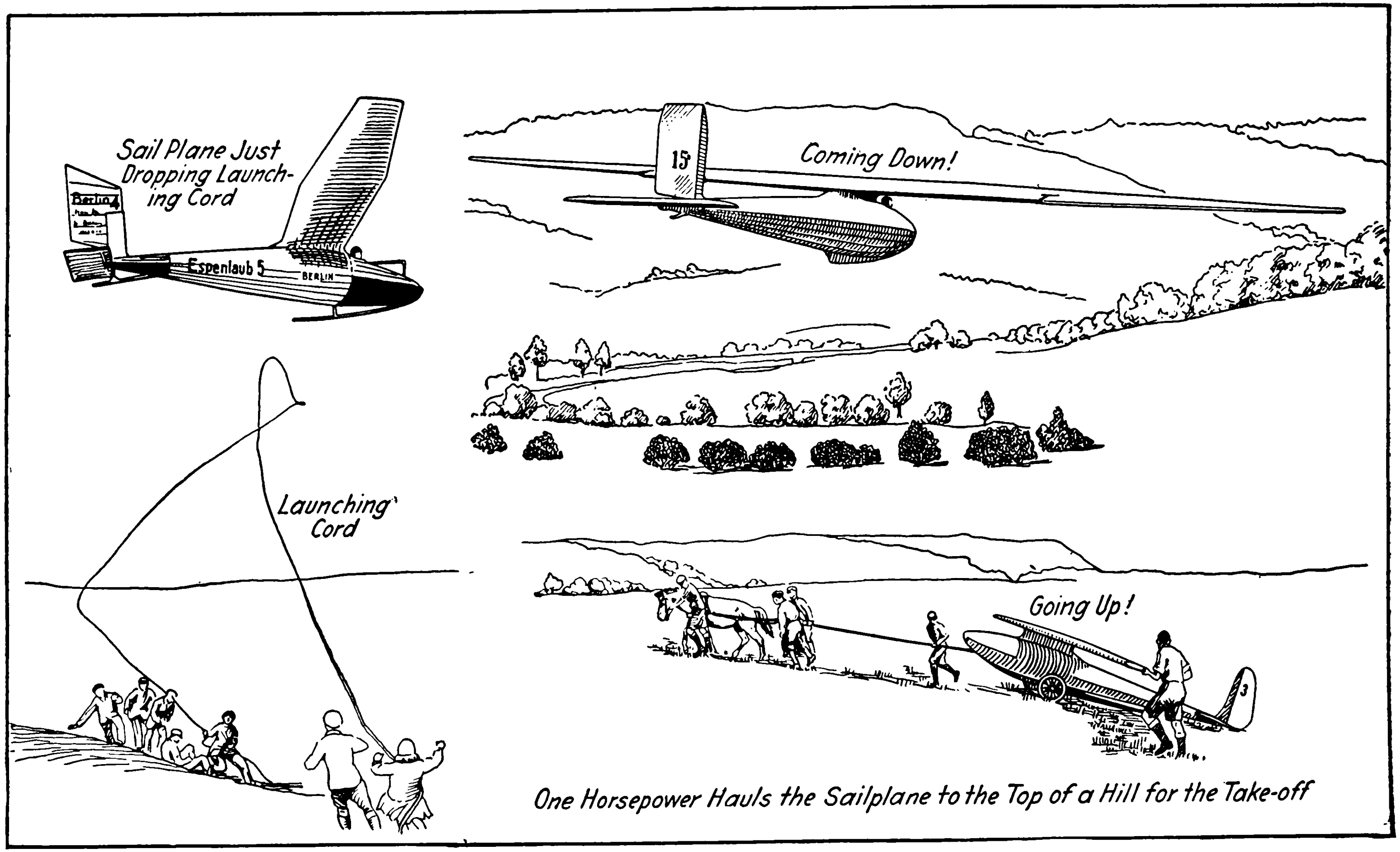


Fig. 5.—The Sailplane or Soaring Machine Differs from the Primary Type Glider in Having Well Streamlined Fuselage and Much Better Aerodynamical Properties. They Are Launched in a Slope Wind by Rubber Shock Cord Just as the Simpler Types Are.

The Massachusetts Institute of Technology led the way in glider efforts in America since the war. J. C. Penney, Jr., and the American Motorless Aviation Club of New York created much favorable sentiment for gliding in the summer of 1928 by bringing to this country three German gliding experts and making possible the sensational soaring flights of Hesselbach. The California Glider Club, Vance Breese, pilot, was the first N. G. A. group to get a glider in the air. Earlier, an individual member, Thomas D. Stimson, of Seattle, had made glider flights and with the exception of the Wright brothers, has been the first to fly an American designed and built machine. Miss Amelia Earhart was the first American woman to make a solo glider flight. Gliders, Inc., Orion, Michigan, were the first manufacturers to confine their activities to the production of gliders. The soaring or sailplane type is shown at Fig. 5 and may be compared to the simpler training type shown at Fig. 4 and a brief study will show how they differ in construction and appearance.

Gliders Must Be Approved.—After October 1, 1930, all gliders will be required to have an approved type certificate or a group two approval. Until that time they will be eligible for licensing if they can satisfactorily pass a line inspection, which may include a flight test if such appears necessary. No engineering data will be required. (Group two approvals are those on aircraft which are not built according to ATC's, but are airworthy. Engineering data must be submitted to the Aëronautics Branch for these approvals and flight tests conducted. Such licenses are usually obtained on experimental craft, those whose designs represent slight modifications in planes holding ATC's, or craft to be built in limited quantities.)

When the regulations go into effect licenses will be obligatory, not only for gliders, but for their pilots and for student glider pilots. The requirements for the personnel, however, will be far less exacting than are the standards for airplane pilots. Student glider fliers will not be required to undergo any medical examination, needing only to pass the tests taken by student airplane pilots. Conditions which the Department exacts of gliders are, briefly, that they shall possess lateral stability, without undue tendency to fall into a spin; good balance, and satisfactorily operating controls. The six-spin test to which powered airplanes are put for their ATC's naturally will be waived for the gliders.

Three Classes of Pilot's Licenses.—Student, non-commercial and commercial glider pilot licenses are provided under new amendments to Air Commerce Regulations announced recently by Assistant Secretary of Commerce Young. Glider student permits authorize the holder to receive instruction and to solo licensed gliders while under jurisdiction of a licensed glider pilot. No physical or written examination is required.

Non-commercial glider license serves the large group desirous of operating gliders only for sport and pleasure. Examination required is flight test, consisting of a minimum of three flights including moderate banks in either direction.

Commercial glider pilot license is issued to applicants physically qualified and who pass special flight test. Normal take-offs and landings, series of general and moderate banks, 360-degree turns and precision landings is flight test. Applicants are also required to pass a physical examination. There is no written examination.

"The Aëronautics Branch has spent many weeks in a study of a policy which would encourage the glider movement in the United

States and at the same time would adhere closely to the Department's principle of competent airman and airworthy aircraft," stated Major Young. "The study included a conference in Washington of all of the Department's supervising and engineering inspectors who are on duty throughout the United States and scores of glider flights were made by these inspectors during the conference. Requirements with respect to the licensing of gliders are to be announced shortly."

A reprint of the airworthiness requirements of the Air Commerce Regulations, Part 3 of United States Department of Commerce Bulletin 7A entitled "Light Aircraft" is included in Chapter 5 for the guidance of sailplane and glider designers and those interested in construction of these aircraft.

CHAPTER TWO

CAUSES AND NATURE OF AIR CURRENTS—PRINCIPLES OF GLIDING

Force of Air in Motion—Structure of the Atmosphere—The Stratosphere—The Troposphere—Air Has Weight—Cause of Winds—Air Resistance—Relation of Lift to Resistance—How Air Pressure Varies with Its Speed—Bumps and Air Pockets—Attraction of Gravity—Moving Air Exerts Pressure—How Gliders Are Supported in the Air.

Force of Air in Motion.—Air in motion may exert considerable force. A gentle breeze creates very slight pressure, but a cyclone or hurricane, which means air traveling at a rate of from 75 to 100 miles per hour, can do considerable damage. Much destruction is caused by tornadoes due to the great pressure of air traveling at a high speed which has sufficient velocity to uproot large trees and tear buildings apart. Winds are caused by the conflict between rising air currents due to the lesser weight of heated air which rises from the earth's surface and the down currents of cold and therefore heavier air which rushes down to take its place.

The physical contour of the earth and variations of temperature as well as seasons of the year all have their influence on air movements termed winds. For example, the hot summer sun beating down on a sandy plain will saturate the earth with warmth and ascending air currents will move at greater velocity than will air currents ascending from a forest. An aircraft, passing from the hot, rapidly ascending air current to the slower moving, cooler air from the forest will lose lift and may drop appreciably in the cooler air column. (See Fig. 6.)

Structure of the Atmosphere.—The Director of the Blue Hill Observatory, Harvard University, Alexander McAdie, who

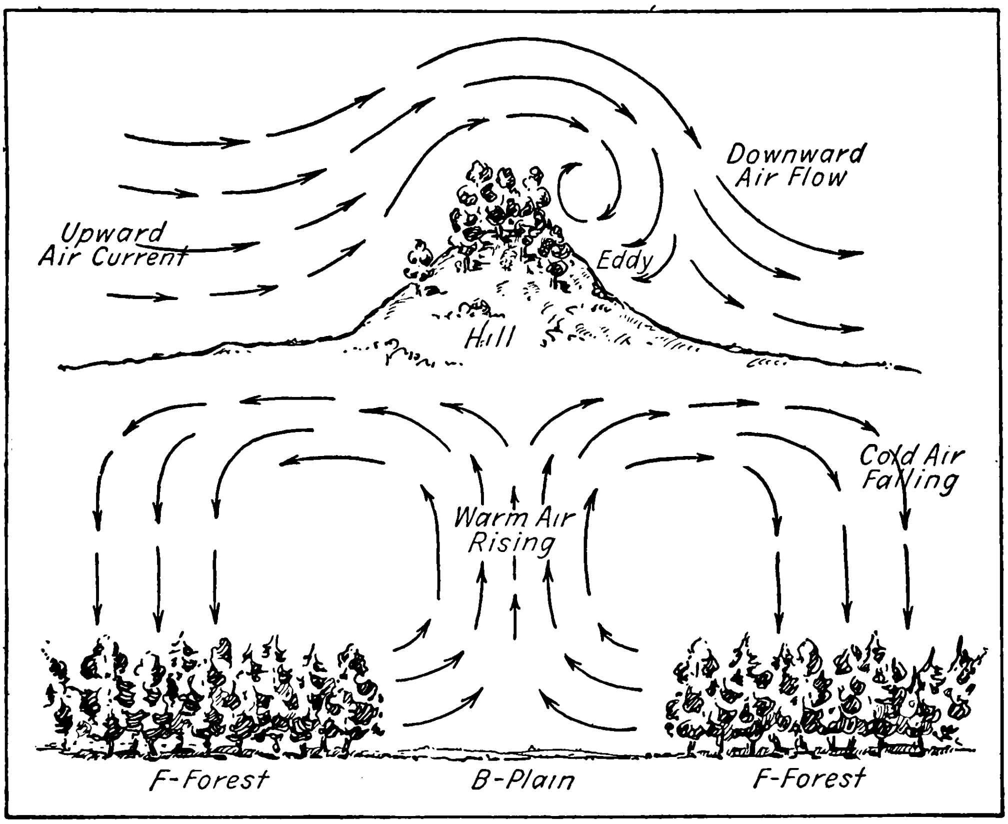


Fig. 6.—Diagrams Showing How Variations in the Nature of the Earth's Surface May Cause Wind.

is an authority on the structure of the air, gives some interesting facts about the atmosphere. He says:

"Air is a mechanical mixture, not a chemical compound. Four-fifths of the air is Nitrogen and other fifth is Oxygen. There are negligible traces of certain rare gases. But there are two additional quantities; independent variables, water vapor and dust, both important as affecting aviation. In fact, it is water vapor that is responsible for most of a flyer's troubles. Fog, poor visibility, snowstorms, thunderstorms, are all manifestations of change of form of water. If there be extreme dryness, wooden parts of the machine are warped; if too damp, there are bad effects. The plane or airship may get an ice coating and the load be so great that there is a forced landing.

"Contrary to expectation and to some degree contradicting fundamental equations in physics, the atmosphere is not homogeneous. Pressure, temperature and even density do not decrease as we go up, at a fixed and uniform rate. We cannot regard the atmosphere as a single layer. Tidal equations cannot be applied. The atmosphere is actually a series of airspheres; and these are not exactly concentric shells. Not only do we find stratification or layers; but even striation."

The Stratosphere.—We know two distinct shells—the lower or troposphere, a region of change, also of convection, about ten kilometers or six miles thick in our latitudes. This is the layer in which weather occurs. An upper shell is the stratosphere, or so-called isothermal region in which temperature does not continue to fall with increase in altitude. Half a dozen airplane flyers have reached the stratosphere or have gone a small distance into it.

The Troposphere.—The lower airsphere, the troposphere, bulges up at the equator and contracts at the poles. If Commander Byrd could have stopped long enough when he was at the North Pole to make an altitude record, he would have passed through the troposphere at 4,000 meters and into the stratosphere. On the other hand, at the equator he would have to go up 17,000 meters to get into the isothermal layer.

A pilot can get pressure and temperature by direct reading, but there is no instrument to tell him the density of the air. It happens that at 8,000 meters the density is practically constant over all the globe. Above this height, air is denser over the equator than over the poles. In fact, density appears to be a function of pressure and temperature in low levels. Hence two words have been introduced into the language—barosphere and thermosphere—one to represent the region where pressure controls and the other the region where density is a function of temperature.

There is but little prospect of any free-flying soaring plane getting out of the lower airsphere though there is a possibility that in the future, towed sailplanes may rise near its upper limits or even pass through it into the upper shell.

Air Has Weight.—That air had weight and offered definite resistance was known to the ancients. Mention can be made of a glider that was constructed early in the eighteenth century by a German architect, Karl Frederick Meerwin, which is mentioned to show that even at that early day considerable was known of the laws of air resistance. He computed that an area of 130 square feet would be necessary to support the weight of the average man, and this was a very good approximation of the truth. He also made the sensible suggestion that experiments be made over water to avoid serious accidents, which advice was followed several hundred years later by Count Zeppelin in Germany and Professor Langley, former head of the Smithsonian Institution, in experiments over the Potomac River at Washington.

Cause of Winds.—Heating air by its contact with the hot ground causes it to rise and cooler air rushes down to take its place. Air over a plain heated by the hot sun will rise faster than the air over a lake or a forest, so the ascensional power will be greater and the cold air will flow in faster, this producing the

WIND

From Beaufort Scale of Wind Force

General Description of Wind	Specification of Beaufort Scale For Use on Land Based on Observations Made at Land Stations	Mean Wind Force at Standard Density		Equivalent Velocity in Miles per Hour
		Mb.	Lbs. per Sq. Ft.	
Calm	Calm; smoke rises vertically.....	.00	.00	0
Light air........	Direction of wind shown by smoke drift, but not by wind vanes....	.01	.01	2
Slight breeze....	Wind felt on face; leaves rustle; ordinary vane moved by wind..	.04	.08	5
Gentle breeze...	Leaves and small twigs in constant motion; wind extends light flag	.13	.28	10
Moderate breeze.	Raises dust and loose paper; small branches are moved...........	.32	.67	15
Fresh breeze....	Small trees in leaf begin to sway; crested wavelets form on inland waters	.62	1.31	21
Strong breeze...	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty...	1.1	2.3	27
High wind......	Whole trees in motion; inconvenience felt when walking against wind	1.7	3.6	35
Gale	Breaks twigs on trees; generally impedes progress	2.6	5.4	42
Strong gale.....	Slight structural damage occurs (chimney pots and slates removed)	3.7	7.7	50
Whole gale.....	Seldom experienced inland; trees uprooted; considerable structural damage occurs	5.0	10.5	59
Storm	Very rarely experienced; accompanied by widespread damage...	6.7	14.0	68
Hurricane	....	8.1	Above 17.0	Above 75

winds as well as ascending and descending air currents. The force of air in motion increases as the velocity of movement augments. Air moving at two miles per hour is a slight breeze and it exerts a pressure of .01 pounds per square foot area on a plane surface at right angles to air flow. An increase in speed of 15 miles per hour is called a fresh breeze and the pressure increases to .67 pound per square foot. Wind velocity may be measured by an instrument known as an anemometer or with a modification of the airplane air speed indicator.

Air Resistance.—The factor of air resistance is a very important one which must be given careful consideration by the designer of aërial craft. It is of considerably greater moment than one would assume on first thought. The shape of the object being forced through the air (or, in fact, any other gas or fluid) will have a material bearing upon the resistance offered to its passage. A "streamline" body has the least resistance.

Air resistance has been estimated to increase as the square of the velocity, so that it will be seen that at ten miles per hour atmospheric resistance is four times what it was at five miles per hour; at 50 miles per hour, which is ten times the speed of five miles, the air resistance will be a hundred times as great. It has been found that air currents moving at the rate of 60 miles per hour have a pressure of approximately 17.7 pounds to the square foot, and from this basis the indication of almost any speed may be determined with reasonable accuracy. In this case it is well to know that the horse power required to overcome resistance increases as the cube of the velocity, whereas air resistance augments as the square of the velocity.

In the same manner in which varying power may be secured by altering the pressure of the wind on the sail of the vessel by changing its position, it will be seen that by varying the angle of a plane in the air that it is possible to vary the degree of sustaining effort. It is apparent that efficient airplane wings must be proportioned with a view of offering minimum resistance to the wind, and it must reach this result with some sacrifice of lifting effect or sustaining power. Wind tunnel experiments have brought out in an unmistakable manner the retarding influence of air resistance and in modern aircraft designs, especially in types designed to fly with little or no power or those powered airplanes intended for very high speeds, the factor of air resistance and its reduction is carefully studied.

The supporting surface of a sailplane may be considered as having some of the characteristics of a boat sail as the power of sustentation or support it has is obtained from the action of wind or air currents in motion over and under its surface. The air movement is usually caused by a combination of the wind and falling speed of the soaring plane or glider. It will soar if the lift component of the slope wind is greater than the falling speed.

Relation of Lift to Resistance.—The resistance of an airfoil or wing section is not nearly as great as that of spherical, cylindrical or rectangular bodies. A properly formed airfoil, inclined at an angle to the relative wind of less than 16 degrees (because the lift becomes greatly reduced if that degree of inclination is exceeded) will have considerably more lift than drift. As the plane progresses through space with sufficient velocity to obtain a sustaining influence due to the air beneath it and the suction effect above it, it is thus able to overcome the attraction of gravity.

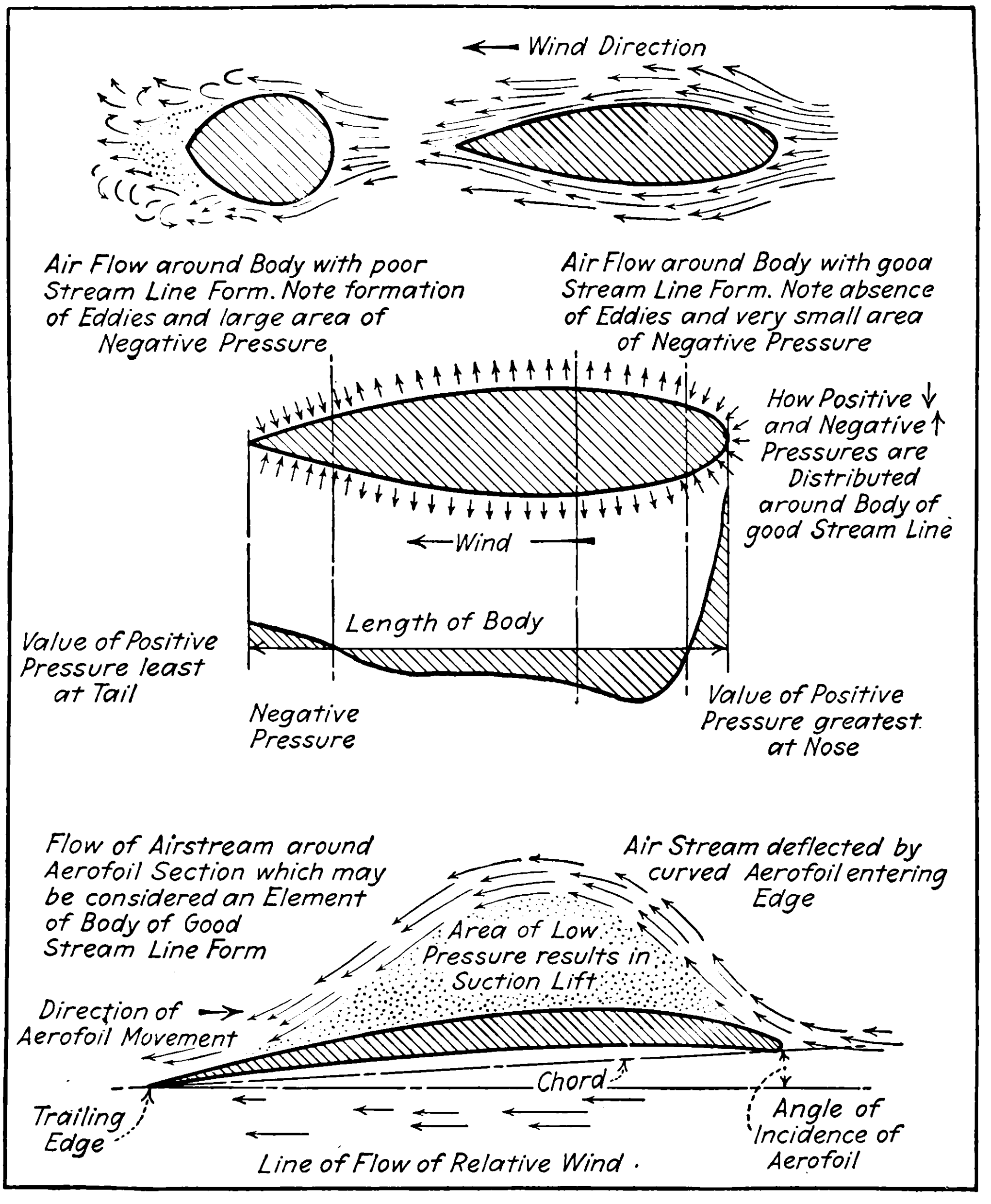


Fig. 7.—Diagrams Showing Air Flow Around Various Bodies and Positive and Negative Pressures Produced by Air Currents. Note Influence of Camber in an Inclined Airfoil to Produce an Area of Low Pressure at the Top of the Airfoil Because the Air Stream Is Deflected Upward by the Curved Entering Edge.

In this connection it is well to state that the lift on the ordinary airplane wing section is not due solely to air pressure on the lower surface of the airfoil, but, on the other hand, a study of the diagram at Fig. 7 will indicate that there is a pronounced suction effect acting at the top, because there is an area of reduced or negative air pressure which, of course, contributes materially to the total lifting effect, averaging 75% on most airfoils.

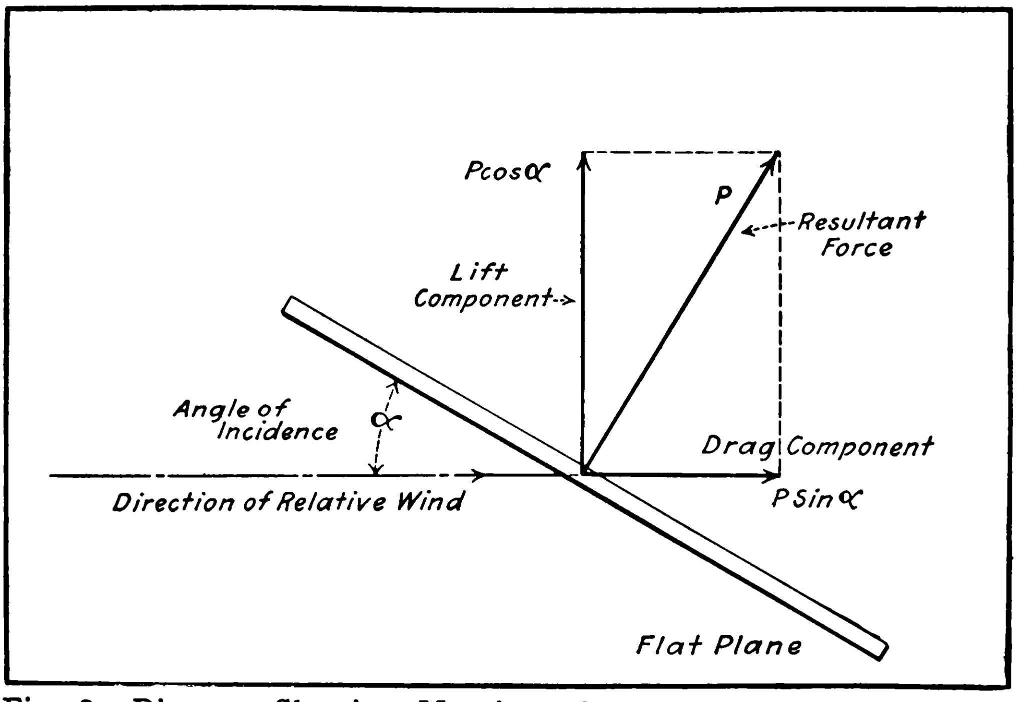


Fig. 8.—Diagram Showing Meaning of Lift and Drag and Forces Represented by These Terms on a Flat Plane. By Using Airfoil Section Planes or Wings the Lift Component Is Greatly Increased and the Drag Component Is Reduced.

It may be stated that this area and the attending lifting influence will vary with the shape of the airfoil, and that this will also depend upon the aspect ratio of the plane, the angle of incidence and the velocity with which it is passing through the air or that of air currents passing over it. To lift the plane, therefore, we must have both compression under the bottom surface and partial vacuum at a portion of the top surface, the direct pressure produced by the former and the increase of lift produced by the yielding of the other raise in ratio with velocity of the airstream. It is apparent that the movement of the air or velocity of the wind must be sufficient to cause a partial vacuum above and compression below to secure either dynamic or static soaring flight.

How Air Pressure Varies With Speed.—The following tabulation will give the wind pressure acting against a square foot area at right angles to the wind at the different velocities:

WIND PRESSURE AT VARIOUS VELOCITIES

Feet per second	Velocity feet per minute	Miles per hour	Pressure per square foot
1.47	88	1	.005
7.33	440	5	.123
14.67	880	10	.492
36.6	2,200	25	3.075
73.3	4,400	50	12.3
102.7	6,160	70	24.103
146.6	8,800	100	49.2

The figures given above have been determined by considering the pressure of the wind upon a fixed object, but there is probability that there would be some departure from these values in the event of an object being driven at the speeds indicated against the atmosphere. The table is, therefore, of value only that it shows that with the increase in air velocity there is a great increase in pressure, which obviously can be taken to mean that there would be a greater sustaining force when the plane is placed at its most advantageous angle of inclination with the relative wind, because it is at this point that the greatest lifting effort will be secured with a minimum of resistance. The lift-drag ratio is greatest when the "lift" force is high and the "drag" or "drift" force value is low. (See Fig. 8.)

The effect of the strength of wind at higher velocities is well known and can be easily understood by any one who has flown a kite. On a windy day there was a much greater pull upon the string than when the movement of the air was less and, unless a favoring air current was found, it was impossible to keep the kite in the air unless one exerted a pronounced pressure under the kite by running along the ground in order to draw it through the air by means of the restraining cord. In still air the kite will not raise itself from the ground, and it will fall as soon as the air lift produced by drawing it through the air stops.

It will be evident, therefore, that if one or more surfaces of the usual airfoil section are attached to a frame that is capable of sustaining a pilot and if the surface curvature and area are sufficient to displace the air to an extent capable of exerting a vertical component reaction called "lift," which must be greater than the entire weight of the apparatus and its load, we have contrived an airplane which will be capable of flight. The amount of wind force required depends upon many factors, and as a general rule the greater the surface of the airplane for a given weight the less the speed that is necessary to drive it through the air to secure sustentation and in case of soaring planes and gliders the less the amount of wind power required to lift it from the ground.

The smaller the wing area, or the more the value of the wing-loading factor is increased, the greater the wind power necessary to secure flight. Airplane or glider design, the same as that of any other mechanical contrivance, is a series of compromises and the final form can only be arrived at by a careful consideration of the many differing factors on which design is based. The difference between a powered airplane and one without power is that the latter can only be flown (short glides excepted) where air currents are favorable. The former produces its own air currents as it is drawn through the air by the motor-driven air screw.

Bumps and Air Pockets.—Bumps are encountered throughout the altitudes in which most flying is done. They are to be found in the entire cloud region below the cirrus clouds. They are not uncommon up to 15,000 feet, but they are most prevalent in the lower stratum—below one mile. Any region regardless of the thickness of the stratum of air may be divided into two parts in a discussion of bumpiness, according to Luckiesch. One part is that close to the ground and the remainder constitutes the other part. Of course, bumpiness near the surface due to uneven topography and artificial obstructions is absent over oceans and great lakes. However, it can be bumpy over the water due to mixed air currents and slightly due to rising air.

In hilly country, in mountains, and even in deep valleys all factors combine to produce bumpiness at times. Air may be deflected and eddied by mountains. It will be cooler at the crest and on shaded areas. It will be hotter over barren rocks in the sun and less hot over sunny wooded areas. Cool air will flow down the slopes from the crest or from the woods. Any of many conditions may be found here and there so that such regions are naturally bumpy. A third type of bumpiness is not as general as those due to topography and to unequal heating of the earth's surface, but it is more serious. This is the bumpiness on the borderline between two great air currents or between two widely different conditions, according to Luckiesch, writing in *Popular Aviation*.

The magnitude of the jar or bump depends not only upon the abruptness of change in the direction of the air current but also upon the velocity and total weight of the airplane and its load.

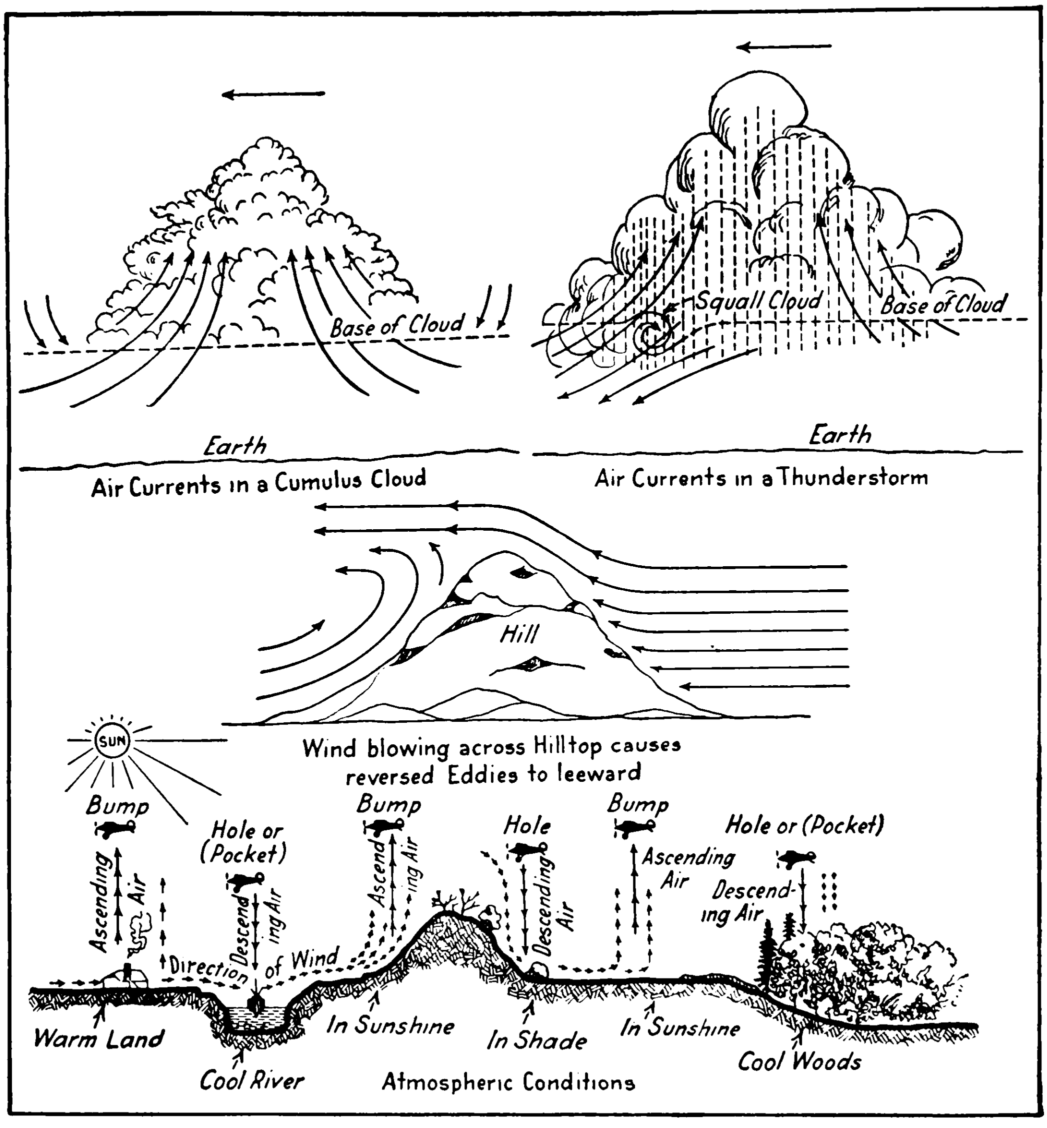


Fig. 9.—How Air Currents Are Produced by Clouds and Elevations on the Earth's Surface. The Illustration at the Bottom Shows the Influence of Ground Configuration and Influence of Water and Trees on Atmospheric Conditions.

Sailplanes will be more easily carried by ascending air currents than motored airplanes and as their speed is less, they will not receive the violent impact a fast-moving, power-propelled airplane will meet when moving across from one air current to another. The sailplane in soaring flight rides the air currents, it does not pass through them rapidly as an airplane with power does. However, a sailplane may be tossed about more in turbulent air than a power plane will on account of its lightness. A light canoe moving along slowly over turbulent water is tossed about by the forces of the deflected water which would make little or no impression upon a heavy boat.

If the turbulence is not too great the bumpiness becomes less and less noticeable as the speed of the canoe is increased. Thus, it is seen that bumpiness depends upon the vehicle and its characteristics as well as upon the medium and its characteristics. The relatively great spread of the wings of airplanes gives the air currents a correspondingly great leverage so that the abrupt sideways tilt is commonly noticeable in bumpy air. If the airplane strikes a deflecting current squarely, the movement of the craft is upward or downward.

Before considering the many forms and locations of bumpiness in the aërial world let us confine ourselves to that really dangerous layer at the earth's surface. The topography of this surface, including trees, hills and artificial structures, is fixed but bumpiness can arise from two causes. When there is no wind there can be a difference in the absorption of heat from the sun which gives rise to upward (convection) currents of air of various velocities. The difference in these velocities depends upon the difference in the temperature of the various surfaces and upon the intensity of the solar radiation. Other conditions being equal bumpiness is less at night than in the daytime. Furthermore, where there is no wind this kind of bumpiness practically disappears when the various surfaces become cooled to the same temperature. (See Fig. 9.)

When a wind is blowing every stationary object deflects the course of the air current just as partially submerged rocks do to the water in a trout-stream. Besides these deflections there are eddies and general turbulence. Much of the force or energy of winds is expended by such deflections and air-movement near the earth's surface and is generally slower than at some distance above it on account of this "friction." An air hole or air pocket is simply a descending current of air and the transition from an ascending to a descending current and vice-versa always results in a "bump" in a powered plane.

Attraction of Gravity.—We will now concern ourselves with defining the attraction of gravity. Every mass of matter that is near the earth if free to move pursues a straight line toward the center of the earth, and the force by which this motion is produced is called gravity. At the same distance from the center of the earth the gravity of different objects varies as the mass. If a body is not free to move, its tendency to go toward the earth's center causes pressure, and the measurement of this pressure is called the weight of the body. Weight is usually employed as a measure of mass. The more the pressure of a body is towards the earth's center, the greater the weight. The body that is said to be the lightest is one that has the least gravity attraction. The attraction of gravity varies directly as the mass, the greater the mass the greater the force acting to bring it towards the earth's center; the nearer the earth's center the less the attraction. A body 2,000 miles under the earth's surface would be attracted with only half the force that would obtain were it at the surface. It is at the surface of the earth that this force is greatest and at great heights it is less. For example, 4,000 miles above the earth's surface gravity is one-fourth the amount it is at the earth's surface. *At heights at which it is possible to carry on experiments the variation is very slight and may be regarded as negligible.*

It will be evident that one of the most important forces to be overcome in flying machines is the attraction of gravity, and considerable power will have to be utilized for this purpose alone. With either primary gliders or soaring planes, it is the pull of gravity as represented by the sinking speed compared to the flying speed and to the velocity of the slope wind that determines the gliding angle or length of glide of the machine after it is launched. As lighter machines have less gravity attraction, all other conditions such as velocity of slope wind, wing loading, etc., being equal, they will have a more gradual gliding angle, *i.e.,* they will glide further after launching than heavier machines. Soaring planes are lighter in proportion to their size than gliders and also offer less resistance to the air because of the streamlining.

Moving Air Exerts Pressure.—All bodies moving through the air have their movement resisted because air is a medium having definite weight, just the same as water resists the passage of a ship through it. The resistance varies with the shape of the object drawn through the air and the speed at which it is moved. A kite is kept aloft by the lifting effect of the wind or air in motion under its lower face, the kite being kept from traveling with the wind by a string leading to the ground. The wind pressure is sufficient to keep the kite aloft, though if the wind dies down the kite will fall to the ground.

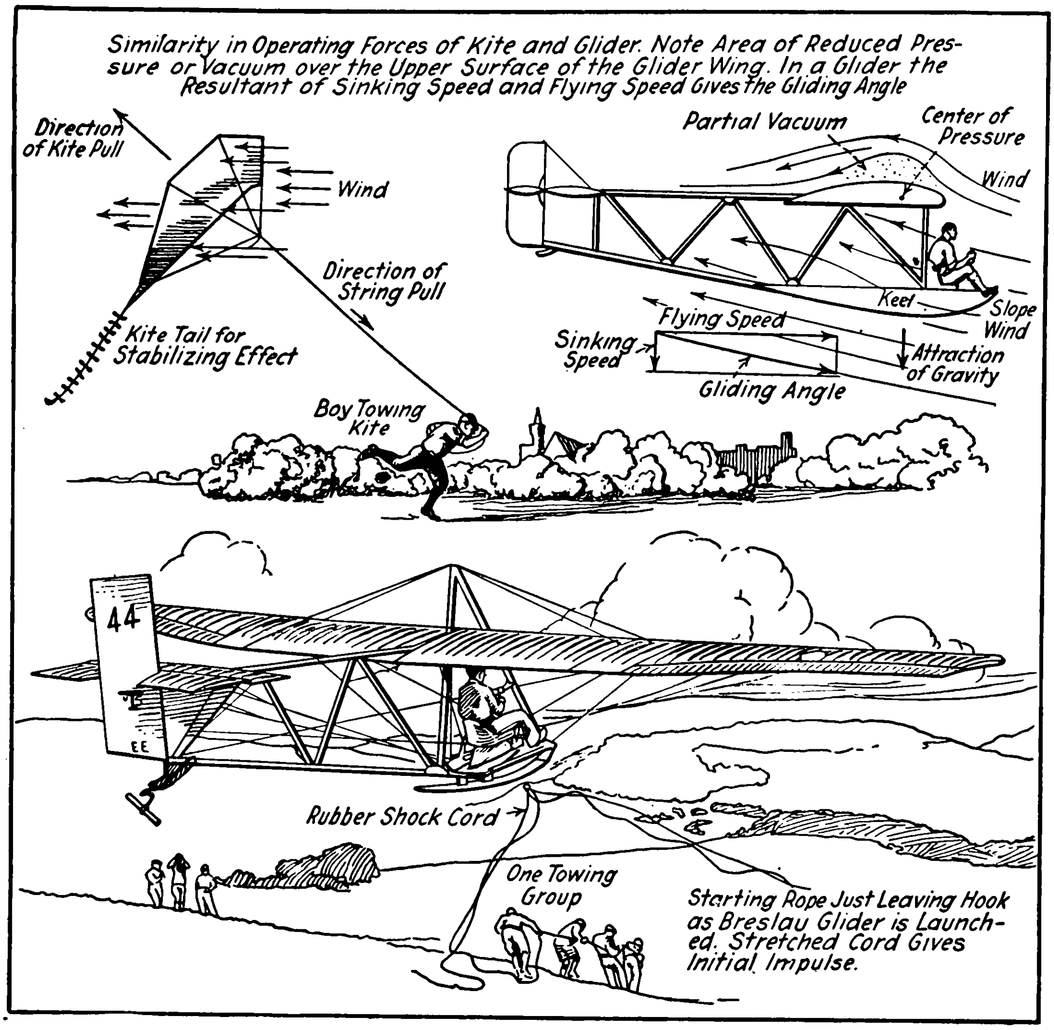


Fig. 10.—The Attraction of Gravity Compared to the Pull on a Kite String, Showing Its Influence on the Gliding Angle of a Simple Training Glider. Bottom Illustration Shows Launching of Glider by Shock Cord Catapult.

The action of a kite is often used to illustrate the principle on which the airplane or glider flies, as shown at Fig. 10. The kite is a simple plane surface, held against the wind at an angle of attack that insures a sustaining effect or lift under its face. A tail is provided to give a stabilizing effect and any one who has flown a kite knows the careful and numerous trials that were necessary before the right combination of tail length and weight was found, to keep the kite from pitching about. The simple kite shown was invented by the Chinese several thousand years ago and is satisfactory as a toy for small boys, but for more scientific purposes, such as elevating meteorological instruments, the box kite was found to have greater stability and lift and could be flown without a tail. This is just another way of saying that the combination of the two tandem-mounted, box-like members with their vertical sides and partitions is more stable than the kite and tail combination. The first airplanes experimented with in Europe by Voisin and Farman were really large box kites provided with motive power and the Chanute and Wright biplane gliders were also evolved from the box kite.

How Gliders Are Supported in the Air.—The motorless airplane of modern form consists of one or more lifting surfaces, which are cambered planes attached to a suitable body member or open fuselage carrying the control surfaces, a suitable landing and starting gear and the pilot. The action of a glider and the way sustentation is obtained is different from that of an airplane. The weight of an airplane is supported in the air because the air lift due to compression under the wings and suction lift above the wings is greater than the weight of the contrivance fully loaded. An engine furnishes power to draw the motored airplane through the air at high speeds by an aërial screw and the high speed of movement compresses the air under the inclined wings. As long as the lift is greater than the weight, and pull is greater than the resistance to forward motion, the airplane will resist gravity and overcome the retarding influence due to air resistance as well; thus maintaining its position above the surface of the earth independently of wind or air currents as well as moving at rates of speed depending upon factors of design, now well known to engineers and under full control of its operator. An airplane can be maneuvered as desired regardless of wind or weather.

The simple type of training glider is usually launched into the wind by elastic shock cord and the force of gravity replaces the pull of the kite string or the "traction" thrust of an airplane motor. As will be seen by the sketch at Fig. 10, the gliding angle of a training type glider will depend upon the ratio between the falling speed and the flying speed and the resultant of these component forces is the "gliding" angle. The flying speed depends on the intensity of the slope wind and the supporting area of the glider. The falling or sinking speed depends on the weight of the glider loaded and the skill of the pilot in manipulating the controls. In a slope wind of a definite value, the skilled glider pilot will be able to make a much longer glide than an unskilled pilot of the same weight because he will have a lower "sinking" speed and a higher "flying" speed which produces a resultant force of a smaller angle, which means a more gradual glide.

CHAPTER THREE

A STUDY OF SOARING BIRDS—INFLUENCE OF BIRD FLIGHT ON GLIDER DEVELOPMENT

Dr. Magnan's Study of Birds—Birds Employ Various Methods of Flight—Soaring Birds Utilize Air Currents—Birds with Largest Wings Have Weakest Muscles—Bird Has Efficient Aërodynamical Form—Center of Gravity Location in Birds—Bird Wing Profiles Vary—Influence of Bird Flight on Glider Development—Nature's Flying Creatures—Loading of Birds' Wings—Wing Area of Birds—Bird Flight Difficult to Imitate—Lessons Taught by Birds—Sailplane Moves in Three Planes—Bird and Plane Form Compared—Plane Forms and Aspect Ratio.

Dr. Magnan's Study of Birds.—Dr. Magnan, Doctor of Science and director of the "L'Ecole des Hautes Etudes," Paris, France, has made an exhaustive study of bird flight and the physiological and anatomical characteristics of various forms of birds. As over 500 different species were studied, ranging from large species such as the albatross and great bustard to very small birds, such as wrens, he has collected 17,000 numerical data; some on wing surface, forms and areas and others on the parts of the organism of birds utilized during flight, such as the tails and muscles of the wing. Dr. Magnan is convinced that the plastic body of the bird, with its fuselage and supporting surface can only be the result of the molding action of the air, which offers considerable head resistance and that considerable data of value to designers of motored and motorless airplanes could be secured by a careful study of birds. Dr. Magnan states:

"To wish to imitate soaring sea birds and practice soaring flight is to seek to make progress in aviation and to enlist aëronautic science in the cause of the airplane without any engine or with an engine of small power and is, consequently, a means of obtaining quickly commercial communication at low cost, due to the utilization of aircraft which, as soon as they are in the air, can be piloted without expense for fuel with a speed approaching that of express trains. It also means an early knowledge of the aërodynamic conditions of flight, which the laboratory alone cannot give, and thus pave the way for great discoveries. It is also the only way to render aviation accessible to every one and to make it popular."

Birds Employ Various Methods of Flight.—In the course of his studies, Dr. Magnan found that birds employ many kinds of flight, but he considers it reasonable, if we would not complicate the problem, to reduce these kinds to two types, flapping and soaring, remembering that, while we have in nature all degrees of transition from one to the other, one of them predominates for each kind of bird. (See N. A. C. A. Tech. Memo. No. 220.) Flapping flight consists in successive blows of the wings, this method being employed more or less, according to the species.

All the birds are capable of flapping their wings and most of them can support themselves in the air by this means though some, like our domestic fowls, can only make very short flights and others, like penguins, have their wings so shrunken that they cannot fly at all. It has long been known that nearly all birds, before rising, endeavor to acquire a preliminary speed by running on the ground with their heads to the wind, like the vulture, the stork and the bustard; or swimming in the water, like the albatross, or by dropping from an elevated place, like the goshawks and the martin; or by jumping to a sufficient height in comparison with their size, like the small waders, and sparrows. At this instant, all species flap more or less violently, in order to acquire altitude.

A large number of species belonging to all the groups, employ flapping flight exclusively. For many, this manner of flight is habitual and is practically continuous. Some birds, after attaining sufficient altitude cease flapping and glide through the air. Most swallows fly thus. They have a peculiar kind of flight, consisting of alternate periods of rapid flapping and a complete cessation of flapping. When the speed acquired seems sufficient to the bird, he closes his wings and shoots through the air like an arrow.

Other birds, like the martins, after a series of strong rapid strokes hold their wings rigidly extended and glide for a short space of time. There are other birds capable of gliding for a comparatively long period of time. Such are all the species provided with large wings, like birds of prey, large waders or long-winged, web-footed birds. They flap their wings much less frequently than the members of the other groups. Their wing strokes are always made slowly and but few in succession. Generally as soon as they have attained a more or less elevated position, according to the species, they glide with their wings outspread at right angles to their bodies. Thus they describe successive circles, each a little lower than the last. This gliding flight is executed even in still air.

Dr. Magnan has stated that all birds flap more or less and glide more or less and that it is not necessary to separate the two kinds of flight. They are, in fact, only two different phases of the same manner of aërial locomotion, one phase being utilized more than the other by the bird during the course of its flight, according to the different conformations of the various species, as clearly demonstrated by his investigations.

Gliding flight, of whatever length, during which the bird loses altitude, must not be confounded with soaring flight. The latter may be continuous, but requires for its production, at least according to Dr. Magnan's personal observations, the existence of a more or less strong wind and its action against the under side of the wings. This view has been supported by sailplane pilots who can only soar where the wind conditions are favorable. He holds the opinion that there are two kinds of soaring flight. In one kind the bird utilizes ascending currents, the wind having been forced to ascend by encountering a mountain, for example, or as a result of the air becoming heated near the ground.

Birds of prey often practice soaring flight, like the eagles in the mountains and the vulture over the desert. With their wings wide open, they can thus rise in the air until lost to view, generally in a spiral motion, without flapping their wings. In the other case, the bird mounts on the wind (which may be horizontal) while facing it. With his wings more or less extended, according to the strength of the wind, he does not give a single stroke, but merely balances, in order to maintain his equilibrium. By means of this wind he acquires altitude, his ascent always being quite slow. In order to hold any desired direction, he uses his tail as a rudder. He also uses it as an elevator, if the wind has a tendency to upset him.

When the bird, which never flies at a great altitude under these conditions, ceases to face the wind (after a turn, for example), he makes a swift glide with the wind behind him and wings outspread, thereby losing in altitude. In soaring flight, there are accordingly two phases. The first corresponds to the first phase of flapping flight with the difference that a soaring bird, in contradistinction to a flapping bird, makes no effort to raise himself and finds the force required for his elevation not in the muscles of his body, but in the surrounding medium. The second phase, on the contrary, is the same in both methods of flight, since both

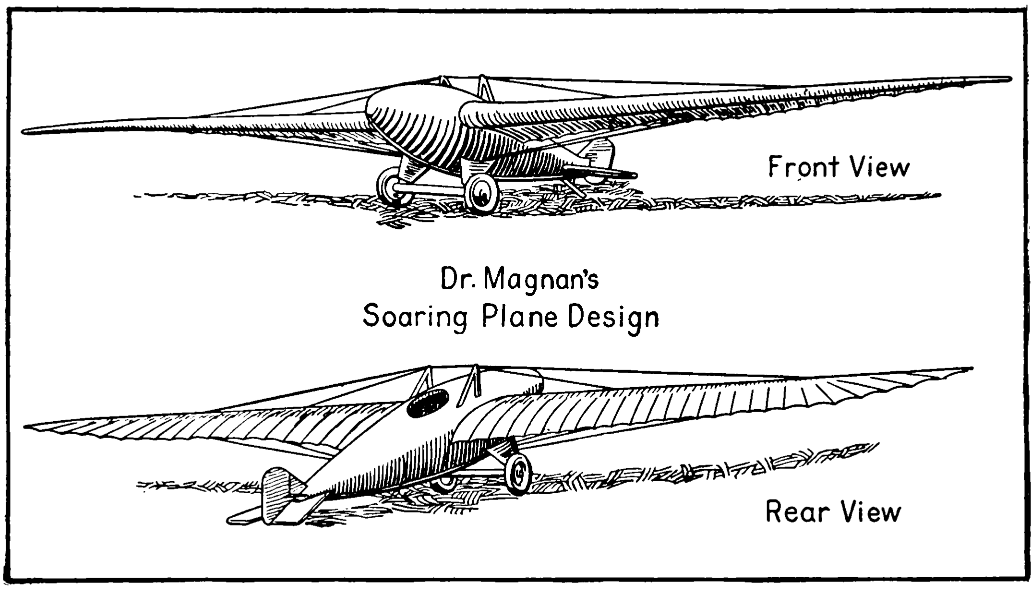


Fig. 11.—Front and Rear Views of Monoplane Soarer Designed by Doctor Magnan from Data Obtained by His Comprehensive Studies of Bird Flight.

the soaring and the flapping bird utilize and combine two forces, the force of gravity and the resistance offered by the air to their fall, according to the area of their supporting surfaces, for the purpose of controlling the speed of their descent.

Soaring Birds Utilize Air Currents.—Good soaring birds, which fly against the wind, can maintain themselves in the air for a long time without giving a single stroke with their wings.

It has seemed that birds made their best flights when the wind appeared to an observer on the ground to be continuous but reinforced at intervals by squalls. This kind of soaring flight can be employed only by certain species having a special conformation. Among birds of this type are the albatross, frigate bird, gannet, petrels and gulls. For soaring flight, the three former species do not require a strong wind. The two latter families, on the contrary, seldom practice soaring flight without a strong wind.

The flapping bird also utilizes the wind. He can also make soaring flights in the theoretical sense of the term, but since his conformation does not enable him to be a true soarer, he only utilizes the wind to diminish his efforts in flapping. Thus the small waders and quails, which possess characteristics recalling in miniature those of the gannets and gulls, succeed in flying across long stretches of sea in their migrations, for which their own motive power would be insufficient.

Birds With Largest Wings Have Weakest Muscles.—Dr. Magnan found that the relative weight of the small pectoral muscles varies, on the whole, like that of the large pectorals and that, moreover, the same as there are groups more or less well equipped with wings, there are also groups more or less well provided with muscles, with this peculiarity, *that the best rigged with wings have the poorest muscles.* We learned in physiology that the work of which a muscle is capable is proportional to its weight. In fact, the strength of muscles is proportional to their size, *i.e.,* to the number of fibers they contain.

The inverse ration which exists, on the whole, between the weight of the pectoral muscles and the relative wing area is, moreover, very easily explained. Flappers have a rather small or very small wing area. They can support themselves in the air only by flapping their wings more or less rapidly. Their down-stroke muscles are well developed, by reason of the expenditure of the muscular energy required by this method of flight. The same holds true for the flapper-gliders. The size of the large pectorals is in proportion to the rapidity of the strokes. They are small on the night raptores, which flap slowly and glide frequently. They are very much enlarged on the passeres like the martins which fly by means of very rapid strokes separated by longer or shorter periods of gliding.

Soarers, on the contrary, flap only to ascend or support themselves when there is no wind. Most of the time they soar by utilizing ascending or horizontal winds or glide through the air with their wings extended and without the least stroke. The muscular effort being small in all cases the large pectorals are less powerful. As regards the small pectorals, the same reasoning applies to the soarers. On the latter, these muscles are small, because most of the time the wings are motionless and also because their lifting may be considered as automatic, on account of their large area. On birds with small wings, the weight of the small pectorals, on the contrary, is ten times as great proportionally as on soaring birds. Furthermore, although the up-stroke muscles of the latter average twenty times smaller than the down-stroke muscles, they are not over three times as small, for example, on the gallinæ. Lifting the wing therefore requires a great muscular effort when the wings are small, this being true even for birds which fly scarcely at all. Their down-stroke muscles are partially atrophied, but their up-stroke muscles are large enough to lift the wings during their rare flights.

In 1911 Dr. Magnan explained the inverse ratio existing between the motive power of birds and the size of their wings. For birds, as well as for airplanes, small wings necessitate a large motive power, but with one point of difference. Hitherto the improvements in engine construction have conduced to the idea that the best airplane is the one propelled by the most powerful engine and capable of carrying the heaviest load. On the contrary, soaring birds, which are the best fliers, have the smallest motive power and carry the smallest load. The same applies to sailplanes used in soaring flights, the wing area is large in proportion to the weight.

Bird Has Efficient Aërodynamical Form.—The master section of a bird is shaped very much like that of a fish. There is, in both, an inversion of the body, *i.e.*, a compression in front in the horizontal plane and a compression in the rear in the vertical plane. The master section of a bird, projected on the vertical plane or on the horizontal plane also has, therefore, the shape of a parabolic curve. If the bird is laid on its side the summit of the curve is toward the head in the vicinity of the greatest width of the body which is always located at the posterior part of the shoulder joint and on the axis of the body, *i.e.*, on the straight line between the beak and the tail. The horizontal plane, passing through this axis, divides the body into two very unequal parts. The ventral part is much the larger and the branch of the master section belonging to it is much the longer. When the bird is laid on its back, the summit of the curve is, on the contrary, situated on the ventral line toward the tail and both branches are equal, producing a good streamline form.

The shape and, consequently, the position of this master section also vary with the manner of flight. Its projection on the horizontal plane is a parabolic curve whose branches are very divergent and whose summit is very much in front of the body proper on soarers and flapper-gliders. For flappers, this projection presents an elongated form. The branches, originating near the shoulder joints, extend backwards with the formation of an acute angle and join on the ventral line near the middle of the wings. The master section is therefore in front of the body in birds of small motive power and much farther back in those of great motive power.

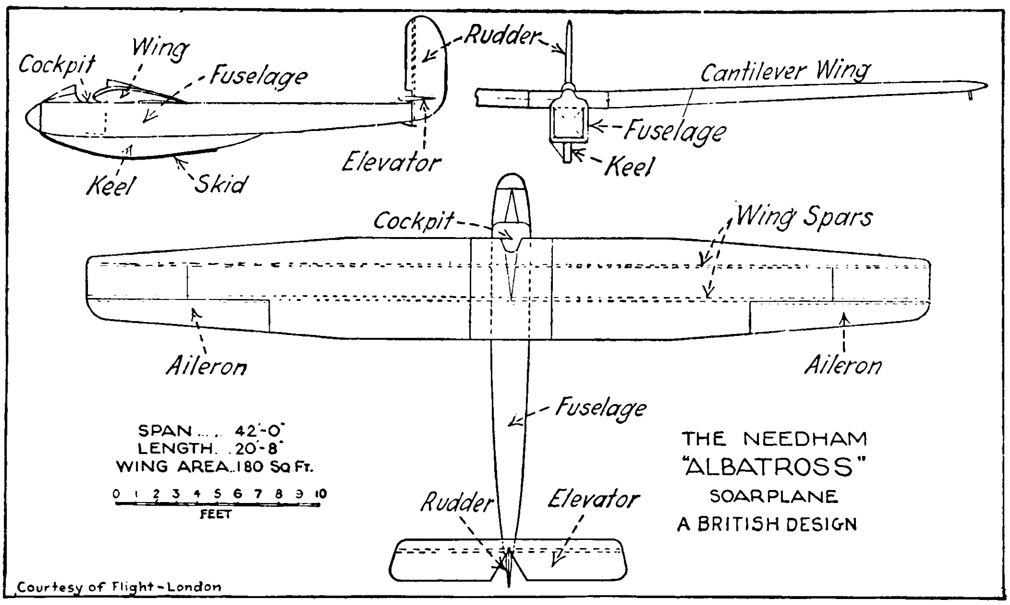


Fig. 12.—Outline Drawings of the Needham "Albatross" Soaring Plane, Showing How Bird Form Is Approximated in Creations Intended for Motorless Flight.

The general shape of a bird's body very evidently resembles the shape of a fish. Both the body and the wing are thicker in front and tapered toward the rear, this conformation being particularly noticeable in all birds with their feathers on. This streamline section (see Fig. 7) produced by nature is also used in man-made soaring planes and powered airplanes where the airflow by the surfaces with the minimum of drag or resistance is desired. The faired fuselage and tapered wing of the modern sailplane closely approximate the shape of a soaring bird, such as a gull or albatross. (See Figs. 11 and 12.)

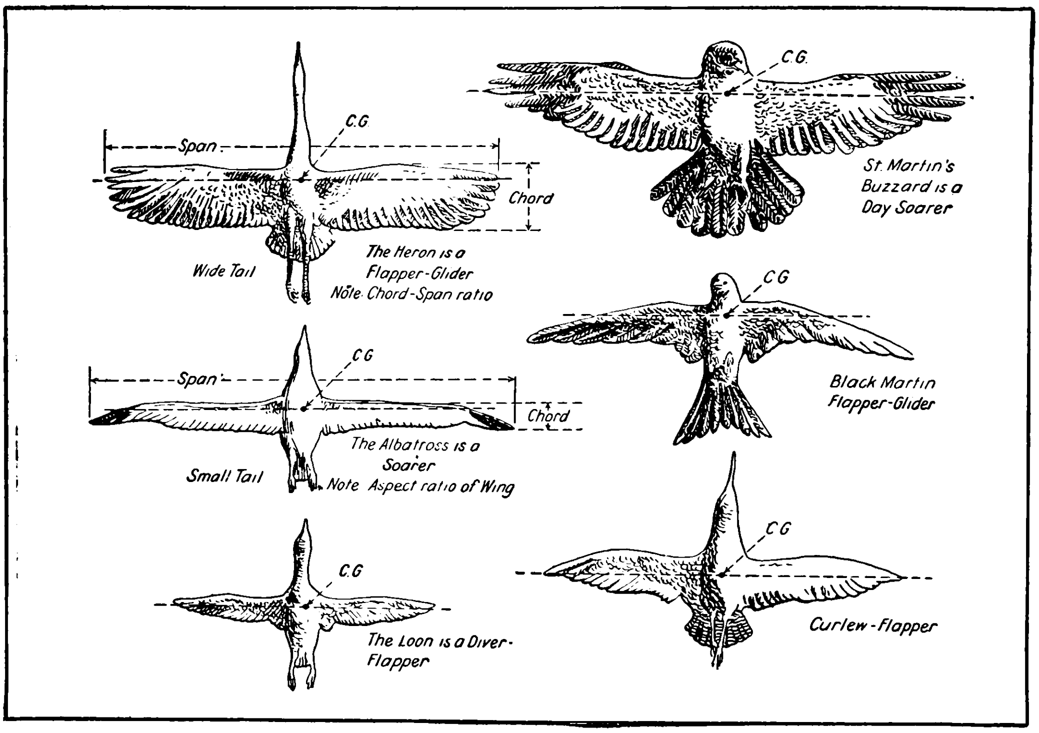


Fig. 13.—Drawings by Doctor Magnan Showing the Center of Gravity Location, Body and Wing Form of Various Types of Birds. The Birds Are Drawn the Same Size to Show Body and Wing Proportions More Clearly, But Actually There Is Considerable Difference in Weight and Wing Area.

Center of Gravity Location in Birds.—Dr. Magnan has also determined the location of the center of gravity of various birds. For this purpose, he employed various methods, which we cannot describe here. It was found that the center of gravity, which is always situated practically in the vertical plane passing through the longitudinal axis, is consequently placed far forward on soarers and flapper-gliders and much farther back on flappers. In the former, it always corresponds to the front third of the wings and is nearer the front sixth in the best fliers. In flappers, on the contrary, it is nearly opposite the middle of the wings and approaches the line joining their middle points in proportion as they are poorer fliers. Moreover, the center of gravity always lies below the longitudinal axis and a little above the middle of the greatest thickness of the body in birds of small motive power and slightly below the middle in those with large motive power. (See Fig. 13.)

Bird Wing Profiles Vary.—The wing profile of the Pondicherry vulture is very peculiar, in that it has a recess on the lower side just back of its leading edge. According to Hankin, similar recesses are possessed by the adjutant, crane, and flamingo, hence by land soarers with a high wing loading. It was therefore assumed that the recess facilitates soaring. According to Hankin the birds with the recessed wing profile soar swifter than those with the eagle or owl wing profile while, on the contrary, the gliding angle of the latter profiles is better than that of the recessed profile. Airplanes with this profile were wrecked in their first tests. The recessed profile is likewise unsuited for dynamic soaring flight because it develops vortices, which increase the drag. The recessed wing section of the dusky horned owl shown at Fig. 14 was modified and became the R.A.F. No. 5 airfoil section shown above it.

Influence of Bird Flight on Glider Development.—Nature had, for hundreds of thousands of years, endowed certain creatures with power to move at will through the air and prehistoric reptiles with enormous wing spreads were the remote ancestors of our present-day birds. Naturally, the first reasoning human beings envied the birds this power to navigate the air and many studies of bird flight were made by early philosophers. It was the study of soaring birds, rather than those that fly only by

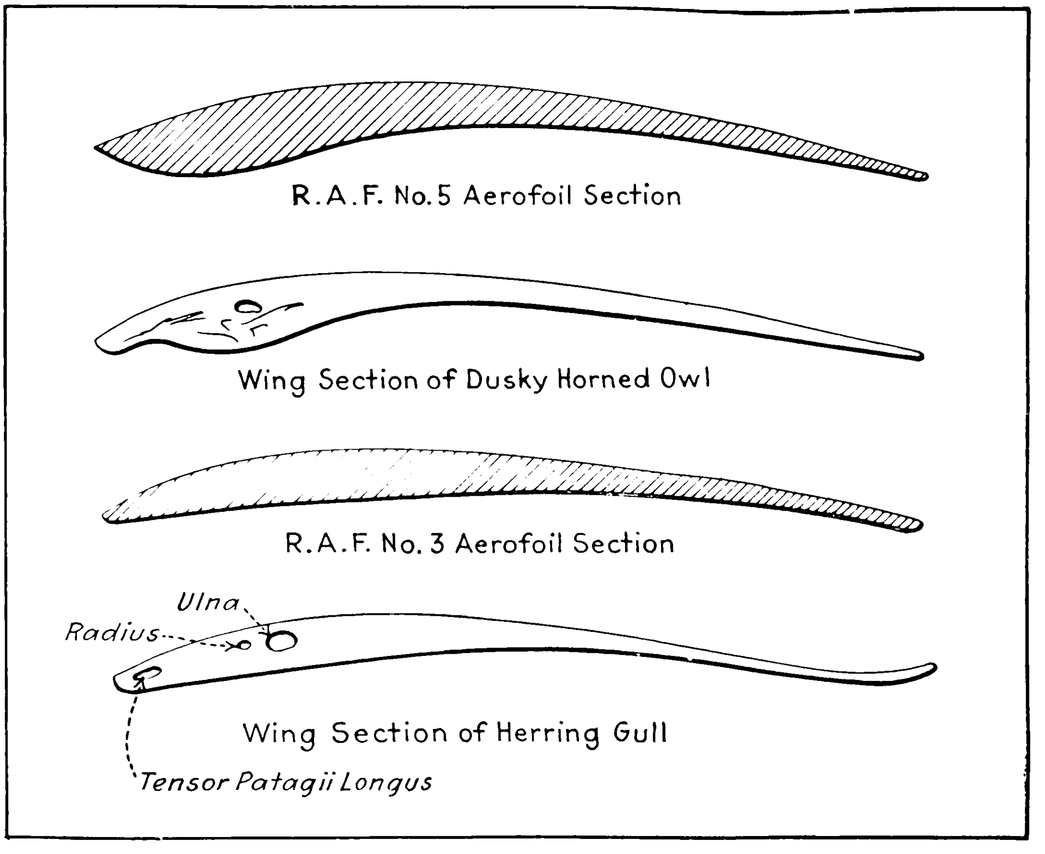


Fig. 14.—How Birds' Wing Sections Compare with Early Airfoil Sections Used on Powered Airplanes.

rapidly flapping their wings, that gave man the first clue to aviation. The reader is asked to study the diagrams presented at Fig. 15. The gull shown at A, is soaring and with wings fully extended, head thrust forward, tail extended and feet retracted, offers the minimum resistance and maximum supporting surface.

