MANUAL of MILITARY AVIATION

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United States Army

MANUAL *of* MILITARY AVIATION

Prepared for the use of

Personnel of Aircraft Troops of the Army, National Guard and Reserve Corps; Officers of the Army, National Guard and Reserve Corps; Members of Military Training Camps; and Airmen in General

BY

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ELEMENTS OF TRAINING IN AVIATION

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INTRODUCTION

The events of the past few years have clearly demonstrated that a strong and well organized air service is a vital accessory of the modern military machine.

Without an efficient air service, an army is blind and impotent against an adversary so equipped. The strength of an effective air service is measured in thousands of properly manned aircraft, organized into properly balanced military aircraft units. This presumes an aircraft industry organized to meet every demand, and an extensive system of aircraft arsenals, depots, training bases and flying stations.

A highly trained, specialized personnel must be provided for the air service. Mechanical or technical training, knowledge and experience are essential. The value of supplementing such training by suitable theoretical instruction cannot be gainsaid.

This manual is intended for use as a textbook, and as a reference work, for such theoretical instruction.

The subject matter of the manual is based on rules, regulations and practice existing in the Aviation Section of the United States Army and upon common practice followed in foreign aviatic organizations.

H. LeR. Müller.

U. S. Army Balloon School,
Fort Omaha, Nebraska.
7—June—1917.

To The Late

LIEUTENANT FREDERICK GERSTNER

United States Army

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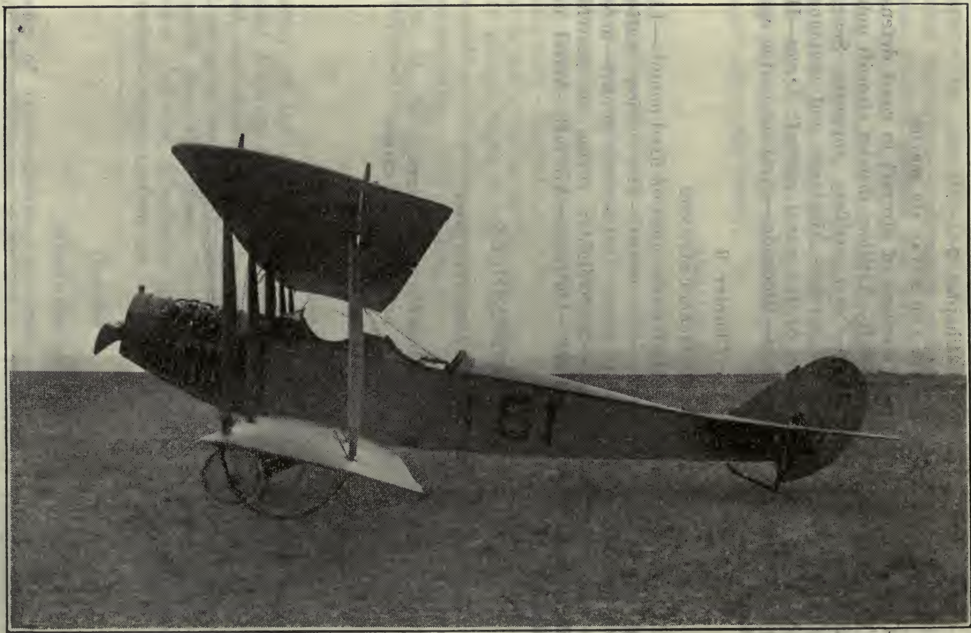
INTRODUCTION



Two-place reconnaissance tractor biplane

HISTORICAL SKETCH OF AVIATION

AERONAUTICS

Aeronautics is the science of navigating the air and is divided into two separate and distinct subjects: AVIATION and AEROSTATION, the first pertaining to heavier-than-air craft, the latter to lighter-than-air craft.

Of all the activities of man, none possesses a more compelling interest than flight. From the earliest day, man appears to have recognized that transportation is the great civilizer and agent of progress. He daily saw creatures of nature sailing easily and gracefully through the air. It appealed to him tremendously. The promised advantages of aerial navigation were enormous. The ease with which the bird glided through the air puzzled him beyond measure, but that very ease held forth the greatest encouragement. Hence, the science of bird flight was first studied by man as manifestly the most promising and hopeful method of flight.

Aviation

Under the influence of constant association with the flying creatures of nature, the ideas of man appeared first in the form of legends and myths and in sculptures of the ancients.

At the beginning of the sixteenth century, an Italian alchemist undertook to fly to France from the walls of Stirling Castle. That he was a man of resource is proved by his explanation that "the wings employed contained some fowls feathers having an affinity for the dung hill, but had he employed solely eagles feathers, his venture would have been successful." Leonardo da Vinci, who lived about the same time, was the first man to approach the subject scientifically. His endeavors were restricted to sketches of wings designed to fit the arms and legs. In the seventeenth century, one John Wilkins, Bishop of Chester, and a founder of the Royal Society of Great Britan, chronicled and discussed several alleged flights. In 1617, a rector named Fleyder delivered a lecture which so impressed a poor, unknown monk, that he undertook to carry out the theories expounded. His apparatus failed and he became the first victim of aviation. Francis Bacon's Natural History refers to flying in several passages and the author appears to have almost grasped some of the scientific principles involved. In 1670, Borelli took up the principle of artificial flight based on the flight of birds. He dealt with theories of bird flight and designed an artificial bird having "A rigid rod in front and flexible feathers behind." Followers adhered to his principles for almost two centuries.

In 1796, Sir George Cayley departed from the flapping wing theory by constructing a model helicopter (horizontal screw machine), which was successful. Steam driven helicopter models followed the Cayley model, but these types never exceeded a thrust lifting one-third of the total weight. Henson in 1843 made the first known attempt to construct a full sized flying craft. His aerostat was the parent idea leading to the airplane of today. Cayley in 1810 had suggested the idea of an elastic plane propelled by a screw. Wendham and Stringfellow at about this time made many more or less successful models.