Lateral balance is obtained by the flexed wing-tip feathers; movements of the tail vary the angle of attack for best meeting the air current. The bird makes these movements instinctively. In alighting, the bird's position changes materially. The body is tilted upward, the wings are changed so they are at a sharp angle with the air currents, the feet are extended and tail depressed. The position of every part is such as to offer maximum resistance and bring soaring flight to a stop. The lift of the wings is decreased and their resistance or retarding power greatly increased by the sharp angle of attack shown at Fig. 15B.

The Le Bris glider, shown at C, Fig. 15, was the invention of a Frenchman who, as early as 1867, conceived the idea of flexing wings to secure lateral balance, and its form was such that if a sufficiently light power plant had been available, the creation would undoubtedly have left the ground and made powered flights at that early date, and as directional control by use of rudders was an ancient art, the machine could have been controlled in flight. A later form of soaring plane shown at Fig. 11 was designed in 1914 by Dr. Magnan, a French scientist previously mentioned for flights in horizontal and slope winds and also closely followed bird form and was based on an exhaustive study of the proportions of soaring and other birds. A typical modern soarplane is shown in outline at Fig. 12. This only approximates the plan form of a bird.

Nature's Flying Creatures.—Nature has provided other creatures that fly besides the birds. The insect world offers many examples of flying creatures. The dragon fly, with its large wing spread, appears to glide at times, as does the butterfly, but other insects can only keep in the air while their wings are vibrating rapidly. The beetle family are wing case insects. (See Fig. 15D.) The membranous members are protected by hard cases when the insect is at rest, and when in flight the wing cases are spread out to offer cambered planes for support while the rapidly vibrating membranes serve as a propulsive medium. Insects such

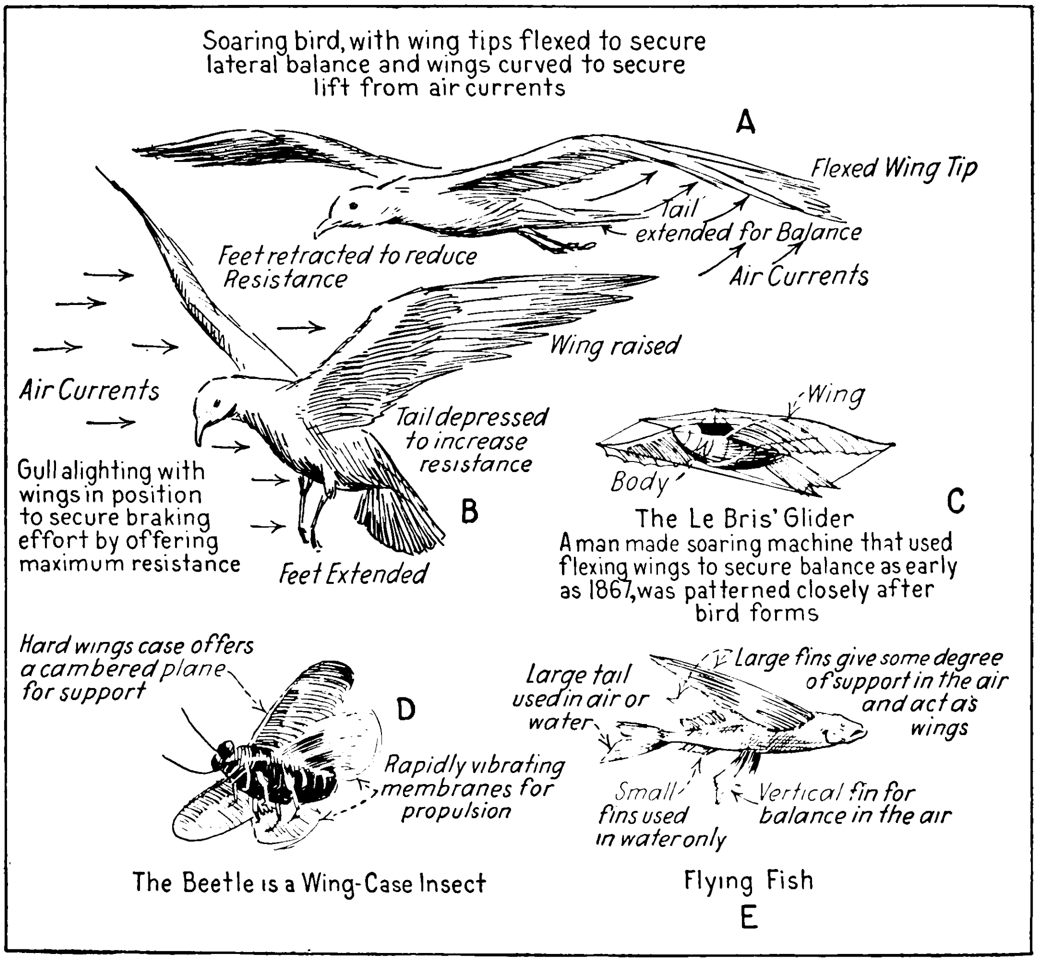


Fig. 15.—Study of Bird Flight Gave Man the Clue to Mechanical Flight. A—Position of Wings and Body of Soaring Gull. B—How Alighting Gull Changes Wing and Body Position to Offer Maximum Resistance and Thus Arrest Forward Motion. C—The LeBris Glider, an 1867 Model, Closely Approximated Bird Form. D—Wing Case Insects Use Hard Wing Coverings as Planes for Support and Membranous Members for Propulsion. E—The Flying Fish Leaps from Wave to Wave and by Extending Its Fins Derives Some Degree of Support from Air Currents.

as beetles have considerable weight and size in proportion to their supporting area, while butterflies have much greater supporting area and can fly with more deliberate and slower wing movements.

The flying fish, as shown in Fig. 15E, is able to leap out of the water and by extending its fins, which are of much larger area than most fish have, it is able to derive some support from the air currents before gravity returns it to its native element. The tail is large and a vertical fin under its body has sufficient area to provide some stabilizing influence. The flying fish is not capable of extended flights, as birds are, but of long leaps from one wave crest to another. Certain reptiles, such as frogs with extremely large membranes on their feet and mammals such as the "flying" squirrel which has a skin joining its front and back legs that can be distended to give it a certain supporting area can make quick, steep glides but cannot soar. The small mammal, the bat, our modern survival of prehistoric times, has flexible membranes of considerable area and powerful muscles by which they may be vigorously flapped so that flights are possible and steep glides can be made by keeping the membranes extended.

Loading of Birds' Wings.—There is some similarity in cross-section of some of the airfoils used for early airplanes as shown at Fig. 14 and the wings of birds. The wing loading of birds, *i.e.*, the amount of weight carried per unit area is light compared to that of flying machines as it varies from a minimum of half a pound to 2 pounds per square foot. The wings of a black vulture, for instance, are loaded 1.25 pounds per square foot. The sustaining members of the dusky horned owl and the tawny eagle are loaded about .90 pound per square foot. All birds' wing sections as well as their plan forms are different and undoubtedly have changed in form as a result of a natural development or evolution depending upon the habits of the birds, such as whether they were gliders, soarers, flappers or swimmers. Soaring planes also have a low wing loading of about 2 pounds per square foot or slightly more but the airfoil sections of modern airplanes and gliders differ considerably from sections of birds' wings, being thicker and shorter in most cases.

Wing Area of Birds.—The student of airplanes may wonder what the proportions of the flying machine devised by Nature are and how the supporting surfaces compare in different birds in reference to their weight and flying power. It is conceded that a study of bird flight and form may be of interest to the student and it is necessary to give this more than passing consideration at the present time because modern sailplane design was influenced considerably by the study of the flight of soaring birds. It has been stated that in prehistoric times much larger creatures inhabited this earth than we know of to-day. These included peculiar flying forms that were neither bird, reptile nor mammal, but which had characteristics of all these. Many centuries ago a large flying creature which was a combination of reptile and bird and which was known as the Pterodactyl existed, and while it is not possible to give the exact size of this creature, from the present existing skeletons reconstructed by modern scientists, it is assumed that the wing spread was about 20 feet and that a supporting area of about 25 square feet was available for supporting it in flight. The weight was 30 pounds and it was estimated that it was capable of exerting about 1/25 H.P.

If we consider the modern birds, among the largest of the soaring bipeds is the condor, which has a wing stretch of 10 feet from tip to tip, a weight of 17 pounds, a wing area of about 10 square feet and which is capable of exerting about 1/30 H.P. The turkey buzzard is a smaller soaring bird which has a wing stretch

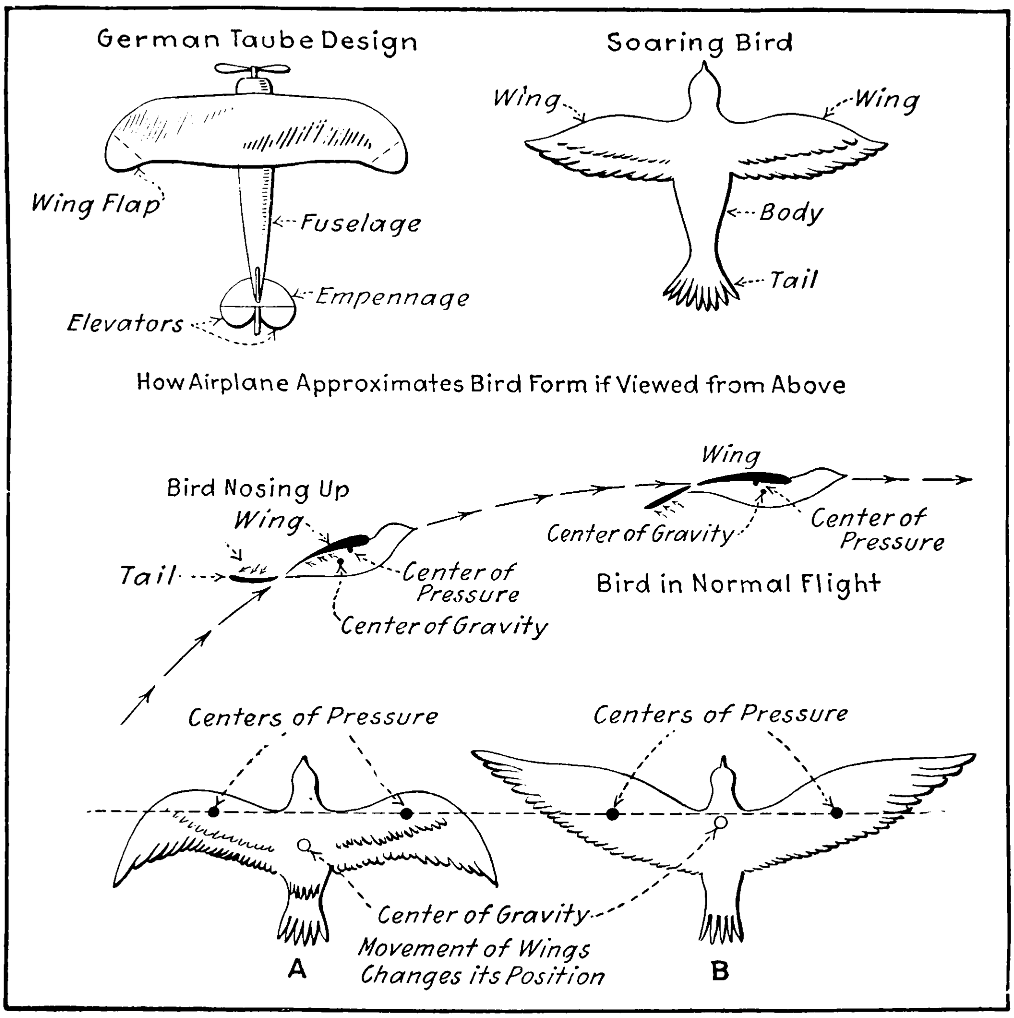


Fig. 16.—Diagrams Showing Plan View of Early German Airplane Design Compared with Plan of Soaring Bird at Top of the Illustration. The Other Illustrations Show How a Bird Can Shift the Relation of Pressure and Gravity Centers by Wing and Tail Movements to Secure Changes of Direction in a Vertical Plane.

of 6 feet, a supporting area of 5 square feet, a weight of 5 pounds and a power capacity of but little over 1/100 H.P. It will be evident that the ratio of supporting surface to the weight of the creatures does not always vary directly with their weight and, strange to say, the larger the creature the less the relative power and surface area needed for its support.

It has been stated that the lungs of a bird, filled with air and the fact that all of its major bones have very light walls and are hollow greatly reduced the body weight in proportion to its size and its form was such that a certain aërodynamic lift was obtained by air pressure under the body while in flight. Then again, much of a bird's bulk is due to feathers, which are light in proportion to their size. When plucked, a large bird shrinks in size in an amazing manner. Feathers are nearly as light as the air they displace and even quills are picked up by the wind and carried away because of their light weight in proportion to their size and supporting area. In modern airplanes and sailplanes, many of the structural members, such as box spars and frame tubes are hollow to save weight just as the bones of birds are and of course, the wings and fuselage are extremely light for their bulk.

Bird Flight Difficult to Imitate.—When one compares the flight of birds with the principles that underlie the support of an airplane or sailplane in the air, it is only because the bird is Nature's flying machine and such comparisons are not fair because a part of the supporting force through which a bird flies is obtained by the flapping of wings, which so far has not been successfully imitated by man-made mechanism. It is not strictly a flapping movement, but one that combines a flapping to provide lift with a forward thrust. Another thing that can never be imitated is the peculiar instinctive coördination of various body parts by which a bird can change its center of gravity in its relation to the center of pressure and secure up or down flight by movement of its head, tail or wings. (See Fig. 16.) Proponents of the early types of suspension gliders thought they could shift their bodies and do this balancing instinctively with practice but they found that the centuries of evolution birds had gone through to perfect their technique could not be condensed in the lifetime of an individual.

A comparison between birds and sailplanes can only be made when one considers soaring birds and then only as long as the creature supports itself by changing the relation of its wings and body so as to secure the support it needs from varying air currents—obviously as soon as the bird starts flapping its wings it ceases to act in the same way as an airplane, which cannot have any relative movement of its supporting surfaces or shift weights so that changes of the center of gravity may be obtained, though the control surfaces can cause center of pressure movement on the wing within reasonable bounds by changing the angle of attack or the incidence of the wing.

Lessons Taught By Birds.—By watching the flight of gulls, the Wright brothers conceived the idea of wing flexing for lateral balance, that next in importance to a light powerful engine, was to make flying commonplace. They observed that the soaring birds, such as gulls, maintained lateral balance by flexing or distorting the tips of their wings so they arranged their supporting planes to obtain a greater positive lift on the wing on the low side of the airplane by flexing down the tip. Studies of bird flight have also led to streamline monoplane designs; the use of wings having much greater span than chord and a plan form for the complete structure when viewed from the top somewhat the same as that of a bird with wings extended. (See Fig. 16.) An observer who noticed that a bird held its talons close to its body when flying suggested the retractable landing gear to reduce resistance, now a feature of nearly all practical amphibian airplanes and being incorporated in some land planes as well to secure an increase in flying speed.

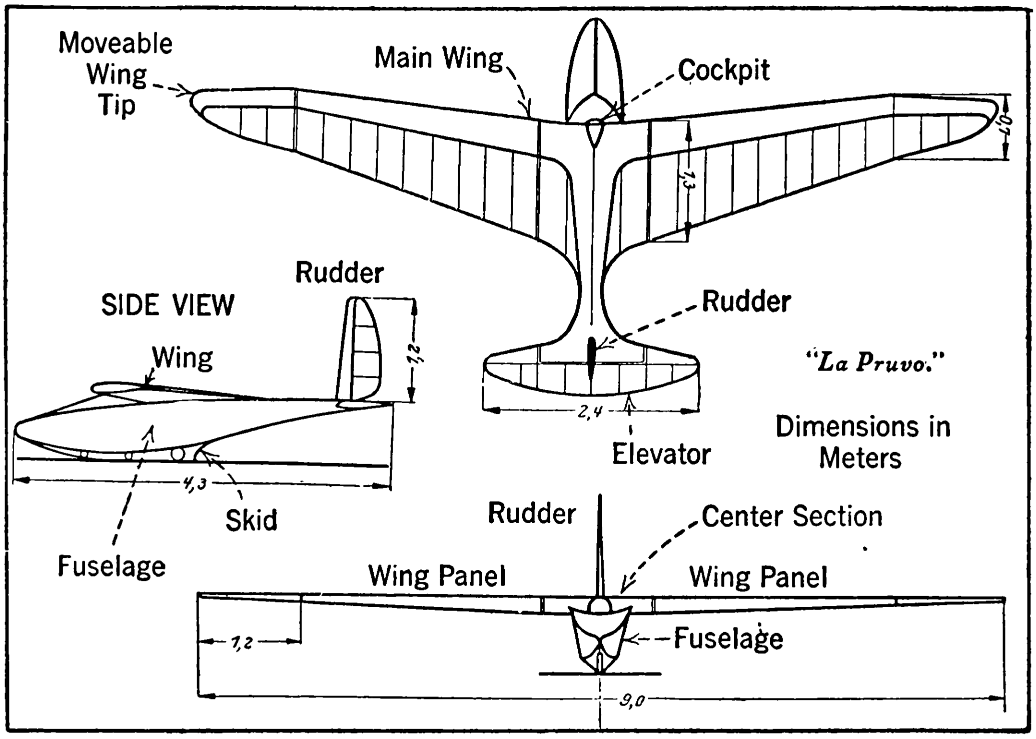


Fig. 17.—Diagram Showing Outline of La Pruvo Sailplane, Having a Plan View That Closely Resembles That of a Soaring Bird with Wings Outstretched and Securing Its Lateral Balance by Movable Wing Tips.

Modern practice for planes and gliders of ordinary size is towards the simplest or monoplane structure and few airplanes are built that utilize more than a pair of wings on each side of the fuselage. The principle of the wide advancing edge is made use of—just the same as obtained in nature's creation. In a bird, which is always a strictly monoplane design because nature's plan seems to be always to provide maximum possible efficiency in its living mechanisms, the body is sustained between two wings that have sufficient supporting area to perform the necessary functions of sustentation during soaring flight, but the control of this is so delicate that by the simple movement or flexing of feathers at the wing tips, not necessarily the movement of the wings or of the body, it is possible to decidedly change the poise or balance of the bird in the air.

The application of such natural force is instinctive with a bird and the utilizing of speed or wind velocity is all performed automatically without materially affecting the progress of the creature. The fact that this instinctive control is not impossible of attainment to a more limited degree by man can be shown by the instinctive balancing which obtains when one becomes familiar with bicycle riding—the unconscious movement of the body so easily accomplished by the rider who has had considerable experience is very difficult for the novice to acquire, and even after several years' rest it is possible for one who is familiar with bicycle riding or who has learned it to get on a machine and ride off without any trouble. By continual practice, the movements of the control stick of airplanes or gliders to secure proper balancing also becomes automatic to a degree.

Of course, the mass of a modern airplane or sailplane is too great to be affected by any conscious movement of the operator, though this principle of leaning the body to secure equilibrium was used in early suspension gliders.

The new system of control, however, does not utilize movements of the entire body, though an inherent sense of equilibrium is absolutely necessary in order that the aviator may tell when his plane is not flying as it should, such as having one wing lower

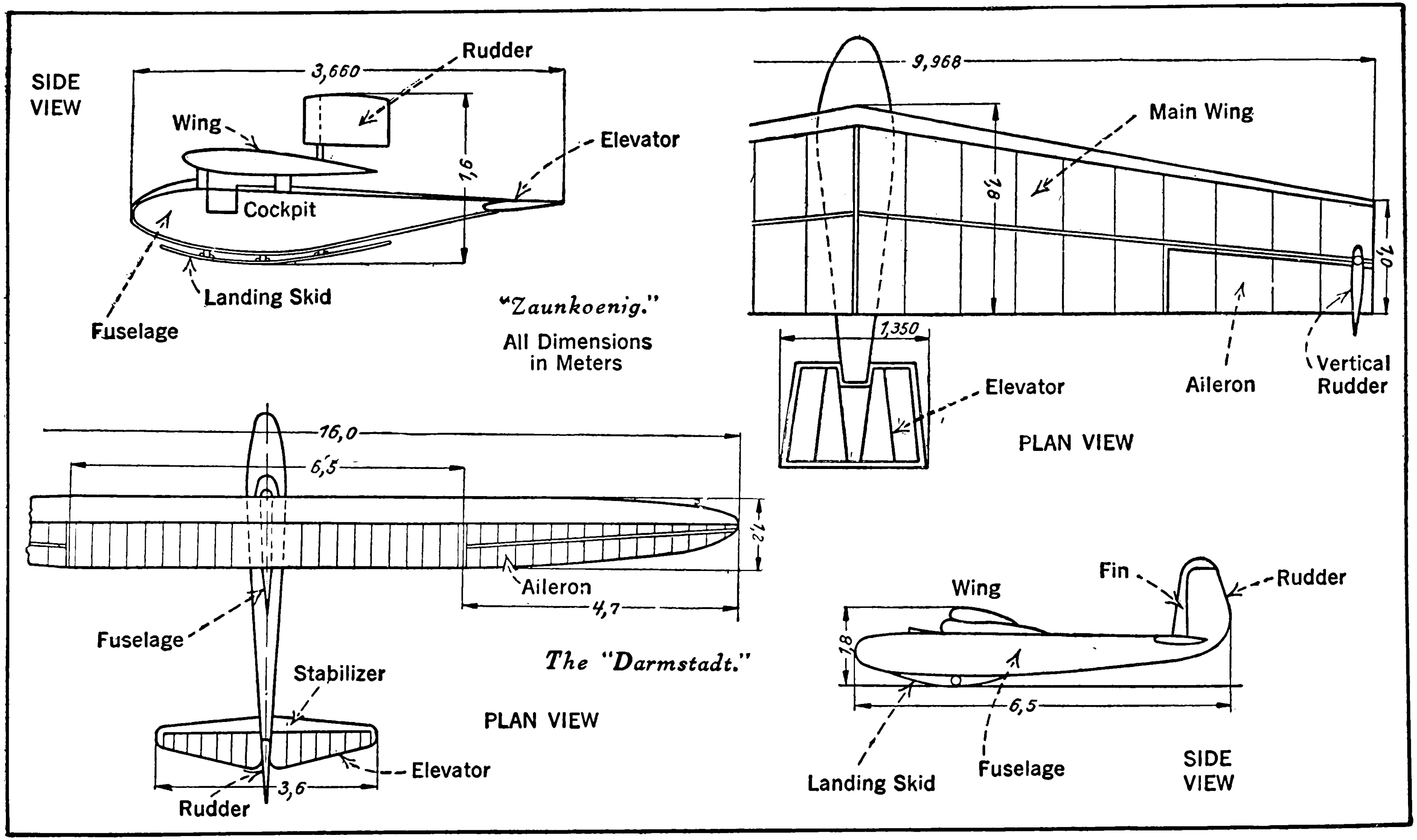


Fig. 18.—Outline Drawings Showing the Dimensions of Two Successful Types of German Sailplanes, One of Which Approximates Birds' Plan Form More Than the Other. The Zaunkoenig Has Its Vertical Rudder Above the Wing Tips, a Somewhat Unusual Construction. The Darmstadt Is a Very Efficient Soaring Design Having a Large Aspect Ratio and a Wing Loading Approximating That of Some Soaring Birds.

than the other, or climbing at too steep an angle. When high up in the air, there is nothing to compare this to except certain parts of the machine which practice and observation tells the operator must occupy a certain position relative to the horizon when in normal flight.

Instruments have been devised to give this information to the airplane pilot so that in a fog or when flying after dark or in a storm, one can have an artificial horizon and navigate and control the airplane properly. As gliders and sailplanes will undoubtedly be operated during daylight hours, for relatively short periods of time and under only favorable weather conditions, complete sets of navigating instruments are not necessary though simple instrument boards with an air speed indicator, a turn and bank indicator and an altimeter are fitted to some of the recently devised soaring planes.

Sailplane Moves in Three Planes.—There are really three axes about which a sailplane structure can operate, so that three distinct sets of control surfaces are required. In the usual form all of the control planes are at the rear of the fuselage and wings. Those at the tail are called the "empennage." The elevator, which consists of two flaps capable of moving up and down, is at the extreme rear of the fuselage and controls "pitching" or up-and-down movements. The rudder, which has a vertical surface, is utilized for the turning or "yawing," as it is called. The lateral balancing or "rolling" control, is produced by the ailerons or wing flaps or by movable wing tips. Wing warping is now obsolete.

Bird and Plane Form Compared.—If one compares the form of a bird with that of some of the late gliders and airplanes, it will be apparent that they are somewhat similar in form, because both have a wide advancing edge or wing spread and that the plane or wing is comparatively short, and, as will be evident, the bird can utilize its tail as an auxiliary wing which aids and directs its flight. The section of a bird's wing is similar in the main, to the cantilever monoplane, being thicker at the point of attachment to the body than it is at the wing tips. While airplanes have flown successfully with wings of rectangular plan, the most efficient of our modern designs utilize wings which not only taper in sectional area but also in plan. It is necessary to provide some form of rudder or auxiliary plane on an airplane in the form of an airfoil which can be lifted or depressed, so that the air will act on the top or bottom of its surface, depending upon the direction it is desired to fly in to correspond to the elevating function of a bird's tail.

The bird has no surface that corresponds to the vertical rudder necessary on an airplane, because it is possible for it to flex its wings and to flap them simultaneously and thus secure propulsive effort and change the direction at the same time. It is also possible for a bird to move its wings forward or back and alter the center of pressure as well as the angle of attack in a way that would be very difficult for man-made mechanism to imitate even approximately, because the bird does it instinctively and probably without thinking about it. This is not possible with the wings of an airplane, which must be immovable relative to the fuselage in order to secure the necessary strength. It is possible, however, to turn an airplane without the use of the vertical rudder by merely working the ailerons which would correspond to some degree to the flexing of the bird's wing tips. The vertical rudder is necessary, however, to make good turns in the man-made flying machine even though it can be dispensed with in Nature's model. (See Fig. 16.)

Plane Forms.—The effect of using wings or planes of the same area but of varying shapes and forms is marked, and also with those of different aspect ratio and airfoil section, but in tests the actual results obtained were so much different as to be the cause of considerable comment. There was no question but that the form of the wing of a bird when extended in soaring flight had proportions that could be followed to advantage by the designer of airplanes; however, the curves of a bird's wings are not easily duplicated in man-made machines, so that various forms of airfoils have been devised that give really good results when driven through the air at sufficient speed by the thrust or push of a propeller.

Experiments have demonstrated that within certain limits the supporting wings of soaring planes should be long when viewed from the front, and short when seen from the side. The best proportions have never been definitely determined and vary in many of the successful creations. The usual aspect ratio of a motored airplane is about 6 or 7 times the depth or width, measured along the chord. In soaring planes the aspect ratio, *i.e.*, that of span to chord may be anywhere in the range from 10 to 15 to 1. Wing spreads of 60 feet with a chord of about 4 feet have been noted in some of the German sailplanes.

CHAPTER FOUR

SAILFLYING AND TYPICAL SOARING PLANES

Grouping Sailplanes into Classes—Monoplane Construction Now Favored—Control of Sailplanes—How Sustained Sailplane Flights Are Made—Meaning of Glide Ratio—Some Typical Efficient German Sailplanes—1921 Dresden School Biplane—1922 Darmstadt Sailplane "Edith"—Darmstadt Sailplane "Konsul"—Hannover Glider "Vampyr" —Hannover Glider "Greif"—Hannover Sailplane "H 6" ("Pelikan") —Sailplane "Der Dessauer"—Darmstadt Sailplane "Geheimrat"—Dresden Monoplane Glider—Messerschmitt Glider "S 13."

Grouping Sailplanes Into Classes.—First of all it is necessary to group sailplanes into classes. It is not always possible to make a definite distinction between gliding and sailing planes, for here and there sailing flights have been made with primitive gliding planes and glides have been made with sailplane types.

The chief method of classification is according to the nature of the control. As follows:

1. Planes controlled by displacing the body weight. (Now obsolete.)

2. Planes controlled by movements of the rudder, ailerons and elevator.

3. Planes controlled by altering the angle of attack or warping the wings or carrying surfaces themselves. These involve the use of movable wings and are still in the experimental stage.

In the first group, planes which are steered by displacing the body weight, are, in general, called suspension or hanging gliders. Most of the motorless planes of the first period of development such as the Lilienthal and Chanute and up to the time of the first

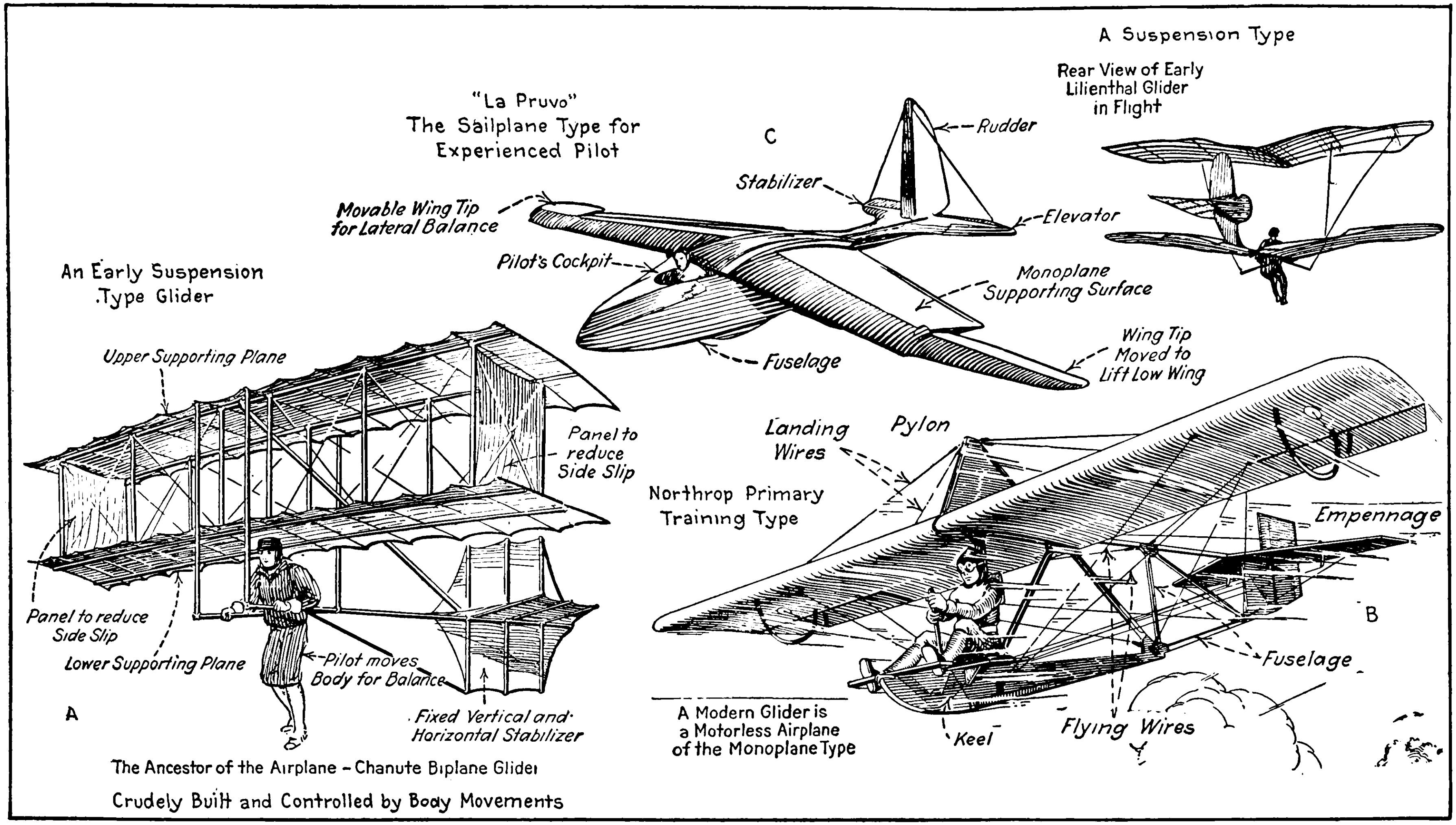


Fig. 19.—Various Types of Gliders and Sailplanes. An Early Type of Chanute Biplane Suspension Type Glider Shown at A. B—Modern Monoplane Training Glider. C—A Monoplane Sailplane Type for the Experienced Pilot.

motored flight, that of the Wrights in December, 1903, belong to this category, which is now obsolete. (See Fig. 19A.)

At the beginning of the sailflying movement most of the sailplanes, as in the motor flying field, were biplanes as shown at Fig. 19A. This is explained by the smaller surface load and the relatively simple construction and the greater strength. Thus, by bracing the two wings by interplane struts in connection with the diagonal wire reinforcing, a great static construction safety is obtained with simple constructive means and in spite of the small span width a great surface area is possible. Through the introduction of the free-carrying or non-reinforced (externally of the wing) design by Professor Junkers the cantilever wing monoplane, however, soon gained in importance, and in the first Rhön contest the tremendous superiority of the non-reënforced wing sailplane had already showed itself. With the same velocity in sinking and the flying speed increased by the elimination of all exterior stays and wires, the gliding angle was thereby decreased, so that in contrast to the reinforced biplane such aërodynamically high grade sailplanes of the new type can sail under comparatively small wind velocities. (See Fig. 19C.)

Monoplane Construction Now Favored.—The free-carrying monoplane with control by displacing the rudders can be considered as a standard, whereas for schooling and instruction purposes the strutted, or braced and reinforced monoplane deserves the preference. The purpose of the schooling plane is to acquaint the student with the initial state of sailflying, which is gliding flight, so that later he may control a high grade sailplane successfully. A wire braced primary training plane is shown at Fig. 19B.

Naturally a less strong ascending current is required for a plane with a low sinking velocity than is needed for a plane with a greater sinking velocity. However, it would be a fallacy to assume that one must build a plane for the static sailing flight which shows extremely low surface load and with a minimum sinking velocity. Such a plane is possible only by sacrificing aërodynamic efficiency because a lightly built plane requires reinforcing struts, stays, etc., on the outside. The detrimental resistance caused thereby consumes a large proportion of the flying speed, which is necessary for attaining a good gliding figure. This is understood when one considers that the gliding angle of a plane is derived as a resultant from the sinking speed and the flying speed; so by increasing the flying speed—precluding constant sinking speed—the gliding angle flattens. Therefore, in sailplane construction, efforts should be made towards low sinking speed as well as towards higher flying speed. (See Fig. 20C.)

Control of Sailplanes.—A sailplane controlled by adjustment of the rudders has three control organisms:

1. The altitude control (for flying up and down).
2. The side control (for flying sideways).
3. The transversal or lateral control (for maintaining transversal stability).

Altitude and transversal controls are operated by a vertical control stick which can be moved to all sides. The side control is actuated by a double foot lever. Corresponding to these three control organs the plane can be turned in the air around three axes as shown at Fig. 20D. These are the transversal axis, A-B, the vertical axis C-D, and the longitudinal axis E-F. The controls operate in the same manner as do those on a motored plane equipped with stick control. The transversal axis is not, as one

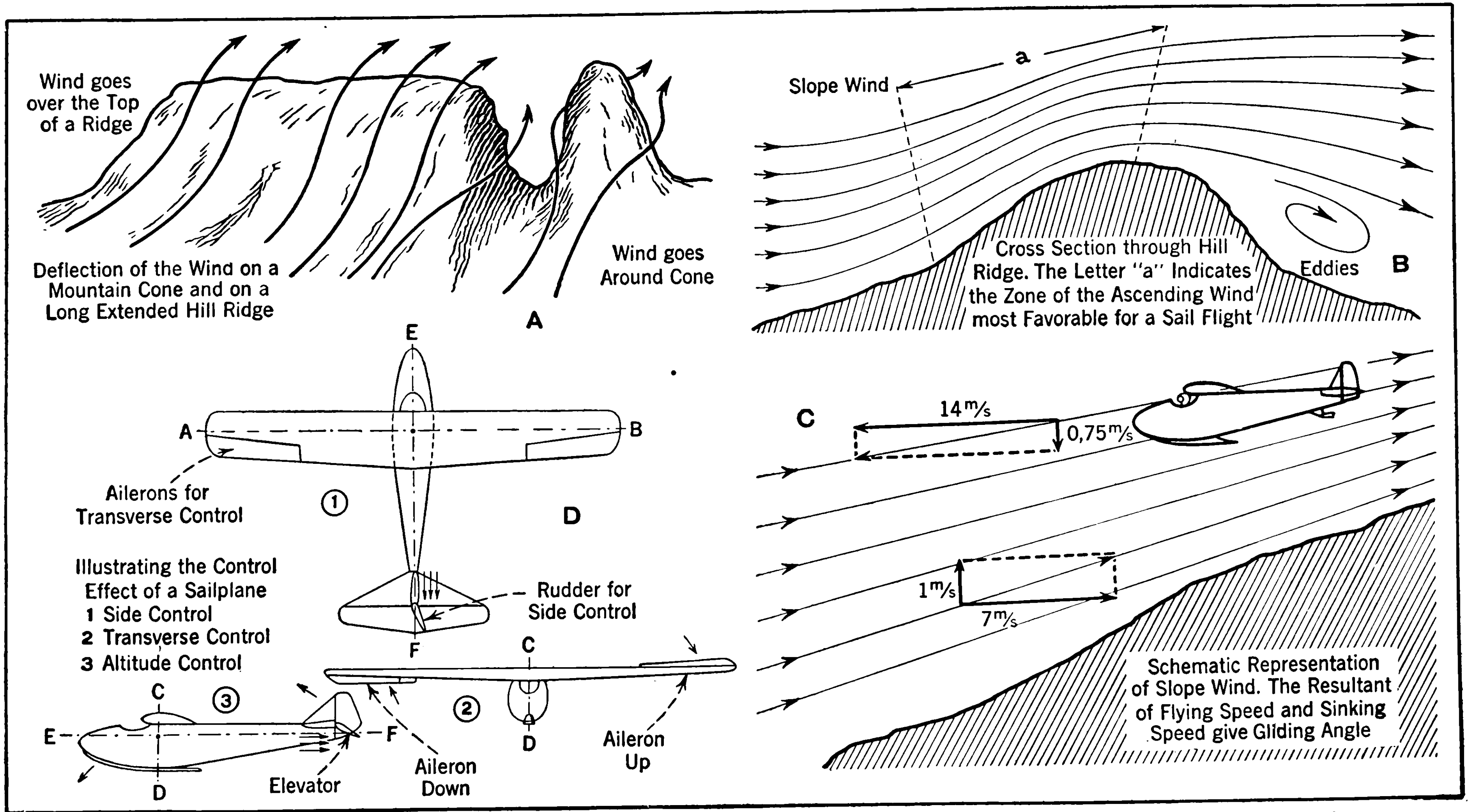


Fig. 20.—Diagrams Showing How Air Currents Are Produced by Wind Passing Over a Ridge of Hills at A and B. The Drawing at C Outlines How the Resultant of Flying Speed and Sinking Speed Give the Gliding Angle of the Sailplane and Also Presents a Schematic Representation of the Value of the Slope Wind. The Sketches at D Indicate the Method of Directional Control Used with a Glider or Sailplane.

would suppose, formed by the center of gravity (point of balance) but by the resultant of the air forces attacking the carrying wings. This resultant, called the average pressure line, is dependent upon the cross-section of the carrying wings, therefore, the profile and the angle under which the carrying wings are exposed to the direction or flow of the air (angle of attack). This is located in about the first third of the carrying wings.

Gusts, that is, irregular winds, attempt to bring the plane out of balance. Gusts attack one side of the wing more than the other, which means that they lift or lower one side of the carrying wing. The machine can be brought back from this inclined position by means of the transversal controls. They are flaps or ailerons which are jointed to the rear beam or tips attached to the ends of the carrying wings and are rigidly coupled so that a positive movement of the one results in a negative movement of the other. They do not differ essentially in construction, operation or effect from the ailerons of motor driven airplanes. The type of sailplane with warping wings forming the third group is not favored.

How Sustained Sailplane Flights Are Made.—It might be well to mention something on how these sustained flights are made. Flights for endurance are considered simpler than those for altitude or distance. They consist mainly in staying in an area or zone favored with an up-current of air of suitable velocity. However, a great deal depends upon the skill of the pilot as he must utilize as much of the energy of the wind as possible. Often the air currents vary in intensity and it is necessary to soar to attain altitude in one current and then glide downward to a point where it is known that there is another up-current, and then to gain altitude again and repeat the process.

A hill or range of hills arranged like a horseshoe is ideal for this purpose, when the wind is blowing toward the open side of the horseshoe, as an up-current established on the entire inside of the range, thus allowing the pilot to glide from one side to the other, soar upwards, and glide back again. To reach great heights, such as those desired for altitude records, one must search more carefully for specially shaped hills that afford the strongest type of up-current. These up-currents have been classified as either convectional or turbulent. (See Figs. 6, 9 and 21.) The convectional currents are caused by warm air rising and being re-

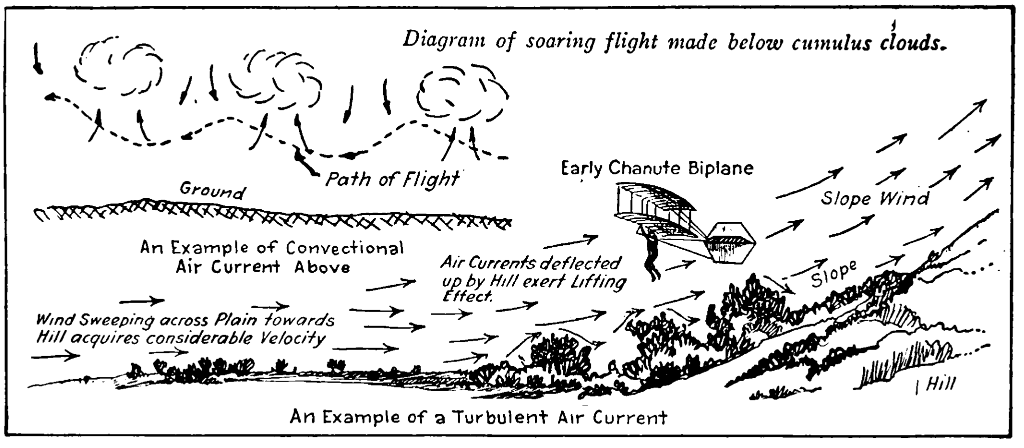


Fig. 21.—Diagrams Showing the Difference Between Convectional and Turbulent Air Currents Used in Gliding and Sailflying or Soaring.

placed by cool air descending. This often takes place over wooded areas, rivers, cities, bare ground surrounded by shaded ground, and under cumulus clouds, when they are forming. Turbulence is usually caused by some obstacle on the ground deflecting a horizontal wind upward, such as a hill, a forest causing an up-current on its windward side, ocean waves, etc. In utilizing these currents a great deal depends upon the judgment of the pilot, who must decide whether it is best to glide to another zone or not. (See Fig. 21.)

Meaning of Glide Ratio.—In making flights for distance it is necessary to get as much altitude as possible before starting, as one's altitude at the beginning determines the length of glide possible before another up-current can be reached. A plane has a definite maximum glide ratio and can go only a definite distance horizontally for a proportional vertical drop. (See Fig. 20C.) This ratio may vary from 10 to 1 up to about 15 to 1, according to Richard Mock, depending upon the aërodynamic efficiency of the plane. (It is usually somewhat lower than the high figure, a good average being 12 to 1.)

The first flights for distance were made in 1922, when it was learned that after one left the original upward current zone one could make use of the energy of the air by gliding to other hills or to bare fields with sunshine on them heating the air above the field. Later, other up-currents were discovered. Of course, to utilize these up-currents one must take into consideration the time of day, local and general atmospheric conditions, etc. The skillfulness in utilizing the natural resources of the air when flying cross-country is considered most important in soaring and is obtained by experience combined with training in meteorology.

After learning to fly cross-country, sailplane pilots desire to fly to a predetermined place and return to the starting point. It is often difficult to return, as the winds usually had changed or varied or, if they had not changed, one was on the opposite, or leeward, side of the hill which aided the first half of the trip. In flying cross-country it has been found possible to utilize the formation of clouds or storms. One can often soar for a considerable period below a cloud that is forming, as it is being formed by warm air rising and cooling, causing its moisture to condense.

Often, high hills almost reach the under surface of clouds and in that way one can gain altitude. It may thus be seen that a soaring plane pilot must always be on the alert to utilize all the possible energy of the air as well as to control his machine properly.

Some Typical Efficient German Sailplanes.—The following description of German sailplanes is from the technical memorandum No. 443 of the National Advisory Committee for "Aëronautics, translated from Der Gleit and Segelflugzeugbau or "The Glider and Sailplane" by Alfred Gymnich. While these types are machines of seven years or more back, they are representative of modern sailplane practice as it is difficult to see how they can be improved in the light of our present aërodynamical knowledge. The following tabulation summarizes some of the important weights and dimensions of the ten types described.

APPROXIMATE DIMENSIONS AND WEIGHTS OF TEN GERMAN MOTORLESS PLANES

Type of Glider	Figure Number	Span ft.	Length ft.	Height ft.	Wing Width ft.	Wing Area sq. ft.	Dead Weight lb.
Dresden	22	26 and 20	14	5	5	....	154
Edith	23	40	18	5	4	161	198
Konsul	24	62	21	4	4	237	287 or less
Vampyr	25	40	18	4	5	172	....
Greif	26	38	17	4	6	161	....
Pelikan	27	49	17	..	..	161	165
Dessauer	28	41	19	5	4	167	253
Geheimrat	29	40	18	4	5	154	176
Dresden	30	40	15	4	4	167	260
Messerchmitt ..	31	46	16	..	..	....	....

1921 **Dresden School Biplane.**—This glider (Fig. 22) was designed by H. Muttray, R. Seiferth and R. Spiess and built by the Dresden Aviation Club in less than two months. The upper wing had a span of 8 m (26.25 ft.); the lower wing, 6 m (19.68 ft.). Both wings had slight sweep backs. The upper wing was continuous and was partially supported by a cabane, while the lower wing was interrupted by the fuselage and had a dihedral

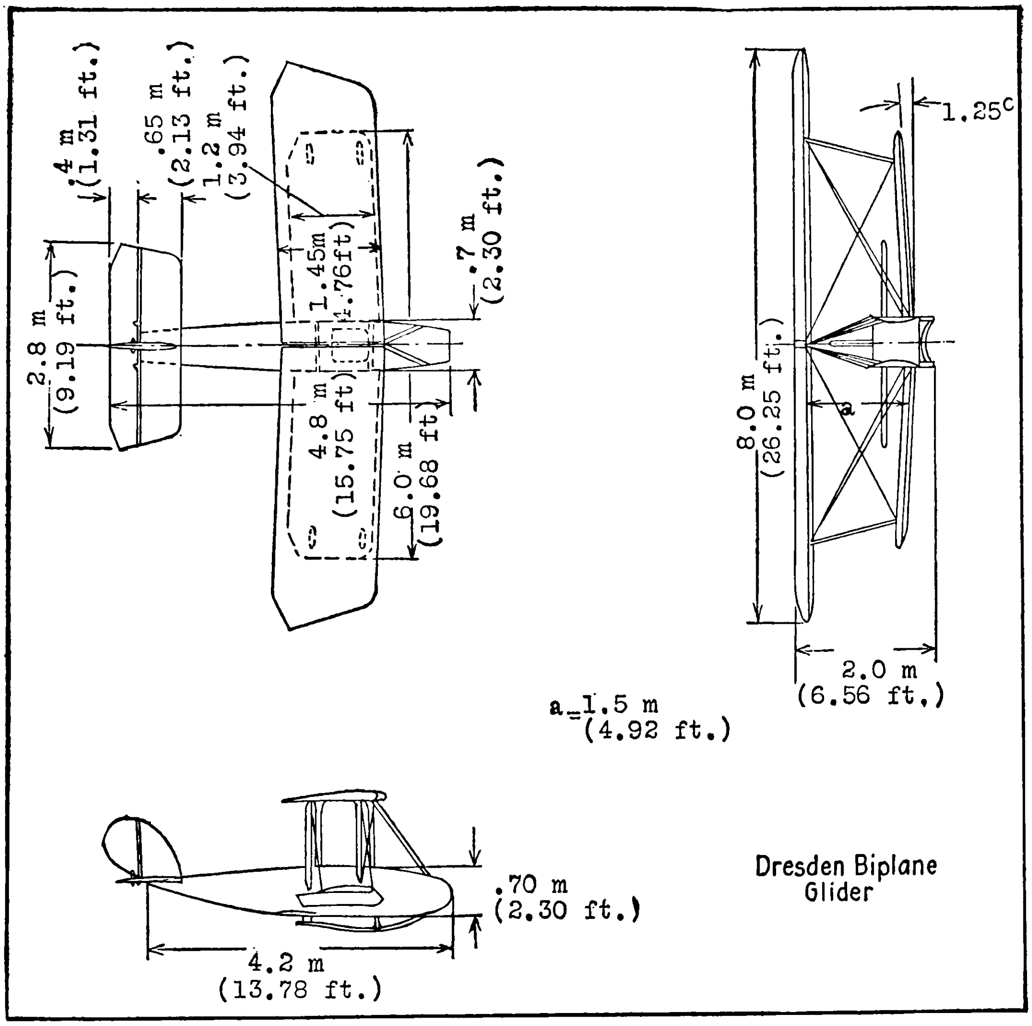


Fig. 22.—The Dresden Biplane Glider Had Twin Runner Alighting Gear.

angle. It lay about 25 cm (9.84 in.) above the ground, where it joined the fuselage and about 40 cm (15.75 in.) at the tips. The incidence or angle of setting of the lower wing was somewhat greater than that of the upper wing. Each wing had two box spars 4 cm (1.57 in.) wide and 6-9 cm (2.36-3.54 in.) thick. The side walls were hollowed in. The leading edge of the medium-thick wings was covered with two layers of veneer glued together so as to give it good penetration. The lower wing was staggered slightly backward. The cabane struts were made by gluing the two halves together. They were streamlined, hollow and wound with linen. They were fastened to one another and to the fuselage without fittings. In fact, the only fittings on the whole glider were for the wing struts. The fuselage was approximately square and had a maximum cross-section of 70 by 70 cm (27.56 in.). It was streamlined longitudinally, the stern being bent upward to protect the elevator. The fuselage was covered with fabric and tapered backward into a horizontal wedge. The elevator and rudder were operated by cables. Banking was effected by warping the wings, although they were doped. The strong landing gear consisted of two laminated wood runners separated by the width of the fuselage. They were joined by two ash arches cross-wise to the fuselage. In addition to the elasticity of the runners, blocks of rubber were employed as shock absorbers. Though of light weight and very flexible, this glider was very strong, as was demonstrated by its many landings on various kinds of ground, including newly plowed fields. The runners were attached to the fuselage only by gluing and binding. The empty weight of the glider was 70 kg (154.32 lbs.), so that with a pilot weighing 70 kg, its wing loading was 8 kg/m^2 (1.64 lbs./sq. ft.).

This glider proved to be especially well suited for school use. Many pilots were trained on it and flights up to ten minutes' duration and 3 km (1.86 mi.) were made with it. Several hundred flights were made without any particular damage. It participated successfully in the 1921-1923 Rhön contests, but was seriously damaged by a fall in the last contest.

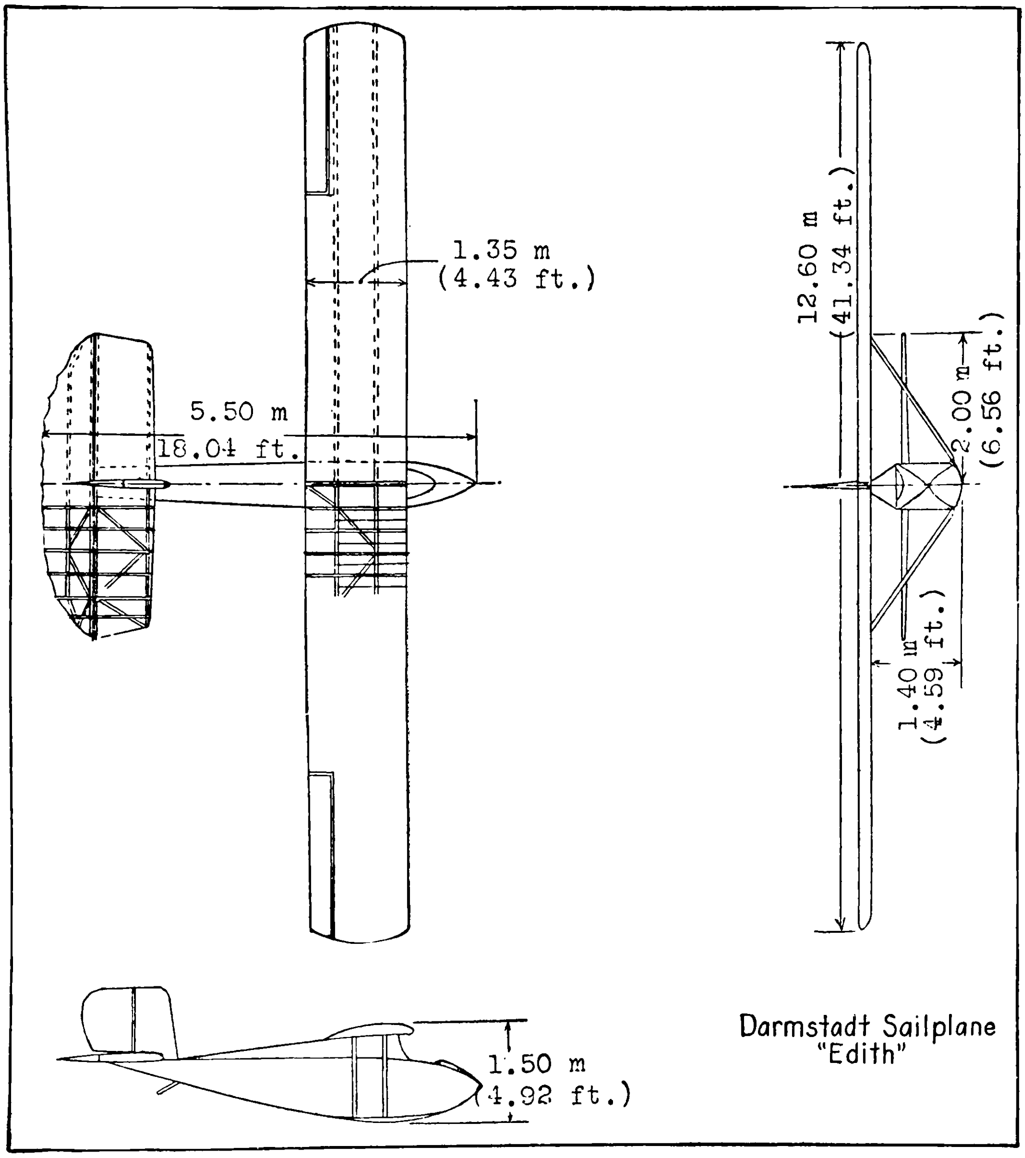


Fig. 23.—Side, Plan and Front Views of the Darmstadt Sailplane "Edith"; Note Large Size of Empennage.

1922 Darmstadt Sailplane "Edith."—This type (Fig. 23) was designed by members of the Aviation Section of the Darmstadt Technical High School and also built by them with the exception of the fuselage. It was originally intended to be used only for school purposes, but made excellent soaring flights in the Rhön contests.

It was a high-wing monoplane with fuselage struts. It had a span of 12.6 m (41.34 ft.), a length of 5.5 m (18 ft.), and a height of 1.5 m (4.92 ft.). The chord was 1.35 m (4.43 ft.) and the wing area 15 m^2 (161.46 sq. ft.). The upper camber of the wing was 17 cm (6.7 in.) and was the same throughout. The wing was divided in the middle and had two spars. At a distance of 2 m (6.56 ft.) from the middle in each direction it was braced to the bottom of the fuselage by a pair of parallel struts. In order to obtain good penetration, the leading edge was covered with plywood. The wing had both main and intermediate ribs, the former being 30 cm (11.81 in.) apart. The spars were braced.

Darmstadt Sailplane "Konsul."—The "Konsul" was designed by Botsch and Spiess, and built by the "Bahnbedarf" Company of Darmstadt. (Fig. 24.) The design was based on two different principles. On the one hand, it was sought to utilize the variations in the slope of the wind (Knoller-Betz effect) and, on the other hand, to develop static soaring flight with especial attention to distance flight. This glider was an overhung high-wing monoplane of 18.7 m (61.35 ft.) span and 1.2 m (3.94 ft.) chord, corresponding to an aspect ratio of about 15. In spite of its great span, it had no struts and only one wing spar. The latter was box-shaped in the 8 m (26.25 ft.) central section and I-shaped in the outer sections. The leading edge, from the top of the spar around to its bottom, was covered with plywood. The spar junctions were made with sleeve couplings according to the Junkers system, the false spars being connected by ball and socket

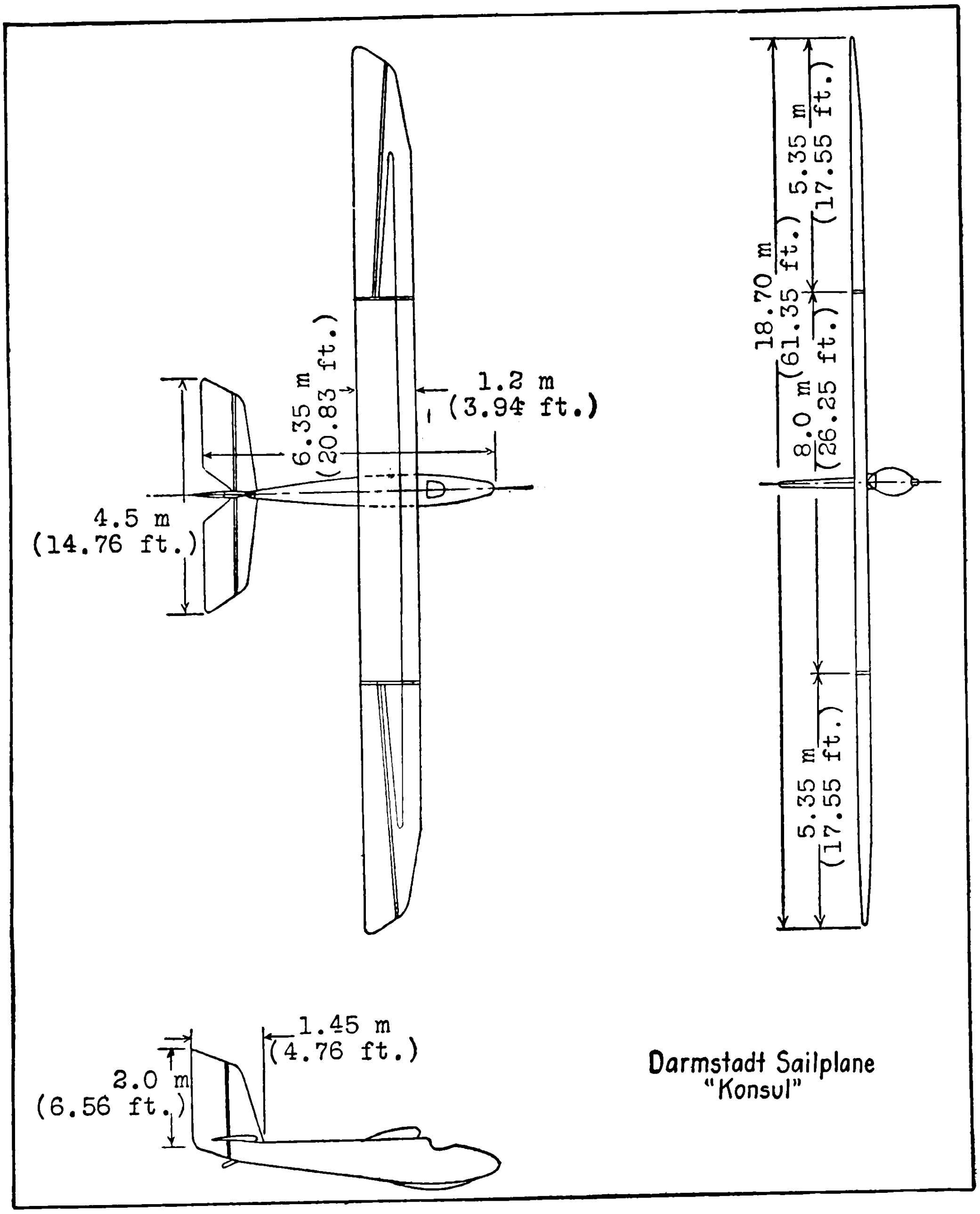


Fig. 24.—Side, Plan and Front Views of the Darmstadt Sailplane "Konsul."

bolts. The profile used was the Messerschmitt S 13 (Göttingen 535). The wing tapered rapidly at the outer ends and was kept symmetrical by reducing the angle of incidence or setting, in order to obtain a perfect warping effect and more favorable lift distribution.

The ailerons were so connected with the steering gear that, when the rudder was not deflected, they operated in the usual manner. In steering to the right, however, any warping maneuver of the control stick actuated the right aileron more than the left one. In steering to the left, this action was reversed. With the enormous span, such a reinforcement of the rudder by the ailerons seemed very opportune. The fish-shaped plywood fuselage had sharp edges, both above and below, which produced the necessary keel effect. The wing area was 22 m^2 (236.81 sq. ft.). The estimated weight of 130 kg (287 lbs.) was apparently somewhat overrated, which would partially explain the unexpectedly high speed of the glider. The best lift-drag ratio was 1:21.4 at 14.8 m/s (48.58 ft./sec.) flight speed. On September 29, 1923, Botsch made, on the "Konsul," a new world's distance record of 18.9 km (11.74 mi.).

Hannover Glider "Vampyr."—At the suggestion of Professor A. Pröll and Engineer H. Dorner, this glider (Fig. 25) was designed by the students Martens, Hentzen and Blume from a rough sketch by Dr. G. Madelung, and was built by the "Hannoversche Waggonfabrik." It was an overhung high-wing monoplane of 12.6 m. (41.34 ft.) span by 1.45 m. (4.76 ft.) chord and had a wing area of about 16 m^2 (172.22 sq. ft.). Its mean aspect ratio was 10. The wing consisted of a middle section of 6.6 m (21.65 ft.) span and two end sections of 3 m (9.84 ft.) each. The Göttingen profile 441 was used, which had, in the central section of the wing, a maximum upper camber of 25 cm (9.84 in.). The end sections were tapered. The angle of incidence (or wing setting) to the upper edge of the fuselage was zero.

It was on the "Vampyr" that the method, subsequently adopted on all high-grade gliders, of constructing the wing with a single

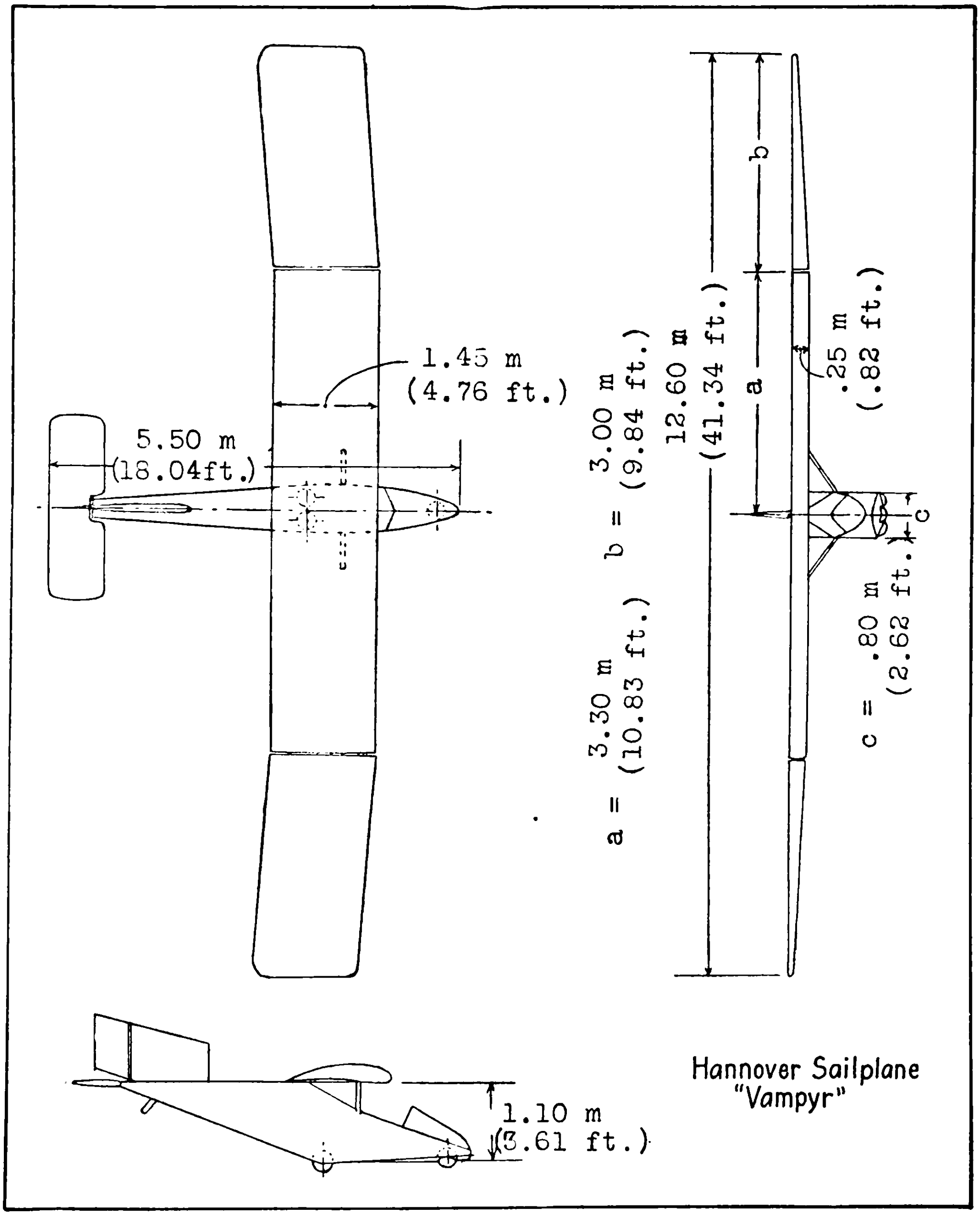


Fig. 25.—Outline Drawings Showing the Side, Plan and Front Views of the Hannover Sailplane "Vampyr."

spar and covering the leading edge with plywood, was first used. The spar was located in the line of mean pressure of the wing and took the form of an I-girder with pine flanges and a plywood web. The ribs, constructed according to the lattice-girder method, were made extremely light. Nevertheless, each rib could stand a load of 40 kg (88.2 lbs.) alone, with one or more intermediate or nose ribs, according to the magnitude of the air forces. From the spar back, the wing was covered with light fabric, well doped and varnished. The wing was attached to the fuselage at three points, the main forward fitting united the wing spar to the main fuselage bulkhead by means of a bolt. Both rear fittings rested on the ends of two reinforced rods, which held the rigid front part of the wing and lay on the upper fuselage longerons. Each rod was in turn fastened by a bolt to a fitting secured to a fuselage bulkhead.

The main fittings were easily accessible through traps, to facilitate quick assembling, and were so secured that, after loosening the bolts, the wing could be shifted so as to remedy any nose or tail-heaviness. On each side of the fuselage the wing spar was connected with the main bulkhead by a short strong strut, in order to protect the wing fittings, which covered only a narrow base, from possible excessive stresses. The end sections of the wing were likewise joined to the middle section at three points. The flanges and web of the wing spar were each held by a fitting which transmitted the bending and lateral stresses to a bolt on the false spar, transmitted the frontal pressure and shared the torsional stresses with the fitting of the main spar. These junctions were also easily accessible.

In the first model of the "Vampyr" in 1921, the trapezoidal end sections of the wings had the usual ailerons. In the 1922 model, the end sections were rectangular with a slight swoop back. The ailerons were omitted and warping was effected by means of an aluminum tube with lateral arms and the introduction of flexible rods into the wing. The balls used to protect the wing tips in the 1921 model were likewise omitted. Curving flight was facilitated by the elimination of the inertia moments due to these balls.

The fuselage showed a peculiar type of construction, which proved very successful and which was subsequently much imitated. Rectangular in its main dimensions, the portion of the fuselage behind the pilot's seat was slanted sharply upward so as to obtain a greater angle of attack in starting and in landing and tapered out into a horizontal wedge. The front portion of the fuselage was slanted downward. It consisted of strong longitudinal ash strips and transverse bulkheads, triangular at the top, forming a streamlines framework, which was covered with plywood and gradually passed over into the rectangular stern. For all its strength and rigidity, the fuselage weighed only about 25 kg (55 lbs.).

The undamped elevator, whose axis of rotation lay in the central line of pressure, was mounted on the horizontal rear edge of the fuselage. It was operated by a rod connected with the normal control stick. The area of the elevator was 1.875 m^2 (20.18 sq. ft.). The rudder, which had an area of 0.48 m^2 (5.17 sq. ft.), was operated by pedals and cables. It formed a continuation of the fin, which had an area of 0.8 m^2 (8.61 sq. ft.). The landing gear also differed from the customary one. It consisted of three balls, similar to footballs, with their axles inside the fuselage. One ball was under the nose and the other two slightly behind the center of gravity. The Vampyr is known especially for the hour-long flights of Martens and Hentzen in the 1922 Rhön contest. In the 1923 contest this excellent glider was unfortunately destroyed through the carelessness of a new pilot.

Hannover Sailplane "Greif."—For continuing the soaring-flight research of the Aviation Section of the Hannover Technical High School, begun with the "Vampyr," the "Greif" was designed by Hentzen and Martens (Fig. 26), again with the friendly coöperation of Professor A. Pröll and H. Dorner. The construction was likewise again undertaken by the "Hannoversche Waggonfabrik." It was sought to effect a considerable diminution in weight with a smaller span, in order to obtain a more maneuverable glider. Especial importance was attached to reducing the air resistance. This over-hung monoplane therefore exhibited especially fine lines. The wing was made in three sections. The central section, however, has a span of only 1.3 m (4.27 ft.) and was firmly secured to the fuselage as a cabane. The trapezoidal wings were each 5.15 m (16.9 ft.), making the total span 11.6 m (38.06 ft.). The wing chord diminished from a maximum of 1.8 m (5.91 ft.) to 1 m (3.28 ft.) at the tips, thus making a wing area of 15 m^2 (161.46 sq. ft.). At the cabane the upper camber was 28 cm (11.02 in.) and decreased uniformly.

The wing had a single spar combined with a rigid plywood leading edge. The spar was an ordinary lattice girder with a plywood web. The flanges and lattices, which were especially stressed in landing, were reinforced. The main ribs were 40 cm (15.75 in.) apart, but light intermediate ribs were added to the front part of the wing. The plywood tubes which, together with the spar, absorbed the torsional stresses, terminated at about the center of each end section. Hence the wing tips were not torsion-proof. In each wing tip the torsional forces were absorbed by a

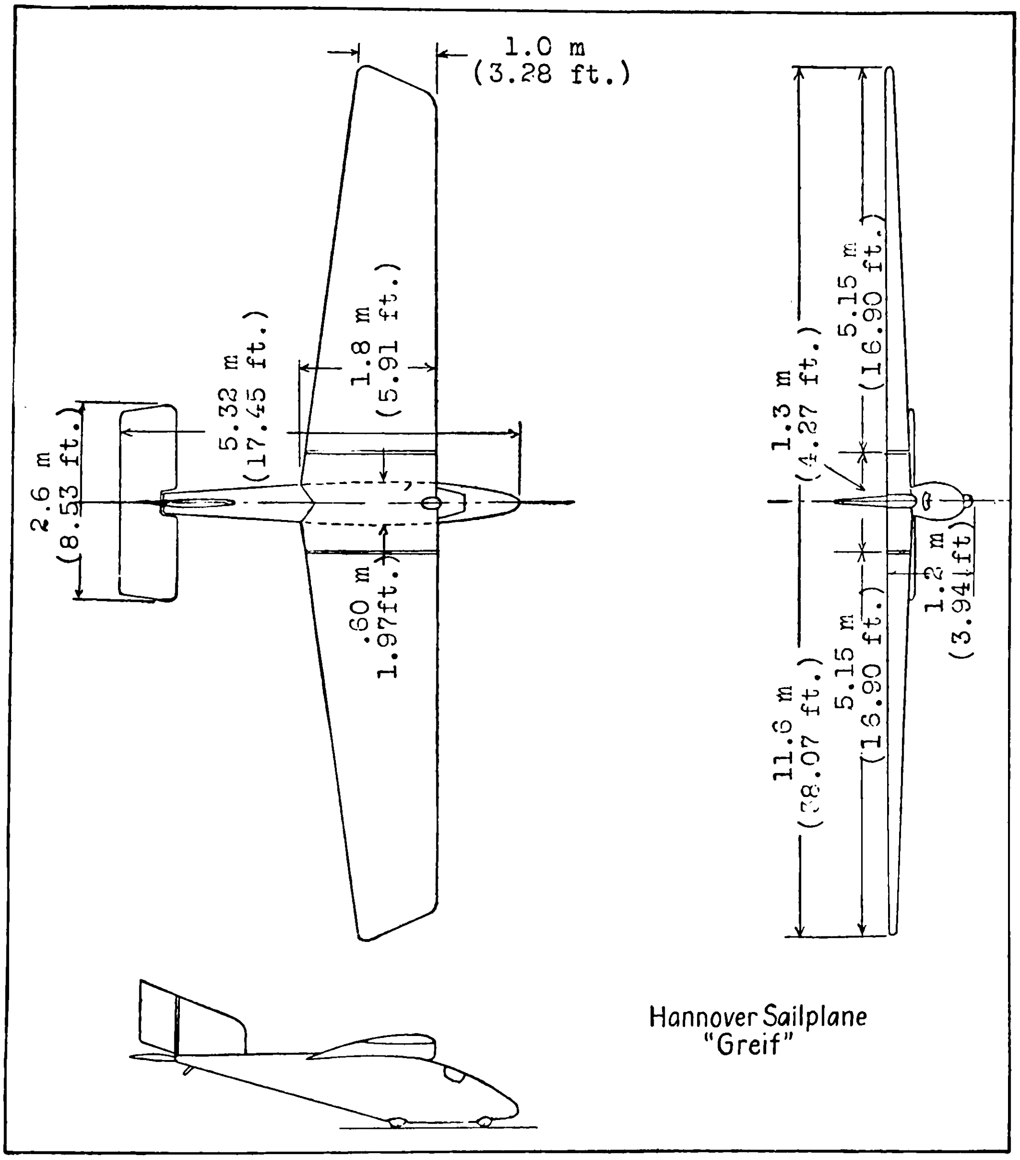


Fig. 26.—Side Plan and Front Views of the Hannover Sailplane "Greif."

duralumin tube parallel to the spar and firmly bound to the end of the latter. It was possible to rotate this tube and thus warp the wing tips. This method of warping proved to be very effective. The lower edges of the wing tips were protected by sheet duralumin. The wings were connected with the cabane, the same as on the "Vampyr." The aileron-control tubes were connected by a claw coupling, which enabled the safe transmission of the stresses. The fuselage was spindle-shaped.

The cabane had a cutaway for the pilot's head, the rest of the pilot being fully enclosed in the fuselage. The fuselage bulkheads were firmly held by four light longerons, since the stresses were exclusively absorbed and transmitted by the plywood covering. The wing spar was firmly attached to the main bulkhead. An auxiliary spar of the cabane likewise transmitted the stresses to a strong bulkhead. From the spars, streamlined steel bands provided for the stress transmission corresponding to every case of loading. The landing gear consisted of only two tandem balls. The undamped elevator, of 1.8 m^2 (19.38 sq. ft.) area, was actuated by a rod. The rudder was actuated by cables in the usual manner. The rudder had an area of 0.05 m^2 (5.38 sq. ft.); the fin, 0.6 m^2 (6.46 sq. ft.).

In the 1921 and 1922 Rhön contests numerous flights were made, including three of 45 minutes each by Martens, Hentzen and Koch, but the "Greif" did not equal the "Vampyr," notwithstanding its better aërodynamic design. This fact is ascribable to the poor aspect ratio and to the complete enclosure of the pilot, whereby the sensing of the air flow was rendered more difficult.

Hannover Sailplane "H6" ("Pelikan").—This soarplane (Fig. 27) was designed by the students Günther, Martens and Meyer, under the supervision of Professor A. Pröll of the Aviation Section of the Hannover Technical High School. It was built by the "Hannoversche Waggonfabrik." It was a remarkable development of the "Vampyr" and "Greif" but, unlike these, had ailerons for the lateral control. The wing had a single spar and

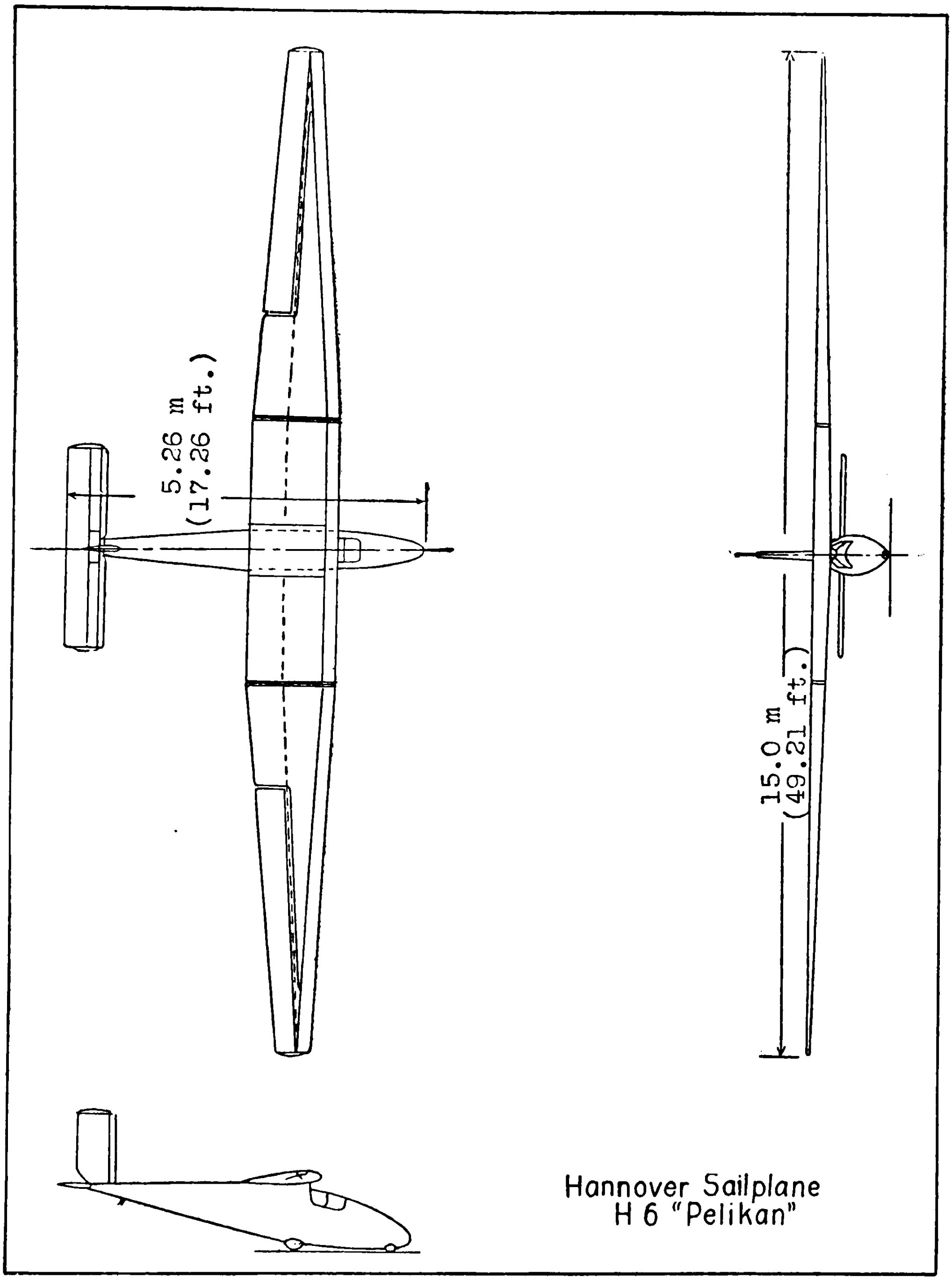


Fig. 27.—Outline Drawings of the Hannover Sailplane "Pelikan" H6 Showing Large Aspect Ratio of the Wing.

was made in three sections. Its front portion was made into a torsion-proof tube in the usual manner by means of a plywood covering. The plywood fuselage had an oval cross-section and tapered to a horizontal wedge. As in the "Greif," the landing gear consisted of two tandem balls. The ailerons were very narrow and long. The elevator and rudder were rectangular. There was no fin nor stabilizer. This glider had the following characteristics:

Span	15.0 m	(49.21 ft.)
Length	5.26 m	(17.26 ft.)
Wing area	15.00 m^2	(161.46 sq. ft.)
Wing loading	9.7 kg/m^2	(1.99 lbs./sq. ft.)
Weight of fuselage	25.5 kg	(56.2 lbs.)
Weight of central wing section	20.0 "	(44.1 lbs.)
Weight of each end section of wing	12.5 "	(27.56 lbs.)
Weight of elevator	3.4 "	(7.5 lbs.)
Weight of rudder	1.1 "	(2.4 lbs.)
Total weight	75.0 "	(165.3 lbs.)

Especially remarkable were the sinking speed of only

0.447 m/s (1.467 ft./sec.)

and the gradual gliding angle.

The "Pelikan" was not finished in time for the 1923 Rhön contest. In the 1924 Rositten soaring-flight contest, under the piloting of Koch, it made a flight of 30 minutes above a comparatively small dune.

Sailplane "Der Dessauer."—This machine (Fig. 28) was designed and built by members of the Dessau Aviation Club with the backing of the "Junkerswerke" of Dessau. The wing was made with a single spar and a torsion-proof plywood leading edge and was divided in the middle. The lower flanges of the two sections of the wing spar were joined at this point and were

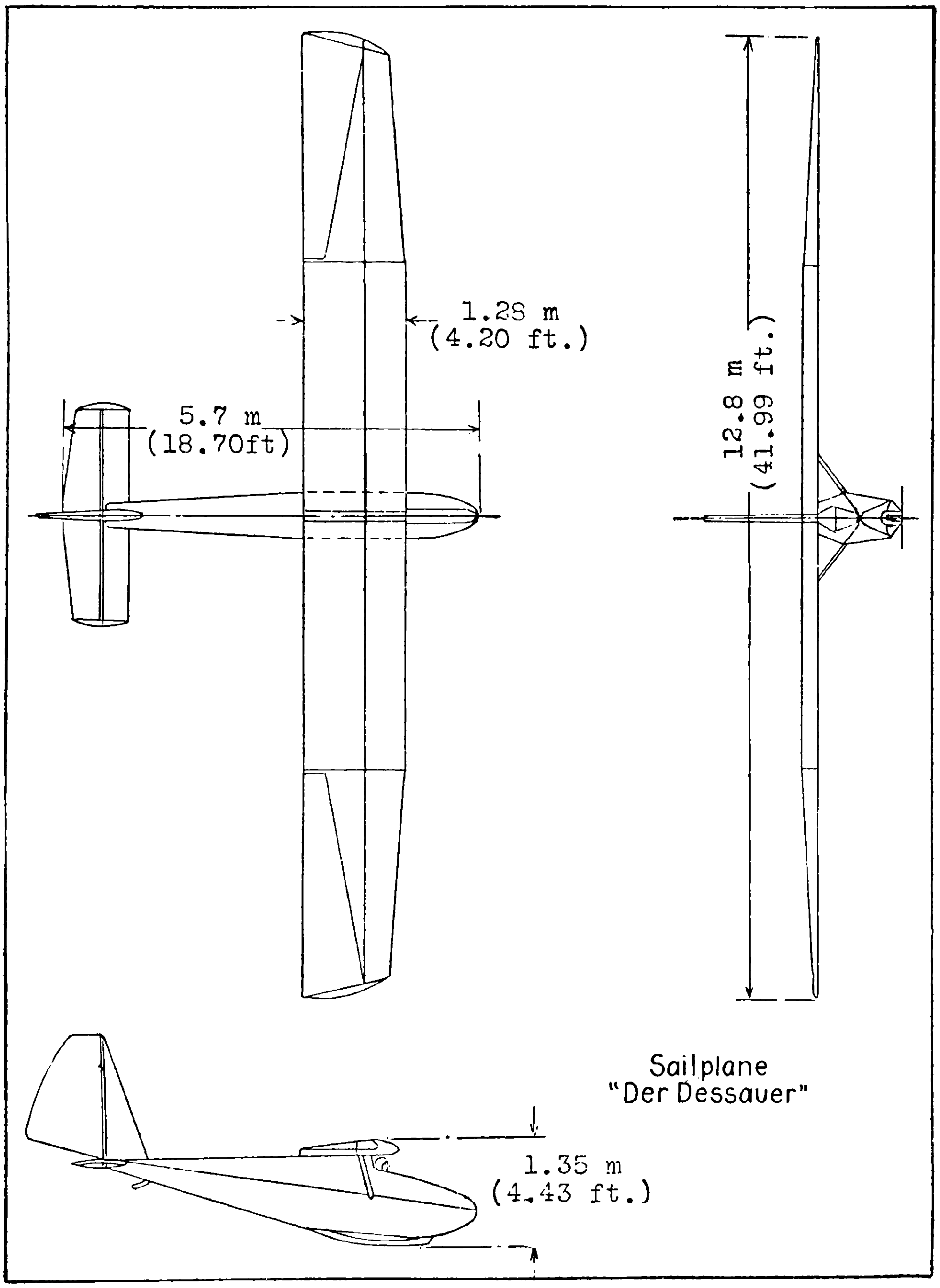


Fig. 28.—Side, Plan and Front Views of the Sailplane "Der Dessauer."

secured to the fuselage by an adjustable fitting for the purpose of trimming the aircraft. The upper flanges butted together and were thus firmly held by compression during flight. For constructional reasons the wing halves were given a uniform cross-section (Göttingen profile 289), while the thickness was gradually reduced in the outer portions. The fuselage tapered to the elevator, its main bulkhead being pentagonal.

The fuselage was built without diagonal bracing, since the plywood covering distributed the stresses. The landing gear consisted of a central runner with an air-cushion shock absorber, the same as was first used by the "Geheimrat." On each side of the fuselage the wing was attached to the main bulkhead by a short, strong strut. In order to soften the landing shock, rubber pads were built into the struts, which yielded about 5 mm (0.2 in.) under compression, but remained perfectly rigid under tension. This glider has an adjustable stabilizer which, like the fin, was entirely covered with plywood. The ailerons and rudder were quite large, while the stabilizer was comparatively small. The aileron controls were constructed on the principle of differential steering, *i.e.*, a given downward deflection of one aileron corresponded to a greater upward deflection of the other aileron and vice versa. The steering controls were actuated by rods and bent levers. The chief characteristics were as follows:

Span	12.8 m		(42 ft.)
Chord	1.28 "		(4.2 ft.)
Aspect ratio		10.6	
Length	5.7 "		(18.7 ft.)
Height	1.35 "		(4.43 ft.)
Wing area	15.5 m^2		(166.84 sq. ft.)

Stabilizer	0.95 m^2	(10.23 sq. ft.)
Elevator	1.5 "	(16.15 sq.ft.)
Fin	0.44 "	(4.74 sq. ft.)
Rudder	1.3 "	(14.00 sq. ft.)
Ailerons, each	1.66 "	(17.87 sq. ft.)
Weight, empty	115.0 kg	(253.5 lbs.)
Wing loading	11.3 kg/m^2	(2.31 lbs./sq. ft.)

In the Rhön contest excellent results were obtained by the pilot Thompson. In this glider the inertia moments were eliminated as much as possible by a good distribution of the load, thus enabling excellent curving flight. On the next to the last flight day, the wings broke just above the ground, apparently due to the resonance vibrations, which were favored by the rubber buffers built into the side struts, and the glider was dashed to pieces.

Darmstadt Sailplane "Geheimrat."—This overhung high-wing monoplane was designed by Nicolaus and Hoffmann and built by the Darmstadt "Bahnbedarf" Company (Fig. 29). It was owned by the Aviation Section of the Darmstadt Technical High School. It had a span of 12.1 m (39.7 ft.); length 5.45 m (17.88 ft.); chord 1.41 m (4.63 ft.); wing area 14.3 m^2 (153.92 sq. ft.). The wing was made in three sections. The central section had a span of 6 m (19.68 ft.) and a uniform profile with an upper camber of 24 cm (9.45 in.). The trapezoidal end sections each had a span of 2.75 m (9.02 ft.) and tapered uniformly. The wing had a main and auxiliary spar and could be rotated around the former by means of the control stick and push-rods. The leading edge was covered with plywood. The lateral control was exercised in the usual way by ailerons.

The fuselage was 4.92 m (16-14 ft.) long and had a rectangular cross section. It was streamlined and ran into a horizontal wedge. The landing gear consisted of two low runners at the outer edges of the fuselage. The space between the fuse-

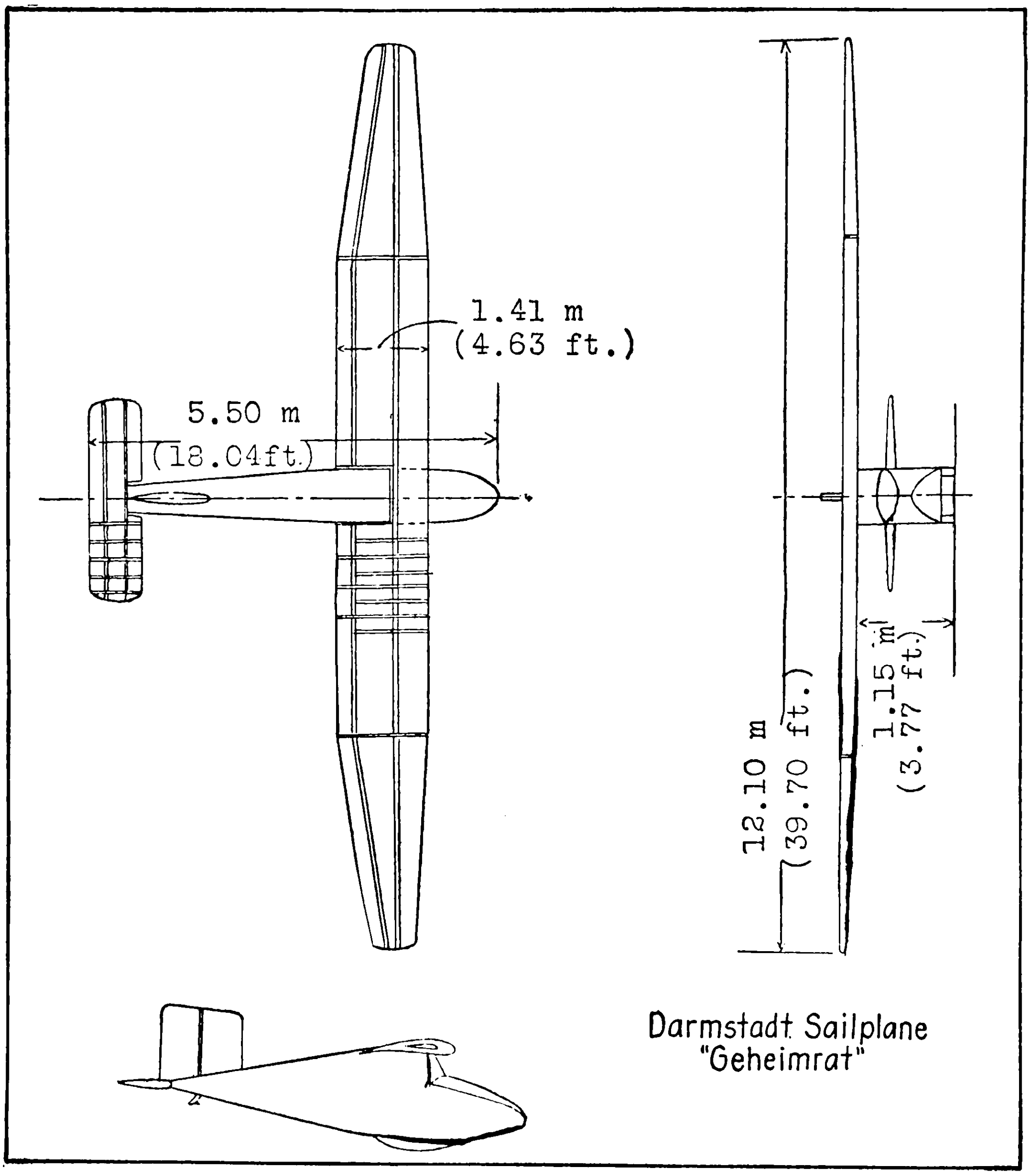


Fig. 29.—Outline Drawings Showing Layout of the Darmstadt Sailplane "Geheimrat."

lage and runners was occupied by an air cushion protected by sheet duralumin. The balanced undamped elevator had an area of 1.4 m^2 (15.07 sq. ft.) and was operated by a lever beside the pilot's seat. The elevator could be given the best angle of attack for the prevailing wind conditions and then locked in position during the flight. In front of the 0.35 m^2 (3.77 sq. ft.) rudder, there was a fin of 0.47 m^2 (5.06 sq. ft.). The wing weighed 43 kgs (94.8 lbs.); the fuselage 28 kgs (61.7 lbs.). The wing loading was 11.5 kg/m^2 (2.36 lbs./sq. ft.).

This creation accomplished excellent results in the 1922 and 1923 Rhön contests. In 1922 Hackmack flew 1.5 hr. and reached an altitude of 320 m (1,050 ft.) above his starting point. In 1923 Thomas won the first prizes for the greatest single and total flight duration.

Dresden Monoplane Glider.—This wing-steered, strutted, high-wing monoplane (Fig. 30) was designed by H. Muttray and R. Seiferth of Dresden, and was built by members of the Dresden Aviation Club. It had a span of 12.2 m (40 ft.); chord 1.35 m (4.43 ft.); wing area 15.5 m^2 (166.84 sq. ft.); aspect ratio, 9.5. The wing was made in four sections, the two-meter end sections being removed only for railroad transportation, to enable it to be loaded into an ordinary closed car. The wing had a box spar with internal diagonal bracing and open-work side walls. The leading edge of the wing was covered with plywood. The spar was computed for a safety factor of 7. Taking into consideration the centers of gravity and pressure of the wing, the position of the axis of rotation of the wing was so chosen that no stresses were developed in the control stick during normal flight. The wing was joined to the fuselage by a special form of cabane.

The wing (Göttingen profile 441) tapered only near the tips, where it changed into a streamlined profile with zero incidence.

The wing tips were pointed, so as to prevent the formation of eddies or vortices. Each half of the wing was supported by two struts which met at the wing. The wings could therefore be

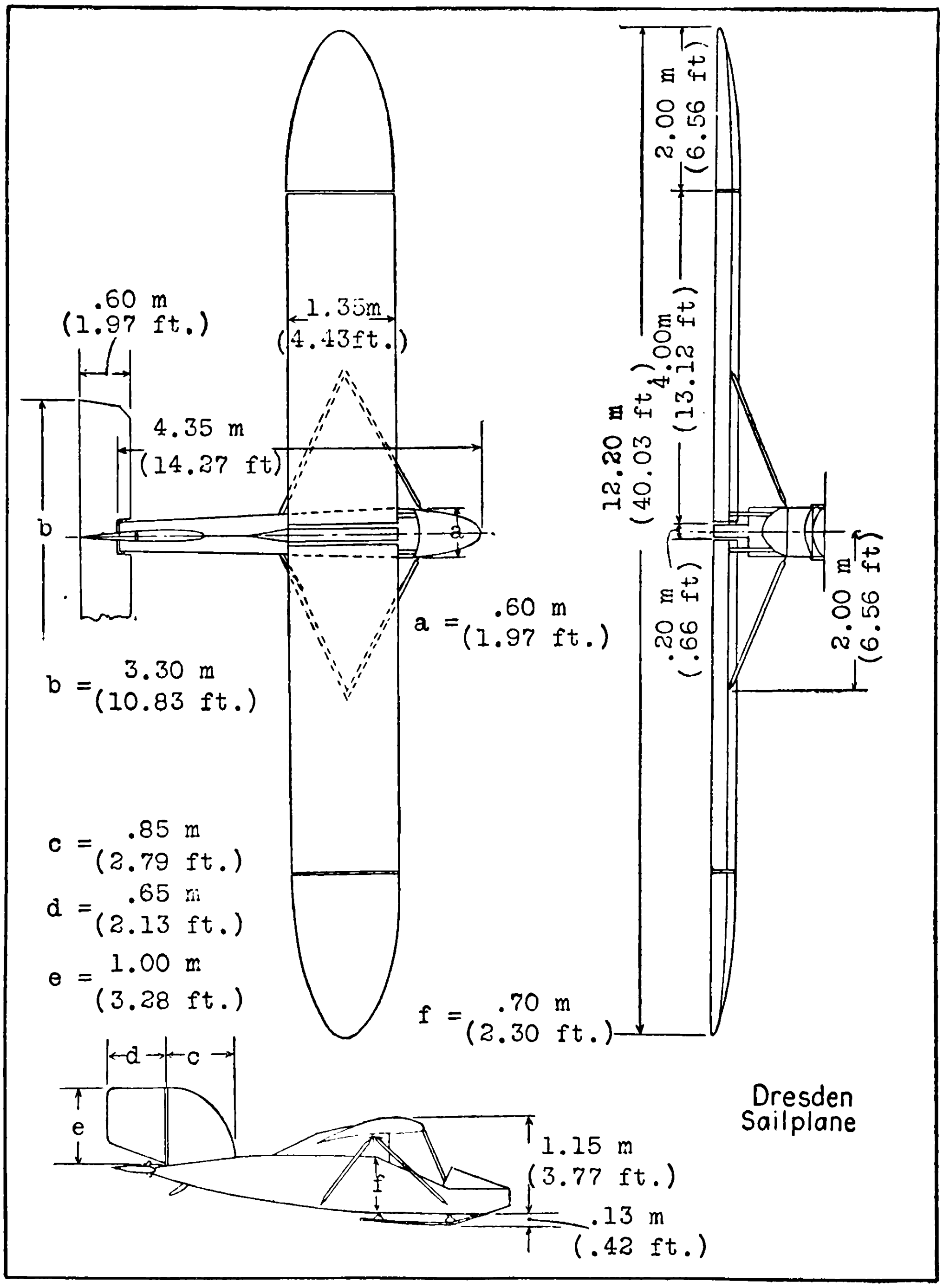


Fig. 30.—Side, Plan and Front Views of the Dresden Sailplane with Movable Wings for Lateral Balance.

rotated in unison for vertical steering and oppositely for banking. The fuselage had a maximum rectangular cross section of 60 x 70 cm (23.6 x 27.6 in.) and tapered to a horizontal wedge for attaching the balanced undamped elevator of 1.9 m^2 (20.45 sq. ft.) area. The 0.55 m^2 (5.92 sq. ft.) rudder followed a fin of 0.66 m^2 (7.1 sq. ft.).

The rudder was actuated by a special lever in the cockpit. Normally, however, the elevator was not operated during flight. In the 1923 contest the wings and elevator were so coupled that an increase in the angle of attack of the wings produced a corresponding deflection of the elevator in the same direction. This simultaneous deflection of the wings and elevator was intended to enable the fuselage to retain its normal position, so as to avoid longitudinal inertia moments. The bow of the fuselage was shaped by ash strips and covered with plywood. The landing gear was the same as on the Dresden biplane previously described. The weights of the monoplane were as follows:

Wing	55.2 kg	(121.7 lbs.)
Fuselage	45.1 "	(99.4 lbs.)
Rudder	3.6 "	(7.94 lbs.)
Elevator	4.6 "	(10.14 lbs.)
4 steel tube struts.................	10.0 "	(22.05 lbs.)
Weight, empty	75 "	(165.3 lbs.)

Including 75 kg (165.3 lbs.) for the weight of the pilot, the Wing loading was .... 12.5 kg/m^2 (2.56 lbs./sq. ft.)

Numerous successful flights were made over the landing field of the Dresden Aviation Club in the "Erzgebirge" (Erz Mountains). The lift-drag ratio was found to be 1:14.6 in still air.

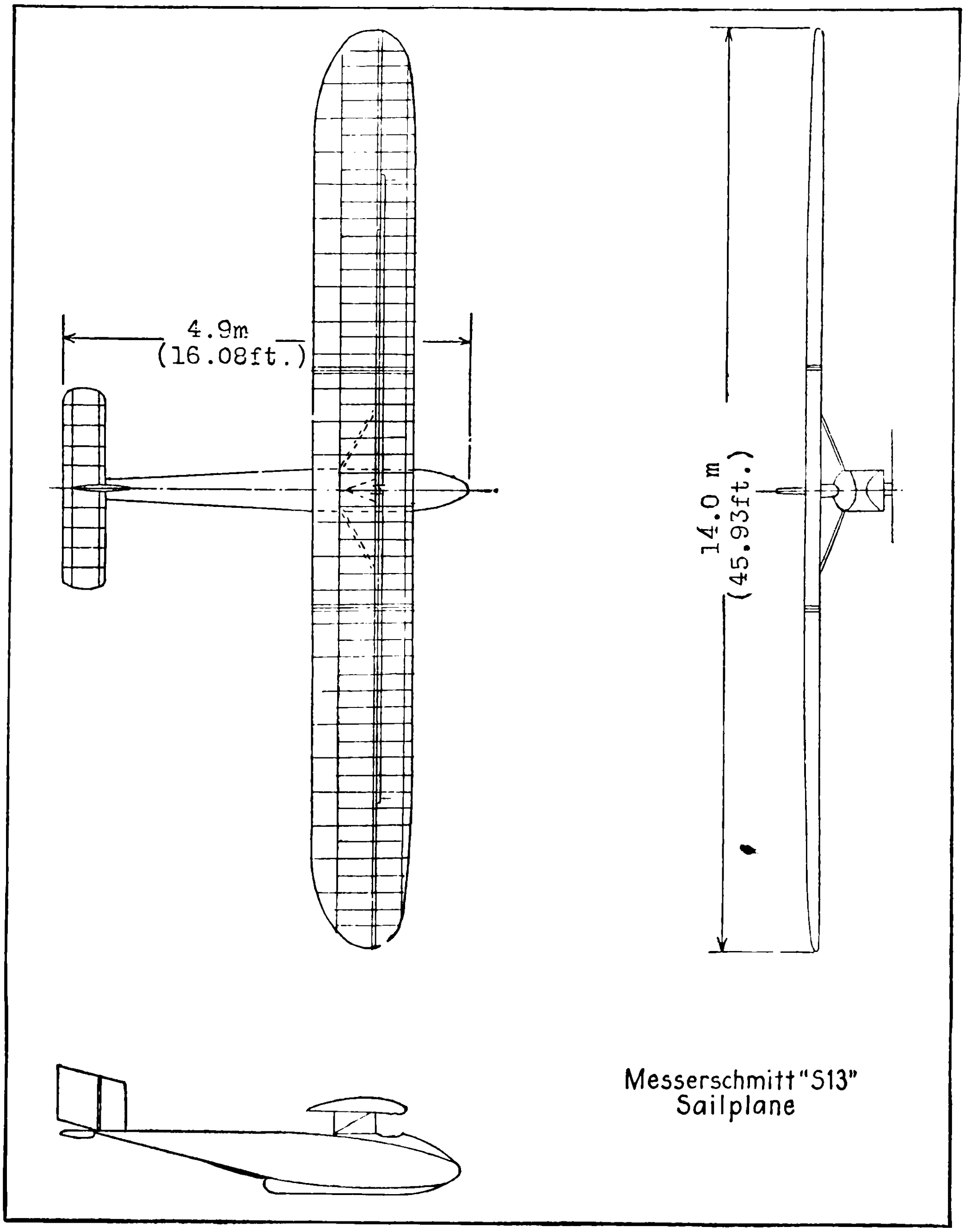


Fig. 31.—Outline Drawings Showing Construction of the Messerschmitt "S13" Sailplane.

In the 1923 Rhön contest, one wing broke about 200 m (656 ft.) above the valley and the glider went into a spin and crashed, thereby losing its elevator also. Through a lucky chance the pilot, Muttray, escaped with a broken leg and a few abrasions. The wing-break, in spite of the sevenfold safety factor, was explained by the presence of an unnoticed internal defect produced by a previous fall.

Messerschmitt Glider "S 13."—Up to the "S 12" Harth and Messerschmitt had developed their gliders together. The "S 13" was, however, designed and built by Messerschmitt alone (Fig. 31). He abandoned the previous two-stick system and installed only one control stick. The stabilizer was made adjustable by means of a lever which could be locked in position. The wing warping was effected by a strong steel torsion tube mounted parallel to the wing spar. The span was 14 m (45.93 ft.) and the length 4.9 m (15.08 ft.). The wing was made in three sections and had a single spar, with alternate main and auxiliary ribs.

The fuselage was rectangular in cross section and streamlined longitudinally. For landing gear, it had a long central spring runner. The wing was attached to each side of the fuselage by a short strut. The wing warping was parallel for one-third of the wing and differential for the remaining two-thirds. The balanced undamped elevator was likewise operated by a rod, cables being employed only for the rudder. Only the central section of the wing was doped, so as not to interfere with the warping. With the "S 14," which differed but slightly from the "S 13," Hackmack made, in the 1923 Rhön soaring-flight contest, a "storm" soaring flight over land and attained a maximum altitude of 303 m (994 ft.). Another glider of this type, equipped with a 500 cm^3 (30.51 cu. in.) Douglas engine, on June 19, 1924, remained in the air Bamberg for 43 minutes and reached an altitude of 600 m (1,968 ft.).

CHAPTER FIVE

HOW TO FORM A GLIDING CLUB

Club Organization—Suggested Constitution and By-laws—Number of Members Per Glider—National Glider Association—Classification of Glider Records—Glider Sporting Licenses—Status of Motored Pilots —Gliders Should Be Licensed—Gliders Must Follow Airworthiness Rules—Requirements on Towed Flight—Airworthiness Requirements of Air Commerce Regulations, U. S. Dept. of Commerce Bulletin 7A, Part 3—Light Aircraft.

Club Organization.—The big majority of the glider enthusiasts over the country are young men and women of very limited means. Therefore, in organizing a club, it is well to have a nucleus of business men or others of sufficient means to purchase the equipment of the club for the first year. All members should pay dues, however, as only those who feel enough interest in the movement to contribute to it will make worthwhile local members. A club of twenty-five members should have not less than $1,000 for the first year's equipment and expenses. A start may be made with as little as $600 as an approved type of glider may be purchased for around $400. If the proper presentation of the subject is made to business men, funds on this basis should be easily forthcoming. Many of the younger business men will want to glide themselves. Once a start is made, the rest is easy.

Organizations such as Aviation Clubs, Aëronautical Societies, Chambers of Commerce, Athletic Clubs, etc., may form a glider section or division and this will be recognized as a glider club on a basis of the number in the particular group. As a general rule, the local newspapers, particularly the aviation editors, are familiar with gliding as a result of the National Educational Campaign which reaches over 800 American dailies. Local persons desiring to organize a club should get in touch with them at the outset. They will give space liberally to stories of what it is planned to do. Often they take the lead in organizing clubs. The National Glider Association will send to any interested group or individual, application forms to be used in organizing a local club. It also provides a standard membership card for local clubs and each organization gets a beautiful membership certificate.

In organizing a club, the best results will be had if the organizer or promoter will restrict the membership to about ten men until organization is completed. He should then call a meeting and appoint a temporary chairman and a secretary. The members should then elect a board of directors consisting of seven members. The board should then appoint or elect the officers from its own membership. The officers will consist of a president, vice-president, secretary-treasurer, and a technical committee of four members. The technical committee will have charge of the flying and of all repairs on gliders, and will organize the ground school course. The temporary officers should then retire and the new officers take charge. The constitution and by-laws should then be read by the president and adopted section by section. The constitution and by-laws appended is a good working model. It can be amended to fit different conditions or added to as needed.

Constitution and By-Laws

This club shall be known as Blank * Glider Club.

ARTICLE I

A special meeting of the club members may be called at any time by resolution of the board of directors, or upon the request of one-half of the glider members, of which meeting notices shall be properly given.

ARTICLE II

The board of directors of the club shall consist of seven members. They shall be chosen by the Blank * Glider Club once a year. It shall be the duty of the board of directors to exercise a general supervision over the affairs of the club.

ARTICLE III

The officers of the club shall be a president, vice-president and a secretary-treasurer. They shall be chosen by the board of directors of the club. A technical committee of four members should be named.

ARTICLE IV

The president shall preside over all meetings of the board of directors and in general shall be the chief executive officer of the club.

* Substitute any desired descriptive name such as "Alexander Glider Club," "Fairfield Glider Club," etc.

ARTICLE V

Club members are to use glider in rotation, so many each day as assigned. Names are to be posted three days in advance and member must sign notice within 24 hours that he will be present on date assigned him, so that if he does not sign then, another can take his place.

ARTICLE VI

Glider must not be taken out without permission of the president or some member of the board of directors.

There will be an instructor or assistant instructor assigned each day, who will be in charge of the glider. Members must obey the directions of this instructor and report to him for flight.

ARTICLE VII

Members will take their instructions from the leader or instructor and do as told, or be grounded for two weeks, or tried by the board of directors.

Any member damaging a glider must help repair same within three days, or else pay for the doing of this work.

Any member signing notice and then failing to appear must pay 25 cents into a general fund or lose his next turn—unless excused.

Number of Members Per Glider.—The board of directors should then appoint a contest committee approved by the National Glider Association and the National Aëronautical Association; this committee to have charge of all timing for both organizations. At this point the question of dues and membership should be taken up. Experience has shown that in an open club where any one over the minimum age can join, the membership should be restricted to 50 members to one glider. The average turnout probably will not be more than 20 members, and with fast work about 50 flights can be made in five hours by the shock cord launching method. In a school or where the members all come from one organization, 30 members per glider are enough.

Much of the club's success will come from the manner in which the training program is carried through. Best results will be had by having the members study some textbook on airplane flying, such as is used by most flying schools in their ground instruction. "Everybody's Aviation Guide," "The A.B.C. of Aviation" or "Modern Aircraft" by Major Pagé and published by the publishers of this volume are examples of standard texts that have been widely used for student instruction.

There is no expense of flying instructor, motor fuel and oil as in the operation of an airplane. Under the club form of glider ownership a person can learn the operation of the controls and acquire the "feel of the air" for less than the cost of one hour of airplane instruction. Preliminary glider instruction is generally given on the ground. Later, brief flights are made in the air. As the control surfaces and their operation are identical to those of an airplane the glider pilot becomes thoroughly familiar with them. He learns to coördinate automatically movement of the controls of the plane almost without conscious effort. In enabling the student to acquire the "feel of the air" or the ability to sense that he is maintaining a sufficient amount of "lift" on the upper and lower surfaces of his wings, the glider renders its greatest service. This skill is more easily acquired than the average person believes.

National Glider Association.—Early in 1928, Edward S. Evans, prominent Detroit capitalist and sportsman, President of the Evans Auto Loading Company, chairman of the Aircraft Bureau of the Detroit Board of Commerce and a director and stockholder in such aviation companies as the Stinson Aircraft Corp., the Bellanca Corp., Northwest Airways and others, conceived the idea of founding a national association for the development of motorless flight in the United States and Canada. Proceeding with this idea, he formed the Evans Glider Clubs of America, later, on January 1, 1929, changing the name to the National Glider Association with headquarters at Detroit, Michigan. In this body Mr. Evans has associated with him some of the leading authorities on aviation in America. Leaders in boys' work, aviation enthusiasts and sportsmen find a common meeting ground in gliding. All wide-awake and red-blooded young Americans are enthusiastic about the sport. They are ready to form the rank and file of any club in any community in the United States which can be financed by the older men who are interested.

Clubs or others desiring to establish ideal soaring locations in their vicinity are invited to send to national headquarters for Government contour maps showing the terrain within a radius of fifty miles of the desired center. These maps will then be referred to the Technical Committee which will recommend various locations which appear desirable. Local committees can then inspect these locations for obstructions and other objectionable features. After the list is reduced to two or three possible locations, national headquarters, if requested, will send out representatives to aid in making the final selection. Actual expenses of those making such a visit will be charged the local organization.

Classification of Glider Records.—The N. A. A. recognizes officially the following classes of glider records:

Duration with return to point of departure.
Duration without returning to point of departure.
Distance with return to point of departure.
Distance air line.
Altitude above starting point.
Speed returning to the point of departure over a distance greater than one mile.

The N. G. A. also recognizes contests for "Landing on a Mark."

Glider Sporting Licenses.—The National Glider Association is authorized by the National Aëronautic Association to license third and second class glider pilots and to supervise the licensing of candidates for the First Class or F. A. I. license in the name of the N. A. A.

For the Third Class license, the pilot must keep a PTG or STG in the air for thirty seconds in a flight straight down hill and give such other evidence to the examiners as they may require that he is competent to handle a simple glider under normal circumstances.

For the Second Class license, the candidate must fly a PTG or STG for one minute down hill, making a full right and a full left or "S" turn.

For the First Class or F. A. I. license, the candidate may enter any type glider and must fly it for five minutes at an altitude higher than the point from which it was launched.

A Third Class license is required before the second test may be given, and the Second Class license must be shown by candidates for the First Class license.

A complete set of the Contest Rules is furnished each club and individual member and additional sets may be secured at cost upon application to National Headquarters.

Status of Motored Pilots.—Motored pilots holding N. A. A. Annual Sporting licenses are eligible for glider contests and individual record attempts even if not holding a glider license. In events not requiring sanction by the N. A. A., motored pilots holding Department of Commerce licenses may compete without glider licenses at the discretion of the Contest Committee in charge. Motored pilots so competing shall be classed with First Class Glider pilots and must comply with rules covering same. (NOTE: Competitions for the Edward S. Evans cash prizes for duration flights are sanctioned by the N. A. A.)

Gliders Should Be Licensed.—Hundreds of gliders throughout the country may be grounded by local authorities unless their owners secure licenses from the Aëronautics Branch. Although according to U. S. Federal regulations, gliders do not have to be licensed unless they engage in interstate commerce which is hardly a likely case, 20 states now require Federal licenses for gliders and glider pilots under terms of their statutes regulating aircraft and airmen. The N. G. A. will require all gliders entering contests after September 1, 1930, to hold Department of Commerce licenses.

The states which require Federal licenses are Alaska, Arizona, California, Delaware, Idaho, Indiana, Iowa, Michigan, Mississippi, Missouri (except solo pleasure), Montana, New Mexico, North Dakota, Texas, Vermont, Washington, Wisconsin and Wyoming.

Although the Department of Commerce has adequate machinery to license gliders as to airworthiness, for a time no formal requests were received by the department for glider licenses or for glider-approved type certificates. Applications had been made for identification marks for 600 gliders, but such marks mean little more than what the term designates, "identification." A license number of a glider, as with powered craft, must be preceded by a "C."

To secure a license on an approved type, it is necessary first to submit a complete stress analysis to the Aëronautics Branch at Washington. Upon approval of the design and completion of the craft, a local inspector will inspect the glider for workmanship and adherence to the approved design. If the completed glider is built in accordance with the approved design, it is then licensed. Powered-plane pilots, who feel they are qualified to fly a motorless craft, will meet with a set-back when they learn that it is necessary to take proper tests and secure another license applicable strictly to gliders. Unlicensed pilots of all classes, including students, must take the same physical examination as required for a powered-plane student's license.

Must Follow Airworthiness Rules.—The general airworthiness requirements for airplanes with power plant are applicable to gliders. Certain aspects of the glider problem differ materially from those encountered in powered craft and must be given special consideration. These are the design loads for wings, fuselages, landing gears, control surfaces and control systems; the material and method used for covering surfaces; the provision for towing;

the equipment and instruments to be provided and the method of conducting the engineering inspection and flight tests. With regard to flight tests, the director of air regulations explains that there are, of course, no quantitative performance requirements for gliders. Qualitatively, it is required that, under all load conditions, they be longitudinally, laterally and directionally stable. They must also exhibit no undue tendency toward falling off into a spin. Any tendency toward wing flutter will be cause for disapproval. Aircraft, in which no air controls are provided, and shifting of the pilot's weight constitutes the sole means of adjusting the angle of attack and obtaining lateral balances, are not considered safe and will not be approved by the Department of Commerce. An efficient longitudinal air control is required. The lateral and directional control may be obtained by weight shifting providing that the stability of the aircraft is such that it will respond properly to such shifting of weight, as determined by actual flight tests, and providing that the pilot may recover his normal position from any other position in any attitude which the aircraft may assume.

Requirements on Towed Flight.—It is explained also that towing of gliders may be practiced by man power, automotive power—such as automobile and speed boats—or by an airplane. In all cases except when man power alone is used, an approved device shall be used for cutting loose the towing cable at the will of the pilot in the light aircraft. In order to eliminate the chance of failure of the main supporting structure due to excessive tow cable pull, the strength of the tow cable shall not exceed two-thirds of the maximum wing structure design load.

Airworthiness Requirements of Air Commerce Regulations

From U. S. Department of Commerce Bulletin 7A.

PART 3.—LIGHT AIRCRAFT[1]

Light aircraft will include airplanes in which the power loading is greater than 30 pounds per horsepower, and aircraft, heavier than air, without power plant.

1. *General.*—The requirements of parts 1, 2, 4, and 5 of Section I shall apply except as herein modified.

2. *Special.*—Special requirements will cover the following items:

(*A*) Design loads for wings.
(*B*) Design loads for control surfaces.
(*C*) Design loads for landing gears.
(*D*) Design loads for fuselages.
(*E*) Control systems.
(*F*) Covering.
(*G*) Towing.
(*H*) Equipment and instruments.
(*I*) Inspection flight tests.

Safety of the power plant will be considered from the standpoint of fireproofness but not from the standpoint of performance or reliability, since such power plant as will be used in light aircraft will be merely an auxiliary and not a necessary essential to safe flight. Propellers likewise will not be subjected to special requirements.

[1] The requirements of this section were prepared with the assistance of J. A. Roché, through the courtesy of Brig. Gen. Wm. E. Gillmore, Chief Matériel Division, Army Air Corps.

3. *Design loads for wings.*—Because of the great variance existing among light aircraft as to aërodynamic characteristics, it will be necessary to base the design loads of the structures upon the performance characteristics, computed or tested, of each individual aircraft. (These characteristics should be described by means of a velocity diagram similar to that shown in Figure 17, Bulletin 7A.)

In this diagram the velocities corresponding to all the angles of attack of the wings of the aircraft are plotted from the point *"o,"* neglecting the effect of the power plant, and the points representing the extreme ends of these velocity vectors are joined by a faired curve. The velocities can be obtained by computations providing the airfoil characteristics, the parasite drag, and the stabilizing forces are known. The results of free flight or wind-tunnel tests can be of assistance in checking the computed velocities. Sample velocity computations may be referred to in Air Service Information Circular No. 444.

In general, it will be necessary to check the strength of the wing structure for the following conditions:

(*A*) Maximum velocity, which usually occurs in a nearly vertical dive. In this case a load factor of 1.5 is required.

(*B*) Foremost center of pressure location for the wing airfoil, which occurs at the attitude corresponding to minimum speed. In this case the load factor will be determined by

$$F = \left(\frac{V\text{max.}}{V\text{min.}}\right)^2 \times .25$$

(*C*) For the maximum velocity corresponding to a gliding path having a slope of 1 in 6. In this case the load factor will be determined by the expression

$$F = \left(\frac{V\text{max.}}{V\text{ path 1 in 6}}\right)^2$$

(In all cases the stress analysis will be made by taking the wing air force vector in the correct location and by applying reactions corresponding to those set up by the tail load and weights carried by the wings.)

(*D*) The wing structure shall be capable of carrying the above load systems reversed in direction with load factors one-half those specified.

(*E*) To insure proper resistance to loads imposed by handling and on wing tip landings, the wing structure shall be capable of carrying the airplane with a load factor of 2 when reactions are applied at the wing tips in a transverse plane through the center of gravity.

Wing ribs.—The wing ribs shall be capable of carrying their proper portion of the load systems corresponding to conditions (*A*), (*B*), and (*C*), for which the wings are analyzed, with a margin of 30 per cent.

4. *Design loads for control surfaces.*—The control surfaces shall be designed to carry loads as described in the following rules:

(*A*) The horizontal tail surfaces shall be designed to carry loads balancing those specified for the wing structure. A factor of 30 per cent will be added to the tail loads thus determined, to insure against failure through unknown and peculiar pressure distribution. The average loading in this condition shall be not less than 6 pounds per square foot.

(*B*) The load distribution shall correspond to that required for airplanes in part 2, Section I.

(*C*) The vertical tail surfaces shall withstand a unit loading which is 75 per cent of that specified for the horizontal surfaces.

(*D*) The ailerons shall withstand the unit loading specified for the vertical tail surfaces.

5. *Design loads for landing gears and tail skids.*—Gliders having a theoretical landing speed greater than 20 miles per hour, or weighing more than 50 pounds empty, shall be provided with a suitable landing gear. This may consist of skids or wheels, but must be resilient to prevent high shock stresses from being imposed on the structure of the aircraft. The landing gear shall be analyzed in the same manner as for airplanes—that is, 3-point landing, level landing, and side load conditions. A drop from 15 inches in the 3-point and level landing conditions will be required. A load factor of 5 shall be the minimum required. In the case of the level landing analysis, if a sliding element is used instead of a rolling element a horizontal component equal to one-half the vertical component shall be used to represent, as correctly as possible, the effect of ground friction. For the lateral design loads the rules and load factors applying to airplanes shall be used.

6. *Control systems.*—Aircraft in which no air controls are provided and shifting of the pilot's weight constitutes the sole means of adjusting the angle of attack and obtaining lateral balance, are not considered safe and will not be approved.

An efficient longitudinal air control is required. The lateral and directional control may be obtained by weight shifting providing that the stability of the aircraft is such that it will respond properly to such shifting of weight, as determined by actual flight test, and providing that the pilot may recover his normal position from any other position in any attitude which the aircraft may assume. The strength of the stick and control system shall not be less than required to carry the maximum air loads on the various control surfaces.

7. *Design loads for fuselages.*—The fuselage structure shall be designed in accordance with the methods prescribed for airplane fuselages, excepting as noted below:

(*A*) The fuselage tail structure shall be designed to carry the tail loads necessary to balance the wing loads.

(*B*) A factor of 5 for landing conditions shall be used.

8. *Covering.*—In view of the great variance of unit loading and styles of construction in light aircraft, the use of cotton, linen, and silk, doped, rubberized, varnished or oiled, attached by means other than usual in the case of airplanes, will be acceptable providing it can be shown that after it is finally processed the fabric and its attachment have adequate strength. In each case where covering materials other than approved for airplanes are used representative samples and test reports shall be submitted to show the suitability of the covering. The specimen shall include samples of the method of attachment of the covering.

The covering tests shall be performed on a sample section of the wing and on a sample section of the horizontal control surfaces. For such tests the covering shall be removed totally or partially from the side of the test section against which it is usually pressed by the air loads, leaving the stitching and taping intact. The covering which is usually pulled away from its supporting structure shall be loaded from the inside with dry, loose sand or lead shot until failure of the covering or its attachment occurs. Notes and photographs shall be made to describe the deformations of the covering at various stages of the loading schedule. The intensity of loading shall be 75 per cent of the highest used during rib and tail surface tests.

9. *Towing.*—Towing of light aircraft may be practiced by man power, automotive power, such as automobiles and speed boats, or by an airplane. In all cases, except when man power alone is used, an approved device shall be used for cutting loose the towing cable at the will of the pilot in the light aircraft. In order to eliminate the chance of failure of the main supporting structure due to excessive tow cable pull, the strength of the tow cable shall not exceed two-thirds of the maximum wing structure design load.

10. *Equipment and instruments.*—Safety belts attached to suitable anchorages shall be provided in light aircraft. The strength of the belt and its anchorage shall be sufficient to withstand a pull of 850 pounds applied to the belt in a manner simulating the loading applied by a person weighing 170 pounds with a load factor of 5.

An instrument indicating the approach of stalling speed shall be provided. This may consist of an air-speed indicator or an angle of attack indicator. In either case this instrument shall be accurate at low speed and provided with markings indicating clearly the range corresponding to unsafe conditions of flight.

11. *Flight tests.*—There are no quantitative performance requirements for light aircraft. It is, however, required that in all load and power conditions they be longitudinally balanced and stable, and that they be laterally and directionally stable. They must respond to their controls in a normal manner, satisfactory to the flight inspector who will make air tests.

Tests made in still air may be required to check the velocity diagram on which the design load factors are based. The light aircraft with full load, shall be dived on a path 30° from the horizontal, for a sufficient length of time to acquire and maintain the maximum velocity corresponding to this path, without developing objectionable flutter in its wings or control surfaces. A demonstration shall be made to show that the light aircraft will readily recover from spins after spinning at least six turns with the center of gravity in the rearmost position likely to be encountered in its normal use.

(The regulations relative to spinning tests apply to motored airplanes and gliders, not to free flying gliders or soaring planes.)

CHAPTER SIX

DESCRIPTION OF MODERN GLIDERS AND SAILPLANES

Trend of Glider Design—Glider Blue Prints—Description of Detroit Gull; Wings—Fuselage—Landing Gear—Empennage and Controls—Specifications of Detroit Gull—Specifications of Evans Gliders—Specifications of Alexander Trainer—Specifications for Cadet II Training Glider—Details of Bowlus Sailplane—Bowlus Wing Construction—A Dual Control Glider—Water Gliders—Powered Gliders—Combination Primary and Secondary Training Sailplanes.

Trend of Glider Design.—A striking development of primary training glider design is the single-track skid landing gear, as shown in side view of PTG at Fig. 32. Wheels have been abandoned on some shock cord launched types because of their resistance and also because of difficulties in stopping when landing on an incline. Most gliders are equipped with skids or runners as originally used by the Wrights, though some that are to be launched by auto-towing have wheels, as shown at Figs. 33 and 34. Most gliders are made of wood. Very thin plywood is the preferred material. Wooden beams and trusses joined by plywood gusset plates are assembled to form the most intricate and elaborate internally trussed bridge works which, when covered in, form extremely light wings. Cantilever wings, weighing less than five ounces per square foot, are built that possess ample strength. In motored airplanes wings weigh at least sixteen ounces per square foot and 24 ounces is not an unusual weight. Of course, the stresses in powered airplanes are greater and the construction must be stronger.

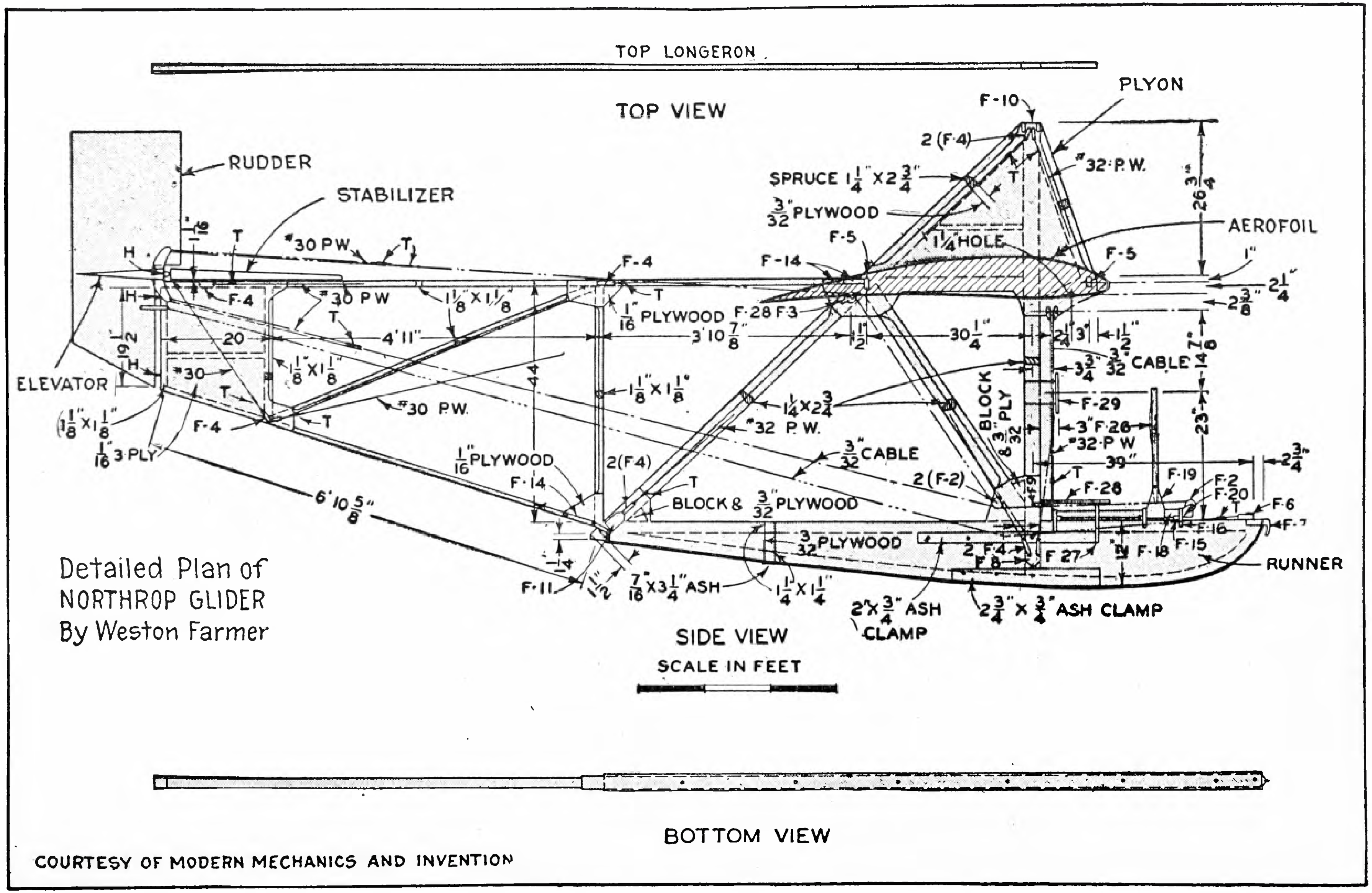


Fig. 32.—Dimensioned Side View of the Northrop Primary Training Glider Showing Sizes of Various Parts and Nature of Materials Used in the Construction.

Waterproof casein glue is used almost exclusively for joining wood parts. Nails are avoided by some designers, since they contribute very little to strength but considerably to weight and deterioration. Other designers use brads to supplement the glue at gusseted joints. The weight of successful gliders varies from about 250 pounds down to as little as 90 pounds. Two persons can handle them on the ground. Much ingenuity has been displayed in facilitating disassembling and road transport. This feature is a great asset after long-distance glides in hilly country because it is not easy to handle and carry a sailplane having a large wing spread on an ordinary motor truck over the usual roads without dismantling it.