In 1867 Pettigrew designed an ornithopter—or flapping wing machine—which presented an excellent imitation of the bird wing. It was elastic and flexible, nearly triangular in shape. It elevated and propelled in rising and falling. A description of the day explains: "It moreover twists and untwists during its action and describes figures-of-eight and waved tracks in space, just as the natural wing does." This was a scientific apparatus.

Thomas Moy, 1874, designed an aerial steamer with a novel engine which dispensed with the heavy type of boiler. It was a partial success.

The real dawn of practical aeronautics dates from 1890 when Professor Samuel P. Langley, Director of the Smithsonian Institute, in America, and Sir Hiram Maxim, in England, undertook their valuable experiments and tests. Both produced models and large flying machines. Langley's self-styled "aerodrome" was the more successful. It consisted of a central body to which were fitted concavo-convex plane surfaces, the convex surface being placed upwards. These planes were elevated at the anterior edge, with the idea of "forcing them through the air by means of powerful screw propellers. The greater the horizontal speed of the propellers, the greater the lift." Remarkable lightness and strength of materials were attained. Steel and aluminum were extensively used. Aluminum brace wires secured all parts of the body to a vertical mast. The framework of the planes was covered with china silk. The body was given the shape of a mackerel. The engine was especially noteworthy. It weighed 60 ounces, and developed 1 H. P. The 4 boilers of thin, hammered copper weighed 7 pounds. The engine was installed in the nose, the boilers amidships, and the tanks in the tail. Refined gasoline furnished the fuel. Steering in this novel craft was accomplished by altering the angle of thrust. Twin propellers were placed at the posterior end of the body. This model made the longest flight on record to that date, when in 1896 it flew a half mile down the Potomac. On that day practical aviation was assured.

A larger craft was then constructed having improved aerodynamical features. It made the first trial flight October 7, 1903. As the craft was leaving the launching ways, the track gave way and the machine pulled violently down, being partially wrecked. On December 8, 1903, the repairs having been completed, the trial was repeated. This time the launching way again failed to function, the rear plane was torn away and as the machine took the air, it stalled, and fell vertically into the water. Neither of Langley's two models carried an operator. A young Washington reporter so travestied the accident that it caused great public amusement and derision at the expense of Professor Langley. The Government had extended Langley financial support in the previous work, but could not be induced to further take the proposition seriously, so he forsook his chosen work, leaving his valuable scientific data to a following of practical men, who were eventually to make his experiments successful. Professor Langley died a few years later, a broken, disappointed man. His practical experimental work had not proved more important than his aerodynamical data, which enabled his imitators to introduce and develop the modern flying machine. His correction of certain faulty data, which were fundamental in character, was invaluable to the science of aviation. It is interesting to note that his first machine was later successfully flown by replacing the steam engine with a gasoline motor. Professor Langley will go down in history as the "Father of Aviation." He gave the world the first successful flying machine and his labor systematized those immutable laws of the science which enabled others to fulfill this dream of all the ages. He was the master scientist; those who followed in his wake and enjoyed the fruits of his labor were largely mechanics and artisans.

Sir Hiram Maxim worked along other lines. His craft was a monster device, having a supporting surface of 2700 feet. The power plant was a remarkable creation, weighing less than 2 pounds per H. P. In the test flight, this machine succeeded in slightly lifting its weight from the track upon which it ran along the ground.

Now followed a period of gliding experiments, which were destined to play an important part in the development of practical aviation. Lilienthal, Pilcher and Chanute, the leading exponents of this dangerous form of flight, deserve a substantial recognition in the history of aviation. Their work proved invaluable in advancing the theory of aerodynamics. Lilienthal and Pilcher studied particularly problems of stability and equilibrium. Both were killed in falls. Chanute developed the automatic features and introduced movable surfaces. He made 1000 flights without accident. From Langley, Lilienthal and Chanute, the Wright brothers obtained the vital data which enabled them to make the airplane a practical device of man.

The Wrights commenced their work in 1900. They first experimented with gliders. Their earliest improvement was the horizontal rudder (or elevator) for steering the machine in the vertical plane, i.e., for ascent or descent. They also devised the "flexing or bending" of the wing tips for "maintaining the structure in proper balance." In 1903 a gasoline motor was installed and the craft flew for 59 seconds. Forty-five flights were made in

1905; in one flight the machine remained in the air for 30 minutes and covered twenty-four and one-half miles. These experiments were made with great secrecy, rumors only reaching the critical, doubting public. The work of automobile engineers was utilized to produce a light, powerful motor. A small plant developing about 25 H. P. was constructed. It was mechanically imperfect but provided a power unit developing sufficient energy in proportion to weight to make flight possible.

Santos-Dumont in France, during 1906, adapted the gas motor to a torpedo shaped gas bag, fitted with air rudders and created the first practicable dirigible in the field of aerostation. He then directed his attention to the airplane, and created a craft fashioned like a T, with the foot of the T to the front, and composed of a series of box kites, two light propellers driven at high speed by a very light and powerful internal combustion motor. The machine had two wheels and skids. In November, 1906, it traveled in flight two hundred and twenty meters in 21 seconds. Henry Farman, in 1907, flew a Voisin machine, a biplane characterized by a horizontal rudder aft and two small balancing planes forward. He employed a single metal propeller driven by an eight-cylinder Antoinette motor developing 49 H. P. at eleven hundred revolutions per minute. Farman made a circular flight of one kilometer in 1908 and won a prize of ten thousand dollars.

In September, 1908, the first entirely successful public flight took place at Fort Myer, Virginia, in a Wright machine, piloted by Orville Wright. He made three flights; remaining aloft 57 minutes in the first, one hour and three minutes in the second and in the third carrying a passenger for a distance of nearly four miles in six minutes. Several days later Wright had an accident, the plane fell and his passenger, Lieutenant Selfridge, was killed. Four days later, a brother, Wilbur Wright, made a new record at Le Mans, France, remaining aloft for one hour and thirty-one minutes, covering about fifty-six miles. A few days later, he flew with a passenger for one hour and nine minutes. On December 31, he established a new duration record of two hours and twenty minutes.