In the glider field the monoplane is the decided favorite. Extremely large aspect ratio is a basic feature of all designs. Wing spans consequently have grown wider and wider and wings spanning 12 and even 15 times their chord are quite common. Of course, it is essential also to avoid struts and external bracing on soaring planes. Structurally, it is a task to build a light wing spanning 30 feet from root to tip on the cantilever principle, having only five-foot base depth or less at the root. Responsible designers of the old school hesitated to risk that, so it took the boldness of college students to demonstrate that it could be done. Klemperer says that the tapering of wings toward the tips has been demonstrated to contribute enough to structural and aërodynamic efficiency to justify the greater manufacturing complication. The soaring planes have done much to demonstrate the merits of the thick and semi-thick wing sections, and the advantages of well-rounded leading edges. In no other aircraft can parasitic resistance be reduced so perfectly as in the modern sailplane. Some of them that have been described in a preceding chapter have nothing but a wing, tail, and a streamlined body just large enough to house the pilot. Every aviator will agree that the field of vision from a glider's cockpit is incomparably better than from that of any regular tractor airplane. One can see to the last second where he is going to land.

A number of rather unorthodox designs have been built and flown as gliders with interesting and varying success. Among them are tandem wings; tailless planes with pronouncedly swept-back wings; slotted wings; machines having the control planes in front of the main wings, and others with flapping wings. The normal gliders are equipped with elevator, rudder, and ailerons and are controlled much like airplanes. Control surfaces are large to compensate for the low air pressure at soaring and gliding speeds, but the tail is short in comparison with the wing span.

Many efforts have been made to eliminate the vertical rudder. Birds have evidently quite good control without it. However, all attempts at copying the ideal warping and folding mechanism of the bird's wings or replacing it by some other device, so far have produced nothing decidedly superior to rudder control. Various kinds of wind brakes mounted on the wing tips, which on a glider have such a long leverage, have been tried with partial success. Flexible camber wings and tiltable wings have been flown successfully, although the advantages claimed do not seem to be exactly in proportion to the complication and increased cost of construction. Some device with which to control the gliding angle independently of the angle of attack and speed does have some definite usefulness, however.

Recording altimeters, air-speed meters, and so-called accelerometers, however, have been of great assistance to both pilots and students. The pilot can, by watching these instruments simultaneously with the horizon and noting the physical sensations, interpret much better whether he is gaining or losing energy. Angle of attack and yaw meters, however primitive they may be, are also a valuable asset, but instruments are of more value to sailplane pilots engaged in soaring than to students undergoing primary instruction by the short glide system.

Glider Blue Prints.—The National Glider Association reports that it is swamped with requests for blue prints of gliders. Most of these requests come from utterly inexperienced people who have been led to believe that any one can construct a motorless airplane. This is not true. A glider is an airplane in every sense of the word, less a motor. Only persons acquainted with the design and experienced with the construction of aircraft should attempt to build a glider. In fact, it takes more skill and ability to construct a high class soarer than it does to build a motored plane. The National Glider Association believes that it would be better for the sport if beginners would purchase their equipment from competent manufacturers. This can now be done. An excellent Primary Training Glider with safety belt and shock cord can be purchased for from $375 to $600 and the superior utility gliders for from $650 to $1,000. As several club members can use the same glider, this brings the cost per individual down within the reach of all.

Yet, in response to a quite general demand, and also for the purpose of having in its files standard or master plans of the Primary and Secondary Training Gliders, the National Glider

Association is having prepared blue prints of the Utility Training Glider. These prints may be purchased when available at cost by individual members or affiliated clubs only which give ample evidence that they have themselves or have affiliated with them, members who have experience and skill in the design and construction of aircraft, and that adequate shop facilities will be available for the construction. These plans will be approved by the Department of Commerce before being issued.

Description of Detroit Gull.—The wings are of standard airplane two-panel construction. The two 17-foot spars of each wing are built of 5/8-inch selected spruce; and ribs are made of spruce and mahogany plywood. Leading and trailing wing edges are fitted with 28-gauge heat treated duralumin. Wing fittings, where the most strain occurs, are of 3/32-inch carbon steel. Wings are covered by the standard aircraft process, with an especially light weight but durable glider fabric, and wing tips are protected by ash strips covered with plywood. Drain holes are placed in the wings for drainage of condensation. Compression struts of the wings are each 3/4-inch square.

Fuselage.—Fuselage struts, of the highest grade Sitka spruce, are machine shaped and sanded; and upon assembly, strut joiners are set with waterproof casein glue, and reinforced with plywood gussets. The keel is built of three 11/16-inch laminated spruce members, tightly clamped and glued; and to it is attached a bottom member of sturdy ash. The keel is of box construction, and is faced on the sides with 1/8-inch plywood cut at a 45-degree angle to give the maximum strength. One 20-inch and one 30-inch longitudinal external keel brace is bolted on the side of each fuselage spar in four places to take up the shock of landing. The seat and back rest are built of five-ply veneer.

(Steel fuselage construction of 1025 welded steel tubing will shortly be available to those desiring same.)

Landing Gear.—For wheel landing gear installation, two steel tubes are nested one inside the other for strength, and are placed through the fuselage in a space provided at the normal point of contact with the ground. The plywood is cut, and the tube axle placed through, with four inches allowed for absorption of shock —which is taken up by a cross-wound shock cord. Small airplane tail wheels are used, with 10 x 3 tires. (See Fig. 33.)

Fig. 33.—Partial Front View of Detroit Gull Training Glider Showing Pilot Seated and Simple Wheel Supporting Gear Employed for Launching the Glider by Towing with Automobile.

Exhaustive engineering experiments, both in the factory and under actual flight conditions, have proven the high degree of safety of the "DETROIT GULL." The safety belt is of high grade cotton webbing, especially designed for gliders, and is tested for 850 pounds stress. Overload drop tests evidence its fine resistance to hard landings; and the ship has a safety factor for load carrying of six and one-half times the actual average load it will ever be called upon to support.

Empennage and Controls.—The rudder is counter-balanced. All tail sections are made of selected spruce and are thoroughly glued and well nailed. Two double-drilled hinges are placed on the rudder, and six on the elevator. The last fuselage bay is counter-braced with plywood, making in actual effect a vertical stabilizer.

Standard aircraft cables, thimbles and ferrules are used throughout, in addition to aircraft cable girdles, regulation aircraft turnbuckles, and copper safety wire. Westinghouse Micarta control pulleys are used exclusively. For aileron and rudder horns, half-inch, five-ply birch is used, which is practically as strong as steel. The control stick is made of heavy welded steel tubing, and is the same size as those used in motored airplanes. The rudder bar is of shaped ash, and is provided with foot straps to prevent the pilot's feet from slipping.

DETROIT GULL SPECIFICATIONS—PRIMARY TRAINING GLIDER

(This Glider is shown in flight in Frontispiece)

It is built to meet the airworthiness requirements of the Department of Commerce and all engineering data have been accepted for Approval Type Certificate.

Length over all	17 ft. 6 in.
Height over all	7 ft.
Span	34 ft. 6 in.
Chord	5 ft.
Aspect ratio	6.8 to 1

Areas

Wing (including Ailerons)	170 sq. ft.
Ailerons	16.5 sq. ft.

Rudder	8 sq. ft.
Fin	3.5 sq. ft.
Stabilizer	10.0 sq. ft.
Elevator	14.0 sq. ft.

WEIGHT

Empty	180 pounds
Useful load	170 pounds

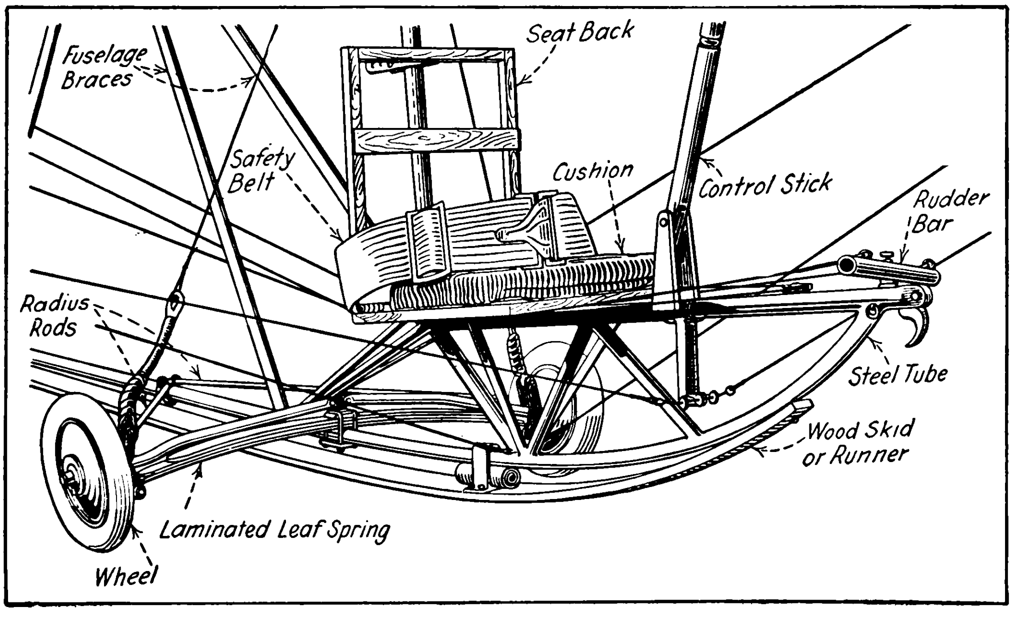


Fig. 34.—Close-up View of Front Part of the Alexander Training Glider Showing Application of Simple Wheel Landing Gear.

Gross weight	350 pounds
Wing loading, per sq. ft.	2.1 pounds

PERFORMANCE

Gliding angle	10 to 1
Landing speed	12 to 15 M.p.h.

REMARKS: Aileron Control at 8 miles per hour. Designed for a maximum speed of 103 m.p.h. in vertical dive. Bracing has a safety factor of 40% against required 20%. All cables have 50% margin of safety. Wing is U. S. 35 B airfoil section.

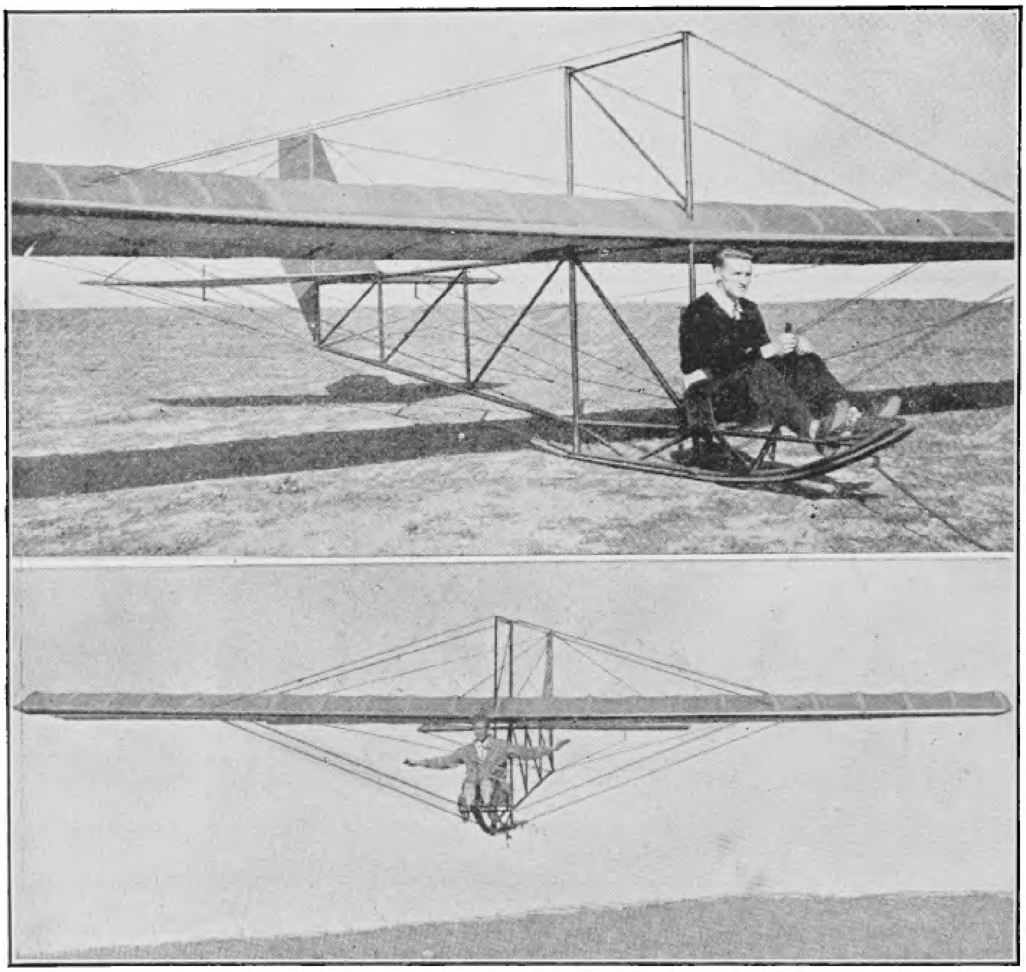


Fig. 35.—Illustration at Top Shows the Evans Glider * Resting on the Ground. Note Steel Tube Fuselage and Extension of Vertical Fuselage Posts Above the Wing to Form Bracing Pylon for Landing Wires. Bottom Illustration Shows Pilot Gliding Hands-off to Show Inherent Balancing of the Design.

* For altitudes of 5,000 ft. or over, 25% additional wing area is recommended for the primary type glider—furnished at an additional cost of $50.00. Manufactured by Evans Glider Co., Los Angeles, California.

SPECIFICATIONS
EVANS GLIDERS (Fig. 35)

Type	Primary	Secondary
Span	34 feet	44 feet
Chord	5 feet	5 feet
Length overall	18 ft. 6 in.	21 ft. 6 in.
Weight	175 lbs.	225 lbs.
Area	170 sq. ft.	220 sq. ft.
Spars	Sitka spruce	Sitka spruce
Ribs	Aërotruss steel	Aërotruss steel
Airfoil	Göttengen 441	Göttengen 441
Fuselage	Aircraft steel tubing	Aircraft steel tubing
Landing gear	Ash skid	Ash skid

Price at factory $247.50, knockdown.
Double wire bracings on both primary and secondary.
Other airfoils optional at slight additional cost.
Safety belts included as standard equipment.
Secondary type has streamline enclosed cockpit.

ALEXANDER GLIDER

Exact designing by airplane engineers has created a glider inherently stable in flight to a high degree. Any beginner may strap himself into the comfortable seat and fly the craft with ease after mere ground instruction in the operation of controls. Careful instruction by skilled aircraftsmen, using airplane methods and the facilities of a giant aircraft factory, has produced a light but sturdy machine combining an ability to float "like a feather" to that of withstanding the buffeting of bad landings by novice pilots. The Alexander Glider is trim and inexpensive. It would be difficult for a group of persons to build a glider for the same price of $375 unless equipped with machines and methods permitting mass production.

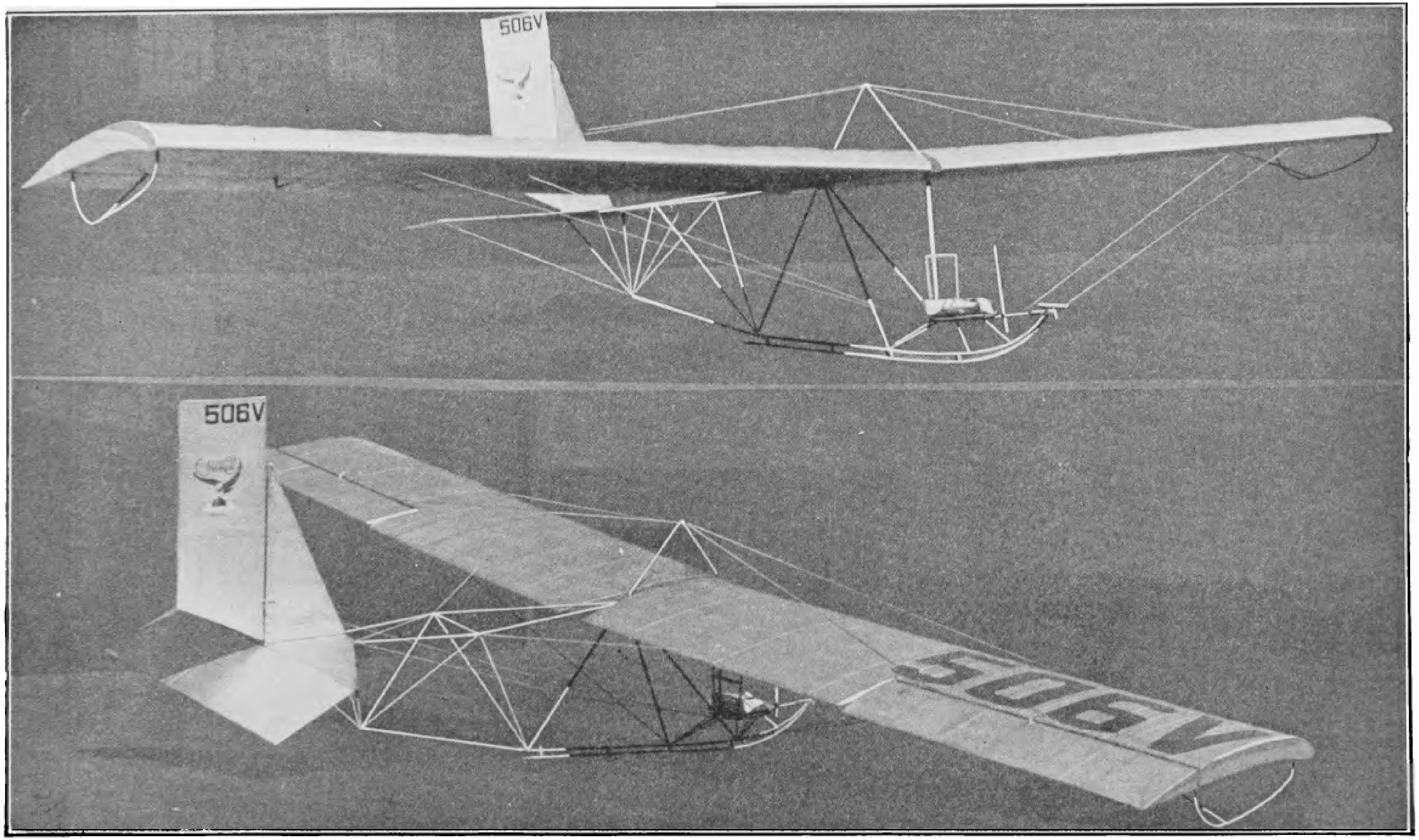


Fig. 36.—Three-quarter Front and Rear Views of the Alexander Trainer, Which Uses a Welded Steel Tube Fuselage and Monoplane Supporting Wing Having Appreciable Dihedral.

A large amount of high-lift wing area and unusually large control surfaces make for a quick take-off, flat-gliding angle, thistledown landing and good controllability at slow speeds. The control surfaces are well balanced and the response highly sensitive. The motorless machine handles easily at the slowest flying speeds.

The test of a good glider, of course, lies in its ability to sustain its pilot for a long duration of time, or to glide a long distance. The test of a superior glider in the modern sense rests in its controllability at slow speeds. If it responds easily to the controls at slow speeds, its pilot may hold it at minimum flying speed and yet return at will to take advantage of a vagrant upcurrent, or side slope of a hill. Sufficient stability likewise has been built into the Alexander Glider to enable it to recover itself from abnormal attitudes. If the beginner on his first flight should be catapulted into the air with a "wing down," as sometimes happens, that wing would automatically strive to rise to level flying position as a result of the dihedral designed into the wings.

The glider pilot is protected from personal injury in event of a bad fall by the following factors: First, the glider, being light, maintains a large amount of sustaining force at all times and does not fall hard. Second, the prow of the main skid, on which he sits, protects the pilot from hitting the ground on a headlong collision. A regular safety belt holds him in his seat. The wings and tail offer similar protection in a sideslip or tailslip. The lighter the glider, the better it flies. The stronger the glider, the longer it lasts. The combined strength and lightness was achieved through the scientific use of seamless steel tubing, with welded joints in the fuselage. By virtue of this steel construction, the Alexander Glider combines lightness with strength and compromises on neither score.

The Alexander Glider is built in the high altitude country to fly in the thin air of the mountains. Consequently its performance is correspondingly better in the heavier air of lower elevations. The buoyancy of the glider is due to its lightness and large wing surface. Flown by a heavy pilot, the Alexander Glider has a "wing loading" of less than two pounds to a square foot. It is less than a fifth of the amount of weight borne by each square foot of wing area on the average airplane.

The glider is equipped with metal wing tip skids which protect the wings on take-offs or landings. Its comfortable seat is adjustable forward and backward so as to compensate for weights of different pilots which in large variations would slightly affect the balance of the machine. Controls operate on an efficient pulley system and are readily open for inspection. The glider is finished in a striking color combination of International orange fuselage and silver wings. At the prow of the main skid is a novel trip catch release suitable for the launching of the glider by both towing and catapulting methods. A wheeled landing gear, as shown at Fig. 34 may be fitted to facilitate towed flights.

A frequent error in glider design was avoided by making the control surfaces unusually large. A glider is customarily flown at near the slowest possible speed in order to attain maximum duration of flight. The slow velocity naturally retards effectiveness of controls which are dependent on the force of air pressure. It must also be remembered that the tail surfaces of a glider are without the additional pressure of the propeller "wash," as with an airplane. Hence correspondingly larger ailerons, elevators and rudder are provided on the Alexander Glider. These "extra" control surfaces, together with the large high-lift wings, make the Alexander Trainer a good secondary as well as a primary glider.

SPECIFICATIONS
ALEXANDER TRAINER (Fig. 36)

Manufactured by Alexander Aircraft Company, Colorado Springs, Colorado.

Type: Primary and secondary monoplane.

Dimensions: Length overall, 16 ft. Height overall, 6 ft. Span, 36 ft.

Chord, 5.5 in. Aspect ratio, 6.66 to 1.

Areas: Wing (incl. ailerons), 198 sq. ft. Ailerons, 27¼ sq. ft. Rudder, 10⅓ sq. ft. Fin, 4 sq. ft. Stabilizer and elevator, 21 sq. ft.

Weights: Empty, 210 lbs. Useful load, 200 lbs. Wing loading, 2 lbs. per sq. ft.

Performance: Gliding angle, 15 to 1. Landing speed, 12-14 m.p.h.

Construction: Fuselage, welded steel tubing, triangular type, uncovered.

Wing, braced, high lift, double camber, spruce spars, spruce ribs, fabric covered.

Equipment: Trip release tow hook, comfortable cushion, shock absorbers, airplane safety belt.

Price (at factory): $375.

REMARKS: Greater weight compensated for by extra large amount of wing area, giving it light wing loading.

Sensitive response to the controls is appreciated especially by the glider pilot when being towed into the air by automobile. In the first stage of the process the glider is pulled down the runway at a fast clip but without sufficient flying speed to take the air.

Until the towing automobile reaches a good speed the glider may be one wing low or "get away" from its pilot unless he is afforded good slow speed control.

SPECIFICATIONS FOR CADET II—TRAINING GLIDER

The Cadet II, shown at Fig. 37, has not been designed to meet the competition of the cheaper open type primary gliders of limited performance. It has been designed and built by an engineer who has spent years in the study and actual design of the highest performing "Darmstadt" gliders in Europe. The Cadet II has been built to conform to the proposed glider specifications of the Department of Commerce. The manufacturers are The Baker McMillen Co., Akron, Ohio.

Type—High Wing Monoplane.
Fuselage—Welded steel—enclosed with fabric.
Tapered wings, span 37 feet 2 inches.
Wing area—160 sq. ft.
Chord—5 feet max.
Control—Tubular to Ailerons.
Aileron area—24 sq. ft.
Horizontal tail surface—19 sq. ft.
Vertical tail surface—17 sq. ft.
Length overall—18 feet 9 inches.
Height overall—5 feet 4 inches.
Weight—230 lbs.
Angle of glide (approximate)—15-1.
Sinking speed (approximate)—3½ feet per second.
Landing gear—16 x 6 air wheel with brake.
Equipment—Special hook for either shock cord launching or towing. 50 yards ⅝-inch shock cord.
Finish—4 coats clear dope and one aluminum with red trimmings. Fittings cadmium plated.

PRICE—$650, plus crating at Akron.

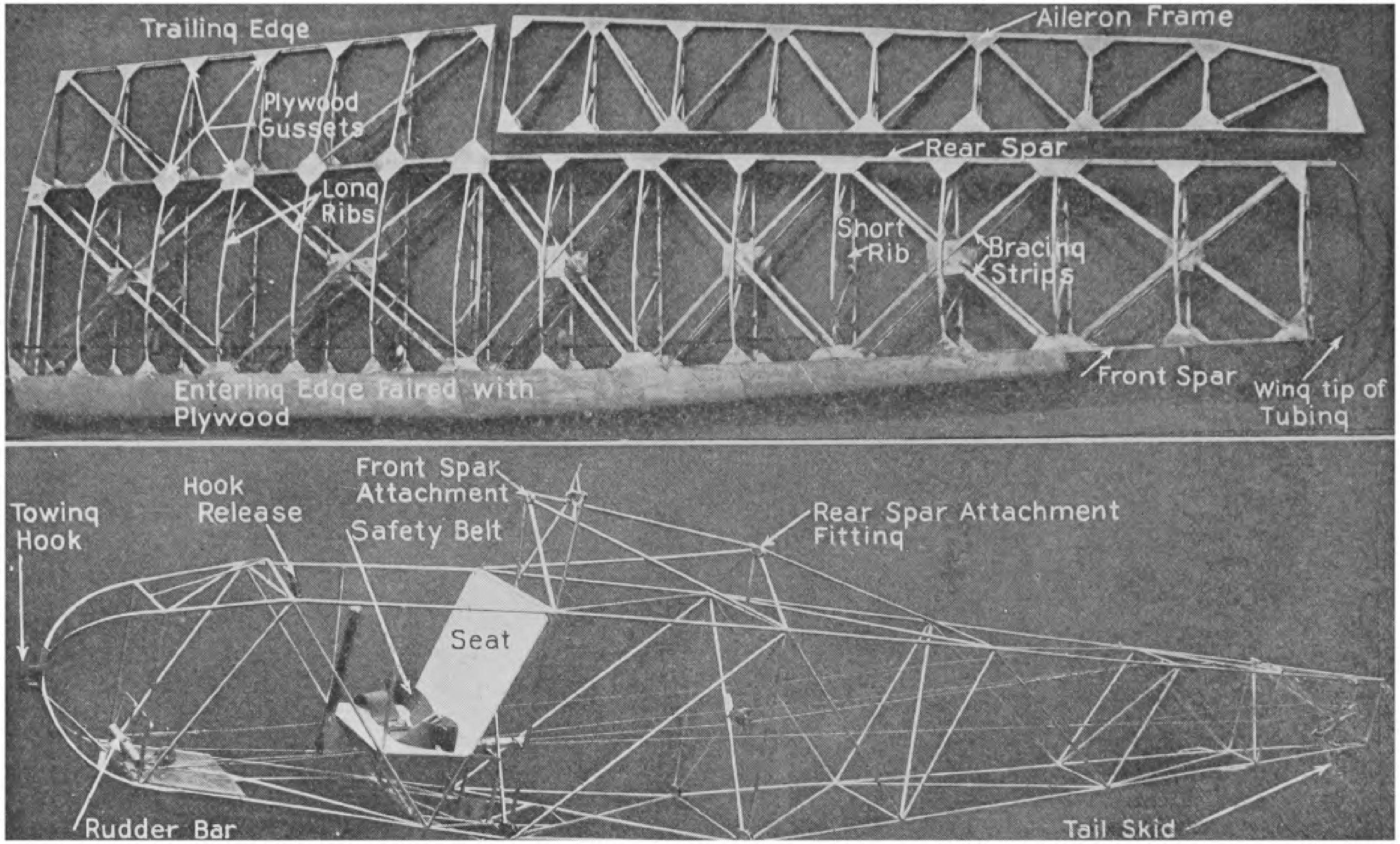


Fig. 36 A.—Wing and Aileron Frame of the Baker-McMillen Training Glider Shown at Top. The Welded Steel Tube Fuselage Shown Below of the Cadet II Training Glider is a Light and Strong Assembly.

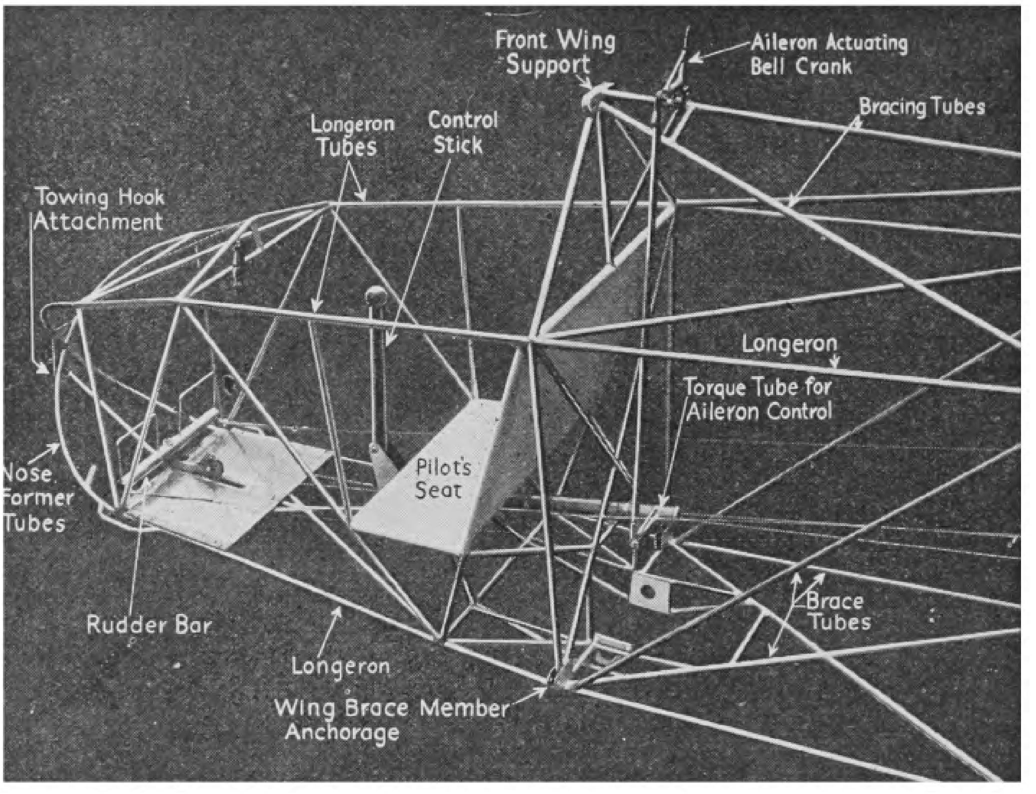


Fig. 36 B.—Close-up View of Pilot's Cockpit Section of Cadet II Training Glider Showing Seat and Control Members, Also Wing and Strut Attachment Lugs.

A new type of training glider, known as the Utility model can be used for all stages of training. The central fuselage and controls carried at the tail are the same on the type used for primary and secondary training and for that employed for soaring, but there is an important difference in that wings of greater span and with augmented supporting area are used on the soaring plane. The Baker-McMillen Cadet II shown at Fig. 37 is an excellent example of a Utility type glider when fitted with a wing spread of 37 feet. Fitting new wings of 48 feet span converts it to an efficient soaring type and the fact that the pilot's cockpit is enclosed on either model familiarizes him early in his training period with the "feel" of a closed-in cockpit and the control of a soaring type craft. Attention is directed to the illustrations at Fig. 36A which show the substantial and light wood spar and rib structure of the Cadet II wing frame with covering removed. The other illustration on the same plate is of the welded metal tube fuselage of the Cadet II glider and shows how closely the best approved powered airplane practice is followed in the construction of a modern Utility type glider or sailplane.

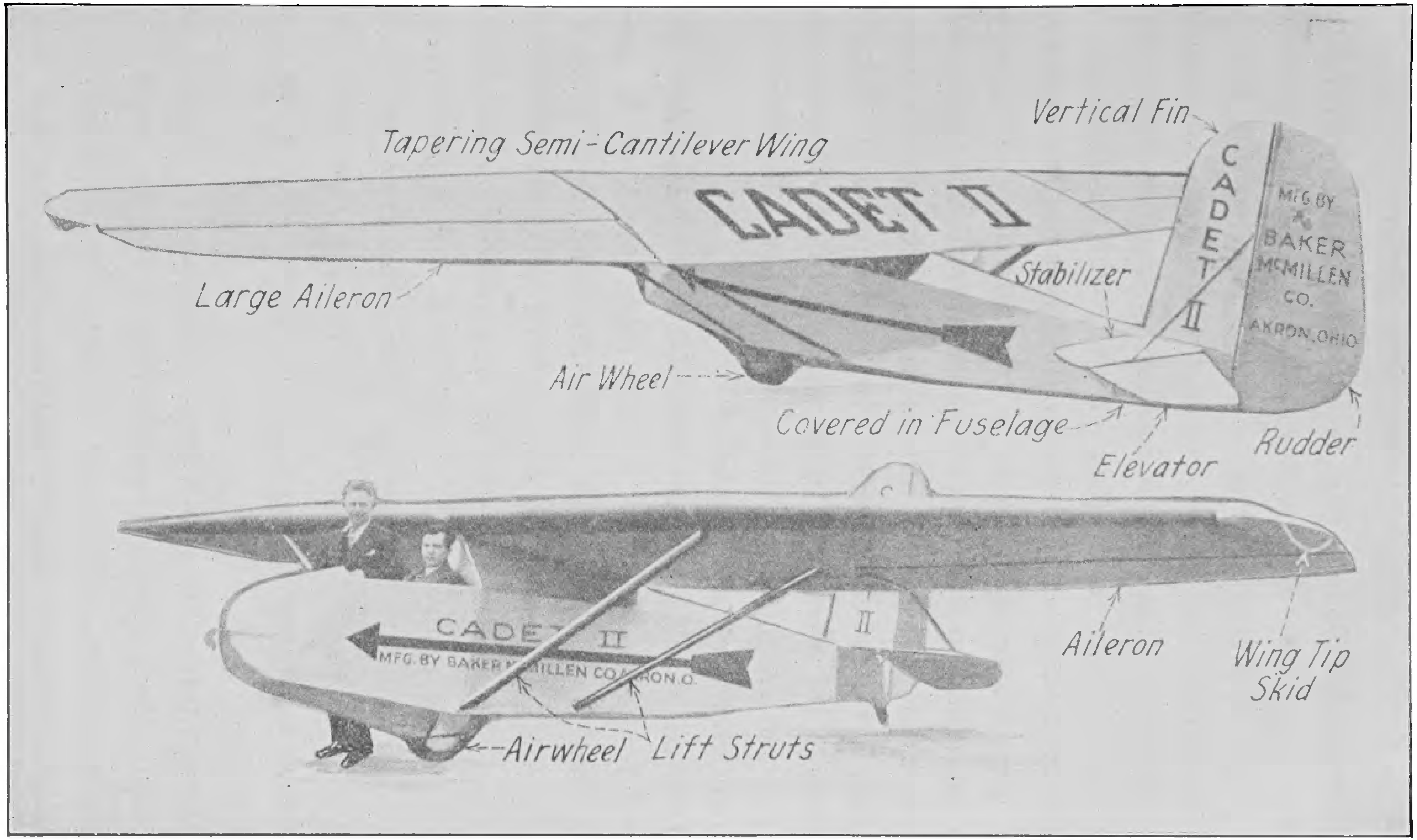


Fig. 37.—Views of the Cadet II Secondary Training Glider. Note Single Airwheel for Landing Gear and Braced Monoplane Wing, Also Fairing of Wing and Fuselage.

Bowlus Sailplane.—This is a tapered high wing, full cantilever monoplane and is illustrated in the frontispiece. The fuselage is of rectangular cross section, tapering to a horizontal wedge in front and in the rear to a rectangular section about 6 inches square. The wing is in three parts. The center section is of six-foot span and is built integrally with the fuselage. The wings are 19-foot lengths bolted to the center section which allows the wings to be dismantled for transportation. The fuselage maximum section is at the pilot's seat where it is 24 inches high, by 19 inches wide. It is constructed of four spruce longerons, ¾-inch by ¾-inch, at the pilot's seat and tapering to ⅜-inch by ⅜-inch at the rear ends. Strut members of the fuselage are of spruce and are similar in cross section to the longeron at the station where they are installed.

Diagonal bracing is taken care of by the use of thin spruce strips 1½ inches wide by 1/16-inch thick, which are moistened and then glued and nailed in position with their center line intersecting the joint of the longeron and strut. When the strips dry they shrink enough to give the structure considerable rigidity. On each side a fairing strip ¼ inch by ⅜ inch is placed on edge for the purpose of holding the cloth away from the fuselage sides. The forward portion of the fuselage from the nose of the wing to the trailing edge, has a V bottom and carries a skid for landing.

Directly behind the pilot's seat is a bulkhead of 3/16-inch thick plywood which extends from the keel to the top chord of the front wing spar. These two bulkheads transmit the load of fuselage and pilot to the wings in flying and to the skid in landing.

The bulkheads have an hourglass shape, being the full width of the fuselage where they attach to the longerons and above that, narrowing to approximately the width of the pilot's head and again flaring out for their attachment to the wing spars. Above the fuselage the bulkheads are boxed in forming a streamlining for the pilot's head.

The center section, which is attached to the bulkheads, is 5 ft. long and has a chord of 5 ft. 6 in. It is permanently attached to the bulkheads. At the rear of the fuselage is a short stub vertical fin, to which the rudder is attached. A light tail skid of conventional type, with rubber shock cord, is built in about a foot from the end of the fuselage, an inspection hole being provided by the use of hookless fasteners.

Controls are of the conventional type using a stick and rudder pedal operating the control surfaces by means of 1/16-inch control wire.

Bowlus Wing Construction.—The wings are of full cantilever construction, tapered in plan form, using U.S.A. 35-A airfoil section. This section gives high lift and at the same time is well suited to cantilever construction because of its deep section, the spars having a depth at the root of 10.95 in. and 9.13 in., respectively. The wings proper are 19 ft. long and have a chord of 5 ft. 6 in. at the root, tapering to 32 in. at the tips and are bolted to the center section by duralumin fish plates.

The spars are built-up Pratt trusses. The top and bottom chords are made up of two strips of square spruce glued and nailed on each side of the vertical and diagonal members, the diagonal members being placed so as to be in tension under flying load. The top chord of the spars is kept horizontal. The lower one slants up, thereby giving a slight dihedral to the lower surface of the wing. The front spar is set at right angles to the center line of the fuselage, the rear one slanting forward in order to keep it as deep as practical. The taper in plan form is obtained mostly by slanting the trailing edge forward.

The ribs are made by cutting a web of 1/16-inch plywood 3/4 in. deep and gluing on this, cap strips 1/8 x 1/16 in., nailed occasionally to hold them while the glue is drying. These ribs are found to be exceptionally light and very easy to construct and are many times stronger than necessary for glider loading. Every third rib is made a compression rib by placing spruce compression members on each side of the web. The wings are braced diagonally in the same manner as is the fuselage, with thin spruce strips.

The leading edge, back as far as the front spar, is covered with thin plywood to give a true airfoil section and to add rigidity. A wire is used for the trailing edge. These wings prove to be extremely strong and rigid, very little flexing being noticed even in flight. The entire glider may be lifted by its wing tips. The ailerons are of the wing tip type using the Göttingen 410 section. They are built up with wooden ribs on a 1 1/4-inch dural tube which rotates in wooden bearings in the outside ribs of the wing. Control wires are attached to horns on this tube. The ailerons are rigged with six degrees less angle of attack than the wings.

The rudder is a balanced, full cantilever type of rather thick section, the entire load being taken by a box spar placed one-third of the chord from the leading edge. The balancing fin is entirely cut away at the lower portion where the rudder is hinged to the stub fin. The ribs of both the rudder and the elevator are of the same type of construction as the ribs in the wings. The rudder is approximately 6 ft. high and has 33 in. maximum chord tapering to a rounded top.

No fixed horizontal stabilizer is provided. The elevator is balanced. The depth of the stabilizer at its center section is approximately the depth of the fuselage and continues the general streamline effect. Both the rudder and the stabilizer are attached to a 3/32-in. duralumin end plate which has ears bent out to make the hinges. This plate is securely attached to the longerons by means of ears.

At the front end of the fuselage a quick release is installed. Wings, fuselage and tail surfaces are covered with No. 100 cambric. This material is light and takes dope well. Three coats of dope are applied, the last one having aluminum pigment.

As far as can be ascertained, the plane has a gliding ratio of approximately 20-1, with a gross weight of 305 lbs. It takes off at 22 m.p.h.

SPECIFICATIONS OF THE BOWLUS SAILPLANE

Span	44 ft.
Chord at root	5 ft. 6 in.
Chord at tip	32 in.
Overall length	25 ft.
Weight, empty	160 lbs.
Aspect ratio	11
Wing curve	U.S.A. 35-A
Wing area	179 sq. ft.

A Dual Control Glider.—One of the first dual control or two place training gliders to be offered the public is illustrated at Fig. 37A. This is known as the Leonard and is manufactured by the Leonard Motorless Aircraft Company, Inc., Grand Rapids, Michigan. It is claimed that glider piloting will be taught in much less time in the two seat form which permits the instructor to accompany the student. This glider was designed by graduate

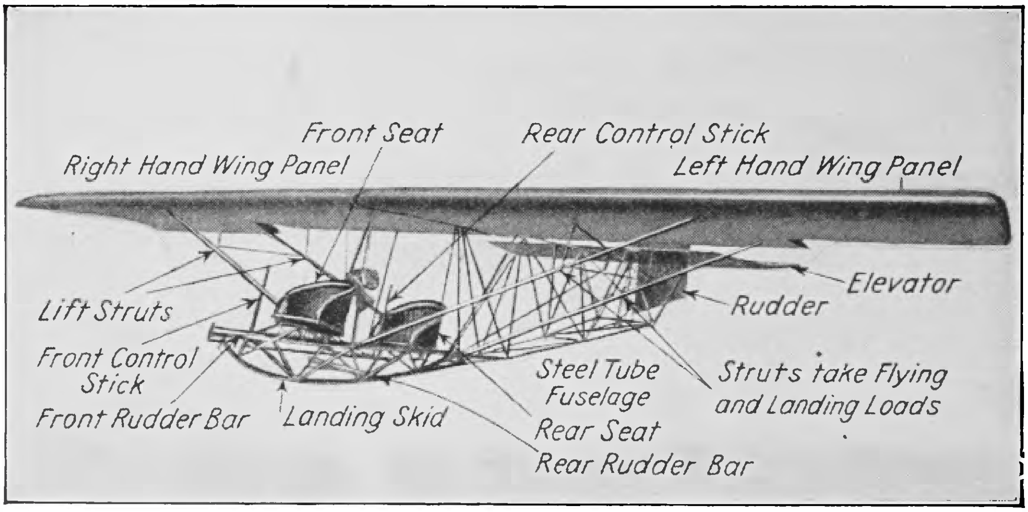


Fig. 37A.—The Leonard Two-place Training Glider Permits Instructor to Teach Piloting with Dual Control.

aëronautical engineers to meet the requirements of the U. S. Dept. of Commerce. The fuselage is of reënforced steel tubing and is said to weigh less than a wooden fuselage of similar size and strength. A feature is the use of struts to carry both flying and landing loads instead of the usual wire bracing which means the glider is permanently rigged upon assembly and the wings may be attached to the fuselage and the glider be made ready for flight in five minutes. As the glider may be operated from either seat, the instructor may make the landings at the start of instruction, thus minimizing the shock of rough landings and attendant damage to the glider. This glider may be equipped with pontoons so it can be launched from water behind a speed boat. The wing span is 34 feet and wing chord 5 feet, the aspect ratio of the wing is 6.8 to 1 and the available lifting area, including ailerons is 170 square feet. The weight unloaded is 205 pounds. Wing spars and ribs are of airplane spruce. The rate of glide in dead air is 15 to 1 and landing speed is 19 miles per hour with both seats occupied by pilots of average weight.

Water Gliders.—Some proponents of the towed gliders believe that the use of a motor boat in connection with a glider fitted with some sort of flotation gear offers advantages that are not present in flying land gliders over flat ground by towing them with automobiles. Water offers unlimited landing space with no buildings, wires, fences or rough ground to confuse and worry the novice. It is stated that the modern boat glider can be flown at altitudes only limited by the length of the tow rope or it may be kept indefinitely only a foot off of the water, entirely at the will of the pilot. The modern glider fitted with flotation gear differs from the early types just as much as the land types do.

The accompanying illustration at the top of Fig. 38 shows an early German biplane type compared with a more modern German design which is now being built in the United States. The early creation was a single surfaced biplane with lateral control obtained by working the wing tips. The elevator was placed at the front as in the early Wright glider and the flotation gear was a pair of cigar-shaped pontoons.

The modern Peel glider shown below the early design at Fig. 38 has a duralumin hull of adequate strength to resist hard landings and good lines for offering minimum air and water resistance. The wings are modern high lift airfoils and the bracing is by means of streamlined tubes. Dual control may be provided as the Peel glider carries two. The glider will climb and fly at twenty miles per hour and will land at ten miles per hour. It is stated that the Peel glider boat, either in tow or in

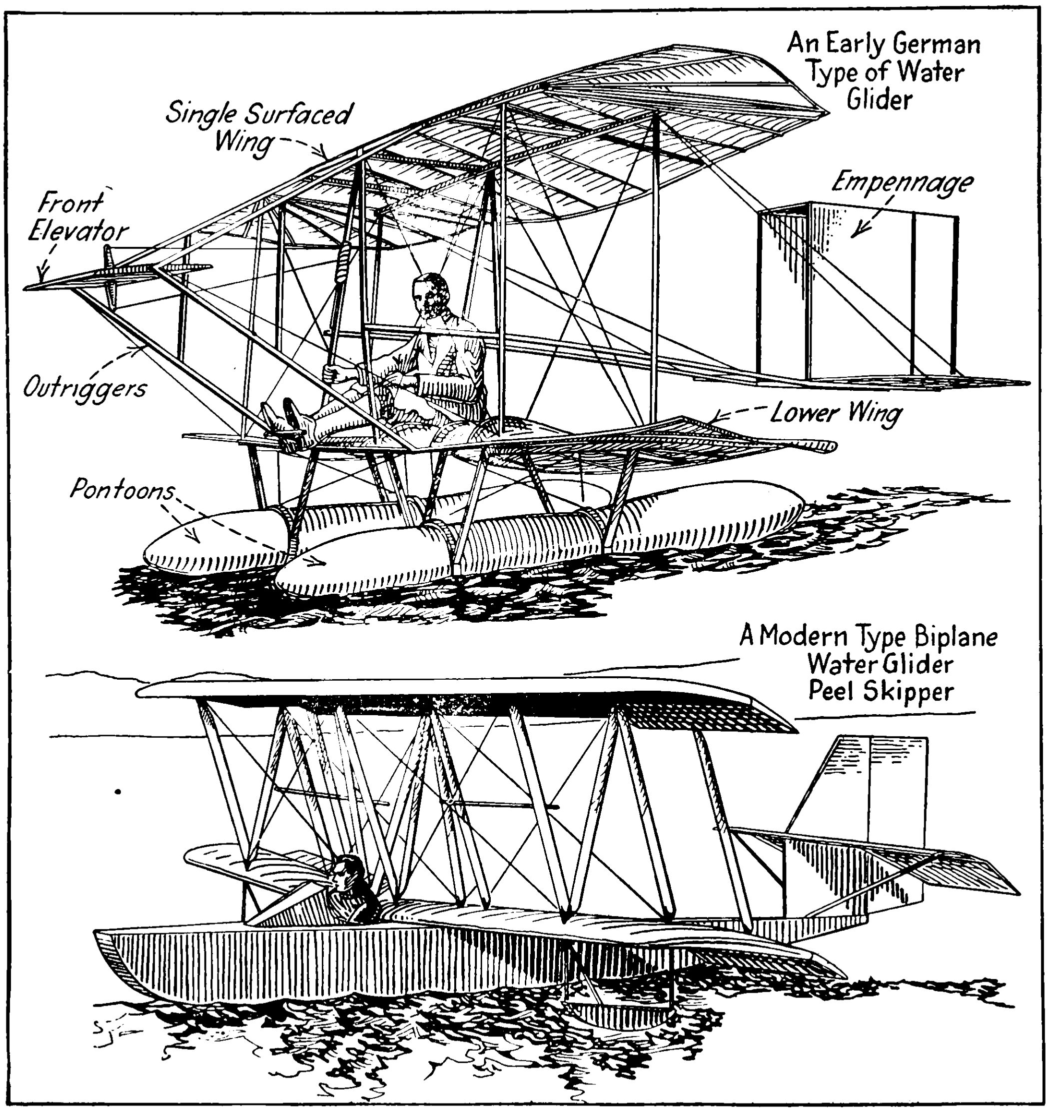


Fig. 38.—Diagrams Showing Biplane Water Gliders of Early and Modern German Design.

free flight is as maneuverable as a power plane as large control surfaces afford a quick response even at moderate flying speeds. Another advantage claimed over land gliders is that no shock cord catapult is needed for launching and there is no need of finding slopes on which to launch it as it can be operated where-ever a boat can go. (Editor's Note: A high speed boat is used for towing the glider so it can fly, so this supposed advantage becomes rather doubtful where funds are limited.) The gliding ratio is given as eighteen to one, which means that from an altitude of a thousand feet it is capable of gliding a distance of over three miles.

SPECIFICATIONS, PEEL GLIDER BOAT

Manufactured by Peel Glider Boat Corporation, Fifth Ave. and 10th St., College Point, L. I., N. Y.

Type: Secondary, 2-place, flying boat, biplane.

Dimensions: Length overall, 22 ft. Height overall, 7 ft. Span, 31 ft. Chord, 54 in.

Areas: Wing (incl. ailerons), 270 sq. ft. Ailerons, 30 sq. ft. Rudder, 8 sq. ft. Fin, 6 sq. ft. Stabilizer, 22 sq. ft. Elevator, 19 sq. ft.

Weights: Empty, 250 lbs. Gross weight, 600 lbs. Wing loading, 2.2 lbs.

Performance: Gliding angle, 15 to 1. Landing speed, 19 m.p.h.

Construction: Hull, duralumin all-metal. Wings, braced, wood spars, steel ribs, linen covered.

Equipment: Dual controls; special equipment.

Price (at factory): $595.

REMARKS: Glider has been towed off water by motor boat to an altitude of 1,000 ft.

THE LAWRENCE BIPLANE WATER GLIDER

The Lawrence biplane water glider, described in *Modern Mechanics and Inventions* for April, 1930, and shown at Fig. 39, is a simple machine that can be built by any one capable of constructing a land glider. The single step pontoon is built of wood

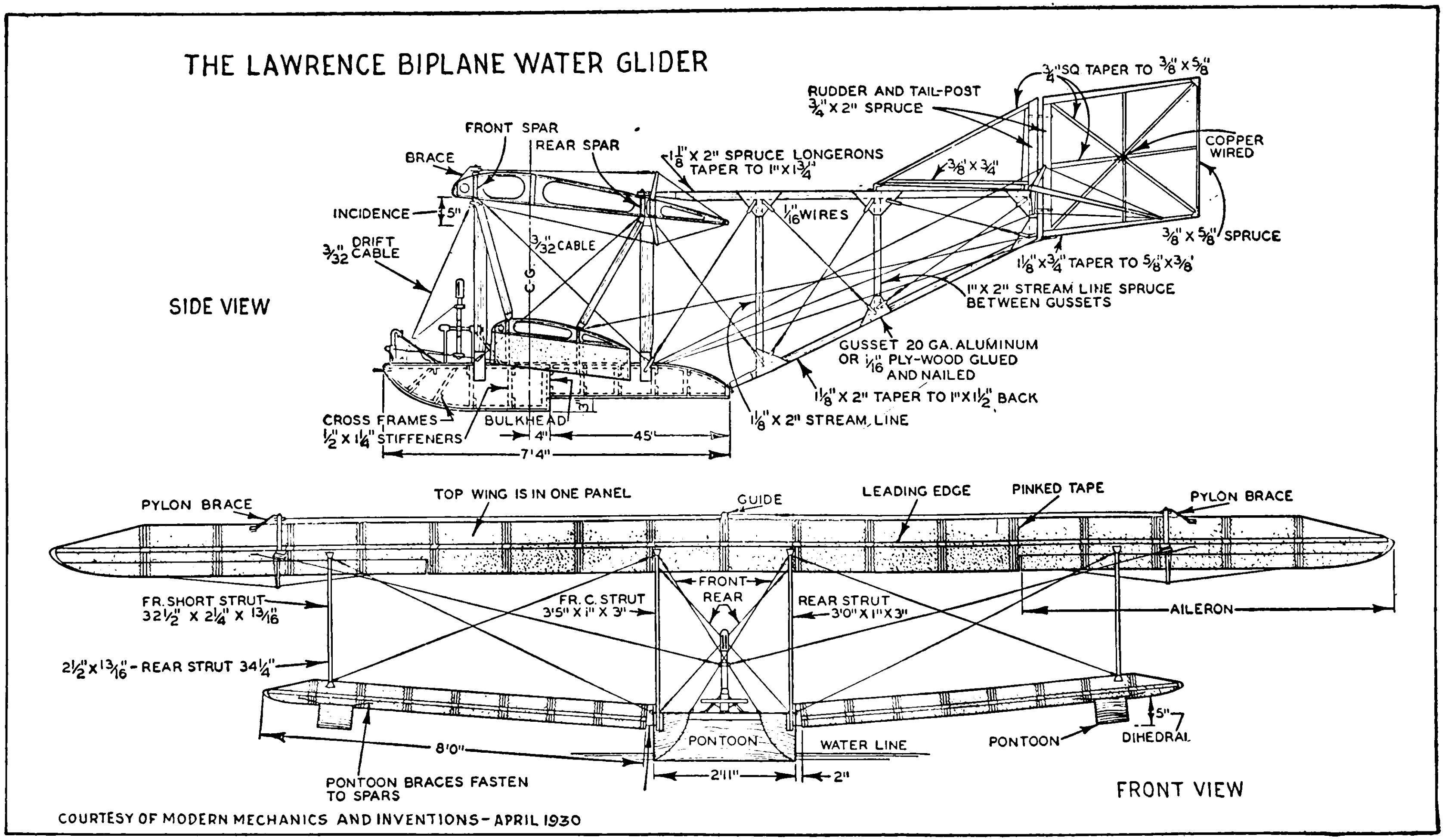


Fig. 39.—Side and Direct Front Views of Lawrence Biplane Water Glider Having Pilot Seated on Single Central Pontoon or Single Step Float. Outrigger for Carrying Controls Similar in Construction to Fuselage of Primary Training Land Glider.

and covered with doped linen to make it water tight. The wings are the usual glider construction and wing tip floats are provided on the lower wings which have considerable dihedral. The empennage is supported by an outrigger corresponding to the rear end of the fuselage of the usual primary training glider and control is by a single stick.

The pilot sits on the deck of the main float, a seat being provided for the purpose on the center of gravity line of the glider. The wing spread of the upper wing is 28 feet, that of the lower wing is about 19 feet 6 inches, including the width of the pontoon. The float is 7 feet 4 inches long and 2 feet 11 inches wide, the step being placed 45 inches from the stern of the float. The wing chord is 6 feet for the upper wing and 3 feet for the lower wing. Some of the main details are clearly shown in the drawing at Fig. 39.

Powered Gliders.—There is some difference of opinion regarding the application of even small engines to gliders and sailplanes. It is hard to define the line between powered gliders and airplanes but most authorities concede that a lightly loaded glider fitted with a small motor and capable of only relatively low speeds has more of the characteristics of the glider than it has of the airplane. In Germany, sailplanes were provided with small engines so the pilot could go from one soaring area to another and keep in the air when there were no favoring air currents over terrain between two locations where soaring conditions were good. Another reason for fitting power was that it became possible for the skilled sailplaner or soaring pilot to get into air currents under cumulus clouds by means of the motor and after these air currents were reached, to shut off the engine and soar. The engine takes the place of the wing flapping that we have seen permits soaring birds to seek favorable air currents. Low-powered engines are used so the load supported by the wing is not over 3 or 4 pounds per square foot. Modified motorcycle engines, such as the Henderson, have made it possible to fly powered gliders at speeds between 45 and 50 miles per hour. The big Harley Davidson or Indian Motorcycle engines or in fact any engine of 70 inches cubic displacement will fly a powered glider.

A typical powered glider, the Crawford, greatly resembles a training glider. It has a wing span of 40 feet and a wing chord of 5 feet with a wing area of 200 square feet. It weighs but 400 pounds complete with a Henderson 4-cylinder motor. The motor is carried in front of the pilot, directly over the skid and drives a two-blade aërial propeller 5 feet 10 inches in diameter by 5-foot pitch through a chain and sprocket reduction of 2 to 1, *i.e.*, the air screw turns at half the motor speed. Crawford gliders have been fitted with Szekely 40 horse power engines, have climbed to 11,000 feet altitude and attained speeds of 60 miles per hour. It is stated that powered gliders get into the air quickly and land more slowly than airplanes do.

There can be no question in the minds of most people familiar with gliding about the relative safety of powered gliders and non-powered gliders. Beginners can best get the feel of the air by using the simplest and lightest form of glider even though the services of a launching crew is required to get them into the air. After they become proficient and are able to control the simple PT type in the air, then they can go to motored gliders and undoubtedly fit themselves for flying airplanes by a carefully worked out course of instructions with the power-fitted glider.

Powered gliders can take off without the aid of a launching crew if provided with power enough and considerable experience in controlling can be obtained by taxiing on smooth level ground and making long flights just a few inches from the ground, under which conditions all control is by the air controls. It is claimed by the operator of a pioneer powered glider school that students are taught to "solo" in about one hour to the point where they can make turns and figure eights. It is stated that turns can be made at relatively low altitudes because it is not necessary to bank a slow flying glider as much as one must bank a high speed airplane and the danger of side slip or going into a spin is very much less with powered gliders than with powered airplane, which features should make them valuable for training powered airplane pilots.

Combination Primary and Secondary Training Sailplane.—A combination sailplane which may be used for ground training, primary and secondary gliding, and for soaring, and which may be converted into a power plane and an amphibian glider, is now being manufactured by the Bowlus Sailplane Co., Ltd., of San Diego. Convinced of the utility of the combination sailplane, the Bowlus company has discontinued the manufacture of primary gliders and is centering its efforts on sailplane manufacture, according to R. E. Pollock, general manager.

By replacing the 14-foot center section with a 2-foot section and removing the wings, the machine may be towed along the ground while the student learns the manipulation of rudder and elevators. Going into the primary glider stage, the 2-foot center section is retained and the wings are attached, the special 2-foot center section giving them a dihedral of 5 degrees. This practically removes the necessity of ailerons, it is said. The landing gear is retained for towing. For use as a secondary glider the 2-foot center section is replaced by the 14-foot section and the wings are attached with the dihedral removed. The wheels are retained.

In making a soarer of the sailplane the large center section and wings compose the regular 60-foot span of a Bowlus sailplane and the wheels are removed so that it may be launched with a shock cord. The sailplane may be converted into a hydroglider by the use of a canvas boot made to fit over the fuselage. This boot is equipped with a skid, so that the sailplane may be landed on water or land. The sailplane is designed so that an engine can be installed at a cost of about $200.

One great advantage claimed for the combination sailplane is that the student uses the same set of controls and the same cockpit from the beginning of his primary training to the time when he becomes a licensed soaring pilot. Moreover, by taking primary training in a cockpit such as provided by the Bowlus sailplane the student is, from the first, taught to watch the horizon and not to look at the ground.

The combination sailplane has the same specifications as the former Bowlus sailplane. The wings are each 18 feet long; each wing tip aileron measures 5 feet. The 14-foot center section fitted when the plane becomes a soarer makes the total span 60 feet. Substitution of the 2-foot center section with its 5 degrees dihedral, in place of the 14-foot center section, when the plane is converted into a primary glider, gives it a 48-foot spread.

The fuselage is 21 feet 3 inches long. The complete sailplane weighs 350 pounds. Removing the landing gear may be done by extracting six bolts. The landing wheels are equipped with 13-inch by 5-inch glider balloon tires.

The price of the new combination sailplane is $1,095 complete at the factory. Bowlus officials say that this combination cuts about 40 per cent from the investment necessary to purchase both a primary glider and a sailplane bought separately.

CHAPTER SEVEN

GLIDING AND SOARING TERRAIN

Gliding and Soaring Flights—Definition of Sailflying—Static and Dynamic Sailflying—Ascending Wind Currents Necessary for Sailflying—Factors Limiting Sailflying—Gliding and Soaring Terrain—Balanced Balloon to Find Rising Air Currents—Use of Smoke Clouds—The Wind Zone.

Gliding and Soaring Flights.—There are two kinds of flights possible in gliders. One is plain gliding. This consists of getting up in the air by some means and coasting down. This is best done from a hill. However good the glider, such a flight can not last long. At best, gliding is but preparation for the more advanced type of flying known as soaring. A soaring flight may last for hours. But this takes untiring practice, favorable terrain, and good winds, besides requiring a suitable ship.

We have learned that there are four general types of gliders recognized; the primary training, the secondary training, the utility and the soaring ship or sailplane. The primary glider is a simple glider of small span, and has an open fuselage. It has a fairly light wing loading (one and a half to two and a half pounds per square foot of surface, including weight of pilot). It is designed for one thing only, elementary gliding. It is sturdy and easily handled. The construction is not refined to any great extent, as high performance is not especially desired.

The secondary training glider is about the same size as the primary glider. The wing may be somewhat longer and narrower. The fuselage is enclosed instead of open. The wings are braced by wires or struts as in the primary glider. This type of machine is less sturdy than the primary training type, and is meant to give the student practice and some soaring experience. It flies decidedly better than the primary type. The construction of this type is not nearly as standardized as that of the primary training type.

Soaring is mostly done in three types of ships. The Darmstadt type of sailplane previously described and illustrated is a glider with a long, narrow, tapering wing. The wing is sometimes over fifteen times as long as it is wide. This wing is entirely self-supporting, no external struts or wires being used. The fuselage is narrow and carefully streamlined to offer the least resistance to air. The tail surfaces are likewise self-supporting or cantilever. Such a craft is usually constructed very sturdily for a glider, weighing around two hundred pounds, and the wing loading with pilot is sometimes more than two pounds a square foot. The span is from fifty to sixty feet. Such a sailplane, in spite of its speed of around forty miles an hour, will descend at a rate of less than two feet per second, and, due to the careful streamlining it will glide fifteen to twenty feet for each foot of altitude lost, if carefully piloted.

The United States is the mother country of modern sailflying flight, for it was no less a person than Orville Wright who succeeded in 1901 at Kitty Hawk in making the first pure sailing flight of nearly ten minutes' duration. However, the experiments of the Wrights found no disciples and the real development and the systematic building of the sailflying movement remained reserved for Germany, whose hands were of course tied in respect to the development of motored airplanes by the peace treaty of Versailles after the World War.

Mr. Alfred Gymnich, in a series of articles which appeared in *Popular Aviation* has outlined the entire subject of sailplane construction and operation in an authoritative manner, especially as the data are based on German experience. This authority defines sailflying as distinct from gliding, though the latter term is generally employed in English-speaking countries in describing flights without power. To be technical in our definition, "Sailflying is maintained flight without loss of altitude, while gliding involves a loss of altitude." For example, an airplane "glides" in for a landing as it describes a flight path at an angle with the ground. A sailplane that remains in the air by upward swoops as well as downward glides cannot properly be said to "glide" nor can it be called a "glider" with strict regard for accuracy.

Definition of Sailflying.—Mr. Gymnich says: "By sailflying we understand a flight without any kind of motor or other driving power in which the energy required for the flight without loss in altitude, is taken solely from the air currents. This distinguishes static and dynamic sailflying. Static sailflying is limited to the landscape, that is, dependent on it, whereas the latter, or dynamic sailflying, is based on the utilization of the inner energy of the wind, among which are turbulent air currents, inversion layers and the like. Static sailing flight is based upon the utilization of thermic ascending winds, as they are conditioned by the differences in the condition of the landscape, and upon the utilization of slope winds. It has not as yet been proved that man has achieved actual dynamic sailing flight, and it is difficult to prove sailing flight in ascending thermic air currents. All great sailing flight achievements have been made in slope winds. For that reason we will concern ourselves only with static sailing flight and will analyze first of all the cause of the upward directed slope winds and their utilization, for human sailing flight."

Static and Dynamic Sailflying.—Flying with sailplanes is being differentiated by common acceptance into two types: the sailing in ascending air currents or static, and the dynamic where the glider descends into the slope wind or is towed into the wind. In ascending air currents the air rises, thereby exerting a lifting power. Since the ascending air currents are many, but small, the sailplane should be designed for a minimum falling speed, so that it will be possible to carry on static flying, that is, non-accelerated flying, which permits carrying out endurance records. This kind of static flying in utilizing the ascending air currents, may be observed in birds. No definite or predetermined direction can be followed by the glider in such a flight. Dynamic sailflying, according to popular understanding, includes flights made in slope winds, though Gymnich gives a more technical and narrower interpretation to the term in the preceding paragraph.

It is very important for the glider sportsman to know where the ascending currents occur, how strong they are, how they can be recognized and utilized. Thus far it has been found that about the only air currents that can be utilized in gliding are those on the windward side of the mountain where an ascending air current naturally exists. Therefore most of the sailflying has been done above the mountain and sand dune slopes. The altitude and the horizontal extent of the ascending air currents naturally differs with the territory and with the characteristics and source of the wind. There are vertical friction movements in the air and these are caused by the descent of air made necessary by ascending air currents. The decrease in friction experienced with air currents when passing above rivers or lakes, results in a descending air current which may be observed at greater altitudes by the dissolution of clouds above lakes and rivers. This opposing friction is especially strong between land and sea. Winds passing from the sea to the land, slow down due to increased friction, so that more wind flows towards the coast than passes into the land, thereby the wind stalls and as a result moves upwards. This effect may be called ascending friction wind or dynamic ascending wind.

Ascending Wind Currents Necessary for Sailflying.—The wind which blows against an obstruction is forced by the resistance of the air, or its power to persist, and by the air which flows after it, to escape either to the sides or upwards. Since the air current always flows naturally in the direction of least resistance it will pass the cone of a mountain, for example, to the side, but in the case of a long extended hill range, it will pass over it, due to the greater resistance at the sides. In other words, the wind adjusts itself to the contour of the landscape as shown at A and B, in Fig. 20.

This ascending air current, which is defined as a slope current, forms the source of energy for sailing flight. The extent of the upward component or the upward force, of this slope wind depends upon the strength of the wind and upon the contour of the landscape. In order to make sailing flight possible, and to achieve a flight without loss of altitude, the upward component must at least be proportional to the sinking speed of the sailplane in quiet air. That is: the wind must flow, in a given unit of time, the same distance upward the sailplane would fall. As the wind is greater than the sinking speed of the sailplane this energy can be utilized for ascending by means of making the correct changes in steering and control.

Factors Limiting Sailflying.—The flight of a sailplane in a slope wind is shown schematically at C in the illustration, Fig. 20, presented in an earlier chapter. The drawing conveys proof, with little difficulty, of the fact that the upward component of the wind is, in a given case, greater than the sinking speed of the plane; so consequently we have a flight without loss of altitude; and thus a gain in altitude is possible. As long as the sailplane remains within the range of this ascending slope wind it cannot sink, provided it is not pressed towards the ground by the flyer in operating the controls. The reader can readily see that the duration of a sail flight is limited merely by the wind conditions and the physical endurance of the flyer himself. It makes no radical difference what way the pilot utilizes the slope wind for a duration flight. With grades that are high, from an aërodynamic standpoint, and with speedy and flexible planes, the pilot will, as a rule, describe circular or elliptical courses within the zone of the ascending winds. (See Fig. 40.)

Regarding the construction of sailplanes, a few general facts must be understood at the start. It might appear to the casual observer that a sailplane differs from a motored plane merely by the absence of motor weight. This is not the case, and even though a few sailplanes are merely imitations of motored planes, and even though sailing flights have been made, under especially favorable conditions, in normal motored planes with the motors stopped, there are essential differences between the two. In the

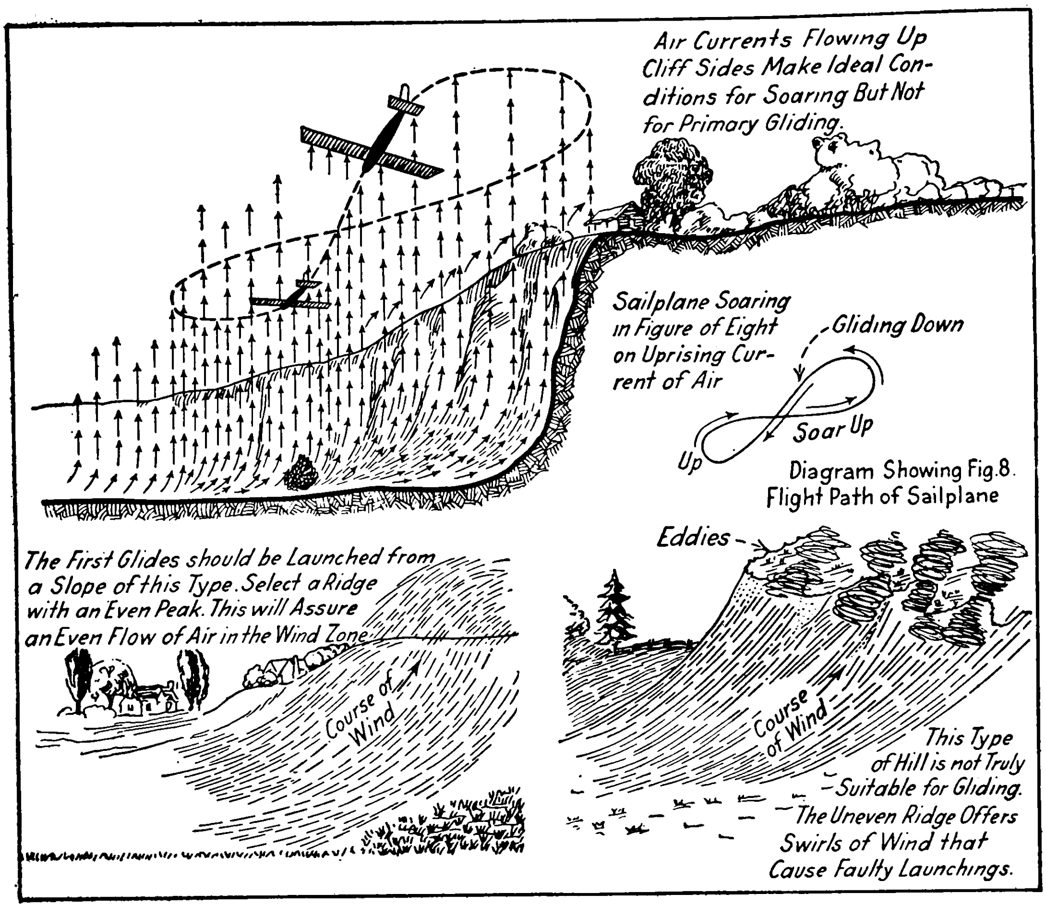


Fig. 40.—Diagrams Showing Types of Hills That Are Suitable to Produce Air Currents for Gliding and Soaring. Hill with Irregular Configuration at the Top Produces Eddy Currents Which May Result in Faulty Launchings.

course of time experimental developments have shown the necessity and advisability of deviating from motor plane construction in the fabrication of either sailplanes or simple gliders.

Gliding and Soaring Terrain.—The location of a site on which gliding operations are to be carried out should be along the face of a hill or bluff which faces the prevailing wind and over which the prevailing wind must rise, thus creating an upward current which may extend several hundred feet above ground; however, the bluff should have a slope that is not too steep because there will be eddy currents if the face of the cliff or bank is precipitous.

In addition to this the ground along the base of the hill should be sufficiently level to permit the pilot of a powerless machine to make a landing without endangering either himself or the glider. The ideal location would be along the face of the hill or bluff, which has a fairly smooth side hill or gully running into it and a level field along the bottom. The machines could then be turned along the face of the hill so that they would receive the full benefit of the rising current along its face for its entire length. (See Fig. 40.)

A good gliding and sailflying territory includes mountains or hills of the proper configuration and of suitable height, favorable winds, smooth ground for landing and various desirable facilities for establishing a summer camp. Experts prefer a mountain territory rising quite vertically from the valley and which recedes uniformly towards the directions of suitable winds, without foothills to alter the air currents. The probability of wind velocities of 20 to 39 feet per second should be at least 50 per cent and certain directions of wind should predominate. The sub-soil should not be rocky but should have large spots covered with humus earth and grass sod to permit starting and landing; small patches of woods do not interfere as a rule. The territory should be easily accessible for traveling and offer tourist conveniences and plenty of accommodations should be available in the vicinity at reasonable prices.

Successful glides depend on the pilot's knowledge of air currents. Hills make good starting points because there is usually an ascending column of air on one side. Any change in the terrain below, as free balloon pilots long ago have learned by experience, means a change in air current aloft. Passing from smooth ground to rough, from open country to a forest, or *vice versa,* from overland to water, all can be utilized by a clever pilot to get more altitude by facing his ship into the rising wind so that the lift exceeds the normal loss of altitude in a glide. As altitude is attained, the ability to stay up longer grows, for air currents are more pronounced and the wind blows harder, as a rule, at greater heights.

For simple gliding, low rolling hills with knolls facing all directions and free of obstructions are ideal. The hills should be from 30 to 150 feet in height. For beginners, only gentle slopes should be used. The slopes should face all directions because gliders should take off directly into the wind and if the slopes face all directions, the terrain can be used with any wind. If that is impossible, slopes facing the prevailing wind should be secured.

It is more difficult to find suitable soaring terrain than it is to locate good gliding ground. In this case, a ridge or chain of hills is preferable to lone peaks. The wind sweeping across the valleys is deflected upward when it reaches the ridge. In the case of ridges, this zone of the up-wind is as wide as the ridge is long and offers greater opportunities for flying figure eights back and forth in duration attempts (Fig. 40). As soaring pilots are of greater experience, steeper slopes with more obstructions can be used. The ridge should face the prevailing wind to get maximum number of flying hours. Wind blowing in off a large body of water has a tendency to deflect upward when reaching the land even where there are no ridges or hills. Therefore it has been found that lower ridges can be used along such bodies of water than is the case inland.

Balanced Balloon to Find Rising Air Currents.—Various methods may be employed to determine the height and speed of

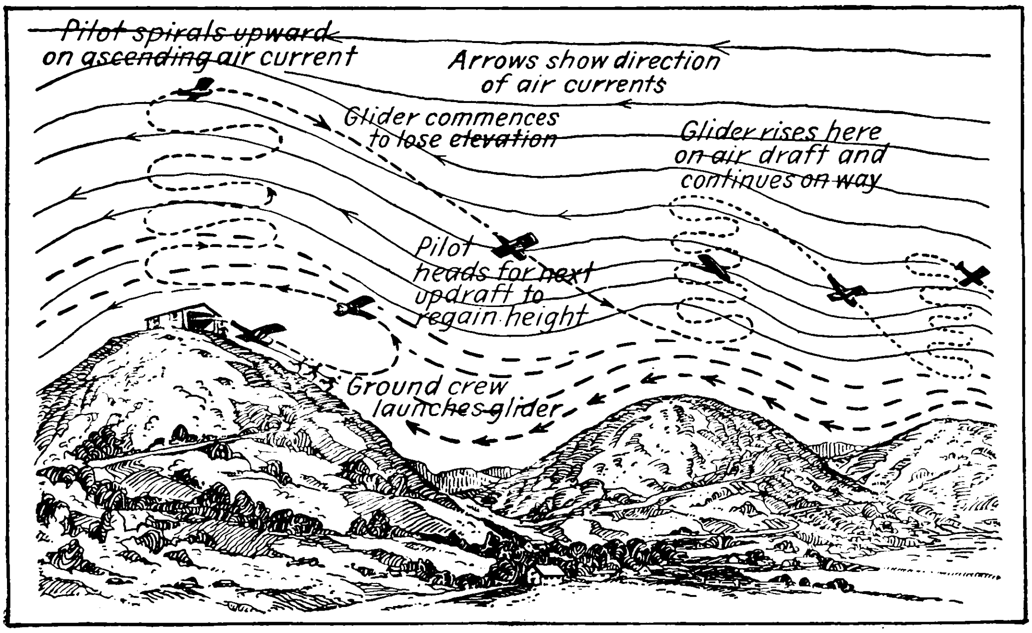


Fig. 41.—Diagram Showing How a Skilled Sailplane Pilot May Soar for Long Distances Over a Range of Hills. On the Windward Side of Each Hill Is an Ascending Current of Air. The Pilot Rises on One Updraft and Glides Down to the Next Updraft Where He Again Gains Elevation.

rising currents, but the simplest and cheapest is through the use of a balanced gas balloon. The equipment required in these experiments may be purchased for a trifling sum. The balloon may be an ordinary rubber toy affair purchased at the five and ten cent store. It is charged with hydrogen. A wide-mouthed bottle with fairly thick walls is partially filled with water into which pieces of scrap zinc are thrown. Hydrochloric acid is poured over the whole and a tight cork is placed in the mouth of the bottle through which a glass tube is passed with the lower end of the tube well above the surface of the liquid. Over the upper end of the glass tube the inflation tube of the balloon is placed, after all the air has been emptied from the bag. The pressure of the gas generated in the bottle will inflate the balloon. On the nipple of the balloon a small silk bag is tied with thread and into it lead or iron filings are poured until the balloon will hang motionless in still air. Should the balloon have a very slight downward tendency, no great harm will be done.

The balloon, after it has been balanced, is launched into the air along the face of the cliff or hill, and if a rising current exists, is carried upward to a point where the current becomes ineffective when it will be blown sharply over in the direction of the wind and may commence to come down due to leaking of gas through the pores of the rubber.

The height of the balloon at the top of its rise may be worked out very simply if two sights are taken on it from points whose distance one from the other is known. Readings should be taken from both points with surveyors' transits which may be borrowed for the occasion. Care should be taken to see that the transit is level and the reading on the vertical scale should be recorded from each point. A triangle should then be plotted from data obtained with the base drawn to a definite scale. The height of the balloon above the ground will then be the perpendicular from the apex to the base, which should be measured on the drawing and corrected according to the scale on which the drawing is made, or the whole thing may be worked out trigonometrically.

Just as it is important to know over what spots upward currents are found so it is to know where the downward currents or "pockets" as they are sometimes called, are located. Every effort should be made to find these spots which should be marked on a map and studied so that they may be avoided.

In the preliminary work of establishing a gliding center cooperation is necessary, just as it is necessary after actual operations have commenced. It is advisable also that those interested in gliding pool their funds so that they may collectively possess the best possible equipment. The interested parties may then assist one another in building and repairing machines and in launching them.

Use of Smoke Clouds.—A study of the air currents can be made by means of smoke cloud, as follows:

Use white phosphorus. This can be had at any wholesale drug house and many retail drug stores. Phosphorus comes packed in cans and is covered with water. It is in sticks about the size of a lead pencil. Care must be used in handling it, as it takes fire as soon as taken out of the water. Take it from the can with a pair of pliers or tweezers and drop it into a pan. It will give off a dense white cloud, and by watching the cloud you can get a good idea of the action of the wind currents. If it does not take fire at once, use a match. Another method is to make a fire of sticks and put in oily waste to make a black smudge or smoke that will indicate wind direction.

The Wind Zone.—In order to rise with any motorless aircraft it is necessary to make use of air currents which move vertically because these winds are themselves rising and are capable of exerting a lifting force upon a flat body, in this case, the wings of the soaring machine. For this reason some authorities believe the ideal spot for gliding is a hill of normal slope well cleared of trees and underbrush and facing into the wind. The air currents sweeping along the ground are deflected upward upon striking the foot of the hill, proceed up the slope and then pass down the hill on the opposite, or leeward side. These air currents passing up the hill form what is called the wind zone, and this wind zone is said to extend into the air for a distance of about twice the height of the hill. For the very best results gliding should be done from the side of a ridge because the wind zone is evenly distributed along the slope and does not form a funnel-shaped mass of air currents as is often the case when a breeze moves up a conically shaped hill.

Upon starting a flight of any duration the machine is carried up the side of a hill and faced into the wind, and the pilot takes his place on the seat and fastens himself in with a safety belt. To a hook on the front end of the fuselage is fastened a long rubberized cable which is pulled taut at an angle of about 30 degrees from a line projected straight in front of the craft, thus forming a huge V. Other members of the ground crew hold the soarer while these ropes are pulled. The men with the ropes start forward at the pilot's command "Walk!" and just as the cables are becoming taut the pilot shouts "Run!" and almost immediately "Let go!" The result is that the machine is catapulted into the air with great force, the cables fall out of the hook and the glider is free.

The air currents coming up the hill take hold of the wings of the little craft and buoy it upward. The skillful pilot allows himself to be carried high above the hill by the force of the upwind and does not glide into the valley. A number of very expert pilots are able to ascend to a moving cloud where they take advantage of the air currents which curl up in front of it. They ride these currents and move across the valley on the leeward side of the hill they started from. Here they descend into the wind zone of the second hill where they allow themselves to be borne upward again until they are able to attach themselves to another cloud going over the second valley. By repeating this process great distances may be traveled. An expert in Germany recently soared for a distance of 42 miles and another was known to attach himself to a storm cloud and ride with it for thirty-odd miles. (See Fig. 41.)

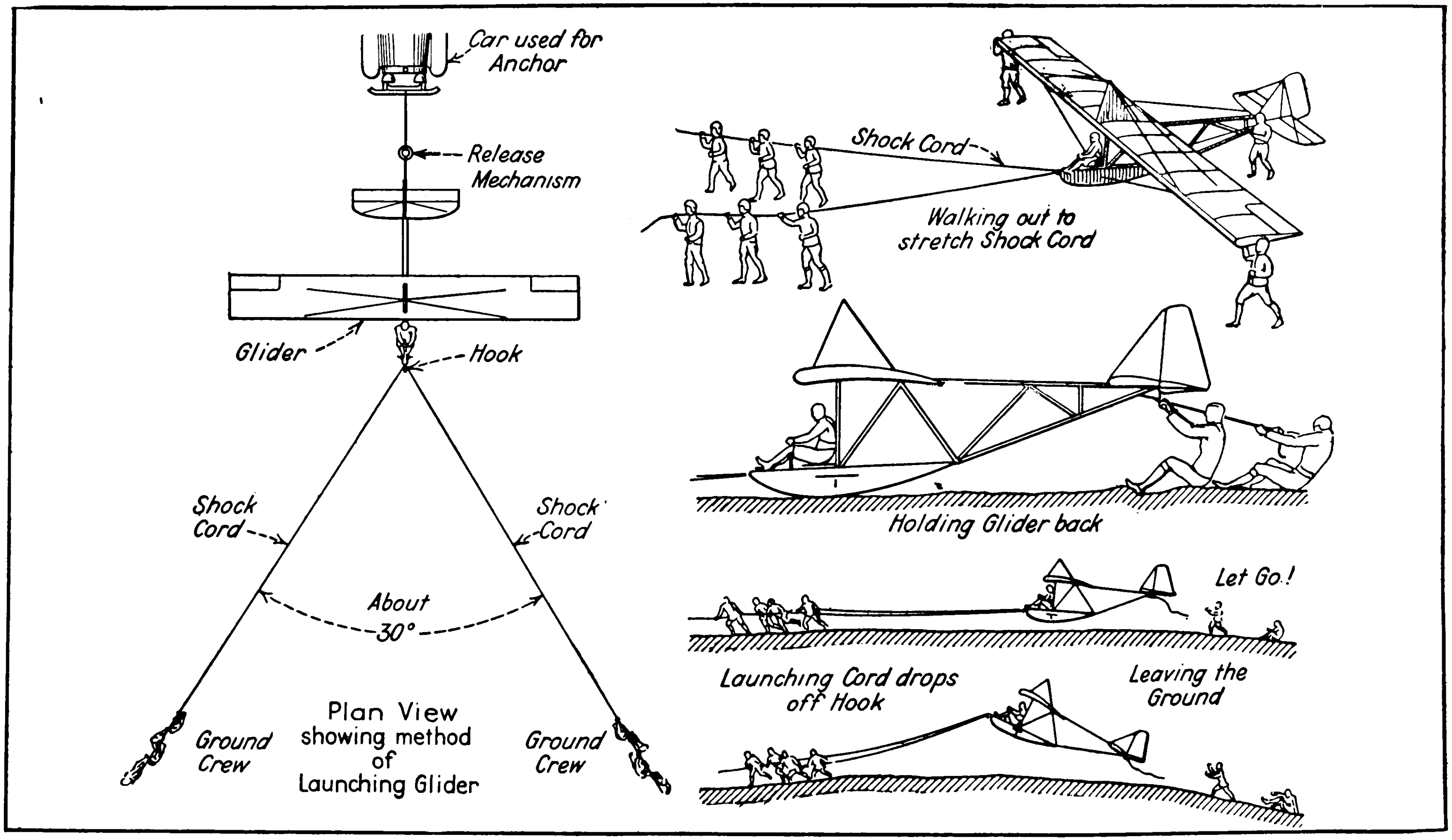


Fig. 42.—Diagrams Showing Method of Launching Primary Training Type Glider by Shock Cord Catapult. Note That Glider May Be Anchored by an Automatic Release Mechanism or a Manual Release Controlled by the Pilot to an Automobile or Other Heavy Object or the Glider May Be Held by Members of the Launching Crew.

CHAPTER EIGHT

TRAINING GLIDER AND SAILPLANE PILOTS

Launching and Flying the Catapulted Glider—Method of Training Sailplane and Glider Pilots—Student Sits in the Open—Soaring—Primary Instruction with Towed Glider—Notes on Towing Gliders—Should a Club Build a Glider?—An Automatic Glider Release.

Launching and Flying the Catapulted Glider.—All persons taking up gliding for the first time should use the Primary Training Glider (PTG), the Secondary ship (STG) or the utility glider. Learning to glide is both an extremely simple and safe procedure providing that instructions given are painstakingly followed. *Gliding by novices who do not follow instructions can be as dangerous as any other reckless flying.* Experience has taught the National Glider Association that any motored pilot **who is willing to follow instructions** can soon fly a glider and also teach his fellow club members to do so. The great difficulty is that they usually expect to do too much at first. A simple glide down hill of eight seconds' duration, is to the beginner, regardless of how many hours he may have had in a motored ship, quite a thrilling experience.

Persons without any flying experience at all should take their first "hop" on level ground or off a very low hill. The glider is pointed directly into the wind. There should be no obstructions ahead for at least two hundred yards although the beginner will not go in all probability a third that distance. There should be a ground crew of from eight to ten persons divided into three sections. Two sections of not less than three men each should be assigned to handle the launching cord. This is a rubberized cable. In the center is a metal loop. This fastens on a hook in the nose of the glider. When the rope is tight it stays on. When the tension relaxes, it falls off.

The modern glider is equipped with standard airplane controls. The pilot takes his seat and is fastened to the glider with a safety belt. (See Figs. 33 and 35.) One man gently holds the tip of the wing to keep the glider in balance. (It is usually equipped with a single runner for landing gear, not the standard wheels of an airplane.) Others take hold of a rope fastened to the tail of the ship. The crew on the launching rope take position so that the rope itself forms a "V" with the point of the angle at the nose of the ship. Care should be taken to instruct the ground crews to walk off together and stay together in order that the glider may not be thrown right or left on the take-off. (See Fig. 42.)

The pilot or his coach, if he is a beginner, commands, "Ready, Walk," and in the case of beginners, the crew walks out ten paces; then "Run," and the crew runs ten paces; "Turn Loose," and the crew at the tail do so and the glider "takes the air," the mechanics of the operation being similar to the projecting of a pebble in a boy's sling shot. Beginners should not be launched in a wind of greater than fifteen miles per hour velocity. It is to be expected that green pilots will frequently break some "ribs" in the glider or otherwise injure it. As the pilot shows progress, he is allowed to take the ship further up the slope and gradually becomes a master of the simpler phases of the sport.

The proper equipment consists of a shock cord or rubber rope ⅞ inches in diameter and 100 to 150 feet long, or ½ inch in diameter and 200 or more feet long. This should have a steel ring in the center to fit into the launching hook on glider. (See Fig. 43.) A galvanized wire rope thimble will serve. If the

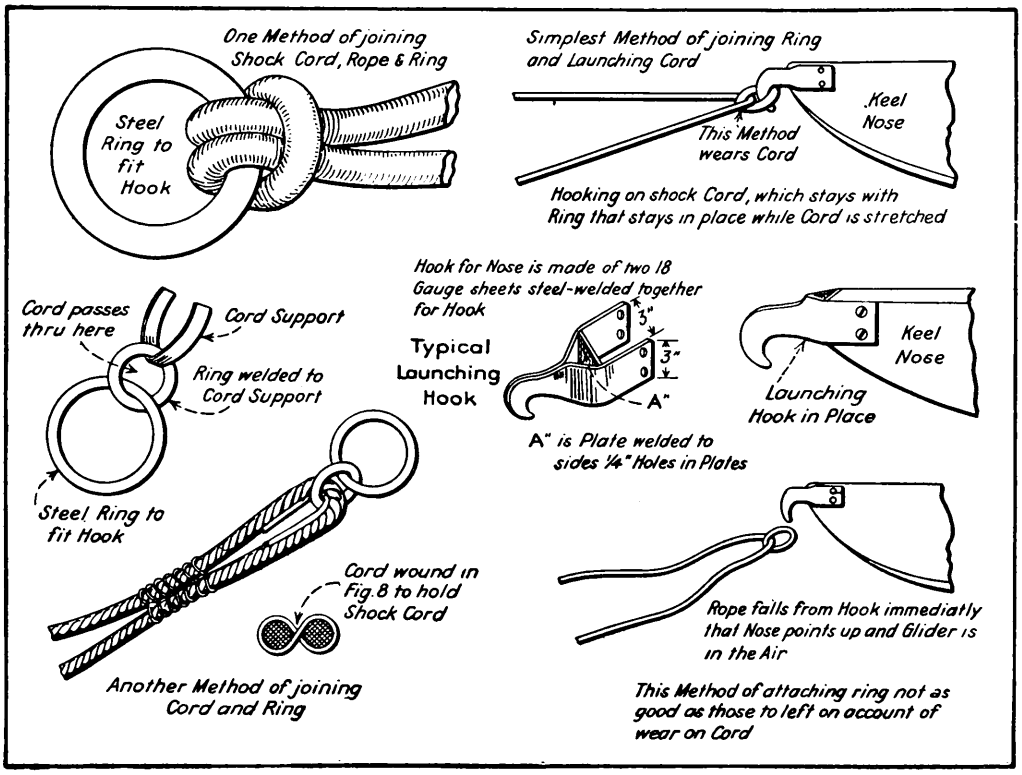


Fig. 43.—Diagrams Illustrating Construction of Launching Hook and Methods of Securing Ring to Shock Cord to Prevent Abrasion of the Cord.

ground is sandy, soft or rocky, a track should be constructed for the skid. A strip of wood four inches wide with side rails makes a satisfactory track. Cross strips, four inches apart, help to cut down the friction, and the take-off will be faster if this track is coated over with old crankcase oil or Albany grease.

A light two-wheel dolly is easily built and will simplify the hauling of the glider back to the starting point. It should be arranged so that the glider can be placed on the dolly with wings behind the tow car. The tail group can then be taken off if necessary and handled as a separate unit. The wings and fuselage can be handled without disassembling. The wing should reach to a point over the tow car so that it can be held by some one riding the running board.

Method of Training Sailplane and Glider Pilots.—In training glider pilots the student usually "solos" from the very start and in that way the instructor can learn the ability of his pupil and in no way endanger himself. (Passenger carrying gliders have been successfully flown.) As there is no engine, it is possible for the instructor to coach his pupil by calling to him from the ground. The primary training or school machines are constructed quite heavily, to endure the hard landings of the pupil and for that reason they are not so very efficient. They are gliders rather than soarers. At the beginning the pupil makes a number of short jumps to get acquainted with the controls and to the sudden acceleration when being catapulted into the air by a rubber rope fastened to the front of the plane. The machine usually picks up flying speed after being dragged over the ground for about 50 to 100 feet and then being catapulted. Should the pilot stall in the air, he can regain flying speed by a vertical drop of about 25 feet. The wing area is so large and the weight so low that the planes can fly at exceedingly low speeds.

Students Sits in Open.—The student usually sits in the open in an entirely unprotected position. This type of construction is claimed to lessen the liability of the pilot being injured in the event of a crash. Since the student has no visible reference for the position of the glider with respect to the horizon, he is obliged to learn to fly by feeling. The student usually begins by making a number of short jumps, merely take-offs and landings. The length of the jumps are gradually increased, the student starting at the base of a hill and progressing upward to the crest. This takes about 18 or 20 jumps in the school machine, before the student is ready for his first soaring flight in what is called a secondary training machine. Conventionally, these are high-winged monoplanes of somewhat higher aërodynamic efficiency than the school machines; they have a fuselage, faired struts, etc., as previously described.

After the student is thoroughly familiar with the machine, and has mastered the controls, he is then launched on a few short glides, or jumps of only a few seconds' duration over level ground. This is to get him accustomed to the feel of the craft in actual flight. Gradually the length of these glides is increased until finally the student is taken a slight distance up the side of a gentle slope and launched from that point. When he has accomplished a simple down hill glide of at least 30 seconds' duration he has passed the "A" test and is ready, after making two glides of 45 seconds' duration, to take the "B" test in which it is necessary to glide for at least one minute and make a right and left turn while doing so.

The final, or "C" test is much more difficult. It calls for a flight of at least five minutes above the starting point. To pass this test the student must use a machine known as a secondary glider or soarer. These gliders, or more properly "sailplanes," which is the name given high performance machines, are of remarkably high aërodynamic efficiency. They are extremely sensi-

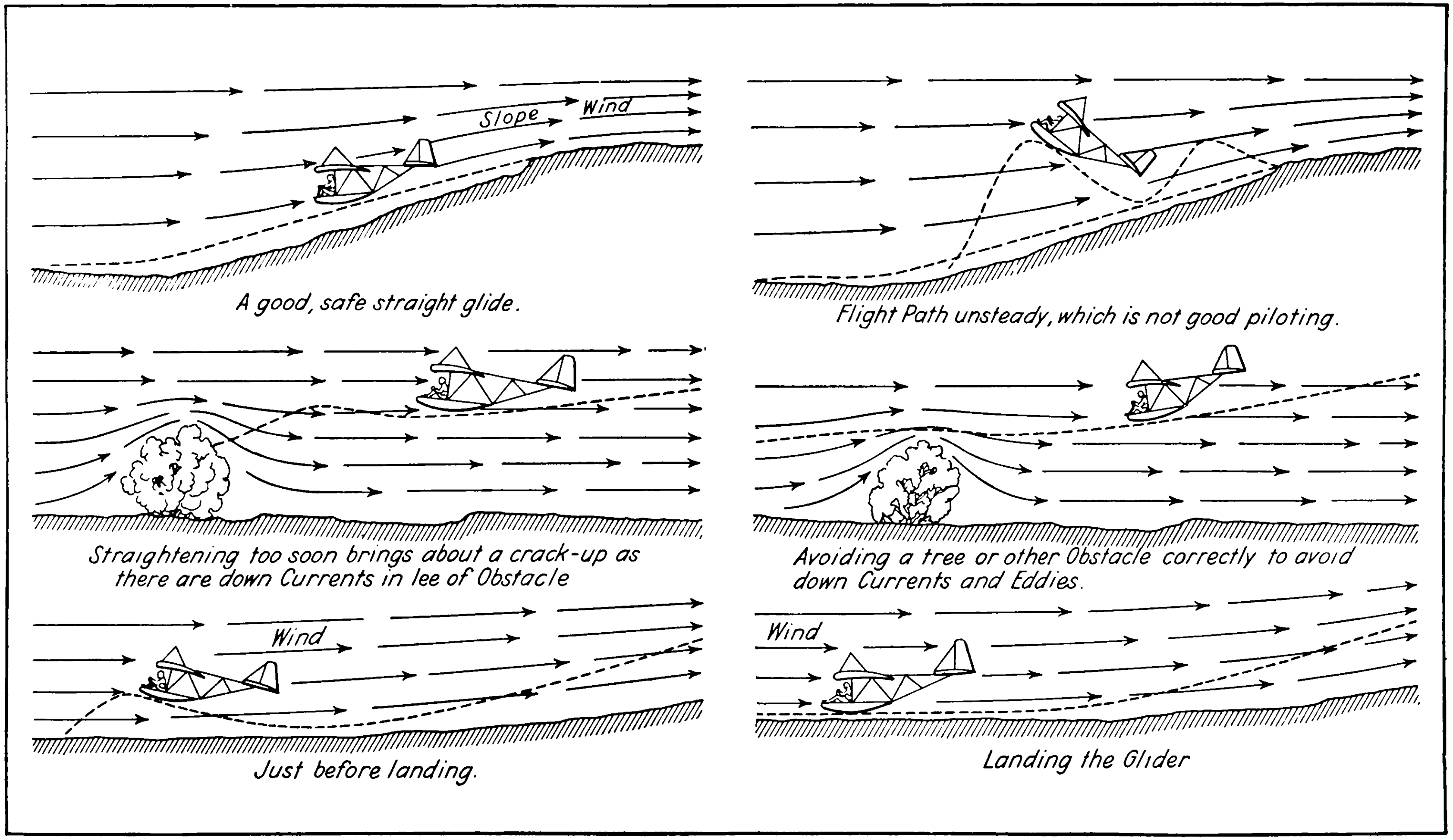


Fig. 44.—Diagrams Showing Various Phases of Glider Piloting. At the Top, Good and Safe and Unsteady, Unsafe Glides Are Compared. The Sketches at the Center of the Page Show Method of Glider Control to Pass Over Obstacle and Avoid Eddy Currents in the Lee of the Object. At the Bottom of the Page, the Correct Method of Landing the Glider Is Illustrated at the Right. It is Not Advisable to Stall Before Landing as Shown at the Left.

tive to the controls and have a large wing span with a high lift airfoil. It is claimed that some of these planes have a lift-drag ratio of 21 or 22, which is exceptionally high when, according to Mr. Mock, it is considered that theoretically, the limit of this ratio for a plane having a fuselage, rudder, etc., is said to be close to 31 or 32.

The one who builds his own machine, either from homemade plans or those furnished by some qualified glider engineer, should take a course of instruction, from a recognized glider school or work out his plans carefully before permitting himself to be launched from a hill into the air. The ground appears very far away to the novice, and unsettled conditions of mind contribute not a little to glider accidents that sometimes befall amateurs. If he proceeds sanely, no harm will come to him. If he cannot attend some recognized school or join some glider club having a competent instructor, the next best method is to take his glider to the top of a hill when there is a good wind blowing and there, the glider firmly staked down in the wind, work all his controls and learn how much they have to be moved to nose the ship up and down or restore lateral stability.

One of the most important things is that a beginner must be started below the top of the slope. Starting from down the slope in this way, the craft takes off at the proper gliding angle or approximately parallel to the slope. When launched from the top, the beginner will usually try to go straight off and will end in a stall. If the wind is more than three or four miles an hour he is caught in an updraft as he gets over the brow of the hill and the angle of attack increases. He is then carried up before he realizes it, gets into a stall, and generally makes a bad landing with damage to the glider. After the student has had sufficient practice on the slope he is launched off the top, where he can learn to take advantage of the updrafts.

Soaring.—Soaring, again, is a different matter. A pilot desiring to become proficient at soaring, is very foolish if he attempts to gain the necessary knowledge by himself from experience. If sufficiently clever and very patient, he might eventually get in some fair flights but the effort would be terrific and the progress painfully slow. Persons desiring to become soaring pilots, should have expert instruction, not only in how to fly the ship but in the fundamentals of meteorology as well. Plans are being developed for several such schools or institutes over the country and pilots desiring to take such courses should communicate with N. G. A. headquarters. In a well organized school and with the average student, the soaring course takes from 30 to 60 days. It is impossible at this time to estimate the cost of such instruction. It is known, however, that in addition to several special schools for soaring, that several of the standard aviation schools are considering putting in gliding and soaring as well.

How slight an upcurrent will sometimes keep a light soaring ship in the air was demonstrated recently in Ohio. The "Akron-Condor" soarer, with W. Klemperer, the famous sailplane pilot, formerly of Germany, at the controls, was being towed from Akron to Cleveland by one of the Goodyear blimps. Near Wallings Corner, the towrope parted while the glider was 700 feet up. In spite of its low altitude, it sailed for five miles and landed in a large field. The pilot had difficulty in landing because the heat currents rising from the ground caused the soarer to float nearly the entire length of the field at an altitude of only a few feet.

Primary Instructions With Towed Glider.—A writer in *Aëronautics* for April 1930, describes one method of teaching gliding in which the machine is towed by an automobile to give the student the feel of the air prior to launchings by any stretched shock cord or "Catapult" launchings. Of course, as there is no noisy motor as in an airplane, it is possible for the instructor to talk to the student in the glider. After hooking up the tow rope, an instructor sits on the back of the car, megaphone in hand, and directs the student while he learns to keep himself steady in the air as the car tows the glider. When a student first leaves the ground in a glider, even if for only three or four feet, he usually overcontrols and shoots the machine up into a stall or steers it suddenly away from its path. That is the reason why, in teaching students, it is well to have them practice constantly on the elevator and rudder until they can keep the ship level about a foot above the ground along a straight line in the full length of the course, or approximately a half mile.

Teaching gliding to enthusiastic boys and to more patient older men proves very interesting. An instructor reports he had a student a few months ago who was 55 years old. He had been interested in aviation for some years, but for the usual reasons never had learned to pilot a plane. Gliders appealed to him, however. On his fifteenth towed ride across the flying field he was taken into the air to an altitude of twenty-five feet, where suddenly the towing rope was released. He landed gracefully without any help. The average student in a powered airplane seldom can make a landing unaided on his fifteenth flight.

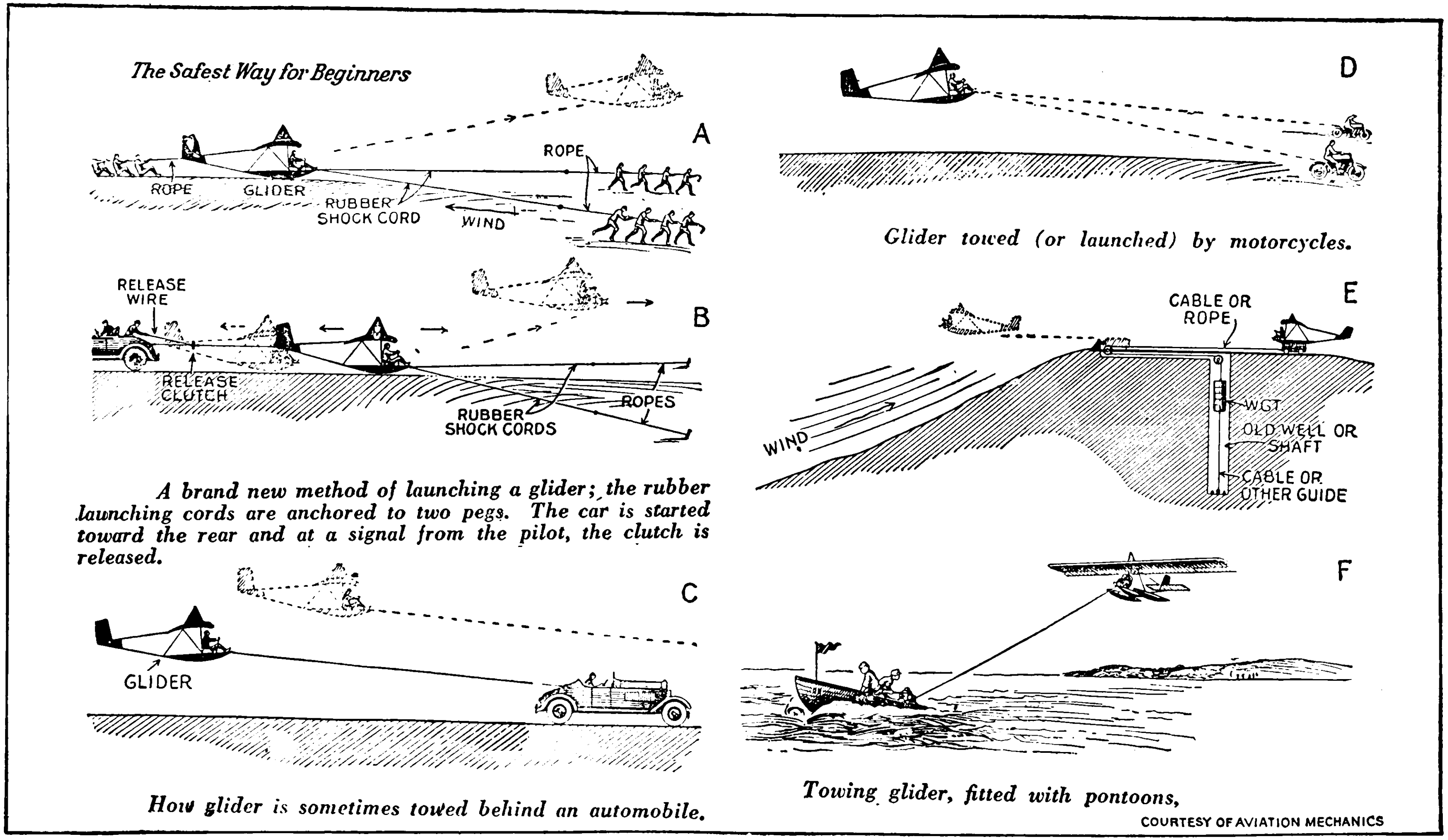


Fig. 45.—Various Methods Employed of Launching Gliders. A—The Safest Way for Beginners Is Shock Cord Catapult Launchings. B—Method Employing an Automobile and Release Mechanism. C—Towing Glider Behind an Automobile. D—Towing Glider by Motorcycles. E—An Elaborate Catapult Device Suited for a Gliding Center or School by Which a Falling Weight Pulls a Launching Car. This Is a Modification of the Early Wright Airplane Launching System. F—Towing Seaplane Glider Behind a Speed Boat.

As soon as a student gains enough knowledge to fly and can maintain a straight line flight across a field at an altitude of 10 to 15 feet, he is ready to go up to 30 feet for a fast flight and quick release. It is at this point that he really begins to learn something about glider flying. By quick release is meant that when the glider is at an adequate elevation, the pilot releases the rope quickly. The student must maintain his speed and climb a little before coming in to land. The quick release method was devised to prepare students for the shock cord launchings they will experience when ready to shoot from hilltops over valleys a long distance below. If a student does not have the "feel of the plane," does not know by instinct and feeling when the release comes, he is liable to stall the plane and crash to earth. Such an experience from the low altitude at which a towed glider flies holds no serious consequences.

After the instructor has inspected the tow rope to see that it is properly fastened and that the release device is functioning as it should, his instructions to the novice will be something like this:

"Take your seat in the 'cockpit.' This is the rather frail seat stuck out in front of the wing. Place your feet on the rudder bar. Take the 'stick' in your right hand and put it in its 'neutral' position or place it so that the elevators and ailerons are in the inactive position. Be sure the safety belt is properly secured. 'Ready? Remember, do not move the stick. This is the first lesson, and your only responsibility demands that you guide the glider straight down the field as the automobile to the rear of which you are attached by a 200-foot rope, gathers speed until the glider is sliding along 12 miles an hour.' 'Keep the stick in neutral. Don't pull back or you'll find yourself in the air. That's fine. Now you're sliding off to the right, so give it a little left rudder. It works just like an automobile steering wheel. To turn to the left, shove out with your left foot.' 'Oh, you did give it left rudder? Too much? Well, one can expect that to happen. Too much rudder and you swung clear away to the left of the flight line. Give it a little right rudder, then. Now you're oscillating. Can't be helped first time out, I suppose. You're overcontrolling, but we'll dampen that out on the next flight. That's better. Now you're in line.'

"So we will drive down to the starting line and repeat the process. If you can guide the glider in the rear of the automobile this time you are ready for your first towed glide. 'Use your elevators now, but don't forget to coördinate the movement of the elevator and rudder. No use rising from the ground if you don't glide the plane along the path you want it to go. You learned to guide it straight on the ground, now you must keep it level in the air.'

"Away you go. The plane gathers speed—and soon takes off without any help from you. It makes short hops the length of the field. As you pull back lightly on the stick, which pushes the nose of the glider into the air, you leave the ground, only to settle back again as you shove the stick forward. That's really all there is to flying a glider in the elementary stages. From this point, practice will perfect the technique."

Notes on Towing Gliders.—The following notes are from the experience of the Alexander Aircraft Company, builders of the Alexander Trainer. They state:

Auto towing can be used with much success, but it is a practice that can easily be abused, whereas the catapult launching method is hard to abuse. But with proper supervision much can be accomplished with this method.

Four hundred feet of ⅛-inch steel cable should be used, or better, 400 feet of ⅜-inch manila rope. The glider should have a manual release so the student can cut loose from the cable. To save the skid of the glider, it should have a simple landing gear, a two-wheel gear preferred. (See Fig. 34.) Then by towing the glider below the take-off speed the student will acquire the feel of the controls.

When the student is ready to take off, the ring on the cable is hooked into the manual release and the other end is wrapped around the bumper or some other part of the tow car and held by some one in the car. About two wraps are enough. In case of emergency the man holding the wire can turn it loose, as sometimes the student gets into trouble and forgets to cut loose.

The tow car should not be driven too fast. If the take-off speed is 15 miles per hour and the wind is 5 miles per hour, the tow car should not be driven faster than 25 miles per hour.

On the first flight the glider should be cut loose just as soon as the student noses down. Under no conditions should the glider be cut loose in a climb, as a stall is sure to result. And if he is not cut loose when he noses down he will slack the cable, the result being that the tow car will jerk the glider up when it takes up the slack.

Sometimes the student will start drifting sidewise; then if the cable is suddenly made taut the glider is jerked around. If the pull is strong enough it is possible to jerk the student out of his seat and perhaps break or bend the skid.

The tow car should be started in second gear and be kept there. If an attempt is made to shift to high it will slack the cable.

When the student is ready to fly, the landing gear should be removed as a side landing is sure to damage it and at the same time is likely to damage the glider.

Best results will be had if the control stick is pushed forward and the student instructed to pull the stick back slowly as he picks up speed. As the glider leaves the ground he should push it forward until he is flying along close to the ground. This method helps to eliminate overcontrol.

Gliders and sailplanes have been towed by airplanes and by speed boats. (See Figs. 45 and 46.) Captain Frank Hawks was the first man to be towed across the United States by airplane in the sailplane "Eaglet." When towed by a motor boat the glider is provided with a pontoon supporting gear instead of the simple skid land gear. The same technique and precautions should be taken with boat or auto towed sailplanes. Flying gliders towed by airplanes should be left only to experts. In fact, special permission is necessary from the Aëronautics Department of the U. S. Department of Commerce before flights can be made in gliders towed by airplanes or other aircraft.

Should a Club Build a Glider.—Many clubs will at first plan to build their own glider, but if they will look into it carefully they find that money will be saved by buying a manufactured glider. The greatest danger in a homemade glider is that if through lack of experience they may make some important part too weak or do not use the right material—this part, if it happens to be highly stressed, may give way. They will find that Department of Commerce approved plans are hard to get; and that even if they get plans, the Department of Commerce requires a stress analysis and load test before they can get a license. In the writer's opinion the only people who should undertake to build a glider are those who have mechanical skill and are familiar with the manipulation of the materials entering into the construction.

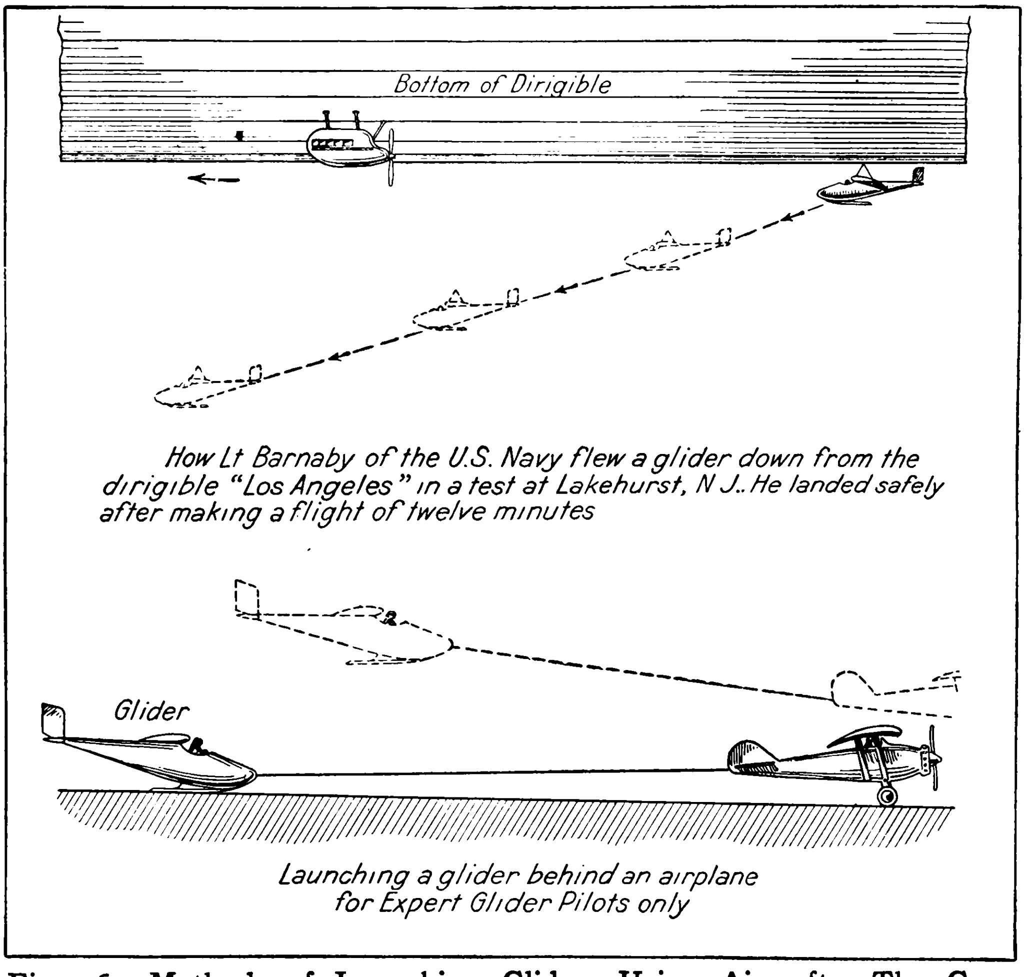
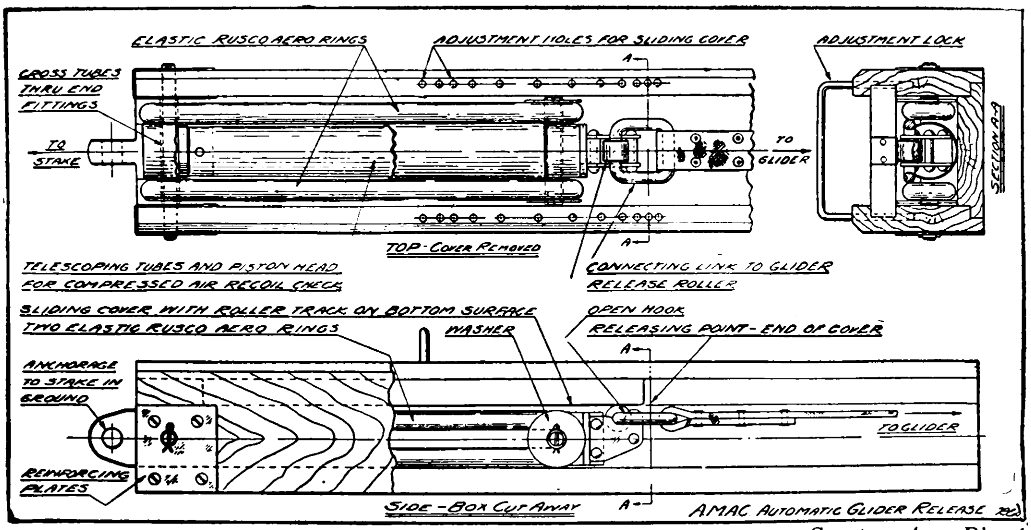


Fig. 46.—Methods of Launching Gliders Using Aircraft. The Government Army and Navy Services May Use Military Dirigibles as Shown Above the More Common Method of Using an Airplane, Possible to Individuals.

Competent wood workers such as pattern makers, joiners, furniture and cabinet makers and others used to fine work will have no difficulties in building gliders. Those wishing to build a glider are referred to the instructions and drawings in the concluding chapters of this treatise.

If the membership of the club includes skilled wood and metal workers or some of the members make a hobby of constructing things and own tools, they can be appointed to the technical committee and much useful experience obtained by constructing a glider. The ordinary assemblage of young people, however, will find it advantageous to purchase a properly manufactured product and save time and in the end some money besides enjoying the gliders sooner. In addition to the advantages enumerated the product of an established manufacturer will probably have U. S. Department of Commerce approval. Much labor will be saved and considerable useful knowledge obtained if a glider is purchased in "knockdown" form. All the parts are complete but some work, such as assembling the wings, covering with fabric and doping as well as rigging and lining up is necessary to complete the machine. This will give the assemblers just as good a knowledge of glider construction as though they had built everything themselves.

An Automatic Glider Release.—Use of the A. M. A. C. Automatic Glider Release, of the type developed by Mr. R. E. Dowd and manufactured by the Russell Manufacturing Co., Middletown, Connecticut, proved of interest at the New York glider carnival held May 1 and 2, 1930, at Bayside, Queens, New York City, the device working handily throughout the meet. This apparatus consists of a wooden box carrying a piston and cylinder bound together with Rusco Aëro Rings of a standard elasticity. The box assembly is staked securely to the ground, while the cord connects the piston and the tail of the glider. A cover, sliding in a groove of the box, may be set for any desired pressure determining the time at which the glider will be released when pulled by the usual shock cord methods from the nose. Thus an auto may carry the regular nose shock cord at a steady speed of say 10 m.p.h.; the glider is released by the box device automatically. The Russell concern's price for the release unit, staking cord, etc., is $35, with discounts available for clubs, manufacturers, etc.



Courtesy Aero Digest

Fig. 46A.—Construction of the A. M. A. C. Automatic Glider Release Device.

Glider fans have been more than inquisitive as to just what sort of a mechanism was contained in the so-called "Magic box" which has been in regular service on so many Eastern airports. The accompanying diagram tells the story. The telescoping tubes furnish a guide for the extension of the Rusco aëro rings which are looped over cross legs. The tension is applied to the mechanism through a short connecting strap which attaches to the rear of the glider. This connecting strap has a small link on the end which hooks over an open hook. As the tension is applied the link tends to unhook but is restrained by the cover. A metal track on the under side of the cover permits the roller to run along until it rolls off the edge. This is the point of release and is adjustable through the sliding of the cover. A lock is provided to fix the cover location at points from 50 to 400 pounds on 50 pounds increments. A compressed air recoil check is provided to absorb the recoil after releasing.

CHAPTER NINE

SOME DETAILS OF GERMAN SAILPLANE CONSTRUCTION

Sailplane Wing Curves—Characteristics of Various Profile Forms—Sailplane Wing Construction—Sailplane Wing Spars—Methods of Sailplane Rib Construction—Internal Wing Bracing—Angle of Incidence of Wing—The Fuselage—Making an Oval Fuselage—Landing Gear—Construction of Skids or Runners—Wheel Landing Gears—Shape of Skid or Runner Important—Use of Tail Skid—The Steering Organs—Elevator Controls Longitudinal Stability—Vertical Rudder—Warping Wing Control—Stick Control Best.

Sailplane Wing Curves.—Of very special importance for the flying qualities of a sailplane is the wing cross section, or profile. With a sailplane there is no compensating for an inefficient wing section by using more power. Thick profiles with considerably rounded entering edge and more or less marked concave arching of the underside are generally used in sailplane construction in Germany where the Göttingen sections are very popular. A number of thick wing sections have been developed as the researches of the aërodynamic experimental station at Göttingen. Therefore, very frequently the profiles tested by this experimental station are being used. One finds the Göttingen profiles 441 and 535 frequently used in the construction of sailplanes. The first one was used in the well-known sailplane "Vampyr," the latter one in the record sailplane "Konsul" and in others. In the United States, several effective wing profiles of moderate and thick sections have been developed, but none have been more popular than modifications of the Göttingen shown at Fig. 47.

In the movement of the supporting wings against the air, a pressure effect is exerted against the underside, due to the adjustment of the supporting wings against the direction of movement, that is, against the direction of the current. At the upper side of the profile the streamlines of the air are pressed closer together, due to the shape given by the profile, which effects an

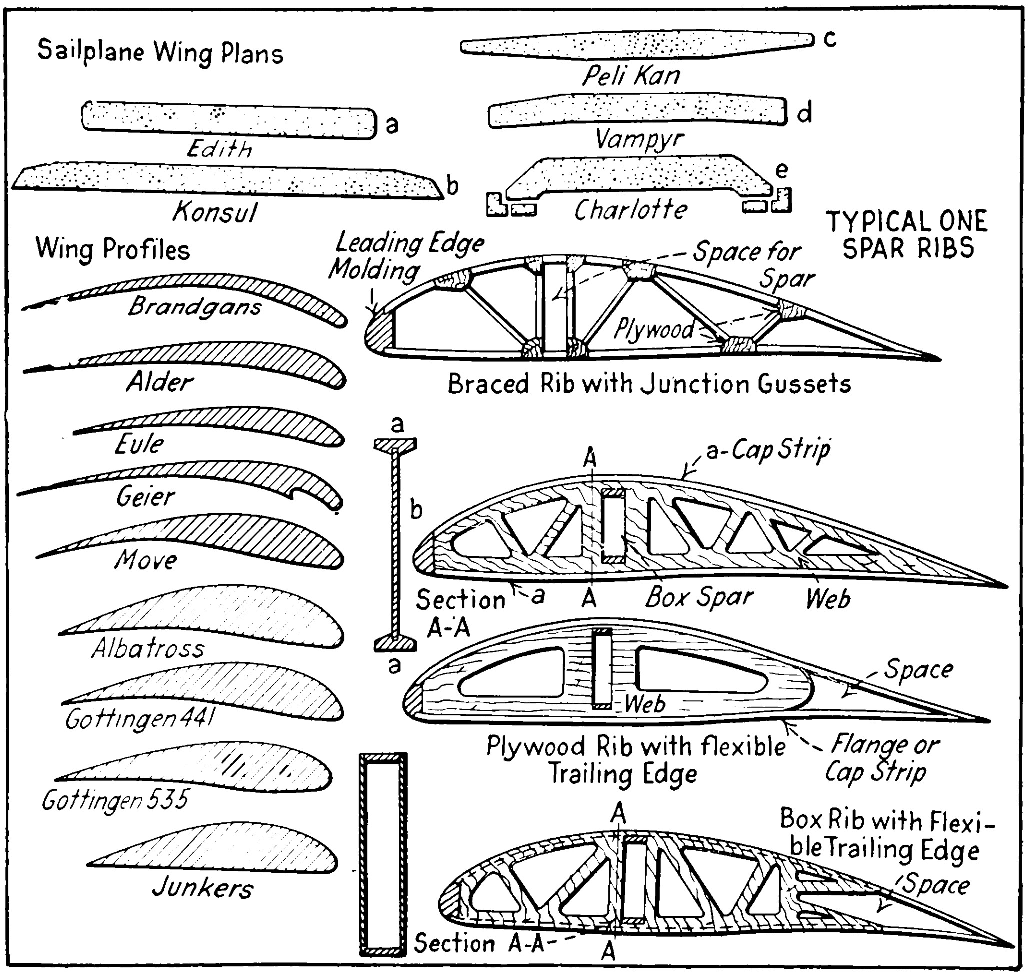


Fig. 47.—Diagrams Showing Sailplane Wing Planes and Airfoil Sections, Also the Construction of Typical One Spar Ribs of the Warren Truss Braced Type and of the Plywood Web Form With Cut-outs and With and Without Flexible Trailing Edges.

increase in speed, which again is always combined with an underpressure or suction according to the laws of aëro- and hydromechanics. The upper side is therefore also suitably called the suction side and the lower side the pressure side of the profile. Suction and pressure combined form the resultant air force, which stands nearly vertical (somewhat inclined backwards) to the chord of the profile; however, the suction effect is usually about two-thirds and the pressure effect about one-third of the total force, though with some airfoil curves, the suction effect may account for three-fourths of the lift.

Characteristics of Various Profile Forms.—Concerning the characteristics of the various profile forms, Mr. Alfred Gymnich says the following:

1. A strong arching or camber of the middle line of the profile results in high auxiliary ascent values.

2. At the same arching of the middle line the profiles with a thickness relation of 1:7 to 1:5 are more favorable than thinner wing cross sections, due to their lower resistance. To this must be added that these profiles permit a free-carrying or non-braced construction, whereby the total resistance of the sailplane is reduced.

3. A slight bending upwards of the trailing edge of the profile has a stabilizing effect, but results also in a depreciation of the gliding angle. Within certain limits this depreciation can be compensated by means of flexible, therefore, automatically adjustable trailing edges.

4. The streamline-shaped development of the entering edge of the profile, or the nose, results in a low or minimum resistance.

5. The suction and pressure sides should be kept as smooth as possible, in order to attain good results; as can be done by avoiding the use of coarse impregnated materials, exterior fittings, instruments, etc.

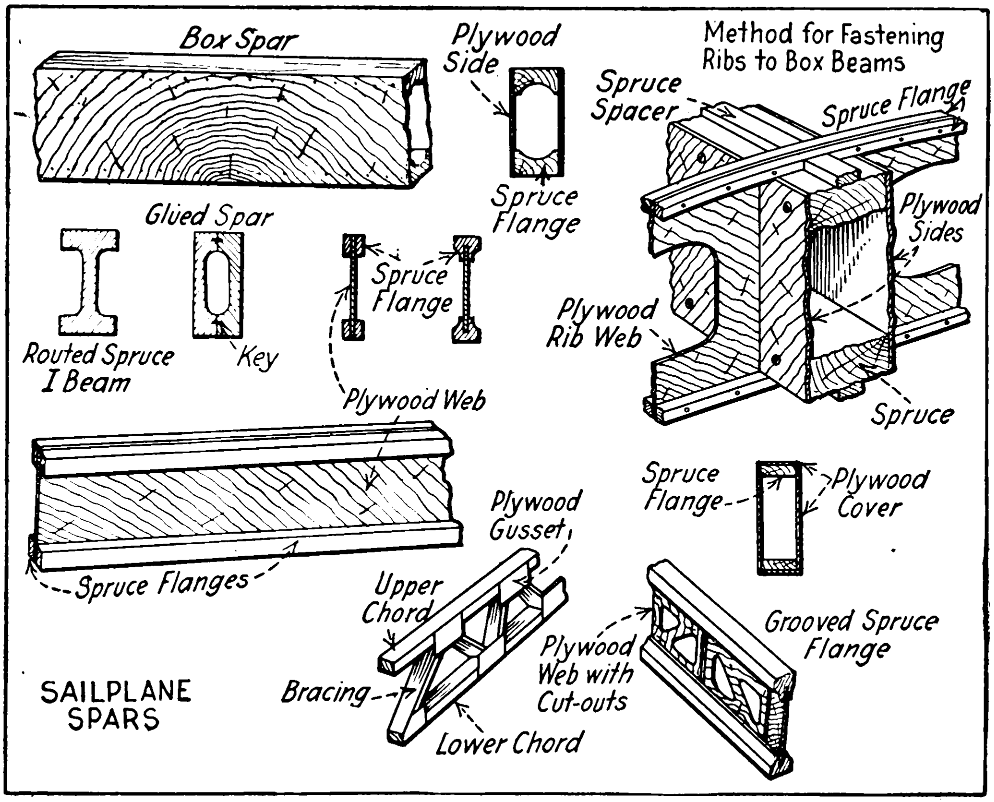


Fig. 48.—Illustrations Showing the Common Forms of Sailplane and Glider Wing Spars of the Box, I Beam and Lattice Girder Types, Also Method of Fastening Ribs to Box Beams.

6. The breaking or flapping of the trailing edge by manipulating the transverse rudder or aileron causes a cutting off of the air streams at small angles of adjustment and therefore a decrease in ascent. Therefore, a special value is to be placed upon a harmonious form to secure smooth passage of air currents in designing the ailerons.

Sailplane Wing Construction.—Depending on the construction, one or two beams are used for building the supporting wings, which are built of plywood planks or spruce beams in box form or I form; and also a number of ribs in the desired profile shape, which are pushed at intervals of 30 to 50 cm. or 11.8 to 19.7 inches across the spars and glued to them by the use of suitable corner ledges or plywood angles. The greater the span width of the sailplane the greater becomes also the lever arm under which the air forces act upon the supporting wings and the stronger must the beams be designed, for these form the actual backbone of the supporting wings. Besides a most exact figuring of the strengths of materials upon the basis of the resistance figures of the construction materials for the weights to be carried, under consideration of a safety factor, it is also advisable to determine the actual strength of a beam or of the beams by means of sand load tests.

The height of the beams is determined by the thickness of the profile, and the latter again according to whether the sailplane is to be built with exterior bracing or with cantilever wings, that is, without exterior bracing. It is always suitable, even when the calculations for strengths do not require it, to utilize the full profile height for the construction of the beams, for the strength of the spar beams lies, above all, in height.

If only one beam is used for the construction of the supporting wings, it should, as much as possible, be placed within the pressure center of the supporting wings. (See Fig. 47.) The beams are called, according to their location and dimensions, leading edge-, nose- or visible-beams, front beam, rear beam and auxiliary beam. If the front beam is designed stronger than the rear beam, or if this relation is reversed, the stronger beam is called the main beam. The location and design of the various individual beams is illustrated best in the drawings.

The shape of the ribs which serve to take up and transmit the air pressure forces to the beams is determined by the profile. The construction of the ribs, as clearly shown in the illustrations, varies from the form having spruce capstrips and cut-out plywood webs to types where lattice work is used for bracing. Some Warren truss types have plywood gussets to reënforce the bracing and to form a firm tie between the capstrips and vertical and diagonal braces.

Sailplane Wing Spars.—The following extracts are taken from the National Advisory Committee for Aëronautics Technical Memorandum Number 439 which is a translation of "Structural Details of German Gliders" by Alfred Gymnich. Box spars and I-girders with plywood webs, which combine small weight with great strength, are now commonly used. The webs are often open-worked so as to resemble lattice girders (see Fig. 48), in which case they are sometimes reënforced by narrow strips glued to the plywood faces and acting as bracing for the flanges. The flanges for the box spars can usually be bought ready-made in all dimensions. Fine-grained, knotless spruce is generally used for this purpose and, when necessary, is first spliced, whereby care must be taken that splices of the upper and lower flanges do not come opposite one another. Then follows the fitting of the plywood webs, which must be done with the greatest accuracy. The webs are glued to the flanges and secured with small brads about the size of cigar box nails. (See Fig. 48.)

The glued surfaces must be firmly pressed or clamped together, because the strength of the spar depends on the perfect gluing of the flanges and webs, and pressure assists in gluing. It is very important to keep the spar straight during its construction. This can be most easily accomplished on a perfectly level support.