This original Wright machine consisted of two planes, concavo-convex, set parallel and superposed, separated by a space of about six feet. The planes measured about forty feet from tip to tip, and were about six feet wide. At a distance of approximately nine feet to the front, a small pivoted biplane structure served as an elevator device. A vertical rudder was situated about eight feet aft. The entire plane and aviator, motor and accessories weighed in the neighborhood of eleven hundred pounds. This craft was launched from a rail and landed on skids.

The following year marked the success of the monoplane. General interest in aviation followed. Aviation meets became popular and competition keen between rival constructors and pilots. Manufacturers encouraged by public support and generous investment in aeronautical ventures—which increased rapidly with every advance in the attainments of aircraft—strove ceaselessly to meet the growing demand for better and improved types. Flyers, encouraged by prizes and honors, became more expert, thereby showing the greater possibilities of airplanes.

Altitude, long distance and duration flight records advanced with leaps and bounds and as these approached a certain approximate limit, aviators turned their attention to difficult aerial feats and finally to aerial acrobatics. It was thus proved that a machine

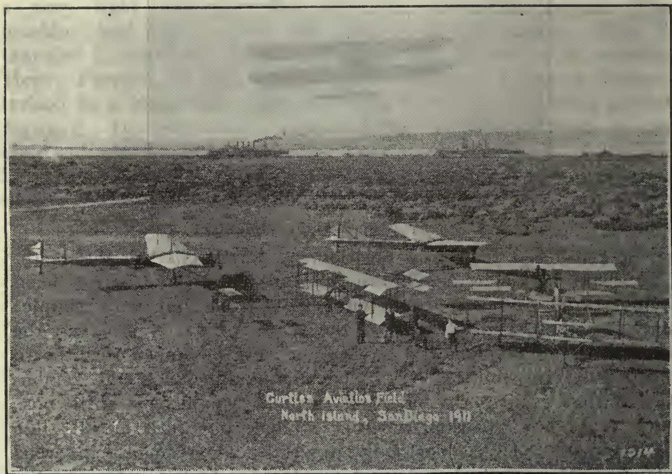
Early type of Wright biplane

can be recovered from any position, with reference to the earth, if at a sufficient height. Gliding without motors had earlier been demonstrated to be not only entirely feasible but very simple; hence, by these explorations of the realm of aerial dangers, the sciences of flight and aerial navigation were advanced to hitherto unsuspected possibilities. A Frenchman named Pegoud demonstrated that a properly balanced airplane would inherently nose down from any position, whether stalled, put into a tail slide (falling with the nose vertically upwards), or from a dangerous side-slip. His greatest and most spectacular feat was looping the loop, previously regarded as an impossible feat.

The first two years of aviation were marked by minor improvements at the cost of many lives. This period may be regarded as analytic rather than constructive. Controversies arose over the merits of many features and types of planes. The question of the relative worth of the biplane and monoplane was opened at this time, but was not definitely settled until the critical test of the present great war, when it was shown that the monoplane has no place in aerial navies, except for the work of very light, high speed destroyers. The discussion of warp vs. flaps or ailerons (for balancing device) has meanwhile culminated in the practical elimination of warping planes, as structurally dangerous in aircraft, and adoption of trailing-edge ailerons or flaps as superior to interplane ailerons.

In the year 1911 Glen Curtiss, an American pioneer pilot and manufacturer, who had succeeded in building a practical airplane about the same time as the Wrights, produced a hydro-airplane, now known as a seaplane. A short while later this noted inventor produced another original type of airplane, the flying boat, and finally created a dual land and water craft.

The first big improvement in aircraft design came as the result of work by aeronautical engineers who demonstrated the powerful influence of streamline form on the efficiency of the airplane. Laboratory work proved that for every pound of head resistance eliminated, nearly ten pounds more weight could be carried. In attest of this, old types of airplanes stand out in sharp contrast with the smooth, rounded, streamline craft of today. With every



Early types of planes

conceivable projection, wires, improperly shaped struts, skids, wheels, motor and occupants, all offering full and unshielded head resistance to the air in flight, the crude airplanes of earlier days fairly ploughed a way through the air with enormous drag and wasted power. Now, by placing all possible projections within an enclosed, streamline body, and by attaching fusiform members to axles, struts, wheels, skids, masts and braces, even to wires and smaller details, a vast amount of power so consumed was released for useful work. With losses resulting from this defect in early planes, and with barely sufficient power to maintain sustentation in flight, with practically no range of speed (difference between the minimum and maximum speeds), and with machines of defective stability, it is small wonder that accidents were frequent in spite of the growing skill of aviators. Famous pilots as well as beginners and novices paid the price of progress in aviation, and for several years it appeared hopeless to attain such a thing as reasonably safe aerial travel. It augured likely that if aviation did not suffer an early demise, it would never prove of any practical value, owing to the ever increasing number of fatalities. Pilots were regarded as supermen to be admired for their courage but to be pitied for their foolhardiness. In spite of discouragement following the first days of flight, diminished public enthusiasm and lack of financial encouragement, aviation survived the critical experimental stage.

Range of speed and reserve power in motors over the actual basic needs, next attracted attention. The demand for better motors was met with lighter, stronger, better constructed and generally more reliable engines of higher power. Streamline forms were brought to a high degree of perfection. Aircraft were designed and built scientifically with greater factors of safety, each model possessing the special qualifications demanded for the particular type; in one case having superior inherent stability, in

Recent experiment in bird-shaped airplane

another maximum controllability. Aeronautical engineers of marked ability evolved fine details of perfection and raised the efficiency of aircraft to a high degree. The science and the industry were thus established upon a firm basis in full enjoyment of public confidence and appreciation.

It was in this condition of development that aviation stood when the great world war commenced in August, 1914, which was destined to raise aircraft as a military weapon to the highest degree of usefulness and value; eliminating surprise, uncertainty and great maneuvering, open field battles; possibly to alter the outcome of the greatest combat in all history.

During the opening phases of the European struggle the air services of the belligerents were inadequately and inefficiently organized, and could not meet the demands made. Only airmen appear to have anticipated the many possibilities of aircraft and the elaborately organized air service necessary to reap the full benefits.