Since plywood sheets can be procured only in certain sizes, the webs must be spliced in some instances. Of course, this must be done before gluing them to the flanges. Here also care must be taken that two splices do not come opposite each other. The flanges are often reënforced with thin plywood, as shown in Fig. 48 in order to support the edges of the webs and thus relieve some of the stresses on the glue. This reënforcement must likewise be made under strong pressure, but only after the glue on the sides of the webs has become well set. Box spars are always used when only one spar is used without the plywood leading-edge former, because they are much more torsion-resisting than I-spars. The latter are used as main spars only when there are two or more spars, or when the whole leading edge of the wing, from the top of the spar around to its bottom, is covered with plywood.

The construction of the I-girder is considerably easier and also cheaper, on account of the smaller quantity of material required. The webs are prepared in the same way as for box spars, but web sections are not joined until after the flanges have been added, the plywood connecting pieces being glued on both sides of the web. The flanges of I-spars are often grooved to receive the edges of the web. This method is not recommended, however, since it increases the cost, with no commensurate advantage. In using such flanges, the web must fit tightly in the groove and the flanges must be driven on firmly after the slots are smeared with thin glue with the interposition of a piece of wood between the hammer and the flange. Any cutting out or "open working" of the spar web is done with the aid of a stencil or pattern after the flanges have been attached.

Methods of Sailplane Rib Construction.—The ribs receive the air pressure and transmit them to the spars. Their shape is determined by the wing profile. There are two main types, those with triangular bracing and those with open-worked plywood webs. The latter are more difficult to make and more expensive, but their greater strength makes them decidedly preferable to the former. The ribs at the junctions of the wing sections and the attachments of the struts are often of the box type since these can withstand greater stresses. The variations in the form of plywood ribs depend on whether the wing is to be rigid or flexible. The web is often a single piece, which is pushed over the spar and secured with corner brackets. It is also made in two or three sections, so that the spars can be made the full thickness of the wing. Webs of the same height are made with a pattern, which always facilitates the work. The task is more difficult when the wing tapers toward the tips. In the latter case, each individual rib must be made with the greatest care from the working design as practically each rib is different.

The intervals between the ribs differ greatly. Some constructors prefer to use many ribs, in order to obtain a smooth surface without hollows—while others use only a few ribs and cover the wings largely with plywood. In general, the intervals are 30-50 cm. (12-20 inches). With greater intervals, intermediate or former ribs are used. These nose ribs generally extend but a short distance back of the main spar and serve

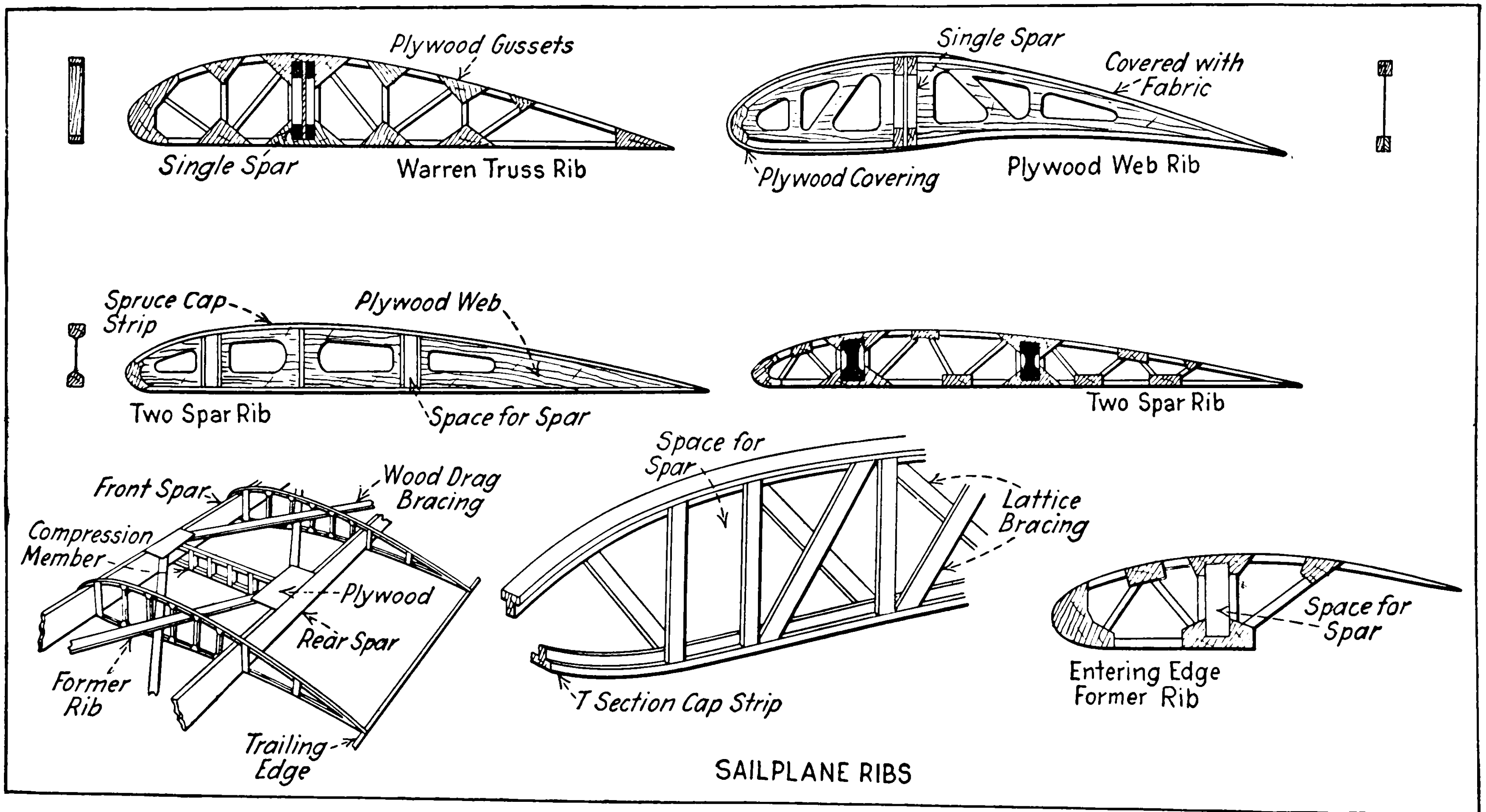


Fig. 49.—Drawings Showing the Construction of Typical Sailplane Single and Two Spar Wing Ribs of Various Forms. Note Use of Plywood Covering Over Leading Edge of Single Spar Wing. The Illustration at the Lower Left Shows Use of Diagonal Wood Drag Bracing in Two Spar Wing.

principally to prevent the hollowing of the fabric and consequent profile changes at the leading edge. (See Fig. 49.)

The weakest point of a rib is at the spar. In breaks, especially of single-spar wings, the failure usually occurs at this point. The risk is not so great with sectional ribs. With continuous ribs, the flanges are often reënforced at this point by pieces of plywood, or special flanges are used, which are wider at this point. Under no circumstances should a large number of nails be used to fasten the rib flange to the spar, since the material is weakened by the nails and would be apt to break. One or two light gauge brads to locate the rib capstrip will not do any harm.

The ribs are pushed over the spars which fit in spaces left for the purpose and are secured by small triangular pieces which are glued and nailed to the faces of the spar. The ribs are then glued at equal intervals to the leading-edge molding. The wing is then strengthened against torsion by the introduction of diagonal side bracing, which must intersect every rib interval or every second interval. This is not necessary on biplanes, since the same object is accomplished by the external bracing. On biplanes every space, or every other space, is braced only by steel wires, in order to prevent any lateral displacement of the ribs. The same method is employed on cantilever monoplane soarers controlled by wing warping. The torsional rigidity is then maintained by the steering controls connected with the control stick, which is operated by the pilot.

Internal Wing Bracing.—In the diagonal bracing, it is important to use firmly fitting attachments which will not weaken the spars. One end of the steel wire is secured to an eye bolt or metal-fitting lug, while the other end is attached to a turnbuckle, in order to be able to adjust the whole wing after the brace wires are installed. (See Fig. 51.) After the wing has been

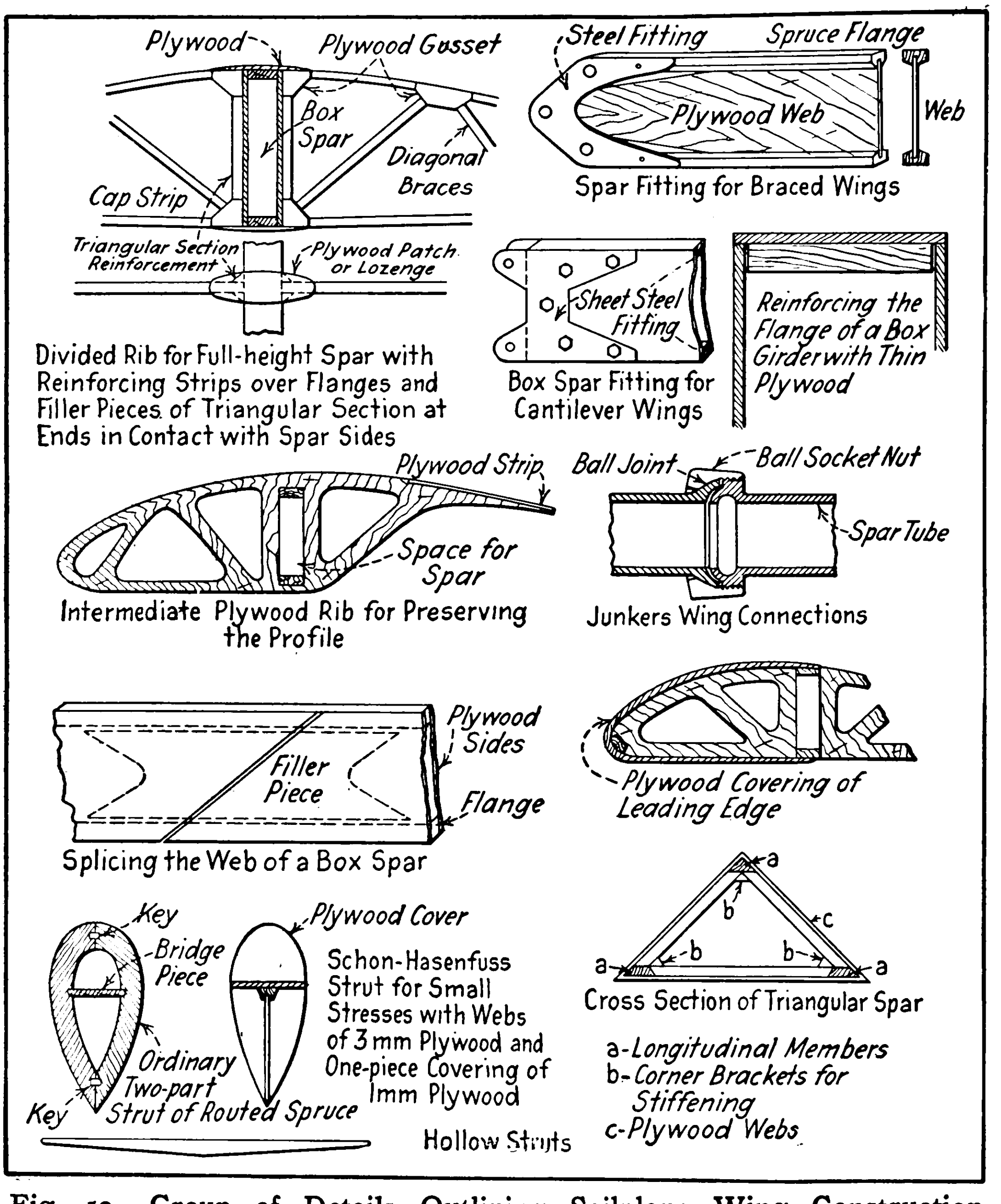


Fig. 50.—Group of Details Outlining Sailplane Wing Construction Showing Spar Attachments to Fuselage; Method of Splicing Web of Box Spar; Use of Plywood Covering of Leading Edge; Section of a Triangular Wing Spar and Two Forms of Lightweight Interplane Struts.

adjusted, all the turnbuckles are secured by safety wiring as shown in Fig. 51. No subsequent alterations can be made in the diagonal bracing, for which reason great care must be taken to adjust both wings symmetrically as regards the angle of setting.

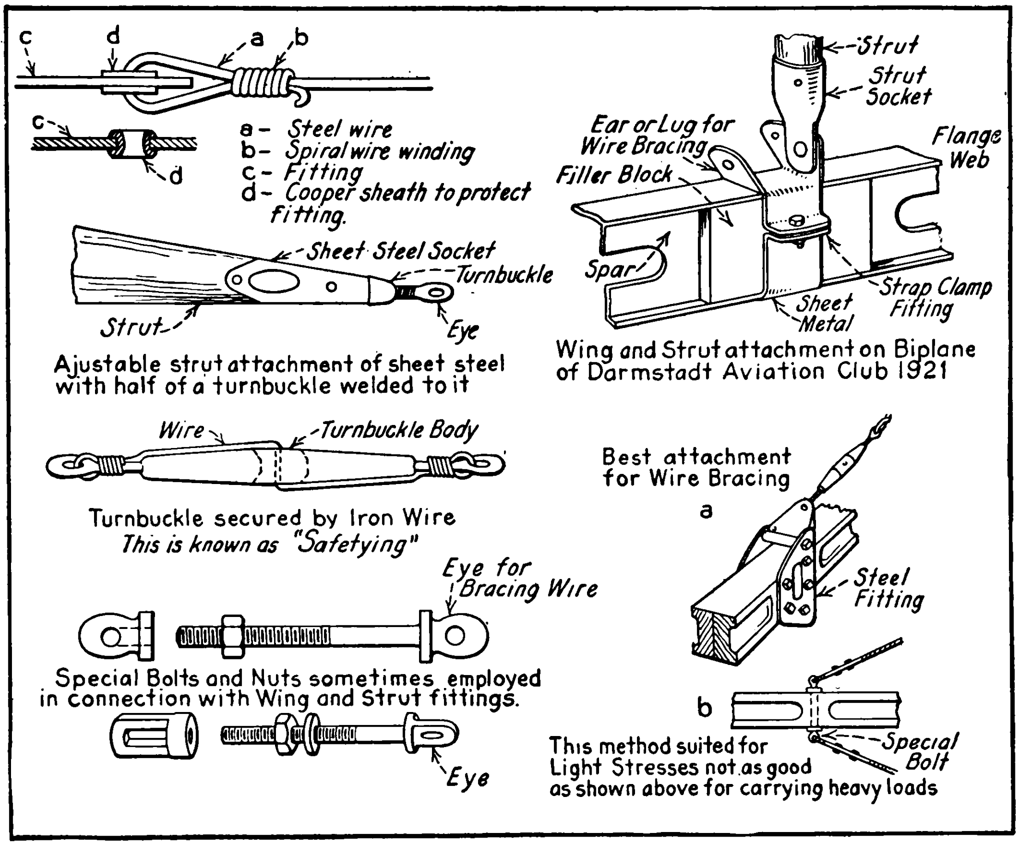


Fig. 51.—Details Showing Method of Attaching Bracing Wires and Struts and Typical Metal Fittings.

Soarers with zero angle of wing setting have often been flown successively. For example, the angle of wing setting of the "Vampyr" was zero at the fuselage. Likewise, wings with a negative or positive angle of setting at the fuselage and a negative angle of setting at their tips, whereby some degree of automatic stability is attained, have been found usable.

Angle of Incidence of Wing.—The setting of a wing depends on its profile, therefore arbitrary lines for the best angle of setting cannot be laid down. It should not, however, be more than four degrees at the fuselage and should diminish toward the wing tips. In no case should the angle of wing setting be greater at the tips than at the fuselage. For wings with flexible trailing edges, the angle of setting can be greater than on perfectly rigid wings. It should also be noted that the angles of glide of two otherwise similar gliders, one of which has wings with flexible trailing edges and the other has perfectly rigid wings, differ greatly from each other. The angle of glide improves with increasing flexibility of the rib ends, since the air can then flow off without forming vortices. This is the case, however, only so long as the flexibility does not give rise to a fluttering of the trailing edge.

The Fuselage.—The choice of the fuselage always depends on financial or structural considerations, for of course the head resistance of an aircraft, in which the pilot is exposed to the air current, reduces the flight speed, which is important for aircraft intended to utilize dynamic soaring effects. This factor drops out for mere gliders which are intended only for sailing in winds deflected upward by mountain slopes. Only the trellis or skeleton type is advisable for training gliders, because it is cheaper to make and easier to repair.

Struts directly in front of the pilot's head should be avoided. On biplanes the wings and tail are best united by four longerons, two for each wing. These may be mutually braced by transverse struts. If it is desired, however, to build a real fuselage, it is not advisable to leave it uncovered. The small additional cost of the covering is fully offset by the improvement in its flight characteristics due to the lessened resistance or parasitic drag.

The fuselage can be made in three different types: with open wood frame; welded steel or riveted duralumin tubes; or wood frame covered with plywood, which distributes the stresses, thus dispensing with the brace wires and more or less with the struts.

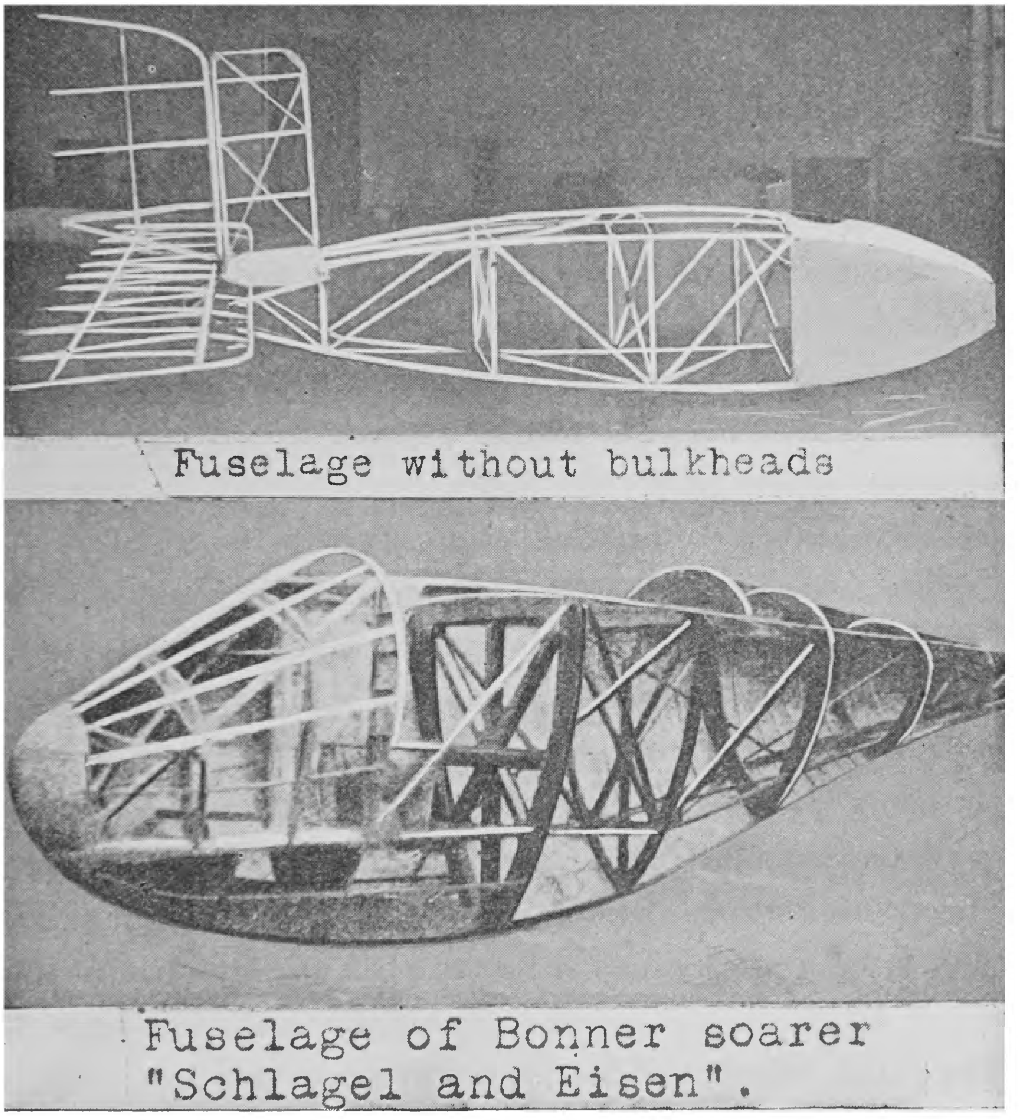


Fig. 52.—Typical Sailplane Fuselages. The Upper View Shows a Wood Fuselage Frame Without Bulkheads To Be Covered with Cloth; the Lower Illustration Shows a Plywood Covered Fuselage with Bulkheads Tied Together with Light Longerons.

The simplest type to construct is the one shown at the top of Fig. 52, which is made of square section throughout and has no specially designed bulkheads. Fuselages of this type are almost always covered with fabric.

If it is to be covered with plywood, the framework can be made of smaller timbers. In the cockpit, diagonal struts and wires must be avoided under all circumstances, since it must be roomy enough not to interfere with the greatest movements of the steering controls. It is better to put up with a little greater air resistance than to handicap the pilot by enclosing him in cramped quarters, thus taking away his view and fatiguing him prematurely by an uncomfortable posture.

Experience has shown that it is advisable to place the pilot's seat so high that his head will be exposed to the unobstructed air current, which greatly facilitates the utilization of favoring winds. Of course, the seat and headrest (if there is one) should be padded. Moreover, it is desirable for all struts and spars in the cockpit to be wound with linen, which not only strengthens the wood but, most important of all in case of accident, also affords protection against splintering and consequent injuries to the pilot. This danger can be still further diminished by using ash for the front portion of the longerons and spruce or pine for the rear portion, the spliced junctions coming behind the cockpit. Ash is strong and tough and has but little tendency to split.

The gluing together of hard and soft wood, however, must be done with great care, since otherwise the glued joints will not hold. It is expedient to spread thick glue on the ash first and wait a few minutes for it to penetrate the pores before spreading glue on the pine. The glued splice should then be put under the customary pressure by hand clamps and wood blocks. It is not advisable to continue the ash longerons the whole distance, since this would unnecessarily increase the weight of the fuselage. Moreover, ash is difficult to work. The longerons and struts should diminish in cross section toward the stern, to correspond to the smaller stresses. In the event of a nose dive, it is desirable to have as little weight as possible behind the pilot.

If the landing gear is not provided with shock absorbers, it is desirable to pad the pilot's seat well or provide it with springs, in order to soften the landing shock for both pilot and fuselage. The fuselage ends in either a horizontal or vertical wedge, which is correspondingly used for the attachment of the elevator or rudder. The vertical wedge is more common on gliders because of the better keel effect, while the horizontal wedge is better for soarers, in order to facilitate deviations from straight flights such as making figure eights to keep in the same ascending air currents.

Steel tubing or other metal had been but little used in the construction of amateur built gliders and soarers in Germany because this required expert workmen provided with specially equipped workshops. This type, though heavier, is stronger and more durable. The securing of the wings to a metal fuselage is simpler and easier. As glider construction is now a department of established airplane factories one can expect a considerable increase in the uses of metal.

The construction of a plywood fuselage requires some experience in monocoque fuselage or boat building, for it can be accomplished only with the aid of a special form. The bulkheads must

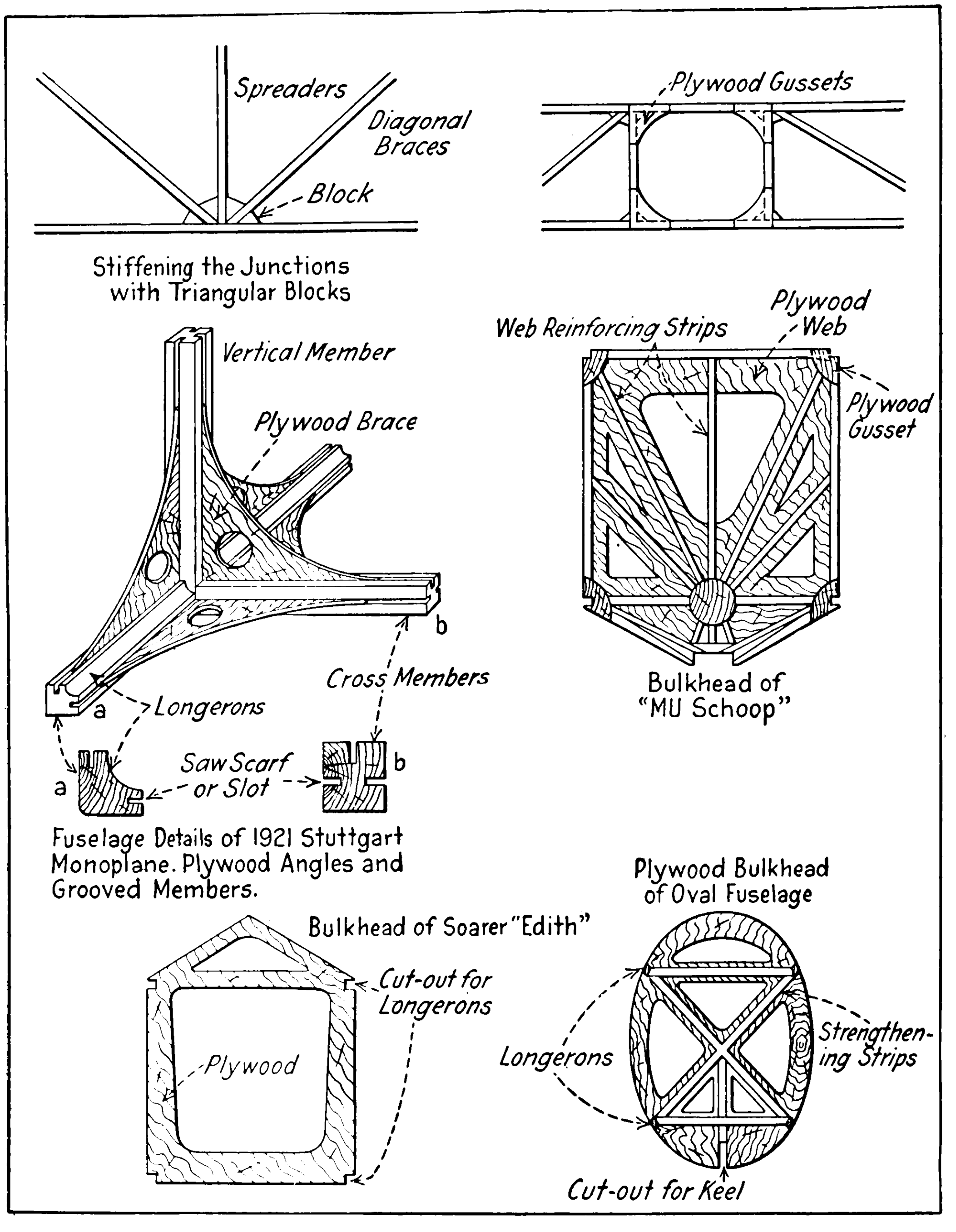


Fig. 53.—Some Structural Details of German Sailplane Fuselages. Note Method of Reënforcing Light Plywood Bulkheads by Reënforcing Strips of Wood Attached to the Face, also Method of Strengthening Fuselage with Plywood Angles Fitting Saw Slots Cut in Longerons and Spreaders in Which They Are Secured with Glue.

first be made in exact conformity with the working designs, which is done in various ways according to the shape and the requisite strength of the fuselage. The front bulkheads, especially those which are designed to receive the wing fittings, are made of heavy plywood, while the rear, less-stressed bulkheads are made of thin strips with plywood reënforcement. One advantage is the elimination of the diagonal struts, since the bulkheads afford sufficient rigidity. The inside of such a fuselage is therefore more roomy, thus facilitating the installation of the seat and steering controls.

Making an Oval Fuselage.—An oval fuselage requires more bulkheads than an angular fuselage for the preservation of its shape. This requirement is met by inserting one or two light auxiliary bulkheads between every two main bulkheads. The number of longerons likewise depends on the shape of the fuselage. In general, four main longerons are employed, with smaller intermediate longerons as required. Round bulkheads, however, require only three longerons. (See lower illustration, Fig. 52, for construction of plywood covered fuselage.)

The actual construction of the fuselage is begun after the completion of all the bulkheads. A board, whose dimensions correspond to the length and breadth of the fuselage, is firmly secured by screw clamps to two paperhanger's "horses." For a round fuselage, a keel corresponding to its bottom line is secured to the board and the bulkheads are attached to the keel by means of screw clamps. For an angular fuselage, cleats corresponding to the number and location of the bulkheads are fastened to the board. The longerons are then fitted into notches in the bulkheads and glued, corner blocks being glued into the angles between the longerons and bulkheads. Then all inner parts, like the seat and steering controls, are installed and, lastly, the plywood covering is added. This is easily done with angular bulkheads.

Glue is applied to the longerons and bulkheads and the plywood nailed on in as large sheets as possible and so that the joints always come on a bulkhead. For round or arched fuselages, the difficulty increases with the curvature, wherefore the plywood plates must be applied slowly, beginning with the narrow side. Both lateral and longitudinal bending must not be attempted with the same plate as this would produce buckling and unevenness. After the upper and lateral portions have been covered, the fuselage is detached from the keel or cleats and its bottom is also covered with plywood.

Sailplane Landing Gears.—Often too little attention has been given to the correct construction of the landing gear. We repeatedly see gliders, otherwise well built and with good flying ability, which experience difficulty in taking off or are damaged in the attempt, due to faulty landing gear. The landing gear must be regarded as an organic part of the glider and not as an auxiliary attachment. The landing gear is also the "starting gear" and it is only in the latter sense that we are considering it this time. Runners are now commonly used on gliders and preferably one central runner instead of the former double-runner system. The few early attempts to use landing gears with wheels met with little success, but some of the more modern gliders are using small wheels such as designed for airplane tail support. The correctly built central runner is doubtless the best solution of the starting problems, since it weighs but little, is easily constructed and offers the least head resistance. The greater friction of the central skid or runner in taking off is of no practical importance.

For example, the "Espenlaub V," which has a very simple central runner, required only two men to launch it in a wind of 4-6 m. (13-20 ft.) per second.

There is no danger that a glider with a central runner will tip over on the wing at a low take-off or landing speed, such danger

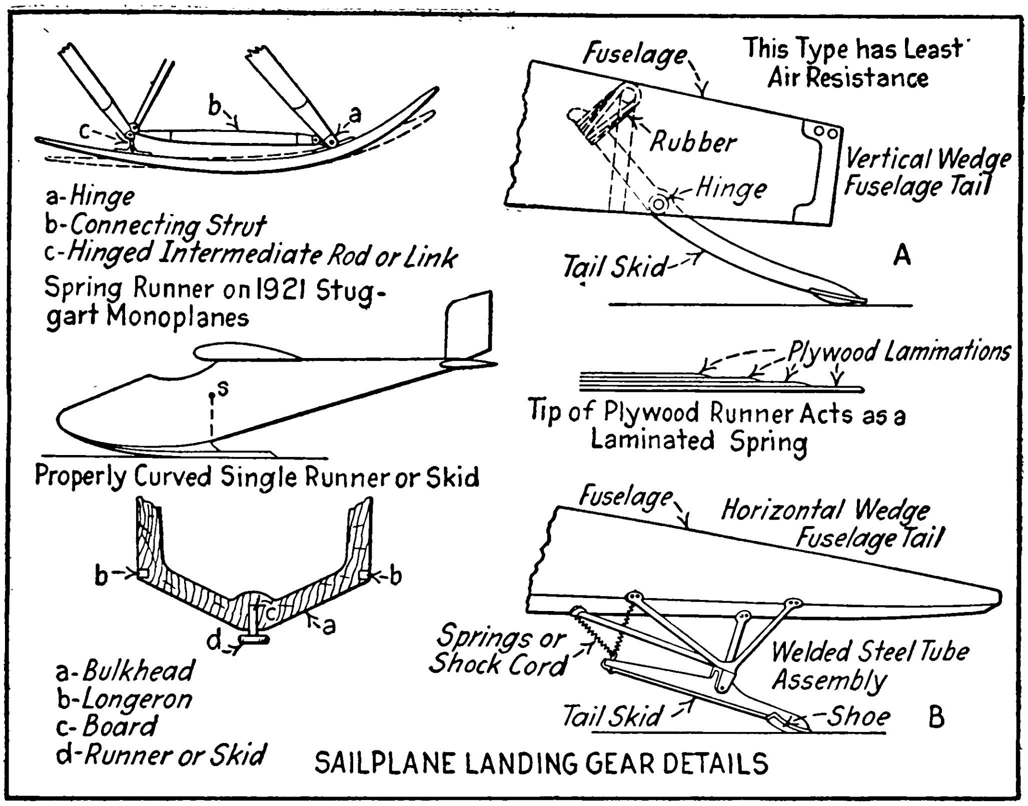


Fig. 54.—Sketches Outlining Sailplane Landing Gear Details Showing Approved Curved Runners or Skids. A Shows Tail Skid Landing Gear for Fuselage Terminating in a Vertical Wedge. B shows the More Complicated Structure Used for Fuselages Terminating in a Horizontal Wedge.

existing only when the glider is standing still. Even then the glider tips so slowly that there is little danger of doing any damage. Hence protecting devices on the wing tips are seldom used, though it would appear that their use would be an advantage. The single-runner type has the advantage over the double-runner type, in that, aside from the smaller air resistance, the landing gear (and hence the whole glider) is less endangered in landing with a side wind, because it is much easier to head into the wind. Nevertheless double runners were often used on early German school machines and on the primitive Wright brothers' glider in order to render the take-off easier for the pupil. Straight rigid runners (the so-called "Sled Gear") are still sometimes used. The reason for this is not plain because flexible, or at least bent, runners can be easily made and greatly facilitate the take-off. The present most common and simplest type of landing gear is the single central runner with projecting and consequently flexible rear end. (See Fig. 54.) With a correct placing and curvature this runner may be considered ideal, especially when the landing shock is partially absorbed by an upholstered or spring seat. The previously mentioned "Espenlaub V" has such a central runner, which is so long as to render a special tail skid unnecessary. In a normal landing, this type of gear distributes the shock evenly between the different joints. The runner itself should be wide enough to prevent its sinking into the ground. A width of 6-8 cm. (2.4-3.2 in.) is generally sufficient, although this depends on the weight of the glider and the nature of the ground. The take-off from a sand dune naturally requires a wider runner than from a grassy field.

Construction of Skids or Runners.—The runners are generally made of ash or elm. Large runners are bent, after being allowed to soak several days in cold water or a few hours in hot water. Forcible bending and gluing, without first softening the wood, are liable to result in the loosening of the runner in the event of a hard landing. It is attached to the bottom of the fuselage with the aid of a vertical board about 2 cm. (0.8 in.) thick and generally made of light plywood. The lower edge of this board is given the desired shape of the runner. The board is then fitted and glued in notches provided for the purpose in the bottom of the bulkheads. It is braced laterally by small blocks and plywood gussets. The runner is then glued and screwed on. Of course the vertical board cannot be used on gliders without any real fuselage. In this case a curved central runner can be attached only with the aid of a "blind" runner.

The runner may be made in thin strips glued singly to the bottom of the vertical board and then secured by screws. By this method the projecting ends can be left of different lengths, as in a laminated leaf spring, in order to make the runner more flexible and springy. (See Fig. 54.) In order to prevent the runner from catching in ruts when landing with a side wind, the bottom strip of the runner is rounded and its edges trimmed.

Wheel Landing Gears.—As already mentioned, wheel landing gears have failed of general adoption, because they are more complicated and expensive and because the facilitation of the take-off is more than offset by the increase in the air resistance or "drag" and in the length of the landing run. However, single, centrally placed air wheel landing gears have been used with good results and with no marked increase in drag. (See Fig. 37.)

An intermediate method between the wheel and the runner landing gears was adopted by the aviation section of the Hannover Technical High School. The gliders "Vampyr," "Greif," and "H6" had rotatable leather balls similar to footballs. They conformed to the shape of the fuselage and each one had a valve provided with a rubber tube. (This was the forerunner of the present Musselman air wheel.) This almost ideal solution combines minimum air resistance with minimum ground friction and good shock absorption. One disadvantage, however, needs to be remedied. If the aviator is compelled to land against a steep declivity, there is danger that the glider will roll backward and be more or less damaged. This happened once at Andreasberg, when Schwarz was compelled to land against a steep hillside, and again in the Rhön Mountains when Martens on the "Strolch" had to land in the same way. In such cases the elevator and the tail end of the fuselage were badly damaged. This danger might be avoided by means of a wheel brake, or a skid or sprag operated by the pilot or by installing the wheels or balls in such a way that they cannot turn backward. The latter would not be advisable because it would greatly reduce the maneuverability of the glider on the ground when being placed in position for launching.

Shape of Skid or Runner Important.—It is better to construct the landing gear in such a way as to afford the maximum maneuverability on the ground. Such is the case when the runner is perpendicular to the line of gravity in every position of the aircraft, which necessitates a curved shape of the runner (Fig. 54). In order to ameliorate any unintentional pitching, which would require constant manipulation of the elevator, the runner is given a parabolic shape. Moreover, a circular shape would cause the runner to press into the ground more and thus increase the friction. It is still better to use spring runners which adapt themselves automatically to the surface of the ground. If the runner is used for the static structure of the fuselage, springiness can be obtained only through the medium of a so-called "blind" runner. This blind runner is used for the static structure and the real runner is so attached to the static runner by means of springs or rubber cords or rings that they can yield and thus allow the runner to fit the ground. In the construction it is only necessary to see that the resting point of the real runner at the various angles of attack does not coincide with its point of attachment to the blind runner.

Use of Tail Skid.—It has already been mentioned that no tail skid is required with sufficiently long runners. With short runners or with ball or wheel landing gears, however, a tail skid may be used to support the tail and protect the tail surfaces. Fig. 54B shows a tail skid commonly used both on airplanes and on gliders, having a fuselage which ends in a horizontal wedge. The method shown at Fig. 54A can be used when the fuselage ends in a vertical wedge. The air resistance is less by this method. The rubber cables must, of course, be rendered easily accessible through a trapdoor. It is desirable for the skid to be capable of yielding somewhat laterally. The life of the skid is thus increased and the stresses on the stern of the fuselage, when turning, are diminished. The height of the skid must be such as to allow a sufficiently horizontal motion of the fuselage to permit increasing the angle of attack in taking off. When possible, it is better to dispense with the tail skid altogether.

The Steering Organs.—While we are striving for minimum sinking speed and angle of glide, we must also endeavor to increase the maneuverability in order to bring the aircraft promptly into the most favorable position for any given air current. Like engine-driven airplanes, gliders require three control organs, namely, for lateral and longitudinal stability and for directional steering. The organ for maintaining longitudinal stability also serves for vertical steering. The control surfaces are made considerably larger on gliders and sailplanes than on engine-driven airplanes, in order to compensate for their considerably lower speed. The commonest error on gliders consists in making the control surfaces too small and therefore ineffective. On "hang" gliders the lateral and longitudinal stability and the angle of attack are controlled by shifting the weight of the pilot. Only a vertical fin, or possibly a rudder, is provided, in order to head the glider into the wind or give it limited directional control. For preserving lateral stability, preference is given ailerons hinged to the outer portions of the wings. The ailerons are so connected that the upward deflection of either one is accompanied by a downward deflection of the other.

The Wing method of control was employed by Harth, Messerschmitt and others, but failed to come into general use. The reason for this is apparent when one considers the difficult construction of the wings for this purpose, and the effort required to change the angle of attack and in the fact that gliders like the "Strolch," "Konsul," "Espenlaub IV," "Hannover H6" ("Pelikan") and others with ordinary ailerons give better results in practice even though such ailerons cause more vortices in theory and therefore should offer greater air resistance than flexible trailing edge warping or wing rocking with its more harmonious transitions of airflow. For static soaring flight, the very slight increase in the air resistance due to the ailerons is of no practical importance, and the controlling effect of suitably dimensioned ailerons is fully sufficient.

Of course, the aileron shape makes a difference, since square ailerons have to be deflected more than oblong ones and produce a greater retarding or breaking effect. Hence the preference is given to very narrow ailerons extending throughout a large portion of the wing span and often tapering to a point toward the fuselage, in order to avoid any break in the trailing edge. (See Chapter Four.) The manner of hinging the ailerons to the wings is also important. The formation of an intervening slot must be avoided in so far as possible or the slot must at least be covered by a strip of plywood. Covering the slot in this manner has prevented the formation of harmful vortices.

Elevator Controls Longitudinal Stability.—Longitudinal stability is usually obtained by an "elevator," which is rotatable about a horizontal axis at the stern of the fuselage. There is often a horizontal "stabilizer" in front of the elevator, but in recent years this has frequently been omitted, especially on the best soarers, in order to make the aircraft longitudinally more sensitive and consequently better adapted for the fullest possible utilization of gusts. Since a sailplane fuselage very often ends in a horizontal wedge, the elevator is easily installed. The longitudinal section of such a balanced elevator is always streamlined. It is built like a wing with I-girders or box girders and ribs. Its center of rotation lies at or slightly in front of one-third the distance from the leading edge. Its axis is usually a steel or duralumin tube, though its attachment to the wood ribs is difficult.

When there is a horizontal stabilizer, the elevator is hinged directly to it, the same as the rudder is hinged to a vertical fin as commonly done on airplane fuselages. On tailless gliders, the altitude and longitudinal control reside in the separately maneuverable ailerons or in wing warping. Since the wing tips are extended backward on such aircraft (which are seldom seen to-day) the leverage thus obtained is generally sufficient for steering and stabilization. The placing of the elevator in front of the wing as done by the Wright brothers and Curtiss on their early creations has been tried only on Klemperer's "Ente" or duck type glider.

Vertical Rudder.—Lateral changes in direction are likewise produced by a vertical rudder at the stern of the fuselage (with the above-mentioned exceptions), which is sometimes preceded by a vertical stabilizing fin. The longitudinal section of the rudder likewise preferably has a streamline shape. The shapes of the elevator and rudder must be such that they cannot interfere with each other, even at their maximum deflection. If the vertical or lateral steering is controlled by the wings or by ailerons, no rudder nor elevator is needed at the stern, but in this case horizontal and vertical stabilizing fins are almost always provided.

Warping Wing Control.—Wing warping originated with the endeavor to take immediate advantage of fluctuations in the wind, without using the indirect way through the elevator. For this purpose, Harth and Messerschmitt warped the whole wing and changed its curvature and thus obtained excellent results above the gentle slope of the Heidelstein in the Rhön Mountains. Not only did Harth gain altitude by thus increasing the angle of attack and changing the flight direction, but often succeeded in taking off without the aid of the starting cable by utilizing a favoring gust. The technical and constructional difficulties and the low structural strength of warping wing-controlled gliders then led to the substitution of ailerons.

On the Darmstadt monoplane sailplane "Geheimrat," which has been described and illustrated elsewhere in this volume (see Chapter Four), the whole wing is rotatable. This is intended only for utilizing the gusts and not for lateral control, as this is exercised by ordinary ailerons. For the longitudinal control there is a stern elevator, which can be operated by means of a small lever. The elevator was adjusted according to the wind conditions and was not operated during the flight. This method enabled the widest adaptation to the most variable wind velocities. Although no elevator is necessary for a wing-controlled glider, the installation of one on soaring planes has been found advantageous. If a wing-controlled glider should, for any reason, be thrown into a nose dive, it would generally be impossible to flatten out again, on account of the strong forces acting on the wings. The greater leverage of a stern elevator would, however, be more effective, and in fact absolutely necessary in such an emergency.

In designing wing-controlled gliders, it is important to use an airfoil profile with relatively small travel of the center of pressure. The correct leverage of the control stick is also important, as otherwise the pilot's strength might not suffice to hold the wings. It is also expedient to provide a maximum deflection limit to prevent overdeflection, which usually causes a fall. All these are disadvantages which militate against the use of variable angle of attack wings.

Stick Control Best.—The operation of the various controls should correspond to the natural impulse of the pilot, for which reason it is advisable not to depart from the customary stick control. The ailerons or wing warping should be controlled by lateral motions of the stick; the elevator by pulling and pushing the stick; and the rudder by the use of the feet just as in airplanes. Wheel control may be better for giant airplanes, but it is not suitable for

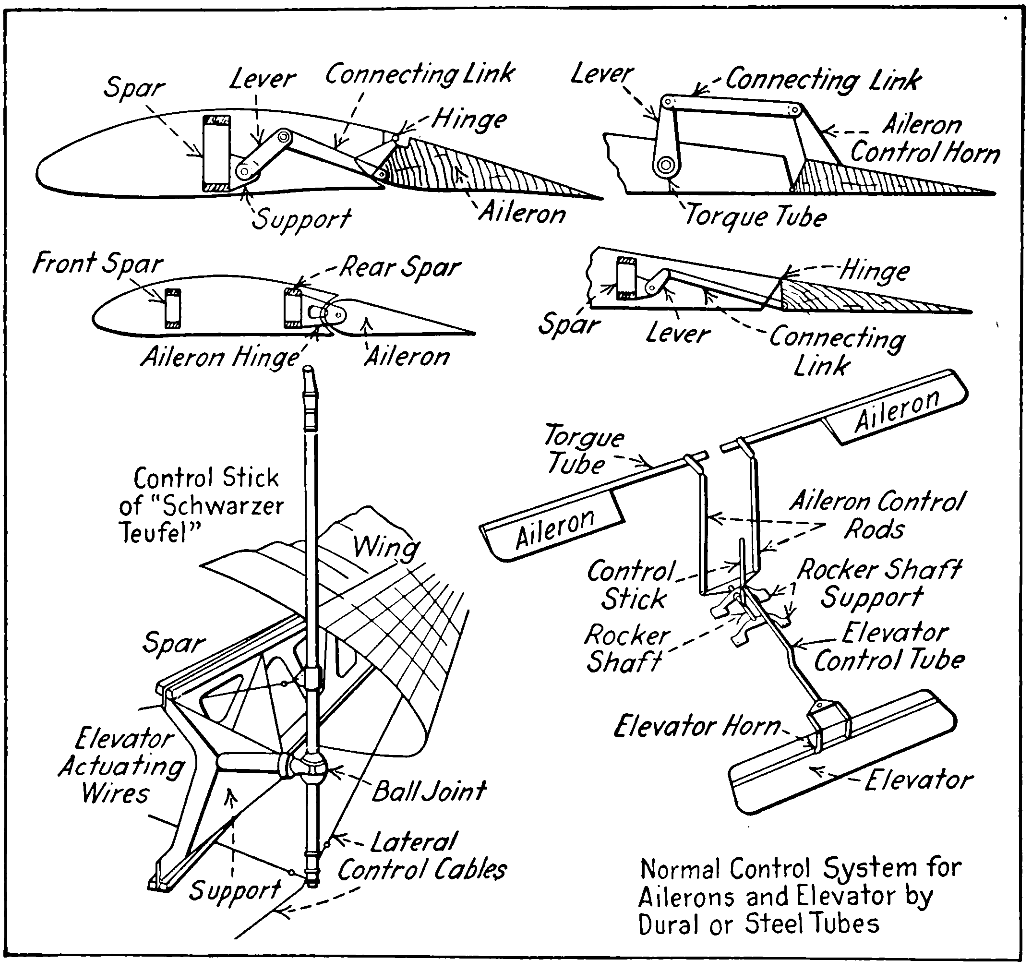


Fig. 55.—Details at Top Show Various Methods of Actuating Ailerons of Sailplanes. The View at Lower Left Shows Control Stick Supported by a Ball Joint. The Assembly at Lower Right Shows Method of Aileron and Elevator Actuation by Push and Pull Tubes.

a glider or soarer, where the pilot must depend largely on the "feel" of the controls. Whenever possible, only one control stick should be used, since, although a second stick can be operated successfully, its presence complicates the piloting and the control therefore becomes different from that of an airplane, greatly reducing the value of the glider as a primary flight instruction medium.

In order to function in two directions, the control stick must have a double acting or ball joint. On the Aachen monoplane, "Schwarzer Teufel" the tubular duralumin stick runs through a hollow steel ball with which it is rigidly combined. (See Fig. 55.) The steel ball is held in a spherical collar of aluminum alloy, so that the stick is movable in all directions. This is a simple and light control stick.

The steering levers and surfaces are connected either by cables which pass over pulleys of the largest possible diameter, or by duralumin or steel tubes in combination with push rods. The latter method is continually becoming more general. It offers greater advantages in assembling and disassembling, and the friction is generally less. The rudder is always connected with the pedals or rudder bar by cables as will be described more in detail in a following chapter.

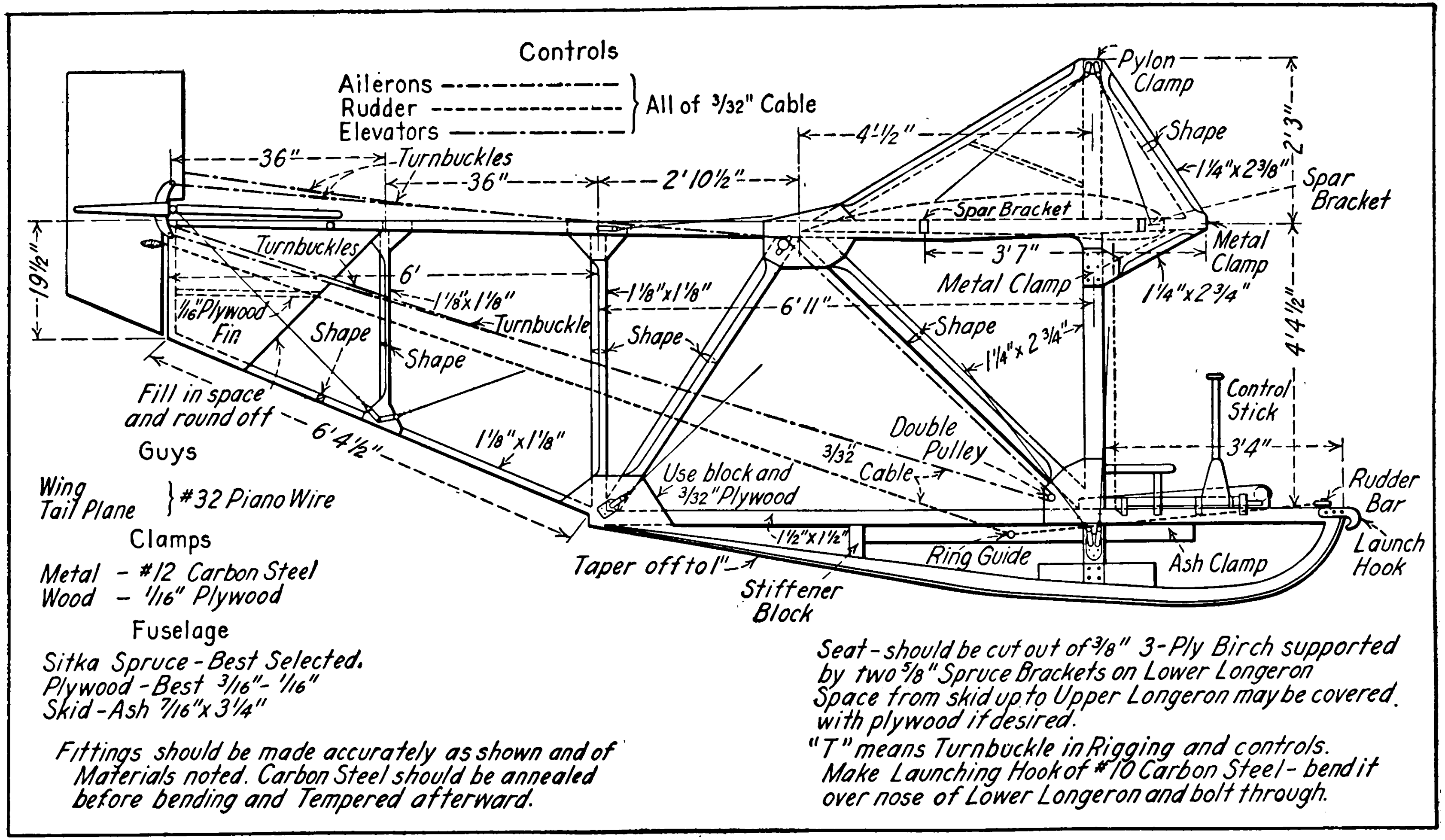


Fig. 56.—Working Drawing of the Fuselage of a Typical Training Type Glider Showing the Various Materials Used and Giving Dimensions of Principal Parts. Note Fairing of Fuselage Struts and Braces and How Control Cables are Guided by Pulleys Attached to Fuselage Members.

CHAPTER TEN

MATERIALS USED IN GLIDER CONSTRUCTION

Description of a Typical Training Glider—Cost of Materials—Specifications for Materials—Building Materials and Woods—Metal Parts—Steels Used in Aircraft Construction—Strength-Weight Factors of Aircraft Materials—Cloth and Dope—Glue—Protecting Fittings—Properties and Uses of the Most Common Woods—Strength Coefficients of Different Kinds of Wood—Wire Cables—Wire Ropes—Weight of Steel Tubes—Weight of Duralumin Tubes—Strength of Turnbuckles—Weight of Sheet Iron and Steel.

Description of a Typical Training Glider.—A typical primary training glider is of the high wing, single longeron, one place, open type, the wing panels being externally braced only with flying and landing wires. All wood employed is Sitka spruce, except for the skid which is ash and some structural braces, which are oak. The PT-2, of Gliders, Inc., for example, has a length over all of 17 feet 5 inches, whereas the PT-1 was 16 feet 6 inches in length. The wing span is 34 feet. Except for a slight cutting away at the leading edge of the wing tips the wings have a uniform chord of 5 feet, giving them an area, including ailerons, of 170 square feet. The total aileron area is 23 square feet.

A modified Göttingen section is often used for airfoils. The wings are nearly always in two panels, joined to the base of the triangular, flat, and covered "cabane" or "pylon" by means of slide fittings and two ⅜-inch S.A.E. aëronautic bolts on each panel. All metal fittings on the glider are of cold rolled steel of varied thickness. Internally, each wing panel is made up of 17 double ribs, covered with plywood cap strips, all gussets in the wing structure being of birch. Birch plywood is glued on and tacked for safety. Drag wires are of 0.049 piano wire, tightened with turnbuckles. All wing spars are spruce, the front spars 5/8 inch thick, 5 inches deep, and 17 feet long. Those in the rear are of the same dimensions, except that they are only 3.7 inches in depth. The wings are covered with fine muslin. Size 0.095 inch piano wire is used for landing and flying wires.

With the idea of inevitable minor crashes on the part of student pilots, some glider designers have made the fuselage in two separate assemblies. The "nose piece" carries the pilot's seat and control system. From the rear of the seat aft is the main fuselage, an assembly attached to the nose piece by means of four oak or ash side braces bolted together and permitting removal for easy repair. All vertical and diagonal members of the fuselage structure are glued and screwed together, with 1/8-inch or 3/16-inch plywood gussets bracing all joints. The longeron may be of 1 1/2 by 2 1/2-inch spruce or 2 inches by 1 1/2 inches for main members and 1 1/2 inches by 1 1/2 inches for auxiliary supports. In constructing the fuselage with a single longeron, designers of the primary gliders say that they were guided by the results of a series of tests which led to the conclusion that the single longeron was less susceptible to breakage in landing than the triangular fuselage.

Conventional push and pull controls, similar to those of the ordinary power-driven airplane are usually installed. The pilot's seat is usually of 1/2-inch plywood and the rudder bar has an ash center, covered with plywood or maybe made of tubing.

All structural members of the tail surface assemblies are glued together, and include full ribs at stress points. In area, the tail surfaces comprise approximately 13 per cent of the wing area. Because of the natural vertical surfaces on the fuselage some primary gliders have no vertical fin. The triangular shaped stabilizer is bolted to the fuselage, in some cases, with two ¼-inch bolts passing through a clamp attached to the upper longeron, and braced with piano wire or with streamline tubing struts.

Cost of Materials.—While the prices for the various materials vary from time to time, the following may be of value as a guide. These are prices prevailing in several supply houses during the summer of 1930. Spruce Rib Stock, ½ inch by ¼ inch for cap strips or 3/16 inch square for truss type ribs, two cents per lineal foot. Casein glue powder, 40 cents per pound. Birch or Mahogany Plywood sheets, 2 feet by 5 feet and 2 feet by 7 feet in 1/16-inch, 3/32-inch and ⅛-inch thickness, 32 cents per square foot. Aluminum sheets, 18 inches by 72 inches, 26-gauge, $2.30 per sheet. Turnbuckles, 35 cents each. Micarta pulleys 2-inch diameter, 36 cents each. No. 14 hard wire, 2 cents per foot. No. 12 hard wire, 2¼ cents per foot. Control wire, ⅛-inch diameter, 7½ cents per foot. Control wire, 3/32-inch diameter, 8 cents per foot. Thirty-six inches wide fabric, 40 cents per yard. Commercial Cotton, 35 cents per yard. Glider fabric, 52 inches wide, 55 cents per yard. Rib nails, ½ inch long, 20 gauge, 50 cents per pound. Ferrules for No. 12 and No. 14 gauge wire, 2 cents each. Thimbles for cable, 2 cents each. Glider safety belt, $3.00. Steel tube, ⅝-inch to 1-inch O.D. 20-gauge, 17 cents per foot; ¼-inch to ½-inch O.D. 20-gauge, 14 cents per foot. Pinked tape, 2½ inches wide, 3 cents per yard. Reënforcing tape, 2 cents per yard. Rib Sewing Cord, $1.50 per pound. Hand sewing flax cord, $1.00 per pound. Straight needles, 12 inches long, 10 cents each; 16 inches long, 20 cents each. Curved needles, 5 inches long, 10 cents each. Spar Varnish, $3.00 per gallon. Silver pigment, $1.25 per pound. Nitrate dope, $1.75 per gallon. Nitrate dope, in 5-gallon cans, $1.60 per gallon; in 20-gallon drums, $1.50 per gallon. 100 feet shock cord, ½-inch diameter, suitable for glider launching, $8.00. 3/16-inch clevis shackles, 10 cents each. Clevis pins, 3/16-inch, 4 cents each. Ribs and all material for building a wood wing frame including spars and compression bracing can be purchased for $40 to $50. A built-up fuselage, single longeron type, without seats, controls or fittings, $30 to $35. Uncovered tail group, less fittings, $12. Complete bill of materials from $90 up. Knock Down Glider, $200 to $250.

Specifications for Materials.—The following specifications are for the material used in the construction of training gliders:

Spruce throughout shall be Government specification Sitka spruce, straight grain, sized to correct dimensions. Lower member of runner shall be steam bent, care being taken not to "burn" the wood in steaming.

Ash for runner shoe and clamps shall be of sound, straight grain, quarter sawed kiln dried stock.

Dope.—Apply, with at least two hours between coats, two or more good coats of any approved aircraft dope. Finish with a coat of spar varnish or colored enamel.

Tail Surfaces (rudder, stabilizer and elevator) are to be made of similar material, in similar manner, aligned, covered and doped same as wing frames, using cord stitching or tacks.

Fuselage.—Make all wood members as shown in plan layout according to dimensions, fit all joints accurately and glue together with necessary blocking and stiffeners. Cover runner, tail fin surfaces and pylon, also "gusset" plates at joints with plywood, as noted, and glue together. Apply and bolt on all fittings.

Glue to be best grade Government specification casein waterproof glue. (Casein glue is always used cold.)

Fittings are to be made accurately as shown on plans and of materials noted. Carbon steel over .05 carbon to be annealed or heated before bending and tempered afterward.

Bolts to be carbon or high tensile strength steel, threaded S.A.E. or U.S.F. 32 thread for $3/16$-inch bolts. After tightening nut into place, cut bolt flush with nut and "rivet" (to prevent loosening) with four center punch indentations in thread circle.

Wire to be "piano wire" looped through fitting, "safety" secured and with loose end doubled back.

Control cables to be seven strand flexible wire cord looped through fitting with "thimble" insert. Bind loop with copper wire bindings, sweated with solder, double back loose end and bind.

Pins for hinges and doubled links are to be carbon steel of proper length and secured with aircraft safety pin or cotter pins.

Turnbuckles to be standard type of correct size to develop full strength of wire or cable and after tightening, secure from turning with copper or iron wire safety coils.

Building Materials.—*Woods.*—Wood was formerly the principal building material for gliders, although it is now possible to make just as light metal structures. This was due to the difficulty of working the metal and to the fact that gliders were formerly made mostly by clubs and private individuals, who seldom had the special tools and machinery required for metal construction. Moreover, wood is more easily repaired than metal. It would be desirable, however, for metal (particularly duralumin, which is used so much in the construction of engine-driven airplanes) to be more used in glider construction, especially for the fuselage. The metal tubes have more uniform strength than wood, which is known to be subject to great fluctuations, depending on its specific gravity and moisture content.

In using wood, therefore, the calculations must be based on the lowest of the given strength values. Of course, only perfectly air-dried wood can be used. It must be absolutely free from knots and must be cut parallel to the grain. Even air-dried wood is subject, however, to "working," *i.e.*, if the humidity of the air increases, the wood absorbs moisture and expands; in the opposite case, the wood dries and shrinks. Those changes occur chiefly at right angles to the grain, the wood "working" but very little in the direction of the grain. Since we know these properties of wood, we must adopt suitable precautions to prevent it from working. In the first place, we must, wherever possible, use plywood, which can be bought from the manufacturers in thicknesses from 1 mm. (0.04 in.) up. Moreover, the finished frame should be painted or varnished and all external parts carefully shellacked. The strength and physical characteristics of ordinary woods differ greatly and their uses differ correspondingly. Full information is given in Table I.

Metal Parts.—Duralumin and steel tubes are used for control rods; S.A.E. 1025 sheet metal for fittings; wire "ropes" for operating the rudders and cables for bracing the wings. Duralumin is an alloy of aluminum, copper, manganese and magnesium, the aluminum constituting about 90 per cent. Its specific gravity is about 2.8, and its breaking strength about 3500-4500 kg./cm.^{2} (50000-64000 lb./sq. in). For airplane and glider construction, it is as good as, if not superior to steel tubing on account of its much lower density. Detailed information on the weights of steel tubes and dural tubes are given in accompanying tables. Duralumin parts, due to their low-melting point (650° C. = 1202° F.), can be welded with oxyacetylene or hydrogen torch and with great care though mechanical joints such as rivets or bolts are favored by most users of Dural in preference to welding.

The term (cable) denotes a number of small wires twisted into a bundle, while the term (rope) denotes a cable made by twisting together several strands of several wires each. The latter is more flexible than the former and is always used when it has to pass over pulleys. However, since it stretches more than the former, the former is almost always used for the direct transmission of forces. For soarer and glider construction, diameters of 2 to 5 mm. (0.08 to 0.02 in.) suffice for either kind of cables. It is hardly necessary to mention that both kinds must be made of steel since iron wires stretch too much and are not strong enough, nor elastic enough to bend around small pulleys. The strengths of both kinds of cables are given in Tables III and IV. Rusty wires generally have somewhat less than half the strength of bright ones.

Steels Used in Aircraft Construction.—Three principal types of steels are used in aircraft to-day. The earliest efforts to adopt steel were made with the ordinary commercial grade, commonly referred to as cold rolled steel or cold drawn steel, having a carbon content of approximately 0.10 to 0.20 per cent. This material is easily worked, either hot or cold, and can be cold drawn to a tensile strength in the neighborhood of 60,000 to 70,000 lb. per sq. in., with a fairly good elongation. However, in brazing, welding or hot forming this steel, the strength increment introduced by cold working is removed, leaving the material in the fully annealed condition, where its strength may be as low as 40,000 lb. per sq. in. This was inadequate for even the earliest military types of motored craft. Specifications were therefore revised by the Army and Navy to call for steel having a carbon content of 0.20 to 0.30 per cent, known as steel No. 1025. This steel, after the heat of welding, etc., retains a tensile strength of not less than 55,000 lb. per sq. in. Its working and welding qualities are practically as good as those of the low carbon steel. As this material is plentiful and of moderate cost, it is suitable for metal fittings of gliders in even the lighter gauges such as No. 16 and No. 18.

Either of the foregoing steels is a "heavy" metal of construction because of its low strength-weight factor. Commercial steel is still used by a few aircraft builders, perhaps through a mistaken idea of economy. Steel No. 1025 is employed where the determining factor is modulus of elasticity and not strength. Its greater mechanical accuracy, uniformity and reliability make it preferable to the commercial grade, aside from its physical properties.

Chrome-molybdenum steel No. 4130X is well on the way to displace both and is to-day virtually the standard material of construction for powered aircraft in this country. The danger of mixing No. 1025 steel with No. 4130X steel in stores or during fabrication has led many airplane manufacturers to abandon the former altogether, using only No. 4130X steel throughout. Chrome-molybdenum steel was carefully studied by the Army Air Service and was found to possess remarkable properties. It can be cold drawn to the very thin walls required in aircraft construction, can readily be bent or formed to desired shapes hot or cold, has excellent welding characteristics and retains a relatively high strength after being subjected to the heat of welding. Furthermore, it responds exceptionally well to heat treatment, developing physical properties better than ordinarily expected of an alloy steel of similar or comparable carbon content. Wherever heat treating facilities are available and steel tubing is used for glider fuselages, the use of chrome-molybdenum tube will result in a material weight saving.

Strength-Weight Factors of Aircraft Materials.—Some typical strength-weight factors are given in the accompanying table. It will be seen that alloy steel when heat treated to a tensile strength of 150,000 lb. per sq. in. is equal in lightness as a material of construction to duralumin. This does not take into consideration savings in weight possible by welding steel as compared with riveting duralumin joints. Steels which are heat treated to a higher strength than 150,000 are "lighter" than duralumin. Good chrome-molybdenum steel may be readily heat treated to a strength of 200,000 lb. per sq. in. with a yield point of 170,000 or over and an excellent ductility and toughness. When correctly treated it is not brittle and has a high resistance to fatigue.