The remarkable results achieved by aircraft in warfare, in spite of deficiencies, thrilled the world. The work was, however, of an elementary character. Little more than reconnaissance was accomplished. This function of aircraft was limited to the discovery and location of masses of troops, and their general composition; major movements and dispositions. As the *impasse* developed on the Western Front in France, more attention was paid to other uses for aircraft, such as artillery fire-control and bomb-dropping. The air services were soon organized on a better basis for military operations. Air duels were fought with pistols and rifles (without any known instances of casualties, however); the need for machine gun planes was thus demonstrated. Contest for mastery of the air ensued. Squadrons and other units were organized to discharge a special duty in the air such as combat, reconnaissance, fire-control or bombardment. Radio was commonly installed on aircraft, rapid fire rifles were mounted, considerable quantities of ammunition, supplies and equipment were carried as the demands of military necessity were met by the ingenuity and skill of designers, engineers and manufacturers. Larger planes and finally great superplanes appeared with added improvements in necessities, conveniences and comforts, while increased radius of action, speed, climbing power and other desirable features, followed in various types of airplanes. Raiding expeditions by great fleets of airplanes and dirigibles became common. Bombardment fleets operated against peaceful cities and fighting lines alike. Great cities, small hamlets, main and minor arteries of communications suffered at the dictate of political or military demands. Large air fleets now operated with the smoothness of men-of-war units. Thus came the inception of aerial tactics, and the higher organization of the services of the air.

Combats between single adversaries, and between units of aircraft became common. The growth of anti-aircraft artillery grew apace with the strides of the air service. Planes, dirigibles and kite balloons suffered severely. Aircraft were steadily driven to higher altitudes for operations, and as the contest between aircraft and hostile military forces on the earth grew, the battle for ascendency in the air increased in intensity. Famous champions of aerial combat came to enjoy international reputations. Such names as those of Captain Boelke, who destroyed 40 enemy planes in air duels, Lieutenant Warneford who single handed brought down a hostile airship, of Immelmann and other notable war pilots, will go down in the roll of honor as the men by whose deeds the airplane came into its own as a super implement of war.

PART I

THE SERVICE OF AVIATION

CHAPTER 1

MILITARY CLASSIFICATION OF AIRCRAFT

There are two classes of aircraft:

a. Lighter-than-air craft;

b. Heavier-than-air craft.

Lighter-than-air craft are divided into *common balloons, kite* (or station) *balloons, and dirigibles.* Heavier-than-air craft comprise the *aeroplane* (or airplane), *man-carrying-kite, ornithopter* and *helicopter.*

(NOTE: The term *airplane,* as used in this manual, will be understood to indicate the more commonly employed designation of *aeroplane.*)

TABLE OF CLASSIFICATION OF AIRCRAFT

*Lighter-than-air craft: (*Aerostat*—a gas bag; *aeronat*—a motor driven gas bag).

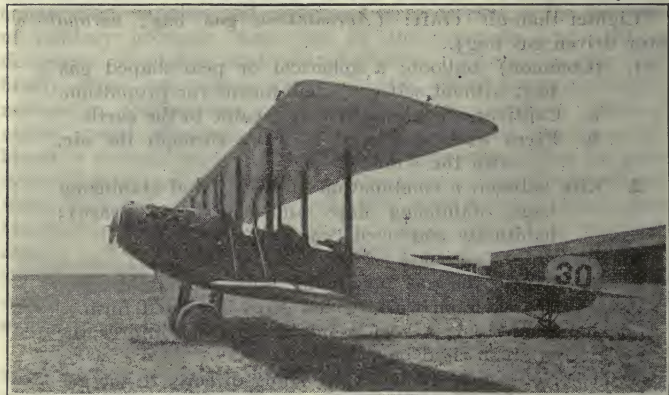
1. (Common) Balloon: a spherical or pear-shaped gas bag, without self-contained means for propulsion.
   a. Captive; when anchored by a cable to the earth.
   b. Free; when employed to move through the air, with the wind.†
2. Kite balloon: a combination of lifting and stabilizing bags, stabilizing flaps and tail cones (rare); habitually employed "captive."
3. *Dirigible:* (aeronat).
   a. Rigid; the gas bag being built on an inflexible skeleton work, which gives it a fixed form.
   b. Semi-rigid; a keel is introduced to reinforce the non-rigid bag.
   c. Non-rigid; the loads are slung directly to the gas bag without the employment of stiffening structures within or about the envelope.

*An aerostat rises in the air for the same reason that a cork bobs to the surface, when immersed in water. If a cork is sufficiently weighted it will not rise in water. If an aerostat is overloaded, it must be assisted by elevating planes to effect an ascent. The practice of denoting all gas bags as lighter-than-air craft may lead to confusion and error. The exception to be noted here, applies to airships, which are ordinarily, but not always, *lighter-than-air;* as, for example: the ordinary grade of hydrogen gas will lift 62 to 70 lbs. of weight for each 1,000 cu. ft. A 60,000 cu. ft. dirigible would therefore lift 3,720 lbs. So long as this airship carries 3,720 lbs. or less, it will rise when released, and is actually lighter than air. If, however, an excess of 1 lb. is carried, the airship is heavier than air and can ascend only by the aid of lifting planes and motive power. The best practice at present, is to load airships heavier than air, at the beginning of a journey. As fuel is consumed, the craft gradually becomes

Heavier-than-air craft: (aeronef—commonly called a flying machine).

1. *Airplane:* a flying machine deriving flotation in the air from pressure under the wings, and up suction on top of the wings, generated by its own self-contained means for propulsion, or by *coasting* under the influence of gravity.
2. Man-carrying kite: a series of box kites on one cable, carrying a basket for occupant, attached to the cable below the kites.
   (Machines that have not proved successful, at the present time.)
3. Ornithopter: a machine designed to fly like a bird, by flapping of wings.
4. Helicopter: a device deriving sustentation in the air from horizontal propellers.