TYPICAL STRENGTH-WEIGHT FACTORS* OF AIRCRAFT MATERIALS

Wrought Metals (Tension)

		S. W. F.
Music wire—0.01-inch in diameter	400,000/7.85 =	51.0
Alloy steel, heat treated, high	200,000/7.85 =	25.0
Alloy steel—heat treated, medium	150,000/7.85 =	19.0
Duralumin	55,000/2.85 =	19.0
Magnesium alloy	34,000/1.75 =	19.0
Alloy steel—normalized	95,000/7.85 =	12.1
Mild steel—normalized	55,000/7.85 =	7.0
Low carbon steel—commercial	40,000/7.85 =	5.1
Aluminum—annealed	12,000/ 2.7 =	4.4

Wood (compression)

Balsam	2,200/0.12 =	18.0
Douglas fir	6,000/0.54 =	11.0
Spruce	4,300/0.43 =	10.0
Oak, white	5,900/0.74 =	8.0

* Obtained by dividing ultimate strength in thousands of pounds per square inch, by specific gravity. (Table by Horace C. Knerr.)

STRENGTH OF MATERIALS RECOMMENDED FOR GLIDERS

The strength of the materials recommended for metal parts of gliders and sailplanes are given below. Heat treated alloy steel has the highest strength-weight ratio, being followed by heat treated Dural, which has a strength-weight ratio about 20 per cent less than heat treated alloy steel.

COLD ROLLED MEDIUM CARBON STEEL (SAE 1025)

55,000	Tensile strength
36,000	Yield point
90,000	Bearing strength (except hinges)
60,000	Bearing strength for hinges and where subjected to stress reversals
55,000	Compression strength
35,000	Shearing strength

NOTE.—All strength values given in lbs. per sq. in.

HEAT TREATED DURALUMIN (17ST)

Sheet	Bar	Tubing
55,000	55,000 (¾″ diam. and below) 50,000 (above ¾″ diam.)	55,000 tensile str.
30,000	30,000 (¾″ diam. and below) 25,000 (above ¾″ diam.)	30,000 yield point
75,000	75,000	75,000 bearing str.
27,000 (above 1/16″ thick) 20,000 (below 1/16″ thick)	30,000	27,000 shearing str.

CHROME MOLYBDENUM STEEL TUBING (AS RECEIVED)

95,000..............Tensile strength
60,000..............Yield point
80,000..............Tension near welds
50,000..............Shear near welds
60,000..............Shear unwelded
125,000..............Bearing, near welds
140,000..............Bearing, unwelded

HEAT TREATED ALLOY STEELS

(Chrome Molybdenum, chrome vanadium, 3½% Nickel S.A.E. 2330)

Ultimate Tension	Yield Point	Bearing Strength	Shearing Strength
100,000	80,000	140,000	65,000
125,000	105,000	175,000	80,000
150,000	125,000	190,000	100,000
180,000	140,000	200,000	115,000

The bearing strength to be reduced to 125,000 near welds.

Cloth and Dope.—Light, closely woven linen or cotton cloth is used for covering the wings and sometimes the fuselage, linen being preferred by some because of its longer fibers, its higher strength and greater durability. The fabric used should be strong and light and fine-meshed. In any case the fabric must contain no starch sizing nor chemical fillers as finish, since this would prevent the penetration of the "dope." The dopes now commonly used are the cellulose-nitrate and cellulose-acetate which can be bought ready for application, either clear or pigmented, from several reliable manufacturers and supply houses. The nitrate dopes are cheaper but acetate dopes are better for first coats because they penetrate the fabric better. In the liquid state this substance is highly inflammable and must be handled accordingly. On doping, the fabric becomes taut, small wrinkles vanish and its surface becomes smooth and perfectly water-tight. The dope can be easily applied with a brush. In about an hour the doped surface is perfectly dry and taut. Its strength is increased about 20 per cent by the customary three coats used on gliders though two coats of dope and one of spar varnish are believed adequate by some glider builders.

Glue.—Cold glue is used exclusively, since this is less affected by water. It is a mixture of casein and chalk, often with the addition of special substances like ammonia, resin, etc., and is sold in the powder form in sealed receptacles. This powder is mixed with an equal quantity of water, taking care to avoid the formation of lumps, and allowed to stand 15-20 minutes before using. Special attention is given to the consistency of the mixture, since thin glue does not possess the requisite strength. Only the quantity required for immediate use should be mixed as it begins to lose its strength after a few hours. Any that is more than a day old should not be used. The powder must be kept in closed boxes to protect it from moisture.

Protecting Fittings.—The fittings, etc., can be protected from rust by plating with copper or nickel, though the most durable covering is zinc or cadmium which is also proof against salt air. A good oil paint is likewise effective. The metal is cleaned and covered with a thin quick-drying linseed-oil paint containing some

TABLE I

PROPERTIES AND USES OF THE MOST COMMON WOODS

Kind	Spec. Gravity		Color	Properties and Uses
	Dry	Green		
Birch	0.75	0.95	White to Yellow	Tough, difficult to split, not very hard, durable in dry form. Used as plywood to cover fuselage and leading edge of wing, also as webs for spars and struts.
Ash	0.90	1.05	Gray to Grayish White	Hard and tough, difficult to split, strong, flexible, elastic, durable. Excellent for runners, edge strips, front fuselage spars or any parts to be bent or strongly stressed.
Pine	0.65	0.85	Yellowish White to Reddish	Soft, easily split, pitchy, quite durable. Used for spar and strut flanges, bulkheads, fuselage and auxiliary spars, struts, etc.
Spruce	0.50	0.80	Yellowish White to Reddish	Soft, easily spilt, pitchy, durable. Shrinks but little. Suitable for fuselage spars, hollow and grooved wing spars. Difficult to obtain free from knots.
Fir	0.60	0.85	Whitish	Soft, tough, not very pitchy, durable when dry, shrinks little, splits easily, somewhat harder than spruce. Same uses as pine and spruce.
Elm	0.70	0.95	Yellowish to Brownish	Hard, very tough and strong, elastic, durable, difficult to split. Shrinks but little. For uses, see Ash.
Maple	0.70	0.90	White	Hard and strong, tough, difficult to split, durable when dry. Used as plywood for all purposes.

good coloring material. When thoroughly dry, a coat of varnish is added. Thick coats of paint cause blistering. Brace wires can likewise be covered with anti-rust varnish. Control cables and pulleys are best lubricated with acid-free mineral oils like graphite impregnated vaseline, which must be frequently renewed.

TABLE II

STRENGTH COEFFICIENTS OF DIFFERENT KINDS OF WOOD

Kind	Tensile Strength		Compressive strength with grain
	Across grain	With grain	
	kg./cm.² lb./sq. in.	kg./cm.² lb./sq. in.	kg./cm.² lb./sq. in.
Ash	20–50 285–711	850–1100 12090–15646	350–450 4978–6401
Spruce	20–40 285–569	500–800 7112–11379	250–400 3556–5689
Pine	20–40 285–569	500-850 7112–12090	400–450 5689–6401
Fir	20–40 285–569	500–900 7112–12801	300–400 4267–5689
Elm	30–50 427–711	600–900 8534-12801	300–400 4267–5689

Kind	Bending strength	Shearing Strength	
		Across grain	With grain
	kg./cm.² lb./sq. in.	kg./cm.² lb./sq. in.	kg./cm.² lb./sq. in.
Ash	400–900 5689–12801	200 2845	30 427
Spruce	400–500 5689–7112	250 3556	50 711
Pine	1000–1100 14224–15646	300 4267	60 853
Fir	500–800 7112–11379	250 3556	50 711
Elm	450–1000 6401–14224	300 4267	60 853

TABLE III

WIRE CABLES

Diameter of Cable		Diameter of Wire		Breaking Strength	
mm.	in.	mm.	in.	kg.	lb.
2.8	0.1102	0.40	0.0157	1160	2558
3.1	0.1220	0.45	0.0177	1470	3241
3.5	0.1378	0.50	0.0197	1816	4004
3.9	0.1535	0.55	0.0217	2190	4829
4.2	0.1654	0.60	0.0236	2615	5766
4.5	0.1772	0.65	0.0256	3070	6770
5.0	0.1969	0.70	0.0276	3560	7850

The individual structural parts and fittings naturally depend on the design and must be specially made. Bolts, shackles, thimbles, turnbuckles, screw eyes, can be bought ready-made. The illustrations require no explanation. The strength of the turnbuckles is given in Table VII.

TABLE IV

WIRE ROPES

Diameter of rope		No. of wires	No. of strands	Diameter of each wire		Breaking strength	
mm.	in.			mm.	in.	kg.	lb.
1.8	0.0709	42	6	0.20	0.00787	330	728
2.3	0.0906	42	6	0.25	0.00984	510	1125
2.4	0.0945	72	6	0.20	0.00787	565	1247
2.7	0.1063	42	6	0.30	0.01181	740	1632
3.0	0.1181	72	6	0.25	0.00984	885	1951
3.2	0.1260	42	6	0.35	0.01377	1010	2273
3.6	0.1417	42	6	0.40	0.01574	1300	2867

TABLE V

Weights of Steel Tubes

	Thickness of Walls			
Outside diameter	0.5 mm. 0.02 in.	1.00 mm. 0.04 in.	1.5 mm. 0.06 in.	2.0 mm. 0.08 in.
mm. in.	kg./m. lb./ft.	kg./m. lb./ft.	kg./m. lb./ft.	kg./m. lb./ft.
10	0.116	0.221	0.312	0.391
0.39	0.078	0.149	0.210	0.263
20	0.239	0.466	0.679	0.882
0.79	0.161	0.313	0.456	0.593
30	0.361	0.711	1.048	1.372
1.18	0.243	0.478	0.704	0.922
35	0.423	0.833	1.231	1.616
1.38	0.284	0.560	0.827	1.086

TABLE VI

Weights of Duralumin Tubes

	Thickness of Walls				
Outside diameter	1.0 mm. 0.04 in.	1.5 mm. 0.06 in.	2.0 mm. 0.08 in.	2.5 mm. 0.98 in.	3.0 mm. 1.18 in.
mm. in.	kg./m. lb./ft.	kg./m. lb./ft.	kg./m. lb./ft.	kg./m. lb./ft.	kg./m. lb./ft.
10	0.085	0.133	0.185	0.241	0.301
0.39	0.057	0.089	0.124	0.162	0.202
20	0.162	0.248	0.340	0.434	0.533
0.79	0.109	0.167	0.228	0.292	0.358
30	0.240	0.365	0.494	0.627	0.786
1.18	0.161	0.245	0.332	0.421	0.528
40	0.316	0.480	0.682	0.820	0.997
1.58	0.212	0.323	0.458	0.551	0.670

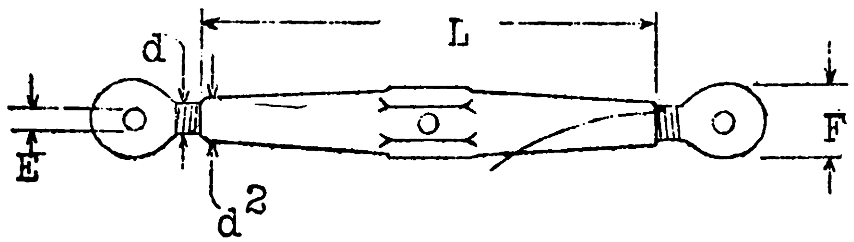


TABLE VII

Strength of Turnbuckles

d Diameter of screw thread	4^2 Diameter of nut	L Total length of turnbuckle	H Length of thread	E Inside diameter of eye	F Outside diameter of eye	Maximum load
mm.	mm.	mm.	mm.	mm.	mm.	kg.
in.	in.	in.	in.	in.	in.	lb.
6.35	10.20	114.1	50.8	4.75	12.45*	3200
0.25	0.40	4.49	2.00	0.19	0.49	7055
6.35	10.20	114.1	50.8	4.75	12.45*	2400
0.25	0.40	4.49	2.00	0.19	0.49	5291
4.76	7.50	101.5	44.5	3.21	9.53	1475
0.19	0.30	4.00	1.75	0.13	0.38	3252
4.76	6.78	82.5	31.8	3.21	9.47	1000
0.19	0.27	3.25	1.25	0.13	0.37	2205
4.76	7.46	101.5	44.5	3.20	9.42	1475
0.19	0.29	4.00	1.75	0.13	0.37	3252
4.76	6.85	82.5	31.8	3.21	9.53	1250
0.19	0.27	3.25	1.25	0.13	0.38	2756
3.97	5.84	66.7	28.6	2.28	7.83*	1000
0.16	0.23	2.63	1.13	0.09	0.31	2205
3.97	5.84	66.7	28.6	2.28	7.83*	975
0.16	0.23	2.63	1.13	0.09	0.31	2150
3.18	5.96	50.8	20.6	1.83	6.33	570
0.13	0.23	2.00	0.81	0.07	0.25	1257
3.18	4.90	50.8	22.2	1.83	6.05	875
0.13	0.19	2.00	0.87	0.07	0.24	1929
2.38	3.71	44.5	19.1	1.63	4.73*	425
0.09	0.15	1.75	0.75	0.06	0.19	937
2.38	3.71	44.5	19.1	1.63	4.73*	400
0.09	0.15	1.75	0.75	0.06	0.19	882

* Special steel.

TABLE VIII

WEIGHT OF SHEET IRON AND STEEL

Thickness		Wrought Iron		Soft Steel		Hard Steel	
mm.	in.	kg./m.²	lb./sq. ft.	kg./m.²	lb./sq. ft.	kg./m.²	lb./sq. ft.
0.5	0.01969	3.90	0.7988	3.93	0.8049	3.93	0.8049
1.0	0.03937	7.80	1.5976	7.85	1.6078	7.85	1.6078
1.5	0.05906	11.70	2.3964	11.87	2.4312	11.77	2.4107
2.0	0.07874	15.60	3.1952	15.70	•3.2156	15.70	3.2156

The full-page construction drawing at Fig. 56 shows the various parts of the fuselage of a typical training type glider and indicates the location of the various main and auxiliary structural elements, the material of which the parts are made and outlines the location of the various pulleys and guides for the control cables.

Liquid Marine Glues.—Liquid marine glues are divided into the drying and the non-drying types. The drying glue does not harden but dries on the surface, the body of the glue which is protected from the air retaining its resiliency indefinitely. The non-drying glue loses some of its stickiness when exposed to the air but never becomes dry. Non-drying glue has no adhesive strength, and when it is placed between two pieces of wood they are easily pulled apart, the glue adhering to both pieces and forming in long strings. This type of glue is used in places where planks will weave and work together and where there is a great amount of expansion and contraction, and is especially valuable when used between double-planking and on battens. Marine glue of the drying type is used for a waterstop where a good adhesive is required in addition to resiliency, and must withstand expansion and contraction caused by weather conditions.

CHAPTER ELEVEN

DETAILS OF TRAINING GLIDER CONSTRUCTION

Typical Airfoil Curve and Ribs—Assembling the Wings—Covering the Wings—Securing Fabric Covering—Doping the Wings—Forms of Bracing and Control Wires—Training Glider Wire and Cable Arrangement—Aligning and Rigging a Glider.

Typical Airfoil Curve and Ribs.—The curve of a typical airfoil for a training glider with dimensions from the datum line at various stations given at the top of Fig. 57 will enable any one to lay out a full size pattern or jig to which the ribs may be made to conform. Three types of ribs are used. Rib A is a compression rib and is strengthened by plywood reënforcements at the nose and adjacent the rear spar so a box section as shown is produced. To make the ribs correctly to conform to the proper wing curve, it will be helpful to make the layout full size on a piece of ¼-inch thick whitewood or plywood and finish the board accurately after the outline is made to the shape desired. The outline of the rib construction jig should be about $1/32$ inch larger all around than the airfoil template. The jig is made on a bench top or any straight board that is sufficiently wide and has $3/16$-inch thick wood blocks cut to the shape of all the open spaces in the rib including the spaces for the spars and so fastened to the base piece by brads or wood screws that when the rib cap strips and vertical and diagonal bracing pieces are laid in the spaces between and outside of the blocks, the complete rib assembly

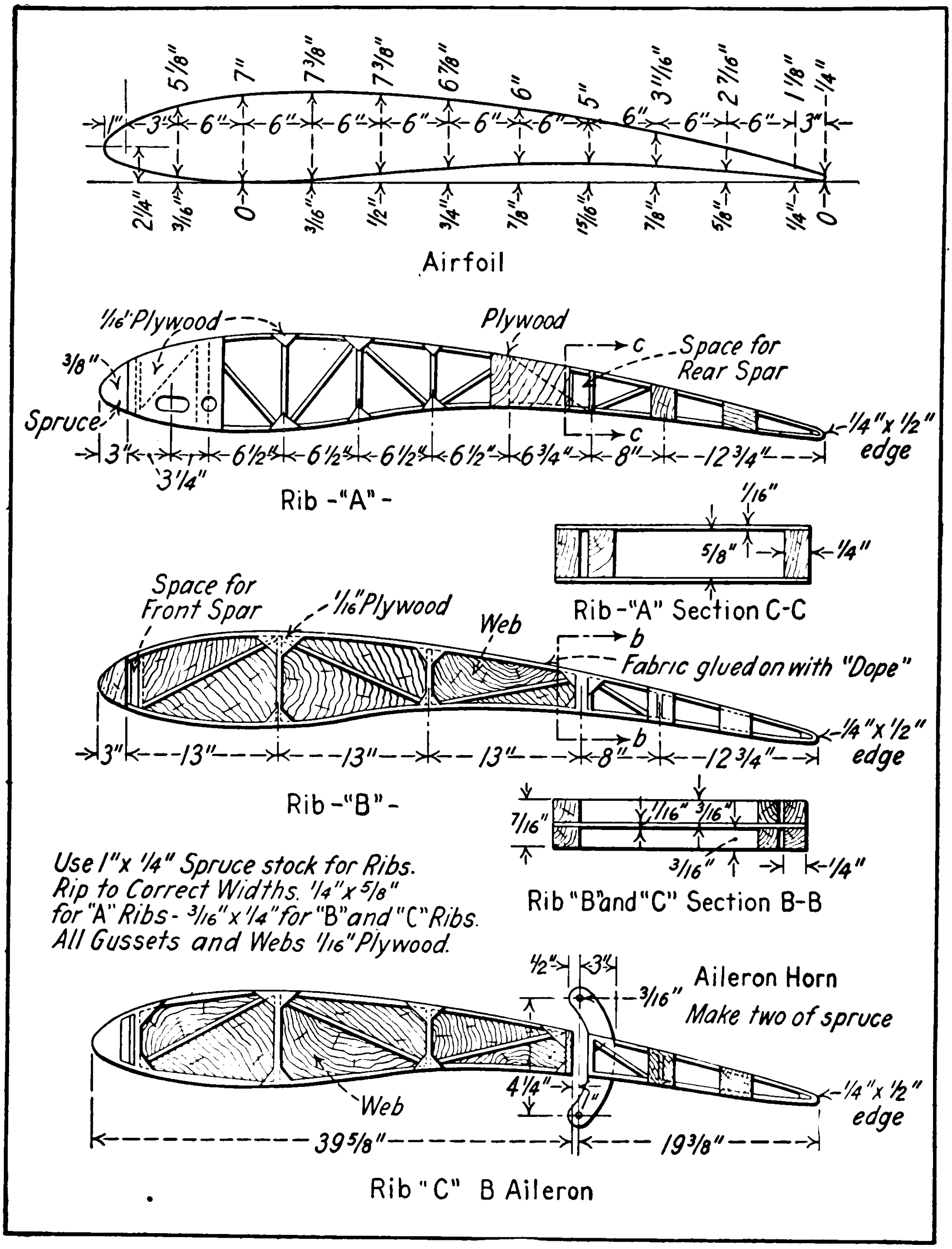


Fig. 57.—Details of Airfoil Curve at Top. Cross Section and Construction of Various Types of Ribs for Typical Training Glider Wing of the Two-Spar Form with Front Spar Near Entering Edge Below.

is produced by the matching pieces and a permanent assembly is secured by gluing and bradding the gusset plates of 1/16-inch birch plywood as indicated for rib A and fastening the reënforcements of 3/16-inch square spruce to the plywood web for ribs B and C, and further strengthening the assembly with plywood gussets glued to the joints.

The rib designated as "B" in Fig. 57 is a former rib and two or three are used to each compression rib shown at "A." These are of different construction. The central web is of plywood and is reënforced by cap strips and diagonal bracing of spruce glued and bradded in place as indicated. Spaces are left for the spars at the nose and near the trailing edge as shown. Some glider constructors leave out the plywood web and build up the rib of 3/8-inch by 1/4-inch cap strips and bracing, using only the plywood gussets or bracing pieces. While the rib is not as strong as that with the plywood web it is adequate and considerably cheaper to build. Former ribs are spaced on about 12-inch centers and each bay is composed of two or three former or B ribs between each pair of compression members or A ribs.

The rib shown at Fig. 57C is the type needed at that portion of the wings where the ailerons are attached. The rib cap strips terminate at the rear spar instead of at the trailing edge molding as is the case with ribs "A" and "B" and the aileron frame is built up with a short spar and with short ribs composed of upper and lower cap strips with vertical and diagonal strut bracing and with plywood pieces to strengthen the assembly. Some constructors use the plywood web only at the end of the wing frame and open frame ribs at other points. Aileron horns may be made of spruce ¼ inch thick or may be cut from sheet metal $1/16$ inch thick, such as Dural or mild steel, reënforced with wood to prevent buckling. The aileron frames are connected to the rear spar of the wing by hinge joints of various types, the simplest being an eyebolt in one piece and a coacting yoke to fit it in the other, two or more being used, depending on the length of the aileron.

Assembling the Wings.—When the wing ribs are completed and the spars planed and properly shaped, the work of assembling the wing can go ahead. Lay out spars and drill for all fitting bolts Slide ribs into position, bolt all fittings into place and glue ribs to spars using shims wherever necessary to insure a solid fit. Be sure to use reënforcement blocks and plywood gussets wherever indicated at the juncture points of ribs and spars. Insert trailing edge strip and glue into place if of wood. At this point assemble all internal wing bay bracing wires, tighten wires and align wing true to ⅛ inch. Install aileron cables through pulleys and see that everything is ready before putting on fabric. Take care in making ailerons. Make ribs with same care as in wing and assemble complete, cutting out aileron horn from hard wood or fitting regular aircraft aileron horn that may be available as standard fittings. Spars of solid section are usually of spruce ½ inch or ⅝ inch thick and about 5 inches deep for the front and 3½ inches deep for the rear spar.

It is important to keep the wing ribs from shifting their position. Spacing strips glued and bradded to the flange of the spar will hold the rib cap strips firmly in position. Compression ribs must fit the spars accurately. The wood frame should be well shellacked and the rib cap strips covered with narrow tape tacked in place before the cloth covering is applied. All metal fittings, unless made of Dural or stainless steel should be covered with enamel. Dural or aluminum fittings and tubes, when used in wing construction are coated with Linoil.

Covering the Wings.—Wings, ailerons, and other control surfaces can now be covered. Many builders use grade "A" mercerized cotton, drawn tight and cemented at all edges to framework and to ribs on rear half of lower surface, with aircraft dope. A special cotton fabric, of somewhat lighter weight than used in powered airplanes is obtainable and is amply strong for gliders. The nose of the wing should be covered with plywood bent to shape, glued in place and bradded with small cigar box nails to filler strips on top and bottom of spar between ribs. Bend forward edge of fabric. Slit fabric at proper points for guy wires and control cables, and reënforce with fabric patches, and with thin leather patches stitched in place to act as a guide for the control cables if internal pulleys are used. These are not needed for the guy wires. The leather patch has a slot, similar to a buttonhole, for the control cable to pass through if the guide sheaves are inside the wing frame.

There are two methods of covering a wing frame. The fabric may be sewed together to form a sheet of the proper width and of sufficient length to go completely around the wing. It may be cut in two pieces, one corresponding to the material needed to cover the top of the wing, the other, the bottom of the wing and these are sewed together to form a bag open at the fuselage end and shaped at the top with the cut-out for the aileron. The covering is cut to paper patterns when this method is employed. The wing frame is slipped into the bag just as a hand is pushed into a mitten and the open end is sewn up. The other method is to fold the sheet around the wing frame, sewing it in place after it has been located with tacks.

Securing Fabric Covering.—The covering, in the form of a wide sheet, having been previously stitched and all seams carefully examined and the linen or mercerized cotton being quite dry, it will be drawn on to the plane starting behind leading edge; half, of course, will be on the upper side and half on the lower. The fabric will be carefully and evenly pulled taut, and tacked down temporarily, all seams being straightened by pulling the fabric at each end. After this, all surplus fabric will be cut off and the two ends of the fabric sewn up, taking care to turn in the edges of the fabric, the joint being along the center of the trailing edge, and, where the aileron gap occurs, along the top edge of the rear spar. Having sewn up all the edges neatly, the next operation is "stringing" the wing to keep the fabric tight to the ribs. This is done with a light, special flax string which is passed through the fabric from the top to the bottom round each rib about every four inches and knotted at each turn, taking care to knot up fairly tight.

The method generally used in covering airplane wings when tacks are used is to tack through strips of narrow fabric tape which acts as a spacing member to prevent the tack heads from breaking the linen, the tacks being spaced about 2 inches apart in addition to the stitching around the ribs. A certain amount of the "dope" penetrating the linen will stick it to the ribs. Wings that have been tested to destruction demonstrate that this method of fastening is extremely strong, and the writer has seen airplane wings that have been damaged in wrecks in which the main spar has fractured and yet the fabric was still held securely to the ribs. One point to be avoided is making holes, with the stringing needle, where it is not intended a string should pass through, the only hole permissible being the one where the string passes through. When the stitching is employed, the cord and knots on top and bottom of ribs are covered with narrow strips of "pinked" fabric about two inches wide which is securely "doped" into place in order to provide a smooth covering and to lessen the skin friction. In order to give a smooth finish to the wing after doping it is sometimes smoothed down with sandpaper and a coat of spar varnish applied. When this much is done, weigh each wing, to make sure that they are reasonably equal in poundage. If not, check up to find the cause of the weight difference. If the wings are duplicated, they should weigh the same. A variation of several ounces is permissible.

Doping the Wings.—It is best, if possible, to dope planes in a room of moderate temperature, and one where this temperature may be maintained, and that may be kept reasonably dust tight. The wing is laid on bearers running longitudinally under the spars, and these can be supported on horses. The dope can be put into galvanized paint cans for convenience and brushes about 4 inches wide should be used. Common, or cheap brushes should not be used as the hairs are likely to come out and spoil the work. Amateurs should not dope wings on rainy or damp days. Wait till fair weather.

To start doping take a fair amount of dope on the brush, and work it from the leading edge to the trailing edge, and then from left to right. Spread it evenly, taking care not to start too big a patch at once. In this manner cover the whole plane, after which a suitable time interval must elapse before proceeding with the next coat, the interval depending on temperature and humidity and the solvents and thinners used in the dope.

There are two types of dope in use at present. These are known as cellulose nitrate and cellulose acetate dopes. The latter is produced from cotton treated with acetic anhydride and acetic acid, while the other is made in a manner similar to the production of guncotton through the use of cotton treated with nitric and sulphuric acids. The acetyl or the nitrate group is taken up by the cellulose to make a new compound which is soluble in certain solvents. The treated cotton is then dissolved in solvents such as methyl, amyl, or ethyl alcohol, acetone, etc., subsequently adding other non-solvent thinners such as benzol, alcohol or benzine. Different kinds of softeners and fire-resisting salts are then added to the dopes. These are usually high-boiling, slow-evaporating liquids. Diacetone alcohol is a representative of this class. Triphenyl phosphate is used for its fireproofing value. A small quantity of urea is sometimes used to prevent the acidity which may be caused over periods of storage. Fire resisting dope is of value on motored gliders but is not necessary on the usual glider or sailplane as the fire risk is practically nil if no motor is installed.

The present practice in doping powered airplane wings is to apply first two coats of acetate dope because of the higher fire-resisting value and because of the fact that the acetyl radical present is ordinarily not injurious to fabric. There is then applied three coats of cellulose nitrate dope. A very taut surface is obtained. Colored enamel is then applied. With this practice no difficulty has been experienced with scaling or cracking of the wing enamel. On the other hand, when a number of straight coats of acetate dope are used very serious scaling and cracking of the subsequently applied enamel may take place. The cellulose nitrate dope, moreover, is very much cheaper than the acetate dope, is readily available, has greater covering properties and gives greater tautness to the fabric. For gliders, two coats of nitrate dope and a light coat of spar varnish will be sufficient. While it is advisable to hand brush the first coat of dope to insure good penetration of the fabric, subsequent coats may be air brushed or sprayed on if a spray outfit is available.

As the drying proceeds the substance contracts and brings the threads more closely together. While from four to five coats of "dope" are applied to the surface of the linen of airplane wings the increase in weight due to the use of the "dope" is only about one and one-half ounces per square yard. The increase of weight when two coats are used on glider wings will be about half this value. The "doping" is said to increase the strength of the fabric by about 20 per cent (higher values are sometimes claimed) as well as tightening it. Tautness is aërodynamically essential and doping reduces the sag though with the materials now in use, any surfaces deteriorating to a slackness sufficient to affect the aërodynamical properties of the machine seriously would have been condemned on their appearance. Another point which has been somewhat neglected is the great extent to which the strength of the wing structure is influenced by the tension of the doped fabric upon it. In general, slackness of the dope will weaken the wing structure, but on the other hand too great tautness will lead to deformation or even fracture, especially of the light wing structures used on gliders and sailplanes which are not and need

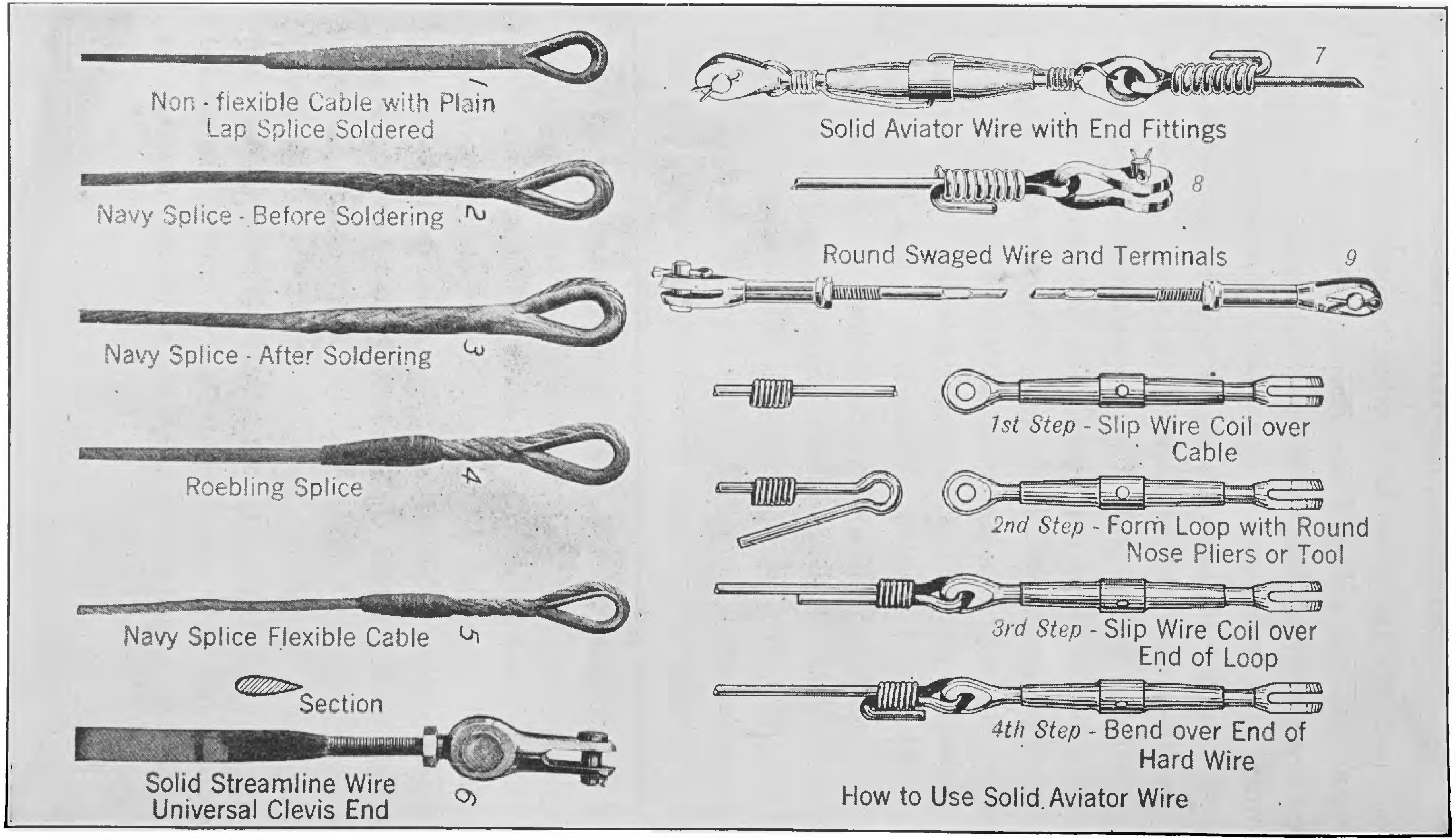


Fig. 58.—Various Types of Bracing Wires and Cables Used in Aircraft Bracing and Control, Showing Splices and Connections Used in U. S. Army Practice. Note Method of Using Solid Aviation Wire Shown at Lower Right-hand Corner.

not be braced internally as strongly as the corresponding surfaces of power propelled airplanes are.

Forms of Bracing and Control Wires.—The stays and brace wires now in general use in aëronautical construction may be divided into five classes: solid streamline wire, non-flexible cable, flexible cable, round swaged wire, and solid aviator or piano wire. The material used for interplane bracing and also for the landing gear and empennage stays in powered airplanes may be either streamline wire, or non-flexible cable consisting of a number of strands of individual wires. For controls, and particularly those which pass over comparatively small pulleys, flexible cable usually is employed. This is quite similar in appearance to the non-flexible, except that its main strands, instead of being wires, consist of a number of much smaller wires. Internal braces or stays in the fuselage and wings are made of either round swaged wire or solid aviator wire, some designers and builders favoring one type and some the other.

One of the most serious difficulties encountered in using any style of stay or brace is the proper looping and splicing of the ends so that the terminal attachments will be as strong as the wire itself. Various types of terminals are used in securing the ends of the brace wires to the parts of the fuselage, wings, etc. For instance, streamline and swaged wires are provided with right- and lefthand threads at the ends, which screw into clevises or internally threaded sleeves having yokes at the outer ends that are secured to plates or eyes fastened to the fuselage or other part to be braced. Adjustment is secured by turning the wire itself, inasmuch as the clevis usually is attached to its mounting by a cross pin which prevents it from rotating. When the proper adjustment has been reached, locknuts on the threaded ends of the wires are screwed down tight against the clevises. The type of terminal used with streamline wire is shown at 6 and that for swaged rod at 9 in Fig. 58.

For either flexible or non-flexible cables, terminals usually are made by bending the cable around thimbles and then securing the free ends to the main part of the strand either by plain soldering or by splicing, as shown in Fig. 58. The splicing operation consists of separating the strands at the end of the cable and also those of the body just below the point of the thimble, and the interweaving the two sets of strands, so that when pulled tight, they will form a compact joint as strong as the cable itself. The splices may be soldered, although this is not always considered necessary with some types of splice. They also are usually served, or bound with fine wire or similar material wound over the full length of the splice. A cable with thimbles spliced into it at both ends is adjusted for length by means of a turnbuckle between one end and its attachment.

Solid aviator wire is secured at each end by forming a loop of the wire itself, slipping a flattened sleeve or ferrule over the main wire and the loop end, and then bending back the end alongside of the ferrule. The various steps in forming such a terminal are shown in order at Fig. 58. Adjustment for length in this case also is obtained by using a turnbuckle at one end.

The chief advantage of streamline wire is that it reduces the parasite resistance. For this reason it is much used on war planes, especially by the British and to some considerable extent in the United States. It is only required, of course, for exposed places, such as interplane, landing gear and empennage braces of airplanes.

In all soldering operations in connection with airplane cables it is very importnat to use a non-oxidizing flux. No flux containing any oxidizing acid should ever be employed as a cleaning agent preparatory to soldering cable splices, especially on cables where its removal would be difficult or where it might get in between the strands and attack the metal. Soldering fluxes specified at the present time, and which are satisfactory on tinned wire, are stearic acid, stearic acid and rosin, or rosin dissolved in a suitable solvent. Where an acid flux has been used, its corrosive effect often may be neutralized by the application of an alkaline solution, such as soda water. However, with stranded cable, where the acid may be driven into the intersections between the fine wires by the application of heat, it is questionable whether any system of washing will eliminate or neutralize the acid. Corrosion may therefore occur in the interior wires, while the exterior appears to be in good condition.

Training Glider Wire and Cable Arrangements.—When an open fuselage type glider is set up, there will be considerable wiring to do. Some of this is structural in that it acts as bracing, the remainder of the wires have to do with the control system. The reader has been told that bracing is usually hard drawn high tensile strength piano wire and that control cables are usually 3/32-inch or 1/8-inch flexible so that they can pass over pulleys easily. The top view of a primary type glider at Fig. 59 shows a conventional layout. Cables extend from the rudder bar back to the rudder control horns. Other cables extend from the stick

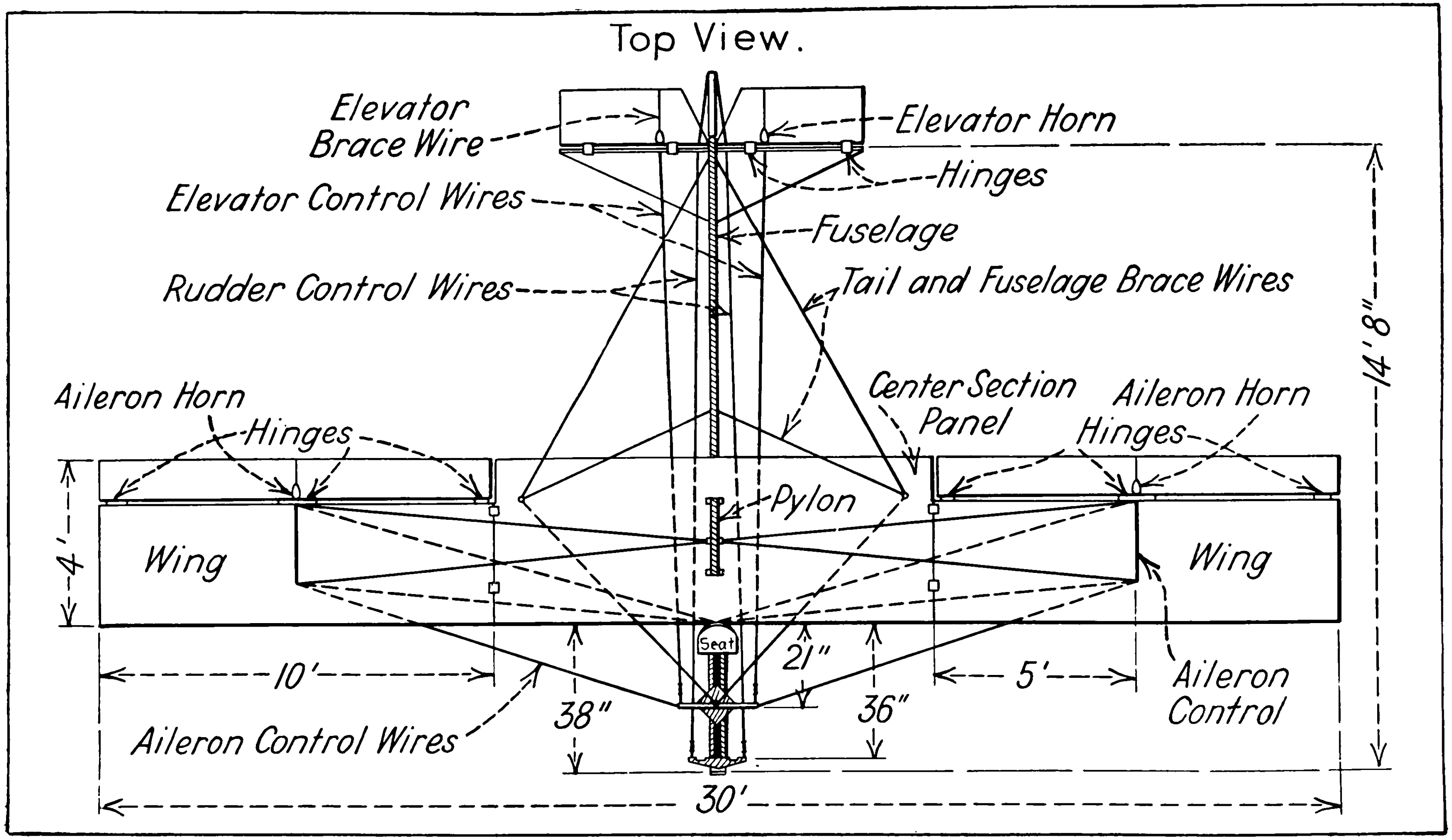


Fig. 59.—Plan View of Typical Training Type Glider Showing Bracing and Control Wires Commonly Used. This Glider Is Smaller Than the Dickson Design But General Arrangement of Bracing Wires Is the Same.

controlled lever to the ailerons and from the stick directly back to the elevators. The diagram at the top of Fig. 60 shows one arrangement of control wires in which the elevators are actuated by levers at the end of a cross shaft and the stick is so jointed that it can be swung from side to side to actuate the ailerons. The scheme outlined may be used in either gliders, sailplanes or motored airplanes.

The control cable arrangement shown at Fig. 61 is that generally employed on single longeron fuselage types of gliders. The rudder control is the same as in the plan previously described. The control stick is pivoted to a support consisting of a fork attached to a tube "A" and the tube carries an arm which is rigidly fastened to it. The tube is slotted to permit the lower end of the stick to be rocked back and forth and actuate the cable passing through the tube, over the pulley at the front end and from that point over the lower guiding pulleys to the point where it joins the V extending from the control horns below the elevator surface. The portion of the cable that passes through the rocking tube "A" which has an oscillating or partial rotating movement on its axis leads over the upper pair of guide pulleys and back to the V of the cable extending from the upper control horns of the elevators.

The aileron control is by the arm or rocking lever that is fastened to the tube A. The arm is rocked by moving the stick from side to side. The control cable from the right side of the arm passes over the rear pulley and makes a right angle turn over the lower wing pulley to the lower control horn of the left aileron. The top control horns of the ailerons are joined by a "follow through" cable so that when one aileron moves up, the other tilts down. From the lower control horn of the right aileron the cable passes over pulleys to the left arm attached to the rocking tube. This hook-up is such that when the top of the lever is pushed to the high side, the aileron on that side of the wing will be tilted up to decrease the lift and that on the low wing will be tilted down to increase the lift. This arrangement of control wiring is used on the Dickson glider, described in some detail in the following chapter with comprehensive working drawings.

The simplified diagram shown at the bottom of Fig. 61 outlines a typical bracing wire arrangement. It will be apparent by study of this plan that the wing must be braced to withstand both lift and drag loads and that the fuselage must be braced to maintain the proper alignment of wing and fuselage. The wing spars must be exactly at right angles to the fuselage longerons. The flying loads are carried by wires extending from fittings on the wing spars down to a suitable anchorage on the keel. These wires are opposed by wires extending from the top of the pylon to attachment points on the top of the wing that are just above the similar points on the lower part of the wing. The load carrying wires are known as "flying" or lift wires and are stressed while the glider is in the air. The opposing wires are known as landing wires and are stressed when the glider is resting on its skid or making a landing. Of course, the landing wires oppose the pull of the flying wires.

We have seen that a glider wing is subjected to both lift and drag forces when the glider is in flight. The resistance or drag (which tends to move the wings backwards) may be taken by external wires extending from the nose of the keel to the fittings

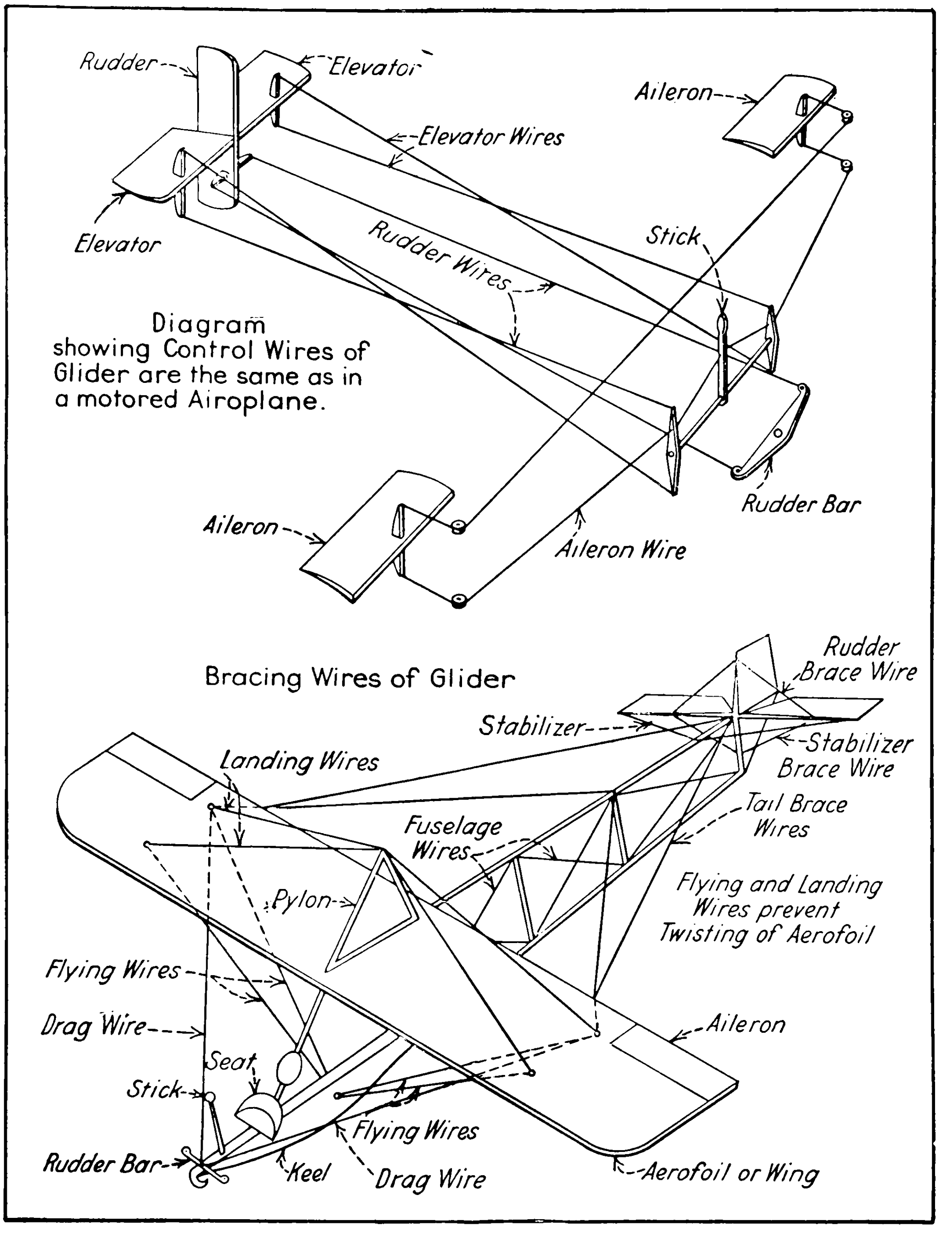


Fig. 60.—Diagram at the Top Shows One Method of Connecting Up the Control Surfaces and Their Actuating Means by Cables That May Be Used Either on Gliders or on Motored Airplanes. The Lower Illustration Shows the Bracing Wires on Which the Structural Strength and Alignment of Any Training Glider Depends. Control Cables Are Not Shown in This View to Simplify It.

of the flying wires on the rear spar. Part of the stress is then carried to the front spar by the compression ribs of the wing. the pull of the drag wires is opposed by tail brace wires extending from the rear wing spar flying wire fittings to the extreme rear of the fuselage upper longeron and also to an intermediate point on the top longeron. All brace wires should be provided with a turnbuckle to insure that they will be properly tensioned. Sometimes the fuselage may be a Pratt truss using vertical compression members or spacers between the upper and lower longerons and wire cross bracing, but more often it is a Warren truss with diagonal and vertical brace members of wood or tubing between the longerons.

It is sometimes necessary to brace the empennage. This is usually done with wires corresponding to the lift and landing wires of the wings; one pair extending from the rudder post to opposite points on the stabilizer rear spar and opposing wires from similar points under the stabilizer spar to the rear post of the fuselage. If no stabilizer is fitted to the glider, a pair of bracing wires extend from the cross piece to which the elevators are hinged to a point on the top longeron of the fuselage. In the diagram at the bottom of Fig. 60, no control wires are shown to simplify details of the bracing wires.

Round wire and cable bracing has been used on training gliders because their flying speed is so low that its resistance is negligible and because such wiring is cheaper than the drawn or swaged streamline section wire bracing so popular in powered airplane construction. When gliders are turned out on a quantity basis, streamline wiring which does away with turnbuckles or splices should be popular. In some gliders, the flying and landing wires are replaced by a pair of streamline section tubing lift struts, these being capable of carrying either flying or landing loads. Tubing is also used on some gliders to brace the empennage.

Aligning and Rigging a Glider.—The alignment and rigging of a training glider is simple. The usual glider has no dihedral and the angle of incidence is determined by the location of the

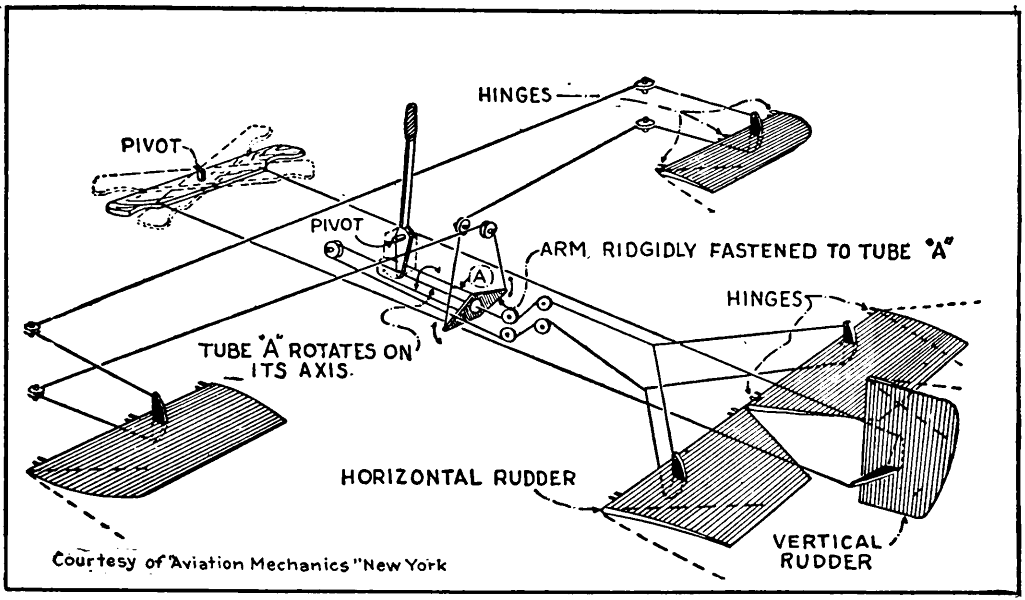


Fig. 61.—A Simple and Popular Hook-up of the Control Surfaces and Actuating Elements Favored by Primary Training Glider Designers. Vertical Rudder Is Removed from Its Correct Position Between Elevators to Prevent Confusion of Lines in Drawing.

spar fittings on the fuselage. Dihedral may be easily allowed for if provided by the adjustment of the landing and flying wires. To increase dihedral, flying or lift wires are lengthened and their opposing or landing wires are shortened. The opposite procedure will decrease or reduce dihedral. In order to make sure that the airfoil or wing will not be twisted, the landing wires on each side should be of the same length and the flying wires must also correspond. If the wing tip is high on one side, the flying wires will be longer than those on the other side and the landing wires will be shorter than the corresponding set.

To insure that the wing spars are at right angles to the fuselage longerons, the fuselage brace wires must be adjusted to the same length and the drift wires must also be the same. In some gliders, the drift loads are taken by bracing inside the wing and there are no external drift or drag wires. With control lever in neutral position, the control surfaces, *i.e.*, ailerons and elevator flaps must be in neutral position also The rudder should point straight back or correspond to the longitudinal axis of the glider fuselage when the control bar is at right angles with the keel or longeron members.

CHAPTER TWELVE

BUILDING THE DICKSON TRAINING GLIDER

When Building a Glider is Justified—Fuselage for Training Glider—Dickson Glider Wing Construction—Wing Ribs—Front Spar—Rear Spar—Leading and Trailing Edges—Wing Fittings—Wing Tip Skid Fittings—Wing Attachment—Aileron Horn Construction and Attachment—Rudder Construction—Elevator Details—Stabilizer Construction—Stabilizer Anchorage—Stabilizer Bracing—Miscellaneous Metal Fittings—Control Unit for Glider—Rudder Bar Construction—Launching Hook—Control Column Details—Torque Tube and Bearings—Control Column Movement—Cable Sheaves or Guide Pulleys—Control Cable Fittings—Aileron Cable Guide Sheaves—Control System of Glider—Bracing Wiring of Gilder.

When Building a Glider is Justified.—There are times when a group of young men who possess some mechanical ability, such as engineering or manual training school students, form a gliding club and as they often have shop facilities such as wood working machinery and tools available, they have a natural desire to build their own glider or sailplane. A number of the very efficient sailplanes of German design which are described in another chapter were built by engineering school students from plans made by their teachers.

The primary training type of glider may be built for a cash expenditure of $100 to $150, but the bill of material for a sailplane will cost from $200 to $250. Plans may be obtained from various sources, some selling for as little as $1.50. In procuring plans it is best to make sure that they are approved by the U. S.

Dept. of Commerce. The primary training glider is simple and within the capabilities of amateur constructors who can take the time to do the painstaking work required. Supply houses will materially reduce the labor by furnishing complete wings and ailerons, a built-up fuselage or tail group or a complete bill of material at very moderate prices. A large amount of work will be saved if the wing ribs are procured ready for assembling to the spars.

The primary training glider illustrated in the accompanying working drawings was detailed in a series of drawings published in *Flight*, the leading English aviation journal, and is known as the Dickson Glider. Even the minor details of construction are exceptionally well worked out and the design is amply strong for the purpose. If the drawings are followed carefully, no trouble will be experienced in building a primary training glider of light yet strong construction and one that is based on a sound knowledge of modern glider design.

As in building any type of aircraft, only the best materials should be employed in primary training gliders. All joints in wood or metal should be carefully made and reënforced as indicated in the working drawings. The various fittings should be precisely made and all machine work such as drilling, accurately performed. Duplicate fittings or parts should be made in jigs or templates to insure interchangeability.

It is, of course, more difficult to work from reduced size drawings than it is from full size blue prints but the amateur mechanics capable of constructing a glider will not find it difficult to transfer the drawings to sheets of heavy drawing paper or even clean wrapping paper to a scale that will permit of easily reading them.

One acquaintance of the writer transferred a fuselage drawing to a portion of the workshop floor, making it full scale, using a heavy black outline. As the laying out was done with straight edges and to accurate measurements, it was easy to work up the various structural parts and the accuracy of the fitting and assembling work was checked by laying the finished fuselage against the full size pattern.

Fuselage for Training Glider.—The detailed drawing at Fig. 62 shows the simple fuselage construction of the Dickson training glider. It consists of a keel member, of which the lower longeron forms a part, an upper longeron separated from the lower longeron by vertical struts and diagonal braces to form a Warren truss and a pylon or landing wire central support at the top of the longeron. The overall length is 15 feet 2½ inches, the overall height is 7 feet 5 inches. The length of the keel member is 8 feet 3 inches. The front end of the keel member is made separately from the rear end and is 3 feet 6 inches long. The lower runner is bent up from a piece of 2 inches by 1½ inches ash or elm, the upper member of the nose piece is made of 1½ inches by 1½ inches solid spruce. Three spacers or upright struts (Nos. 16, 17 and 18) 1 inch by 1½ inches separate the curved and straight chord members (Nos. 14 and 15) and the entire assembly is strengthened by $\frac{3}{16}$-inch plywood glued and screwed with small gauge wood screws to each side.

The front end of the fuselage, or nose piece is attached to the main structure by 1½ inches by 1½ inches spruce strips on each side held by 2 B.A.* mild steel bolts and nuts and large diameter washers under the nuts to keep them from sinking into the wood.

* British Aeronautic. S.A.E. Aeronautic may be used in the United States.

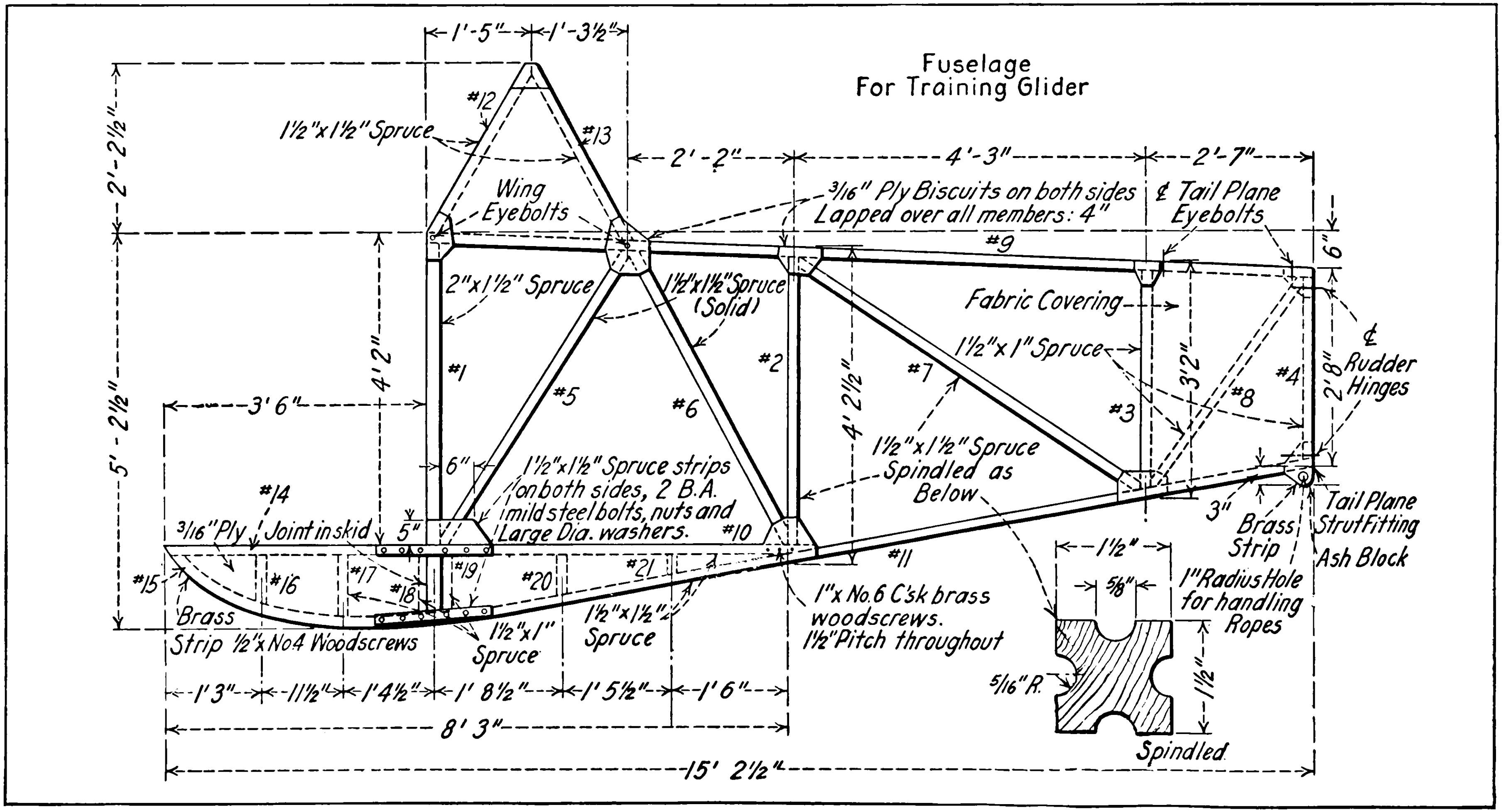


Fig. 62.—Dimensioned Drawing Showing the Structural Members of the Dickson Training Glider Fuselage. Note the Two-piece Keel, Joined Together with Wood Straps at Vertical Strut No. 1, and How Members at Rear of Fuselage are Spindled out to Lighten Them.

The construction shown can be changed by substituting extruded dural or mild steel straps made of standard angle or channel section stock to secure the necessary side stiffness. Triangular-shaped filler blocks 1½ inches thick of spruce are glued into the corners and the 3/16-inch plywood gussets or "biscuits" are fastened in the usual way to reënforce the joints.

The main portion of the fuselage is very simple in construction. It consists, or rather starts with an upright post (No. 1) of 2 inches by 1½ inches spruce attached to a longeron of 1½ inches by 1½ inches solid spruce at the top and a similar member at the bottom. The next vertical upright (No. 2) is 1½ inches by 1½ inches spindled section spruce and the space between the front and second upright struts is braced by two diagonal members (Nos. 5 and 6) also of 1½ inches by 1½ inches solid section spruce.

The lower part of the front upright is continued down to meet the curved runner piece, that member being separated from the longeron (No. 10) directly above it by 1 inch by 1½ inches spruce spacer blocks (Nos. 19, 20 and 21), the whole assembly being tied together by 3/16-inch thick plywood walls glued and screwed to form a rigid box section. After the nose piece is attached to the fuselage, a brass strip, about 1/16 inch thick by 1½ inches wide is secured to the runner by ½ inch by No. 4 Brass wood screws, well countersunk. This strip extends from the prow to the point beyond the second vertical strut.

The second bay of the fuselage is formed by a third vertical upright (No. 3) which is of 1½ inches by 1 inch spruce of solid section and a diagonal brace member (No. 7) of 1½ inches by 1½ inches spindled section spruce. The third bay of the fuselage is completed by the fourth vertical strut (No. 4) and a diagonal brace (No. 8), both of 1½ inches by 1 inch spruce. The fourth vertical strut forms the rudder support. The last bay may be covered in by fabric, 1/16-inch plywood or sheet aluminum of light gauge, to form a vertical fin. The rudder post terminates in an ash block having a 1-inch radiused hole for the hold-back rope. It is reënforced by a brass strip. (See Fig. 67 also.)

A careful inspection of the drawing at Fig. 62 will show that the main fuselage is composed of an upper longeron No. 9 extending from the front to the rear posts and resting on the tops of No. 1, No. 2, No. 3 and No. 4 vertical struts, which separate it from the lower longeron No. 11 and the longitudinal brace or false longeron No. 10. Longeron No. 11 is attached to the bottom of vertical post No. 1 but is not secured directly to the bottom of post No. 2 as the end of longeron member No. 10 tapers off at that point to form a support for longeron No. 11. It is secured to the bottom of vertical posts No. 3 and No. 4, however. Diagonal braces No. 5 and No. 6 are solid spruce 1½ inches by 1½ inches, brace No. 7 is 1½ inches by 1½ inches spruce spindled out to lighten it and diagonal brace No. 8 is of solid section 1½ inches by 1 inch spruce. All these members are tied together by gusset plates of 3/16-inch plywood, lapped over all members at least 4 inches and securely fastened by glue and small brads or brass wood screws, the latter being preferred.

The pylon or landing wire brace structure is a simple triangle made of 1½ inches by 1½ inches spruce having the apex 2 feet 2½ inches above longeron No. 9. The frame members No. 12 and No. 13 are tied together by 3/32-inch plywood or by sheet aluminum to form another vertical fin as well as to strengthen the inclined frame members. It is held in place by $\frac{3}{16}$-inch plywood "biscuits" cut to the shape indicated and forms an integral part of the fuselage. All the gusset plates are of different shape except those at the rear end of the fuselage which are simple triangular members that are practically the same. Two of each shape will be required, one for each side of the fuselage at every joint where vertical, longitudinal and diagonal brace members meet. Attention is directed to the location of the wing anchorage eyebolts at the front end of the fuselage, the tail plane anchorage eyebolt at the rear end and the eyebolts serving as rudder hinges on vertical post No. 4. Detailed drawings accompany this chapter to show the construction at these points to which the reader is referred.

Dickson Glider Wing Construction.—The wing structure for the right-hand main plane is shown at Fig. 63. The left-hand wing is exactly the same except that it is reversed, wing end C being at the side that wing end D is at in the drawing. The aileron is at the outer wing tip in each case. The wing ribs have the Clark Y. H. Airfoil section with a 5-foot chord and 17-foot span for each panel. The ribs are of the two spar type and are of the Warren truss construction, built up of spruce cap strips with vertical bracing posts at the spar openings and diagonal bracing at intermediate points, the whole assembly being held together by $\frac{1}{16}$-inch plywood "biscuits" glued and bradded on both sides as indicated. Each wing panel has 6 "A" ribs, 4 "B" ribs, 4 "C" ribs and 1 "D" rib. The ailerons have two "E" ribs and 4 "F" ribs each.

Ribs.—The "A" ribs are built of ¼ inch by ¼ inch spruce

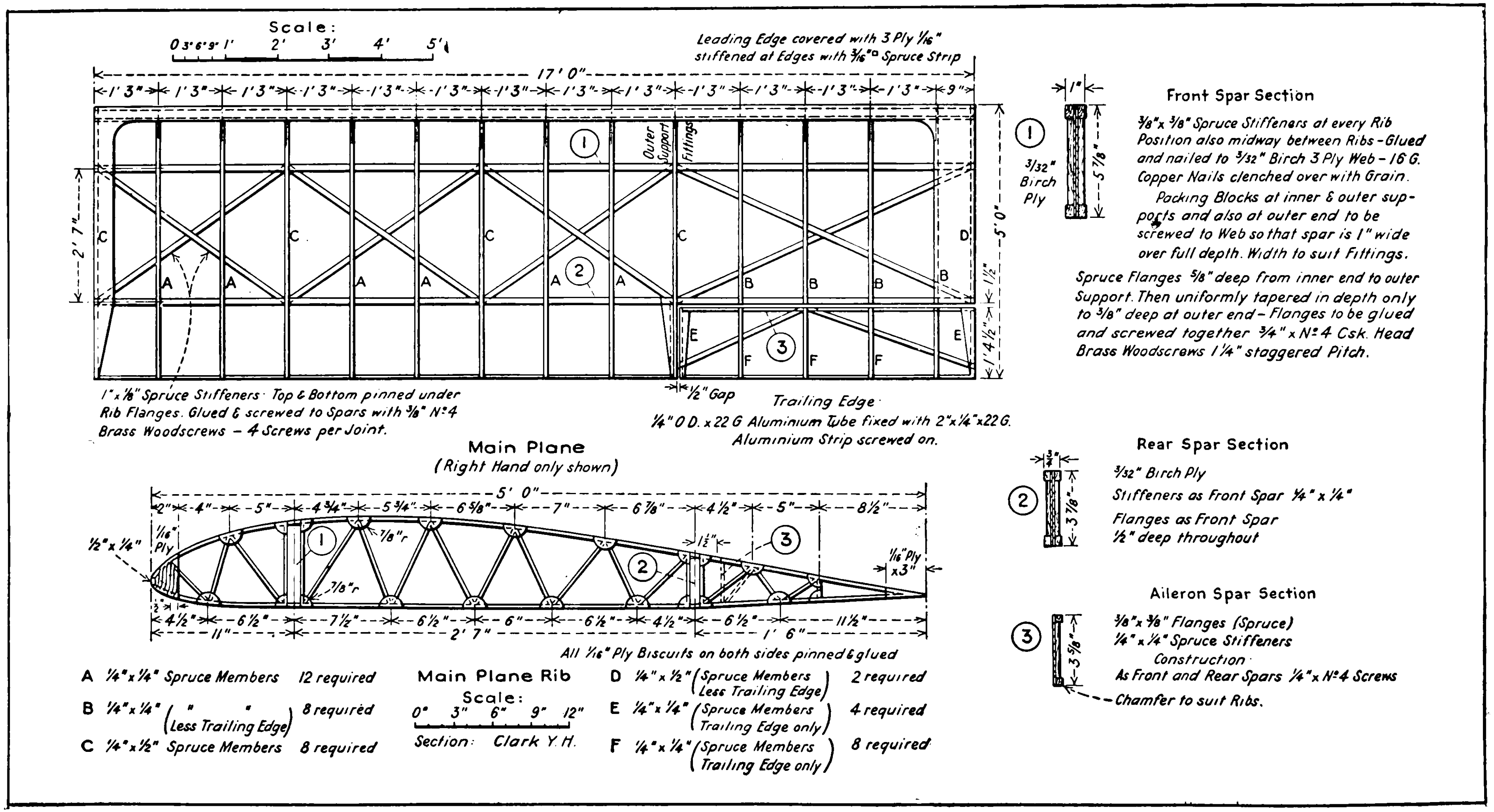


Fig. 63.—Detailed Drawings Showing Right-hand Main Plane Assembly of the Dickson Training Glider, the Sections of the Wing Spars and the Construction and Airfoil Section of the Clark Y. H. Wing Rib.

members, as are the "B" ribs except that they terminate at the rear spar and are minus the trailing edge to allow for the aileron. The "C" ribs are used as compression members and are the same in construction as the "A" ribs except that the cap strips and braces are ¼ inch by ½ inch spruce. The "D" ribs are made of ¼ inch by ½ inch spruce, also, but have no trailing edge. The "E," or aileron ribs, which are represented by that portion of the "A" rib from the rear spar back are trailing edges only and are reënforced with plywood braces at the top and bottom as indicated. The "F" aileron ribs are just the same as the trailing edge of the "A" rib or portion 3 and are made of ¼-inch by ¼-inch spruce members.

Front Spar.—The front spar No. 1 has ⅜-inch by ⅜-inch spruce stiffeners at every rib position, also between the ribs, which are glued and nailed to $3/32$-inch birch 3-ply webs. Copper nails, 16 gauge are clinched over with the grain. Packing blocks are used at inner and outer supports and also at the outer end to be screwed to the web so that the spar is 1 inch wide over full depth and of suitable width to suit fittings. (See Fig. 64.) The spruce flanges of the front spar are ⅝ inch deep from inner end to outer support, then uniformly tapered, in depth only, to ⅜ inch deep at the outer end. The flanges are to be glued and screwed together with the web interposed with ¾ inch by No. 4 countersunk head brass wood screws, 1¼ inches staggered pitch.

Rear Spar.—The rear spar section has a $3/32$-inch birch ply web with stiffeners of ¼ inch by ¼ inch spruce the same as the front spar with flanges ½ inch deep throughout applied as in the front spar. The aileron spar section has single flanges of 3/8-inch by 3/8-inch spruce with 1/4-inch by 1/4-inch spruce stiffeners, the top and bottom of the flanges being tapered or chamfered to suit the angularity of rib cap strips.

Leading and Trailing Edges.—The leading edge of the wing is composed of a strip of 1/2-inch by 1/4-inch spruce which ties all the ribs together and is then covered with 1/16-inch three-ply stiffened with 3/16-inch square spruce strip. The plywood is extended down to the trailing edge as shown at the outer end of the wing at C and to the rear spar as shown at D, on both top and bottom of the ribs. The trailing edge is composed of 1/4-inch O.D. 22 gauge aluminum tube fixed to the rib ends with 2-inch by 1/4-inch 22 gauge aluminum strips screwed or bradded to the cap strips. The ailerons are 1-foot 4 1/2-inch chord and 5-foot 8 1/2-inch span, a gap of 1/2 inch being allowed for between the inner end of the aileron and the "C" rib of the wing at that point.

The wing frame is stiffened by 1-inch by 1/8-inch spruce pieces running diagonally instead of bracing wires. The stiffeners are used at top and bottom and are pinned under the rib flanges with brads and are glued and screwed to the spars with 3/8-inch long No. 4 brass wood screws, four screws being used per joint. The ribs are spaced on the spars on 1-foot 3-inch centers except at the tip of the wing, where the spacing is 9 inches.

As detailed instructions have been given in previous chapters for rib and spar assembly and for making a jig and template to make sure the ribs all have the proper contour it is not necessary to repeat these suggestions. All wood surfaces should be varnished internally and painted at points where the fabric touches with non-sticking paint or shellac.

On the main planes the ribs are to be taped together by a "bridging" of ⅜-inch wide double tape. There should be two lines of tapes running between and parallel to the spars, spaced equally. The tapes are to be run on top and bottom or ribs, crossing through the wing between each pair of ribs, so that from behind or in front the tapes have a lazy-tongs aspect. The fabric should now be sewn to ribs, the stitches being passed right around the whole rib and through the fabric, blanket stitching being used. Each stitch, 2 inches from its fellow, must be knotted. Note that the fabric should not be tacked to the woodwork, but should be sewn together to form a sheath like a pillow slip, in which the wing frame fits. Double lock stitching is best for the lapped seams, as produced by awning makers' or upholsterers' sewing machines.

Strips of fabric should be doped on all sewn joints and rib stitching, and the whole surface should now be doped. A scheme of doping can be obtained from any dope manufacturer, who will also supply the right kind of dope for the job.

Care must be taken that all components are "rigged up" square, and that there is no twist in the wings. The assistance of an experienced aircraft rigger is of great value in this connection. The ailerons should be "rigged up" 2 degrees on both sides.

All wooden components must be carefully varnished to prevent damp damaging them, but no parts are varnished where dope is to come in contact. Shellac is used at these points. All metal fittings must also be painted. Care must be taken that all wooden parts attached to one another are correctly glued before screwing or pinning.

The readers' attention is called to an omission in the aileron frame drawing. On the arrangement drawing of the aileron, shown with the main plane, a spruce strip should be shown running the full length of the aileron at a position 5½ inches from the trailing edge. This strip is to be ¼ inch wide and 1 inch deep, inserted between the flanges of the ribs and pinned and glued in position.

Wing Fittings.—A number of details of construction are given at Fig. 64 for various attachment and bracing wire fittings. The outer front spar support fittings are shown at the top of the illustration and practically the same construction is used on the rear spar so it is not necessary to duplicate the drawings. Of course, the rear spar is only 3⅞ inches in depth, so strap fittings having only two bolt holes instead of three can be placed at the angles required to insure a true and direct pull of the bracing wires. The upper strap is a piece of ¾-inch wide by 14 gauge S.A.E. 1025 mild steel cut so the distance between the holes at the extreme end positions is 1 foot 5 inches and to allow for the ⅜-inch radius at each end, the total length of the strap should be 17¾ inches, for the front spar and about 14¾ inches for the rear spar. The strap is bolted to the spar by 3 No. 2 B.A. bolts with large mild steel washers between the nuts and the spruce packing block. The projecting ear or lug is bent back 3½ inches on the front spar and forward about 3½ inches on the rear spar for attachment of the landing wires.

The flying wire support on the lower portion of the spar is

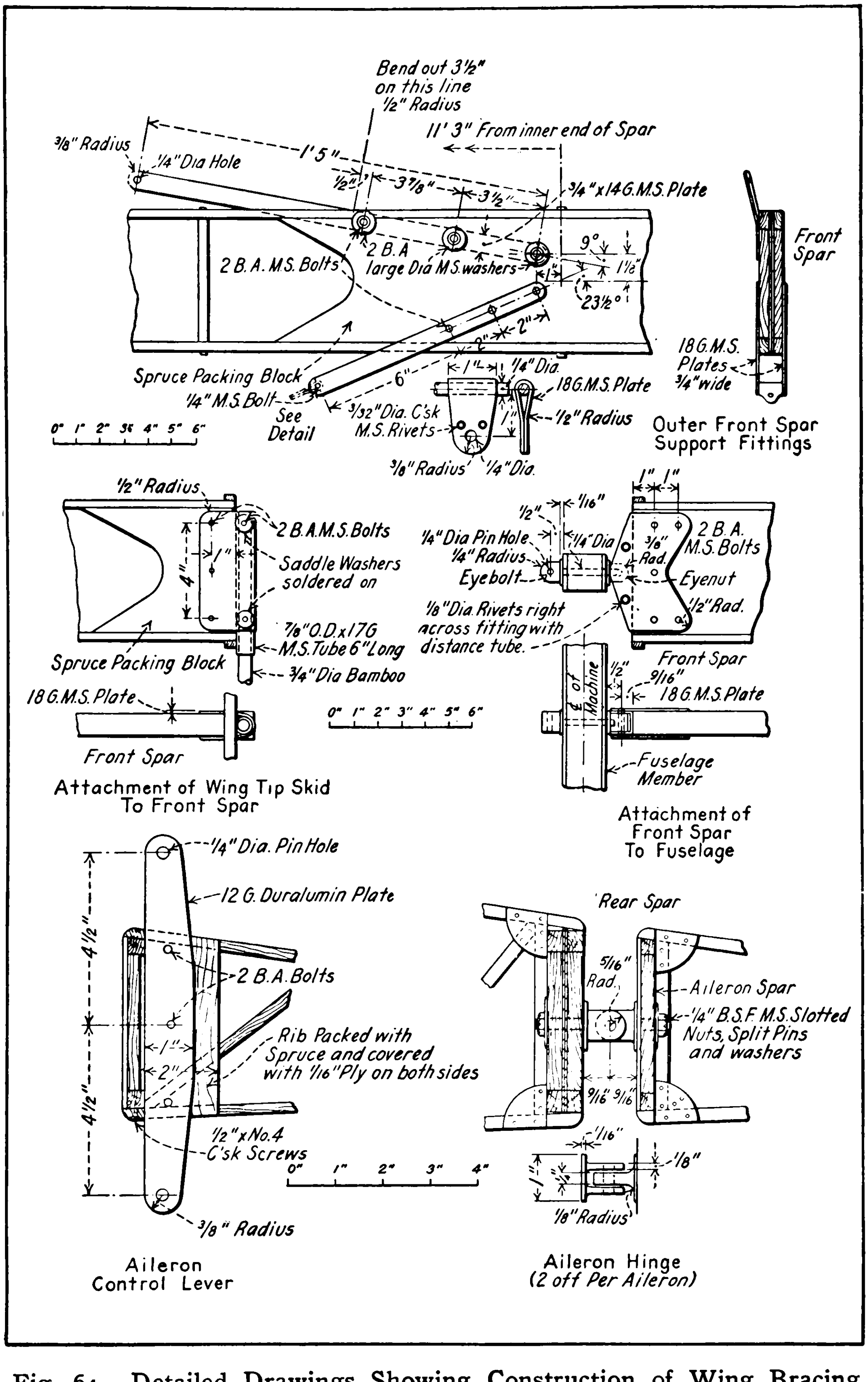


Fig. 64.—Detailed Drawings Showing Construction of Wing Bracing and Attachment Fittings of the Dickson Training Glider and the Method of Attaching Aileron Control Horn and Hinges.

composed of two 18 gauge, ¾-inch wide mild steel plates, with outer and inner end holes 10 inches apart, center to center. The straps will be 10¾ inches long to allow for the ⅜-inch radius at each end. The flying wires are attached to a swivel or hinge fitting made up of 18 gauge mild steel plate as shown in the detail, this being held by the straps attached to the spar by a ¼-inch diameter bolt. The landing wire fittings are inclined toward the pylon top, those on one main plane pointing toward corresponding fittings on the other plane. The landing wire fitting is inclined on a 9-degree angle, the flying wire fitting is inclined 23½ degrees to the spar flange as in the detail.

Wing Tip Skid Fittings.—The wing tips may be provided with skids if desired, these being arcs of ¾-inch diameter bamboo or aluminum tubing. The front spar fitting is duplicated on the rear spar, being the same except that its depth must correspond to that of the spar. The fittings are made of 18 gauge mild steel plate and are bolted to the wing spars through suitable packing blocks. Three bolts are used on the front spar fitting and two bolts on the rear spar fitting.

Wing Attachment to Fuselage Longeron.—The method of attaching the root end of the wing spars to the top fuselage longeron member is very simple and is the same for both front and rear spars. As will be seen by referring to the fuselage assembly drawing and the wing assembly the spar center lines are 2 feet 7 inches apart, so the eyebolts are spaced that distance apart in the fuselage longeron. The bolts pass through well reënforced points of the fuselage. The bolt is a special type using a nut of the same shape as the head, as shown in the lower left-hand corner of Fig. 51 in Chapter Nine.

Some authorities prefer anchorage members for wings that do not pass through the longerons, but the shearing strength of even a 1/4-inch body bolt is ample to provide a large margin of safety on a lightly loaded glider, where the wings are braced with flying and landing wires. The fitting on the root end of the spar is composed of a pair of 18 gauge mild steel plates shaped as indicated, that bolt to the spar web through spruce filler blocks. To prevent buckling of the outer ends of the plates, they are held together by two 1/8-inch diameter rivets passing through distance tubes. The fitting on the rear spar will, of course, correspond to the space between the flanges of that member. Two front spar fittings and two rear spar fittings will be needed per machine. The front spar fittings are the same because they are symmetrical about the center line and can be used as either R. H. or L. H. fittings. The same applies to the rear spar fittings and to the strap fittings for the landing and flying wires. Eyebolts of 3/8-inch body will provide a better safety factor than the sizes indicated for spar support.

Aileron Horn Construction and Attachment.—The illustrations at the bottom of Fig. 64 show how the aileron horn is attached and the use of male and female eyebolts for control member hinges. This type of hinge is used for the vertical rudder and for the elevators as well as for the aileron. The aileron control horn is also used in the vertical rudder and elevators. It is cut out of a 12 gauge Dural plate and is secured to a packing block of spruce by 3 No. 2 B.A. bolts as indicated. The control horn is 9¾ inches long and has 1/4-inch pin holes at the extremities separated by a space of 9 inches, center to center. Six of these members are necessary, five being drilled as shown,

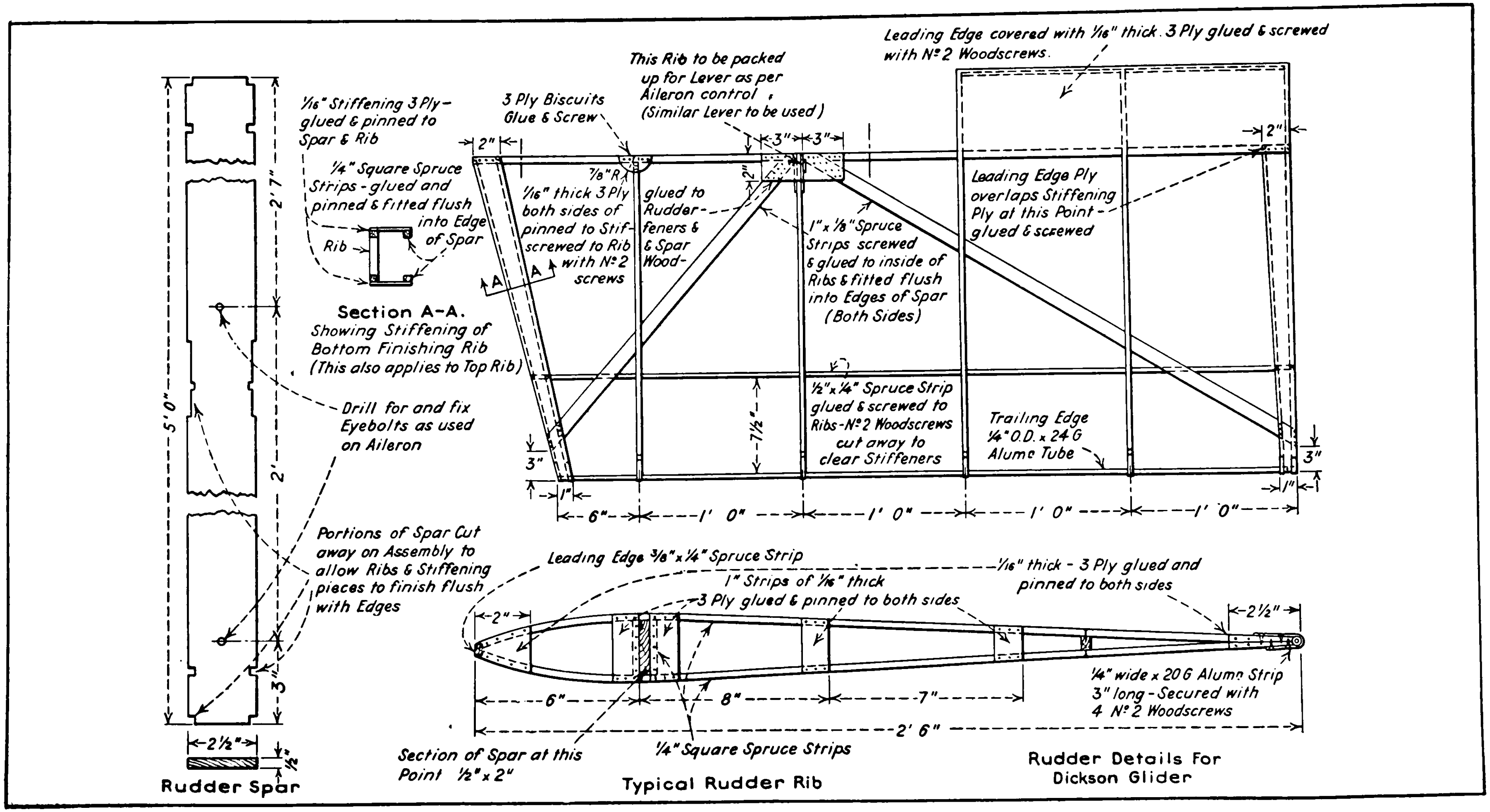


Fig. 65.—Detailed Drawings Showing the Rudder Frame Assembly Construction for the Dickson Training Glider, Also the Method of Making the Rudder Ribs.

the other being drilled to correspond to the socket fitting shown at Fig. 69 that is installed on the torque tube of the control unit.

Rudder Construction.—The balanced rudder of the Dickson Glider is shown in detailed drawings at Fig. 65. The rudder frame is simple in construction and has but one spar. This is a piece of spruce ½ inch thick, 2½ inches wide and 5 feet long with cutouts to allow for rib ends and stiffeners so the finish will be flush with the edges. The spar is drilled for the hinge eyebolts similar to those used on the aileron and shown at Fig. 64. The first hole is drilled 3 inches from the bottom, the top hole is on 2-feet or 24-inch centers from the bottom hole and 2 feet 7 inches from the top of the spar. Three full ribs are used as shown in the sectional drawing detail and three short ribs. The rib cap strips are of ¼-inch square spruce and are spread apart by 3-ply glued and pinned to both sides as indicated. The leading edge of the balancing section is a ⅜-inch by ¼-inch spruce strip and the leading edge is covered with 1/16-inch thick 3-ply glued to the ribs and glued and screwed to the spar with No. 2 wood screws. The trailing edge is composed of a ¼-inch O.D. 24 gauge aluminum tube attached to the ribs by aluminum strips and wood screws. The fourth rib down from the top is packed up with spruce fillers and a control lever is fastened to the rib just as for the aileron as illustrated in enlarged detail at Fig. 64.

Attention is directed to the method of stiffening the top and bottom of the rudder with 1/16-inch plywood, glued and bradded to spar and rib and having ¼-inch square section spruce strips glued and pinned and fitted flush into the edge of the spar in cutouts made to receive them. The rudder frame is braced diagonally with 1-inch wide by ⅛-inch thick spruce strips screwed and glued to the inside of the ribs and fitted flush into the edges of the spar on both sides. This makes a very light but strong control member. The frame may be covered with plywood or with fabric, just as the wing frame is.

Elevator Details.—The detailed drawing at Fig. 66 shows the elevator construction. The same elevator does duty on right and left of the glider tail because it is symmetrical in design and need only be reversed in position to serve equally well on either side. The method of construction of the frame is the same as employed for the rudder previously described. Five ordinary ribs are used in each elevator and two special end ribs with plywood stiffening, as shown in rudder detail. The trailing edge construction is similar to that of the rudder. The spar end, however, is tapered for a distance of 6 inches from the end as shown, the section reducing from ½ inch by 2½ inches at the main section to ½ inch square at the top. Cutouts are provided in the spar to allow ribs and stiffening pieces to finish flush with the edge. Diagonal bracing composed of 1-inch by ⅛-inch spruce strips is applied just as it is in the rudder. Two elevators are needed for each machine. The span of one elevator is 5 feet 4½ inches, the chord is 1 foot 8 inches. The control lever is attached to a point 10½ inches from the angular end of the aileron. The reason the aileron is cut at an angle is that space must be provided for the travel of the vertical rudder.

Stabilizer Construction.—The stabilizer or tail plane of the Dickson Glider is built up similar to the frame for the elevator and rudder except that the main spar, which is at the rear, is long enough to attach both elevators to it. The details of construction

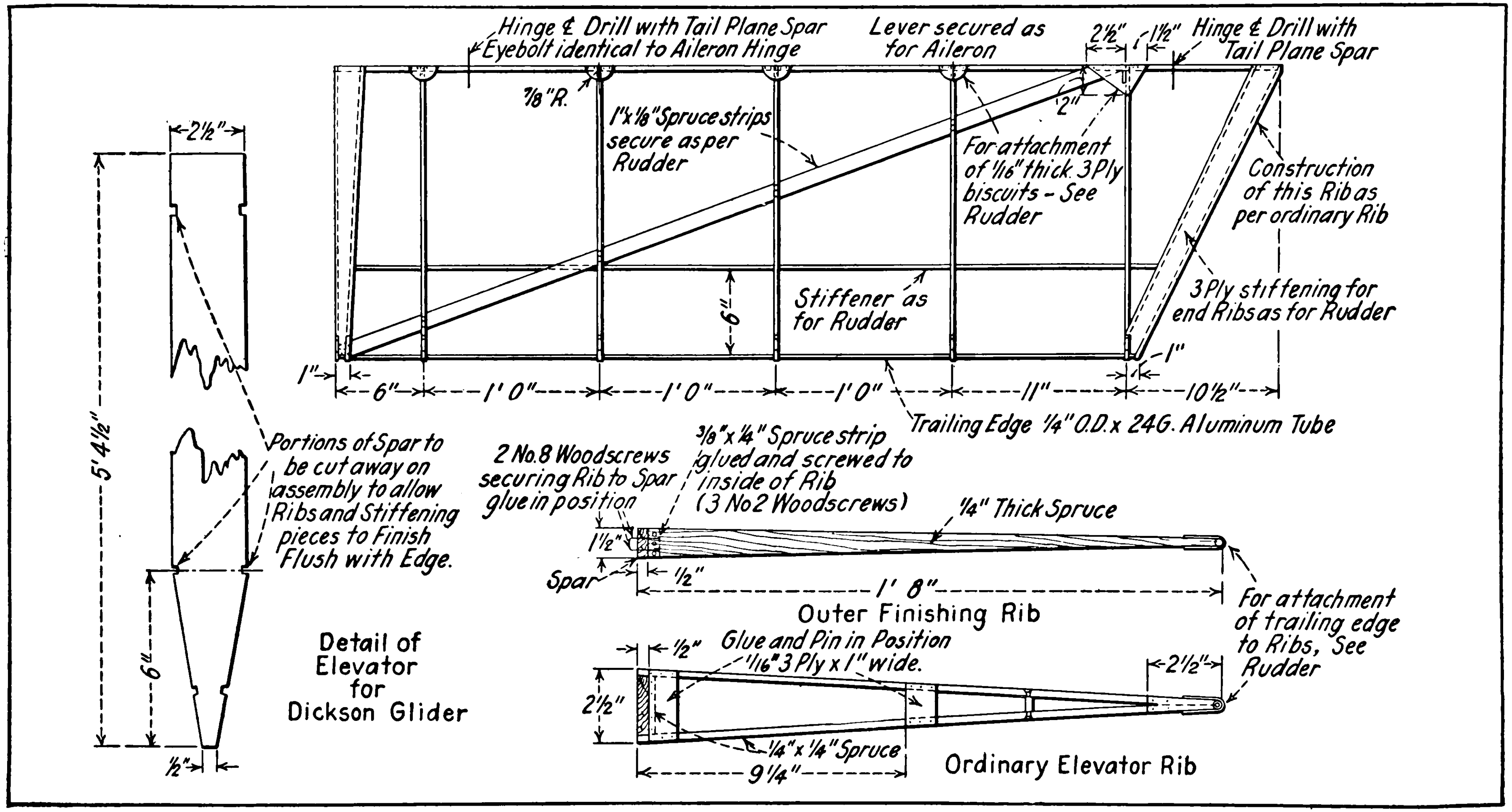


Fig. 66.—Detailed Drawings Showing the Elevator Frame Assembly Construction for the Dickson Training Glider, Also the Method of Making Ordinary and Outer Finishing Ribs.

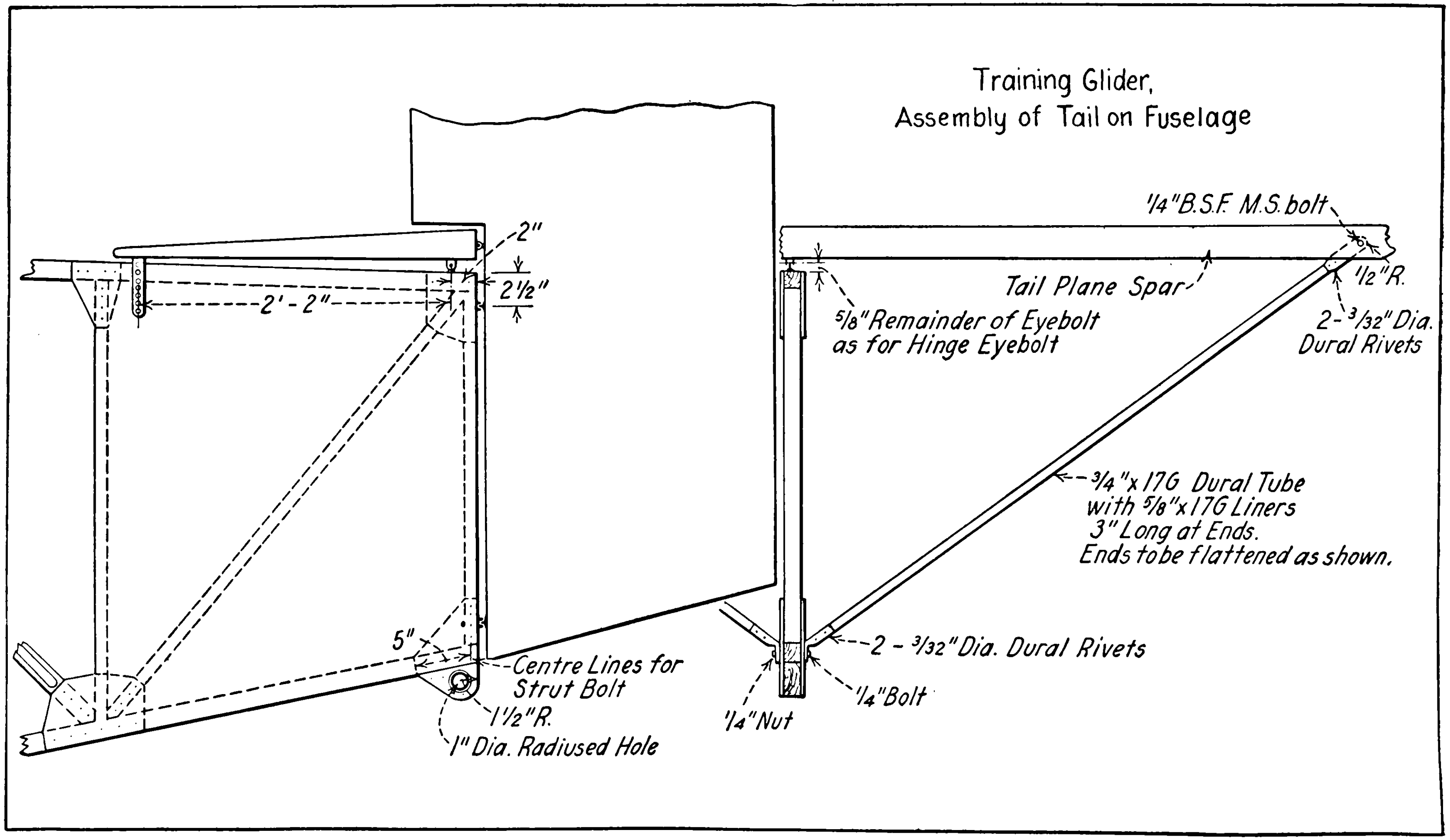


Fig. 67.—Assembly Drawing Showing How Tail is Assembled on the Fuselage of Dickson Training Glider.

are modified because the tail plane is triangular in plan form as shown in the schematic drawing of the control system given at Fig. 71. The tip ends of the spar taper from points 6 inches from the ends just as the elevator spar ends do and the total length is 10 feet 10½ inches. The leading edge of the stabilizer or tail plane is finished off with aluminum tube just as the trailing edges of the rudder or elevators are. The rib construction is similar to that employed for the other control surfaces, except that all ribs on each side of the main rib vary in length, becoming shorter as the ends of the spar are reached. Sketches showing the construction of the stabilizer and tail plane are given at Fig. 72.

Stabilizer Anchorage.—The tail plane anchorage is extremely simple. The rear or spar end is held by an eyebolt arrangement similar to that employed as a rudder hinge as shown at Fig. 67. This eyebolt is placed 2 inches from the rear spar and passes through a filler or spacer block of spruce placed between the wide cap strips of rib "A" (Fig. 72) which blocking acts as a reënforcement. The front end of the stabilizer frame has an adjustment strap extending down as shown which is perforated with a number of ¼-inch holes so that the stabilizer leading edge may be raised or lowered as desired. The strap is in the form of a U piece and is attached to the main rib by a ¼-inch bolt passing through the spruce filler block at the leading edge. The center distance between the strap and eyebolt center lines is 2 feet 2 inches.

Stabilizer Bracing.—When the tail plane is installed on the fuselage, it is braced by two diagonal ¾-inch by 17 gauge Dural tubes, with ⅝-inch by 17 gauge reënforcing members, 3 inches long at the ends, held by two ³⁄₃₂-inch diameter, Dural rivets passing through the tube and the reënforcement. The ends of the brace tubes are flattened as shown at Fig. 67 and one end is bent at an angle so it can be bolted to the lower longeron while the upper end is bolted through the main spar of the tail plane or stabilizer. By using tubes, no other diagonal bracing is required as the tubes carry both landing and flying loads on the tail plane spar.

Miscellaneous Metal Fittings.—The metal fittings required in building a glider are simple and as stresses are low compared to those in a motored airplane, ample strength is obtained by using low carbon or mild machinery steel, which is much easier to handle by amateur constructors and which does not require heat treatment after bending as high tensile strength alloy steel does. Bends should be gradual and not abrupt and if all bends are made over a ¾-inch rod as a mandrel, the strength of the material will not be impaired by bending.

Details of some of the wiring plates and fittings are given at Fig. 68. That at A is a fitting for connecting the bracing wires to the wiring plates and 24 are required per machine. All the bracing wires should be of 15-cwt. cable (1500 pounds breaking strength), with one 15-cwt. turnbuckle interposed in each wire, at a convenient position. Sketch at B is the standard double wiring plate and 3 right and 3 left hand are needed per machine. One off each hand is required at the pylon top for the landing wires, and one off each hand for the lift wires which is placed under the seat attaching to the longeron member directly under the pylon apex, and one off each hand for the rear face of the rear spar at the outer supports to take the rear fuselage bracing wires. The single wiring lug shown at C is required for the bottom fittings at the rear of the fuselage to take the fuselage bracing wires and two off each hand are required. All fittings

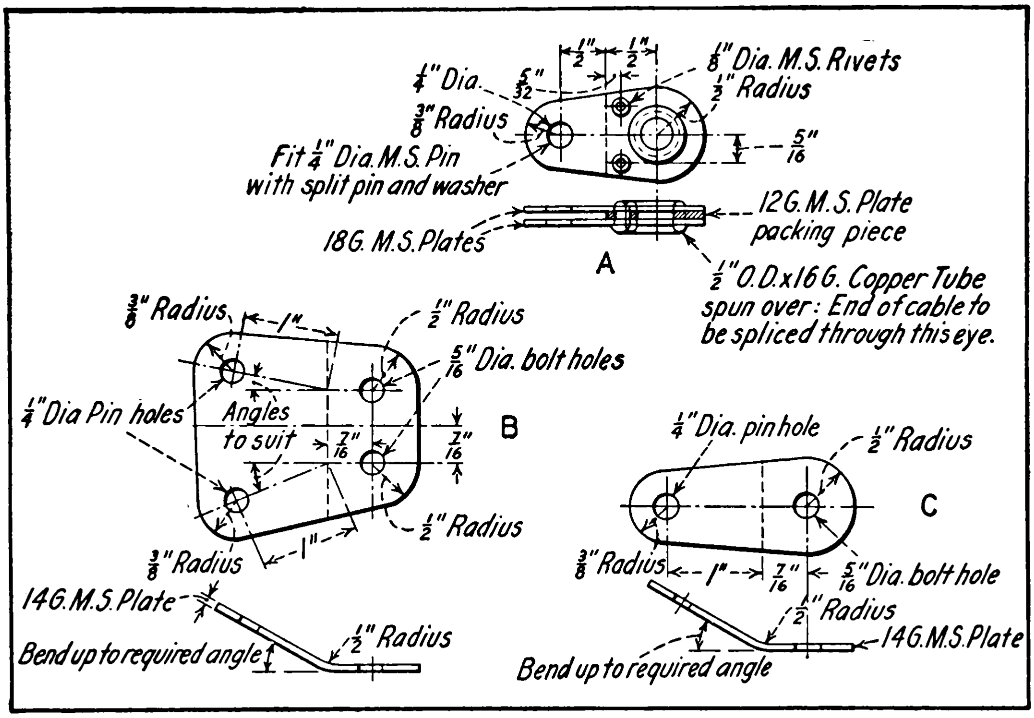


Fig. 68.—Wiring Fittings for the Dickson Training Glider. A—Fitting for Connecting Bracing Wires to the Wiring Plates, 24 Required per Machine. B—Double Wiring Plate, 3 Right Hand and 3 Left Hand Required Each Machine. C—Single Wiring Lug, 2 Right and 2 Left Needed Each Machine.

which have been bent must be heat treated after bending, if made of alloy steel or high carbon steel and should be heated to a low red heat to facilitate bending. A simple and satisfactory heat treatment will consist of heating to a low or dull red heat and quenching in oil if more definite instructions relative to the composition of the alloy steel used is not available. Either mild steel, chrome-nickel, or molydenum steel plate may be used for fittings, the latter two requiring more careful handling and heat

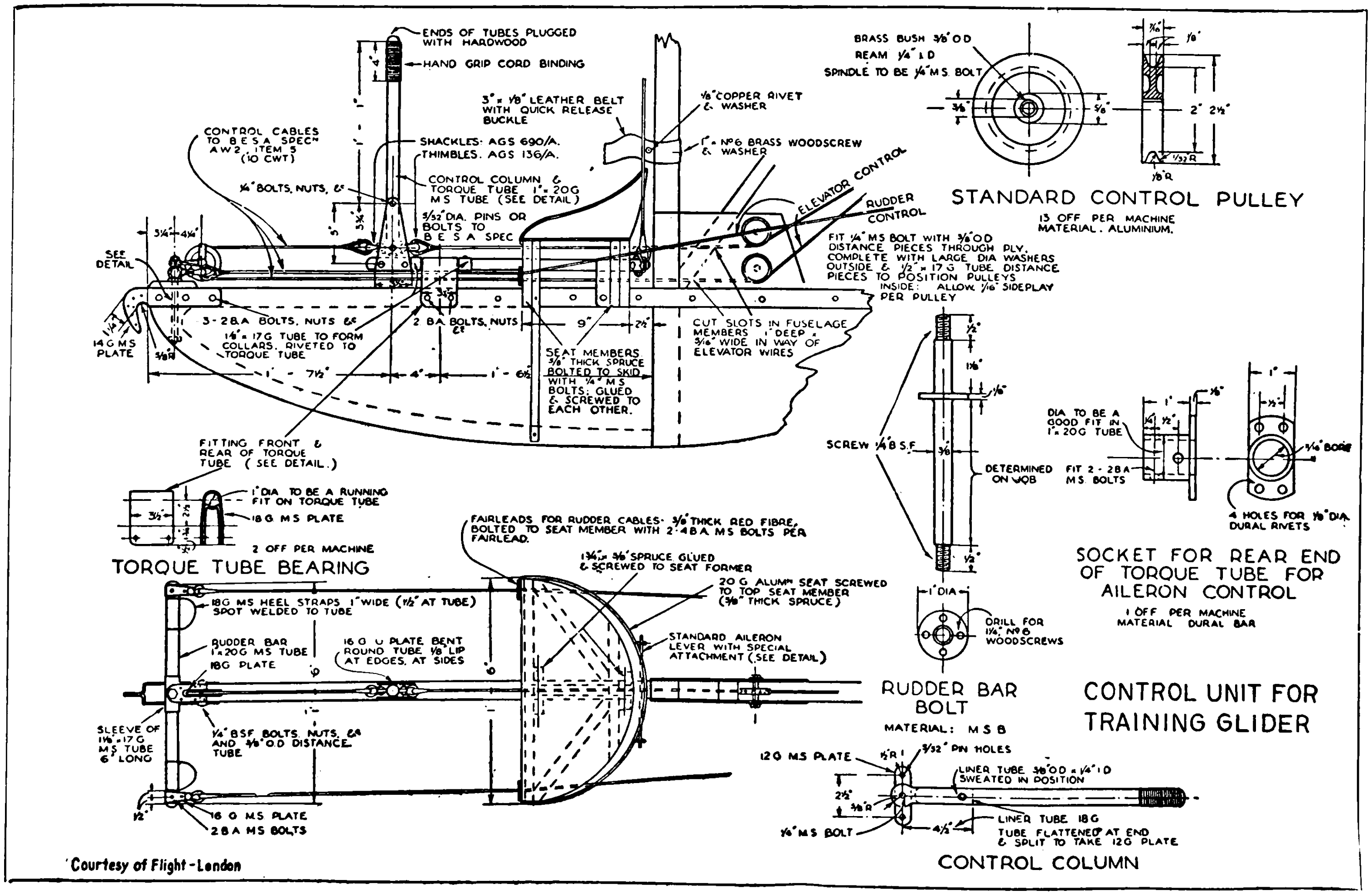


Fig. 69.—Control Unit for the Dickson Training Glider. Note Arrangement of Seat, Control Stick and Cable Guide Pulleys, also Location of Rudder Bar and Towing Hook.

treatment than the amateur is apt to give them. If not properly heat treated the strength properties of alloy steels are not enough superior to a good medium carbon fitting steel (S.A.E. 1025) to warrant the extra cost.

Control Unit for Glider.—The elements of the front end of the Dickson training glider with special reference to the arrangement and construction of the seat and control system parts are clearly detailed at Fig. 69. We will first consider the construction of the seat. This is made of a seat bottom member approximately semicircular in form, 1 foot 6 inches wide and 9 inches deep made of $\frac{5}{8}$-inch thick spruce or $\frac{1}{2}$-inch plywood, to which a seat back made of 20 gauge aluminum is attached by a series of screws. The seat is supported by braces of $\frac{5}{8}$-inch thick spruce bolted to the skid with $\frac{1}{4}$-inch bolts and glued and screwed to each other, two of these being diagonal bracing members extending down to the curved runner at each side.

Fairleads for the rudder cables, which are detailed in Fig. 70, are attached to the seat bracing members as indicated. A 3-inch by $\frac{1}{8}$-inch leather safety belt with quick release buckle and of sufficient length to encircle the girth of a fairly large person is attached to the front fuselage vertical support post by a No. 6 by 1-inch brass wood screw and washer. Supply houses carry webbing safety belts which have been especially made for gliders and which are available at lower cost than a leather belt would be.

Rudder Bar Construction.—The rudder bar is a 1-inch by 20 gauge M.S. steel tube, having a reënforcing sleeve of $1\frac{1}{8}$-inch by 17 gauge steel tube 6 inches long welded to the center. The rudder bar is completed by 18 gauge M.S. heel straps welded

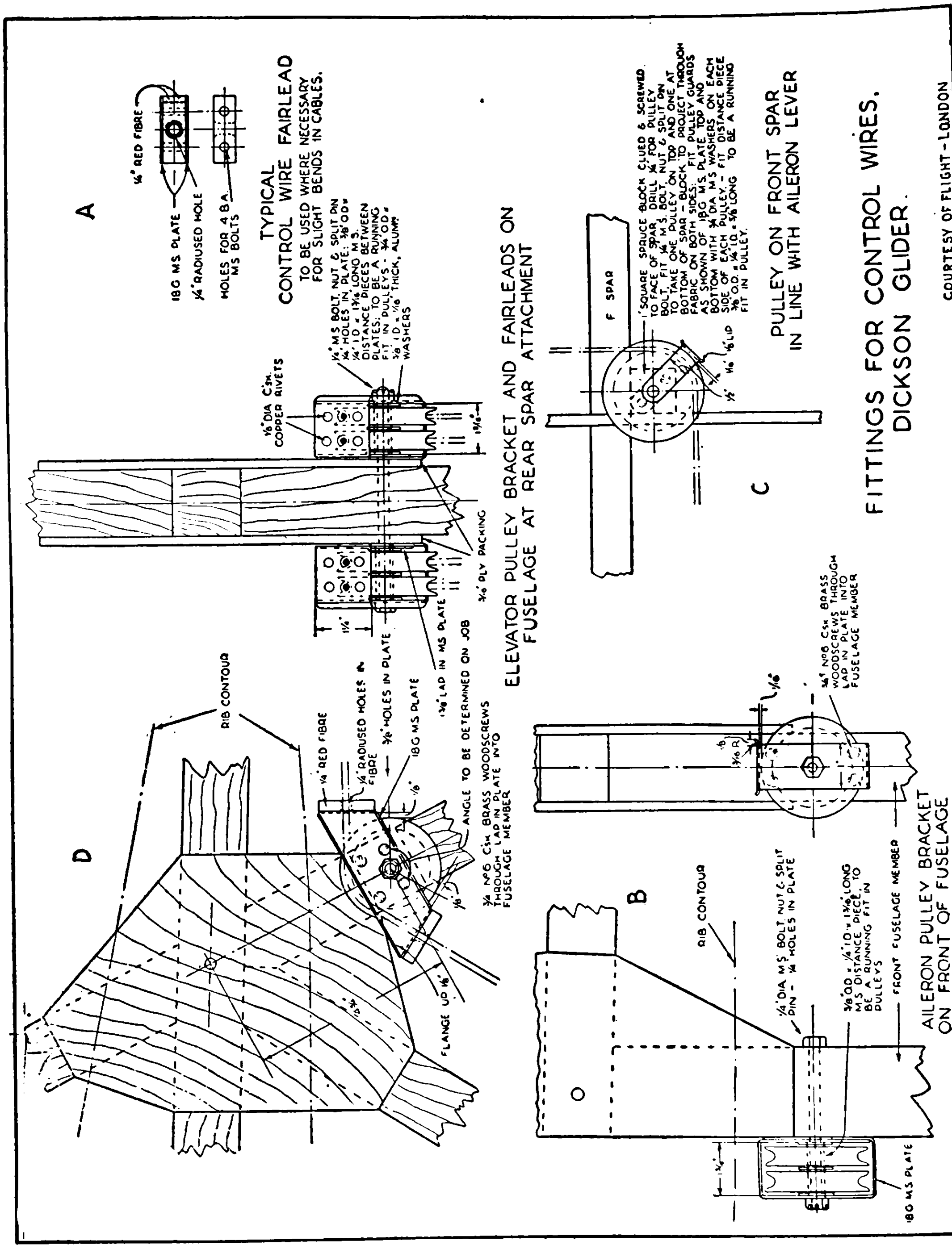


Fig. 70—Details Showing Control Wire Fittings, Pulleys and Control Wire Fairleads for Dickson Training Glider.

to the tube and 16 gauge M.S. plate fittings at the end to which the standard shackles for rudder cable attachment are secured. A 3/8-inch clearance hole is drilled through the rudder bar so it can swing on the special supporting bolt (shown in enlarged detail) which passes down through the nose of the fuselage, passing through both curved and straight longeron members. A hardwood packing block about ½ inch thick is placed under the center of the rudder bar, and a flange on the rudder bar bolt is screwed to the top of the packing block with 1-inch long wood screws which go into the longeron and through the packing block.

Launching Hook.—The launching hook is made of two pieces of 14 gauge M.S. plate cut to the shape indicated and bent to fit the prow of the fuselage to which it is fastened by 3 No. 2 B.A. bolts passing through the top member. The front portions of the hook may be riveted together or may be welded at the edges to form a solid piece of twice the thickness of the 14 gauge side plates.

Control Column Details.—The control stick or column is composed of a piece of 1-inch by 20 gauge M.S. tube, 1 foot 4¾ inches (16¾ inches) long, the upper end of the tube being plugged with a hardwood piece that is a drive fit in the end of the tube, and which is rounded over to form a ball end. The hand grip, 4 inches long, is made of ⅛-inch diameter cord binding. A very good finish for the hand grip is a rubber grip as used on bicycle handle bars. A liner or reënforcing tube, 18 gauge, is forced into the end of the column and is held in place by a ⅜-inch O.D. (outside diameter) by ¼-inch I.D. (inside diameter) hollow rivet which is welded in place and which acts as a bearing for the ¼-inch bolt used as a support about which the lever or column may be rocked back and forth to control the elevators. The liner tube is flattened at the end and is split to take the 12 gauge plate fitting shown in detail of the control column, this rocking on a short ¼-inch bolt and being designed to receive standard shackles to which the elevator control cables are attached.

The control column is supported by a special bracket shaped as shown in the side view, made up of 16 gauge sheet, bent in the form of a U around the torque tube. The distance between the center of the bolts holding the U bracket to the torque tube and the bolt on which the control column swings is 5 inches and the U fitting is 3 inches wide at the bottom. There is ample space between the upstanding ears of the U member for the control column to swing back and forth in and also to clear the shackled and thimbled control cable ends.

Torque Tube and Bearings.—The torque member or rocking shaft is of 1-inch O.D. by 20 gauge steel tubing and it is supported by special torque tube bearing fittings made up of 18 gauge steel plate as indicated in enlarged detail. Two of these are required, one for the front end of the torque tube, the other for the rear end support. They are fastened to the top member of the fuselage keel with No. 2 B.A. bolts and nuts. Short pieces of 1⅛-inch by 17 gauge tube, about ⅜ inch long are riveted in place with ⅛-inch rivets to act as collars to prevent longitudinal movement of the torque tube in the bearings.

The U piece supporting the control column is bolted to the front end of the torque tube and a special socket fitting, made from the Dural bar or brass or steel, as shown in the enlarged detail at Fig. 69, is bolted to the rear end. This is provided with holes for 4⅛-inch Dural rivets by which the same kind and size of control lever which is used on the rudder, elevators and ailerons, is attached to the rear of the torque tube. The socket is bored to be a tight fit on the control tube and is bolted to it by 2 No. 2 B.A. bolts, one passing through the tube end and socket vertically, the other horizontally. When the socket is assembled properly on the torque tube, the control lever should be horizontal when the control column is vertical, *i.e.*, they should be at right angles to each other.

Control Column Movement.—It will be seen that the control column is capable of a back and forth motion, in which case it rocks on the supporting bolt at the top of the U piece, or it may be rocked from side to side, in which event it also rocks the torque tube in its support bearings by virtue of the side pressure on the U supporting fitting. The side to side motion actuates the aileron control cables. These are attached to the ends of the lever by standard shackles as indicated at Fig. 69 and 71.

Cable Sheaves or Guide Pulleys.—An enlarged detail is given in the upper right-hand corner of Fig. 69 showing the dimensions of the standard aluminum sheave or control cable guide pulley, of which 13 are required on each glider. Three of the pulleys are brass bushed with a 3/8-inch O.D. tube which is reamed for a running fit on a 1/4-inch O.D. bolt. In those cases where pulley guards are used, the bearing bushing must be a running fit on a 3/8-inch diameter spindle or a spacer tube. Ten pulleys are bushed with a 3/8-inch I.D. bushing. One of the pulleys is carried at the prow of the keel by a special strap fitting made of 18 gauge plate and fastened to the top of the rudder bar bolt as indicated. This pulley is one of the three hav-

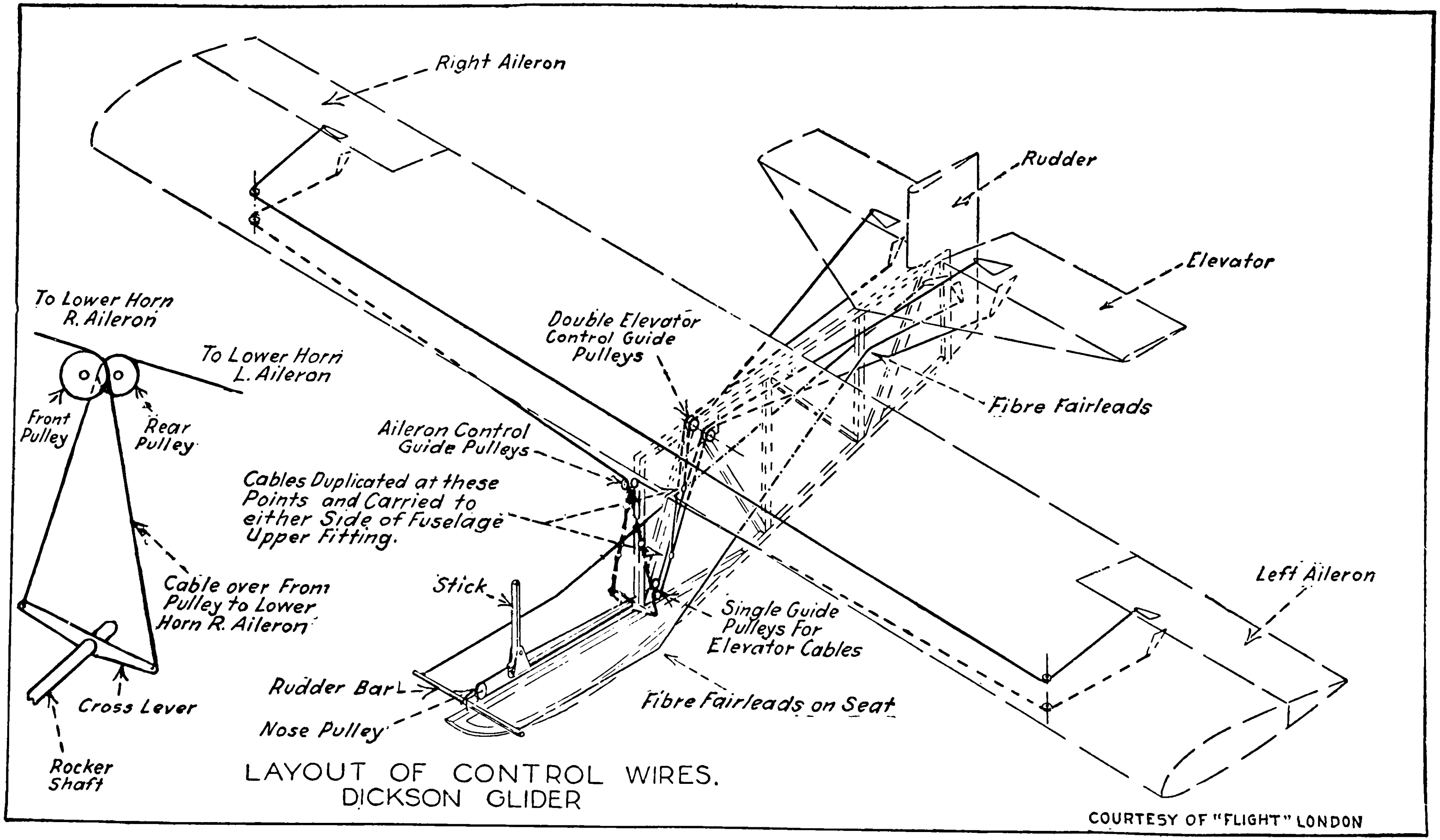


Fig. 71.—Complete Schematic Layout of the Control Wires of the Dickson Training Glider. Note the Cable Guide Pulley Arrangement on Front Vertical Strut to Permit Cross-over of the Cables to Aileron Control Horns.

ing a ¼-inch I.D. bushing. It is around this pulley that the elevator control cable is carried, coming from the front ear of the plate to which it is shackled on the bottom of the control column. The cable then passes around the guide pulleys carried between the extensions from the plywood gusset plates reënforcing the joint between vertical post No. 1, diagonal brace No. 5 and horizontal brace No. 10. (See Fig. 62.)

While the drawing indicates that slots should be cut through the fuselage vertical and diagonal brace members 1 inch deep by 5/16 inch wide to permit the cables to pass, it would undoubtedly be better practice to drill holes through the pieces and provide fairleads of short lengths of aluminum tubing of ⅜-inch O.D. which would pass through both vertical and diagonal pieces and be well greased inside after assembly. If the tubing ends were allowed to project through for about ⅜ inch on each side and were flared out or bell-mouthed they would remain in place and the strength of the vertical and diagonal bracing members would not be materially weakened at one of the most important joints of the fuselage assembly. Standard aluminum or Micarta pulleys with oil or graphite impregnated bushings may be secured from supply houses cheaper than they can be made by the amateur.

Control Cable Fittings.—Some enlarged details for the control cable fittings of the Dickson Glider are given at Fig. 70. The red fiber fairlead, used where there is only a small bend in the cables, as under the seat for the rudder control, are made by sandwiching two pieces of ¼-inch thick red fiber between 18 gauge plates and providing holes for No. 4 B.A. bolts. This is clearly shown at A.

The aileron control wires, as shown in schematic drawing at Fig. 71, pass over two pulleys carried over the pilot's head and immediately below the wing spar attachment on the front face of the No. 1 vertical fuselage member. (See Fig. 62.) This is shown in an enlarged detail at Figure 70B. The two sheaves are carried inside a box frame made of 18 gauge steel plate, the front and rear of which are separated by a spacer member made of 3/8-inch O.D. by 1/4-inch I.D. by 13/16-inch long steel tubing on which the pulleys are a running fit, the bore being enlarged to take a brass bushing having 1/32-inch walls and a 3/8-inch I.D. The pulleys are separated by brass, aluminum or steel washers, and the entire assembly is bolted in place with a 1/4-inch diameter bolt of the proper length. Before the sheaves or pulleys are inserted, the 18 gauge frame member is attached to the fuselage front member by 3/4-inch long No. 6 brass wood screws which pass through the lapped parts of plate into the fuselage member.

Aileron Cable Guide Sheaves.—The aileron control cables must also pass over guiding sheaves in the wing frames. The sheaves are lined up with the aileron lever, so when the cable is bent around them it will connect directly with the aileron lever. A 1-inch square spruce block is glued and screwed to the face of the spar and is drilled for a 1/4-inch diameter bolt. The block projects through the fabric on both upper and lower surfaces of the wing. Pulley guards to keep the cable from falling out of the groove are made of 18 gauge steel plate on both top and bottom pulleys as shown in the detail "C," Fig. 70. The sides of the pulley guards are separated by spacer members of 3/8-inch tubing on which the sheaves are a free or running fit.

This tube is ⅝-inch long and has a ¼-inch I.D. Enlarged bore bushings are provided in the pulleys, and washers are inserted between the pulley bearing boss sides and the guard sides to provide good running clearance.

One cable guide sheave is placed at the top and one at the bottom surface of the wing. The ¼-inch bolt is long enough to include the spacer block and both pulley and guard assemblies. The bolt is inserted from the top with nut and split pin lock at the bottom. The distance pieces will keep the pulleys from binding on the sides of the boss because of the spacer members used to separate the guard members and the wood block even if the nut is tightened up all the bolt can stand. All guide sheaves must be a free running fit on the supporting bolts or spacer tubes on which they rotate.

Reference to Fig. 71 will show a group or cluster of double pulleys at the point of juncture of the diagonal braces No. 5 and No. 6 with the top longeron No. 9 of the front station of the fuselage and immediately below the rear pylon support No. 13. These pulleys are to guide the elevator control wires and the enlarged detail is shown at Fig. 70D. These pulley guards carry fairleads of red fiber on each inclined face as indicated. The construction of the guards is the same as previously described, 18 gauge steel plate being used with spacers to prevent binding the sheaves when the through bolt is tightened up and the laps in the plates are fastened to the fuselage member with ¾-inch long No. 6 wood screws. These screws must be inserted before the pulleys are assembled into the guard frames.

Control System of Glider.—The diagram of the Dickson Glider is shown in perspective at Fig. 71 and the various control

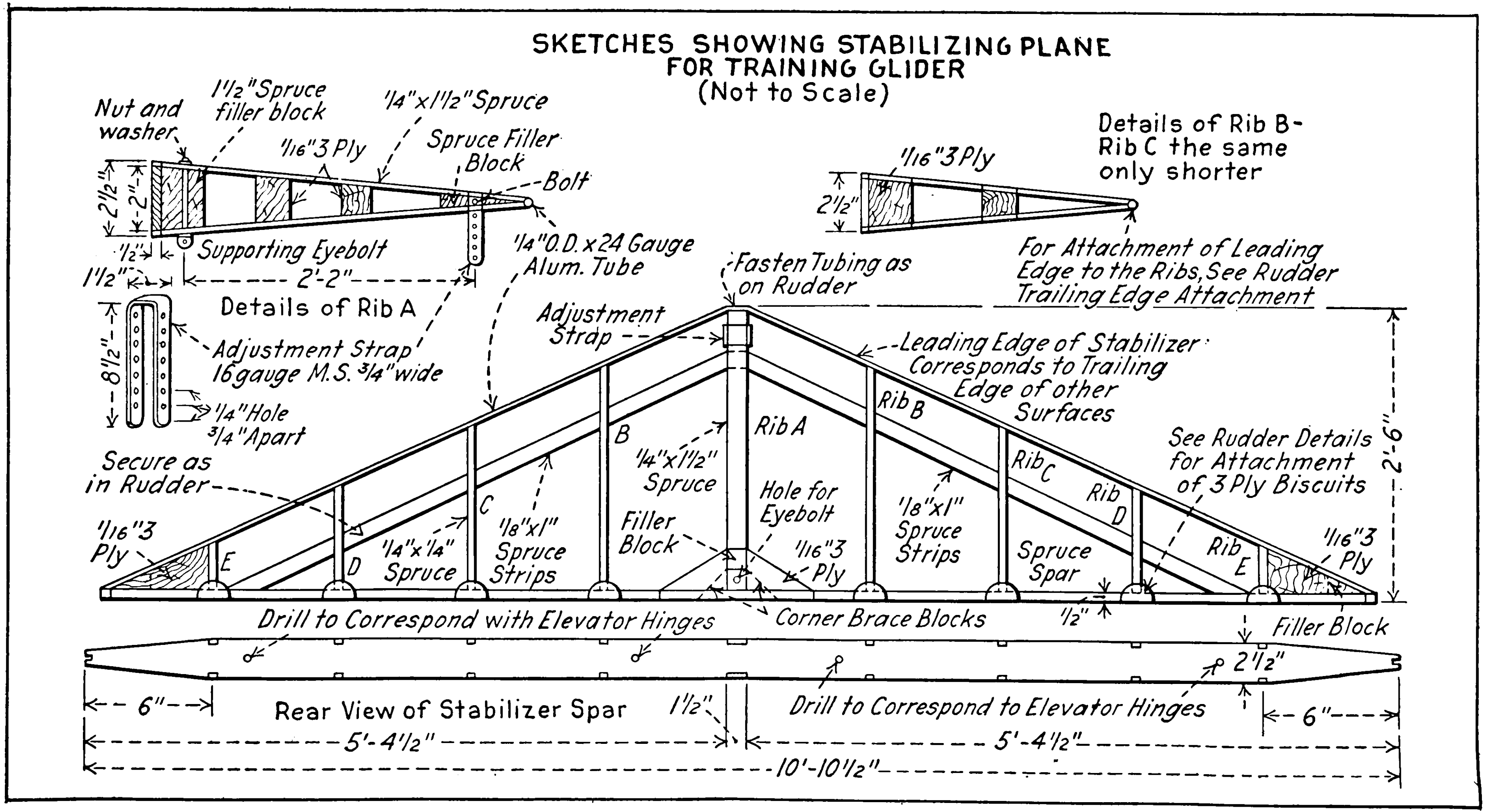


Fig. 72.—Sketches Showing the Construction of the Stabilizer or Tail Plane Frame of a Typical Training Glider.

cables are clearly indicated as well as points where they are guided by pulleys or fairleads. The rudder bar is supported by its center at the nose of the keel and cables extend from each end, through fiber fairleads on the seat from which point they are carried toward the top longeron of the fuselage. A pair of fiber fairleads is attached to the compression member or vertical strut immediately forward of the rudder post to guide the cables to the control horns on the rudder.

We will next trace out the aileron control cables. The control stick is hinged to a support which is secured to a rocking tube on the skid top carrying a lever or cross arm at the rear of the pilot's seat. A pair of guide pulleys or sheaves are carried on the vertical strut No. 1 immediately back of the pilot and above his head and in line with the cross arm or lever on the torque tube placed directly beneath the sheaves. The control cable from the left side of the cross lever passes over the front pulley and to the lower guide pulley attached to the right wing spar which permits a right angle turn of the cable to the lower control horn of the aileron on the right wing. From the upper horn of the right aileron the cable passes over a pulley on top of the wing spar and directly over the wing to the top pulley of the left wing spar and joins the top control horn of the left aileron with the similar member of the right aileron. The cable joined to the lower left aileron control horn passes over the lower guide sheave and from thence to the guide pulley on the vertical strut No. 1 and to the right side of the cross lever on the torque tube.

When the control stick is pushed toward the high wing, the cable hook-up is such that the aileron on the high side is raised so the air pressure strikes its top and that on the low side is depressed so the air pressure strikes the under side and increases the lift.

When the control stick is pushed over to the right side, the lever on the right side of the rocker shaft goes down, that on the left side of the rocker shaft goes up. As the lever end goes down, it pulls on the cable passing over the rear pulley of the vertical strut assembly and the lower control horn on the left aileron follows the movement of the cable and is rocked on its hinges so the lower surface is at a greater angle of the attack to the wind than the airfoil is, thus increasing the lift. The follow through cable which joins the upper control horns of the ailerons pulls the right aileron up so its upper surface has a greater angle of attack than the airfoil and the high wing is tilted down.

The stick is supported in a bearing member that permits it to be rocked sideways and moved back and forth at the top at the same time as shown in Fig. 69. A cable is attached to the lower end of the stick in such a way that it passes over a guide pulley at the glider keel nose from which point it runs over a guide pulley attached to the keel or skid gussets back of the pilot's seat. As there are two elevators, each having an independent control cable these cables pass over double guide pulleys on the top longeron and are attached to the control cable actuated by the stick at a point between the lower single cable guide pulleys and the upper double guide pulleys.

The hook-up is such that when the stick is pushed forward, the elevator surfaces are tilted so the air currents hit the lower face and thus lift the tail and depress the nose. Pulling the stick back moves the elevators in a reverse direction and the air currents strike the top surfaces, which depresses the tail and elevates the nose. When the nose points up, the glider climbs if there is an upward current of air or if it has sufficient airspeed; when it points down the glider returns to the ground or glides on a downward path.

Bracing Wires of Glider.—The assembling and rigging of the Dickson training glider will not be difficult after the various parts are completed and made ready for installation. The fuselage should be completed first and all metal fittings, control unit, seat, wing anchorage and tail plane anchorage eyebolts and control member hinge bolts installed. The double wiring plates, shown at Fig. 68B should be attached to the pylon top and to the main keel so the flying and landing wires may be attached. The bracing wire arrangement typical of training gliders shown in the lower illustration at Fig. 60 is used on the Dickson Glider and the instructions given in the preceding chapter for wire work, wing covering and construction and glider alignment can be followed in completing the glider. When one considers the numerous views of training gliders given in preceding chapters, the reader able to build the various parts will have no difficulty in assembling and rigging them to form an airworthy glider.

THE END

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