Military Aircraft. From the above table it is seen that there are three types of gas bag, or lighter-than-air craft and four types



This machine combines the strength of the biplane with the low head resistance of the monoplane

of flying machines, or heavier-than-air craft. Of these seven distinct types of aircraft, all but the ornithopter and helicopter have proved practicable. The man-carrying kite is of doubtful mili-

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lighter-than-air, and if a descent is desired, without loss of gas, the craft must be *forced down,* just as it was *forced up.* This system greatly increases the load carrying capacity of airships. The important conception, in this instance, is the fact that a dirigible is not necessarily lighter-than-air. Hence the above classification, as generally accepted, is subject to exception.

†This practice is now followed in military work, only for training purposes in the instruction of kite balloon and dirigible pilots.

tary value. The kite balloon and dirigible have entirely displaced the common balloon (of the spherical and pear shapes), except for training functions, as the latter have neither possessed sufficient stability, when captive, nor permitted controllability when free, whereas the kite balloon and dirigible have demonstrated these qualities, respectively, to a high degree. The airplane is therefore the only successful type of flying machine *(aeronef)*. Hence the airplane, the dirigible, and the kite balloon having survived the experimental stage and having withstood the severe tests of field service, constitute the standard craft of modern aircraft forces.

The following analysis deals strictly with these types of military aircraft.

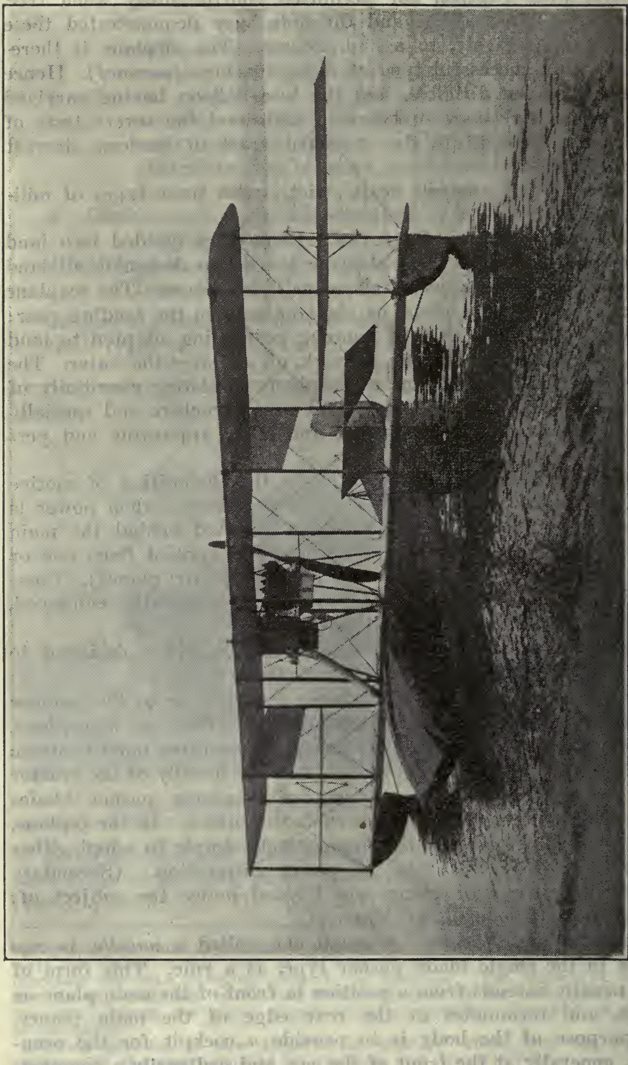
THE AIRPLANE AND SEAPLANE. Planes are divided into land and water craft. The term *airplane* is used to designate all land machines, the term *seaplane*, all water flying planes. The seaplane differs from the land plane or *airplane* only in the landing gear; the wheels-and-skids type of running gear being adapted to land work, and floats, or pontoons, to work, on and over the water. The *flying-boat* is a special type of seaplane, consisting essentially of a boat body, attached to the normal wing structure and specially designed to carry the occupants, and other apparatus and perform the functions of floats.

Special Distinctions. According to the disposition of motive power, airplanes or seaplanes are called *pushers*, when power is derived from one or more propellers situated behind the main plane (or planes); *tractors*, when power is applied from one or more screws placed in front of the main plane (or planes). Combination *pusher-tractor* planes have been frequently employed, i. e., using both propellers and screws.

(NOTE: The term *screw* applies to a *propeller* designed to pull; the term *propeller* denotes a *pushing* action.)

Arrangement of Plane Structures. According to the number and disposition of planes, one above the other, as *monoplane, biplane, triplane,* or *multiplane,* structural features must conform to the design. For example, monoplanes are usually of the tractor type, mainly because the problem of disposing pusher blades (propellers) offers almost insuperable difficulties. In the biplane, triplane or multiplane, it is comparatively simple to adopt either the pusher or tractor type of power disposition. (Secondary structural features of planes are treated under the subject of: *Action and Adjustment of Matériel.*)

Fuselage and Nacelle. A small car, called a *nacelle,* is employed in the single blade pusher type, as a rule. This form of body usually extends from a position in front of the main plane or planes, and terminates at the rear edge of the main planes. The purpose of the body is to provide a cockpit for the occupants, generally at the front of the car, and ordinarily a compart-



Flying boat

ment for the power plant, normally at the rear end of the structure. In this type the tail controls are carried on outriggers, secured to the main planes outside the radius of the blade. The nacelle type of plane is an ideal arrangement for the purpose of obtaining maximum vision to the front, or an unobstructed field of fire for combat planes. Structurally, the *nacelle* type is inferior to the fuselage type, in which a main, central fish-shaped body extends from the nose to the tail, in a single unit. This form of body generally carries the screw at the nose; the motor compartment, cockpit and streamline tail, from front to rear, terminating at the rear controls. The *fuselage* type offers more advantages than the nacelle type, but possesses many undesirable features. The chief advantage of the tractor type rests in the arrangement of power at the forward end, which in the case of a minor fall operates to favor an escape from severe injury to the occupants. In the nacelle type, the position of the motor at the rear constitutes a menace, in the event of a comparatively slight fall.

Monoplane; Biplane; Triplane. The monoplane cannot be made structurally as rugged as the biplane or triplane. Great differences in views exist upon the relative merits of monoplanes and biplanes. It is generally conceded, however, that the biplane is superior, except perhaps in the particulars of high speed and celerity of response to control. Some authorities claim that the monoplane lacks the required degree of stability. The *tandem-monoplane* is a type in which one plane follows another. The type is now practically obsolete. The biplane has equaled or exceeded every performance of the monoplane with the exceptions noted above. Special types of biplanes and triplanes have almost attained the high speed mark of the monoplane. The success of the triplane is comparatively recent, but it is notable and promises greater possibilities. Structurally it is a superior type.

The *tractor biplane* is the most common and popular type of airplane at this time.

Types of Military Planes. The entire structure of the air service is based on the major war functions of aircraft. These functions comprise:

a. Reconnaissance;
b. Artillery fire-control;
c. Bomb-dropping;
d. Combat.

Types of planes are selected that will fulfill these functions or perform auxiliary or related duties, either in the field or in the training camp. A given model of airplane should be adopted with reference to the variety of duties to which it can be profitably assigned. In this way a multiplicity of types and models is avoided.

Airplanes are grouped and classified for convenience, as *military planes* and *war planes.* The distinction is made between airplanes for employment in war service and for other military uses.

Military Planes (unarmed):

1. Training machines;
   a. Primary type (useful for artillery fire-control);
   b. Advanced training type (useful for tactical reconnaissance);
   c. Miscellaneous training types: solo training planes, high speed craft.
2. Dispatch planes (strategic reconnaissance types may be used);
3. Miscellaneous types.

War Planes (generally armed):

1. Reconnaissance machines;
   a. Tactical (short flight type);
   b. Strategic (long flight type);
   c. Intermediate scout type;
   d. Fire-control type.
2. Combat machines;
   a. Pursuit (or destroyer) type;
   b. Cruiser (or patrol) type;
   c. Battle-plane type;
   d. Super battle-plane type.
3. Bombardment machines (usually planes having large load carrying capacities.

Military Planes. Training machines are specially designed craft for the instruction and training of pilots. Various types are used to meet the requirements of the work, from the elementary to the advanced stage of flying. Dispatch planes are selected with reference to cruising radius and speed. Types useful for other purposes should be employed, whenever possible. Special types may be required for transporting supplies, having great load-carrying capacity at the cost of other dispensable qualities.

War Planes. Aerial reconnaissance is divided into *strategic* (conducted at distances of about 200 miles), and *tactical* (at shorter distances). The service has brought a demand for three types of planes—the *strategic,* the *tactical,* and the *intermediate* scout types.

Reconnaissance Machines. The prime requisite of the strategic type is a large fuel capacity, as great distances must be covered without a landing. High speed is almost as desirable. The air work involved is of such a general nature that the pilot can ordinarily accomplish his duties alone. Certain kinds of *strategic reconnaissance,* however, require the special services of an observer. This necessitates an altogether different kind of craft from the one-place (single-seater) type; probably a dual or multiple-motored plane of large proportions. In either case the type should have great speed and a large fuel capacity, with sufficient *range-of-speed* (difference between high and low speeds, in miles per hour) to enable the scout to cruise slowly over an objective for detailed work.

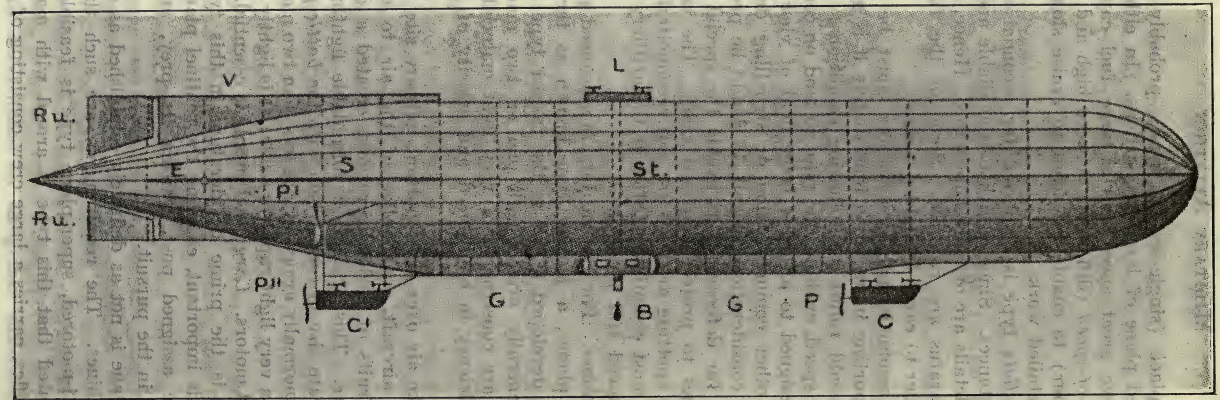
The *intermediate* type is employed for reconnaissance flights over shorter distances. Since less time is available and objectives less extensive, details are of more importance. Hence, an observer and radio apparatus are required. Some of the fuel may be sacrificed in order to carry the added weight.

In tactical reconnaissance, observations must be made with great detail, reporting information immediately it is gained. The *tactical* type should fulfill the following conditions: It must be capable of slow speed, enabling the pilot to land on comparatively small plots; designed to afford a large field of view; equipped with radio or other communication or signalling devices; and whenever other considerations permit, it should be provided with a machine gun for defense. This avoids the special assignment of combat planes to protect unarmed craft. The tactical type is also used for spotting artillery fire and reconnoitering artillery positions. The most essential qualities of the artillery fire-control type are slow speed and stability.

Combat Machines. For station duty at advanced posts, rising against enemy planes, a *pursuit* type known as the *destroyer-plane* has been developed. This is the fastest type of airplane used. It is generally armed with one or two machine guns. *Pursuit* planes are constructed of very light materials to obtain the required efficiency in high speed and celerity of response to control.

Patrols of the air over an important military site for defense against hostile aircraft, and police of the air to deprive the enemy of the fruits of aerial operations, created a demand for the *cruiser-plane.* This craft is a formidable fighting machine, but is of moderate size in comparison with the *battle-plane.* The cruiser-plane is normally armed by not less than two machine guns, and possibly by a very light rapid-fire rifle; it is lightly *armored* to protect crew and motors. Large fuel supply is essential, as a broad cruising radius is the prime desideratum in this type. Great range of speed is important, enabling the sentinel plane to cruise *slowly* over the assigned post, waiting its prey, and to dart *swiftly* forward in the pursuit.

The battle-plane is not as definitely established as other types of combat machines. The requirements are such that nothing short of a multi-motored, super-plane type is feasible. It may be generally stated that this type is armed with machine guns and rapid-fire rifles, carries a large crew consisting of pilot, navi-



Rigid dirigible (Super-Zeppelin)

KEY: B—bomb platform; C-C¹—cars; G-G—gangway; P-P¹-P²—propellers; E—elevator; S—stabilizer; St.—stairway; L—lookout platform; V—vertical fin; Ru.-Ru.—rudders.

gator, observer, gunners, engineers, and radio operator; the vital parts are armored, and the craft is thoroughly equipped to do major fighting in the air. The functions of such a craft are devoted entirely to combat, but bombs are frequently carried.

Bombardment Machines. The bombardment type is essentially a weight carrier. It is usually a multi-motored, super-plane type, equipped with proper facilities to transport large supplies of bombs, and fire-control and other apparatus for accurate bomb-dropping.

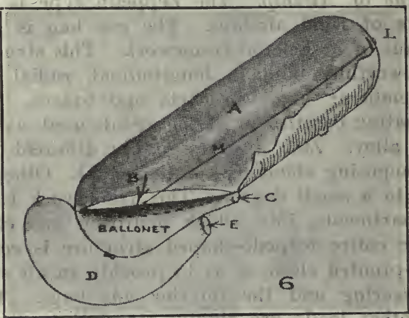
Summary. From the above brief analysis of the major uses of aircraft, it is plainly evident that *military* and *war planes* must be especially designed and built to discharge a certain military or war function, as in one case speed is of prime importance; in another, cruising radius, range of speed, or some other quality is the paramount requirement. It may be accepted as postulate that very few of the desired, or required qualities can be combined in any one machine. Hence the need of many types of airplanes exists, in order to discharge the variety of aerial duties that devolve upon the air service in warfare. Multiplicity of types, however, is to be discouraged on the grounds of complicating the technical and supply problems.

THE DIRIGIBLE. There are three types of dirigibles, the *rigid, semi-rigid,* and *non-rigid.*

Rigid Type of Airship. The Zeppelin type is the foremost representative of rigid airships. The gas bag is given a rigid form by means of a skeleton framework. This structure is made of metal, powerfully built in longitudinal, radial and annular, channeled members; angle brackets and braces. Aluminum is the predominating constituent of the metals used, averaging about 89% of the alloy. Zinc appears in the different members for stiffening, composing about 8% of the metal. Other constituents appear only to a small degree. This framework is divided into several compartments, into which hydrogen gas containers are secured. The entire torpedo-shaped structure is covered with a heavy, water-proofed cloth, so as to provide an air space between the outer covering and the interior gas bags. The gondolas (cars) and other loads are rigidly attached to the framework. Passageways are constructed from the cars to admit inspection of the interior and communication to the roof of the airship, where machine guns or rapid-fire rifles may be installed for offensive purposes. The airship has followed practically the same steps of development as the airplane, with respect to streamline refinement and motor improvement. The latest model of super-Zeppelin is 540 feet in length, 64 feet master diameter, weighs 33 tons, of which 11½ tons is the *live load.* The displacement is 1,100,000 cubic feet of gas. The craft is propelled by four power plants, of 250-300 H. P. each. The maximum speed is about

60 m. p. h.; the cruising radius about 1,000 miles. The normal complement consists of 2 officers and 15 men. The armament comprises 6 machine guns and a number of rapid-fire rifles.

Semi-Rigid and Non-Rigid Types. That the semi-rigid and non-rigid types of dirigible have not enjoyed the success of the rigid type, up to this time, is established. The semi-rigid type consists of a gas bag, elongated in form, usually from four to six diameters in length. The necessary shape is sustained by internal gas pressure. Formerly a network of rope was attached to the envelope to carry the loads. The best suspension practice at present is to employ either a belly-band or crows-feet patches. A stiff beam is slung below and parallel to the bag, and the loads are secured to this beam. The non-rigid type differs from the semi-rigid type only in that the beam is omitted, weights being slung directly from the belly-band or suspension patches, around the gas bag. The kite balloon discussed hereinafter as possessing notable military value, is distinctly a non-rigid craft. In the arrangement of load suspension it differs from the type discussed here, in this manner: the basket for the observers and other loads is slung by ropes attached to patches or to a flap of specially strong and durable fabric encompassing the envelope at the horizontal median line.



Captive balloon. A—gas bag; B—ballonet wall; C—ballonet intake; D—air rudder bag; E—rudder bag intake; M—automatic valve; G—position of basket

THE KITE BALLOON. The kite balloon is a captive balloon, consisting of a gas bag, having a cylindrical shape, and carrying some type of stabilizing bags. The combination is such as to give it weathervane stability and resistance to "pocketing." "Pocketing" is the effect of indenting the gas bag, caused by the wind, a tendency that seriously reduces the lift, increases the unsteadiness of the craft in a gusty wind and forces the captive balloon to lose considerable altitude. The kite balloon has displaced the pear-shaped balloon, an improvement on the spherical type for captive work.

The kite balloon will operate safely under any weather conditions to the extent of a 45-mile wind, and has been flown in a wind of 50 miles per hour. The common balloon is useless under these conditions. For military use, the kite balloon serves as lookout, scout and fire-control station. The kite balloon should be given the protection of anti-aircraft guns, and airplanes, if possible, as the balloon is extremely vulnerable to attack by hostile aircraft.

The kite balloon derives its name from the fact that it combines certain features of both the kite and the balloon, retaining the advantageous and eliminating the undesirable ones. The kite type of balloon consists of a cylinder-shaped bag, inflated with hydrogen gas, the lower section of its rear-end being partitioned off to form a ballonet or interior air bag, open to the rush of the wind from the front, by means of a bottle-shaped neck. An exterior air bag, similar to the one contained in the envelope, is attached in a like manner and below the first one. This bag serves as a rudder for the ship. Stabilizing planes, or flaps, are attached to the main bag to help maintain steadiness in flight. A tail consisting of a cable carrying inverted cones is attached to the aft-end in some models. The observing basket is slung by suspension ropes from the main envelope and adjusted to give the desired inclination to the gas bag. The craft is anchored by a cable to a mechanically operated windlass on the ground. The envelope rides upon its mooring rope at an angle of about 45 degrees to the horizontal. The craft will nose into the wind like an anchored ship, swinging with the tide. The wind bellows out both the interior and exterior bags, through the funnel-shaped openings to the front. This action causes the exterior bag to act as a rudder. The pressure within the interior air bag reacts upon the hydrogen pressure within the envelope. This reaction maintains as much pressure within the gas bag, as outside. That is, the outward pressure of the gas will just balance the pressure of the wind and the bag keeps its shape, obviating "pocketing." If, however, the pressure within the bag rises dangerously, an automatic escape valve acts. In some types, the escape valve must be actuated by the operator who must depend upon a gas manometer. This is an instrument which indicates the internal pressure of the gas bag. It is apparent that a rise in pressure within the bag will act upon the flexible fabric partition, before rupturing the inelastic envelope. To this fabric partition is, in some types of kite balloons, attached a rope connected to a valve in the nose of the airship. As the gas pressure forces the flexible partition outwards, it exercises a pull upon the rope and the valve is opened. When excessive pressure ceases, the flexible partition relaxes and the rope yields to the spring device that closes the valve. In most types, a self-contained, automatic safety-valve is used, comprising merely the trap-door and tension springs arrangement, common to balloon construction.

The kite balloon can fly without wind, but some types perform indifferently well in calm air; others are dangerous in high winds. The kite balloon is infinitely better than the common balloon for captive or *station* duty, since the former remains reasonably steady in a fluctuating wind, can be transported on the ground with greater facility, and is less difficult to conceal on the earth. When engaged on military observation duties, observers manning a kite balloon are in telephonic communication with stations on the ground.

A small ballonet called a "nurse" constitutes a part of the equipment of dirigibles and kite balloons. This "nurse" is a small balloon, filled with hydrogen gas for replacing the diffusion or loss of gas. It is very convenient to handle under service conditions.

For use in the field, a kite balloon is usually housed in a portable canvas shed, in a trench, or within an embrasure. Protection may be secured by a combination trench and embrasure. In the absence of adequate shelter or protection, balloons should be anchored in the lee of a forest or hill. For use with a fleet, the kite balloon is carried in the open hold or lashed to the deck of a ship.

The man-carrying kite is of questionable military value, difficult to handle, capable of flying only in a stiff breeze, and exceedingly dangerous owing to the possibility of a sudden fall of the wind. Kites may be profitably used for deceiving the enemy and drawing his fire.

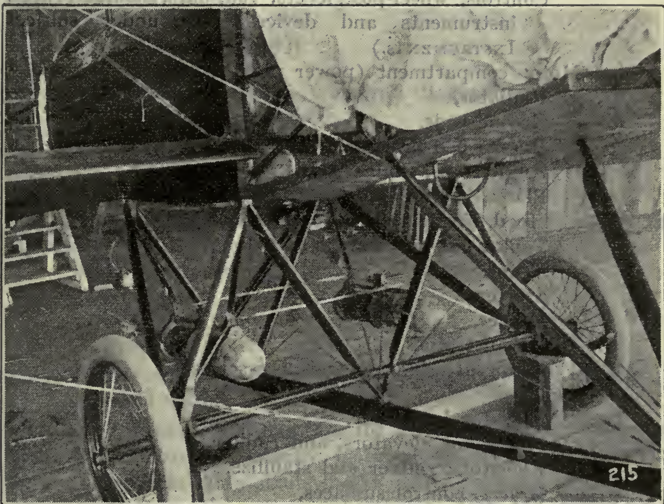
THE SERVICE OF AVIATION

CHAPTER 2

NOMENCLATURE OF AIRCRAFT

1. **Tractor Biplane** (single motored).

The standard type of tractor biplane consists of a main central body containing the motor, cockpit, tail fins and controls, the entire unit being known as the fuselage. This body is mounted



Details of chassis structure showing method of carrying heavy bombs

on a chassis or running gear. Either to the body or to the chassis are attached the right and left wing structures. The balancing planes form a part of the wing structure.

Body. (Note: Some types have two fuselages and a central nacelle, containing from front to rear):

Motor compartment,
Cockpit,
Tail,
Tail fins, horizontal,
Tail fins, vertical,
Rudder or rudders,
Elevators.

Integral parts of fuselage:
- Longitudinals (also called longerons),
- Spreaders (horizontal struts),
- Fuselage struts (vertical members),
- Fittings, angle irons, braces,
- Cross-stays.

Accessories:
- Tractor screw (propeller operating on motor shaft with thrust bearings set for *pull,* as reversed from *push*).
- Blades, tips, hub and plate.
- Instruments.
- Cockpit (integral parts and installation of):
  - Controls, wheel-post, levers, foot-bars, shoulderbraces, instruments and devices (see under subject INSTRUMENTS.)
- Motor compartment (power plant):
  - Radiator,
  - Engine beds,
  - Engine bed braces,
  - Angle irons, engine beds,
  - Plates, engine bed, front and rear,
  - Hood, side plates, floor plate, cowl,
  - Tanks, gas and water,
  - Motor,
  - Starter,
  - Muffler,
  - Exhaust pipes,
  - Motor attachments and accessories.
- Tail:
  - Elevator lever axle,
  - Masts, for elevators, and rudder,
  - Elevators, rudder and stabilizer,
  - Braces, control surfaces,
  - Skid, tail, and braces,
  - Rudder post and hinges,
  - Cross-stays, lift and drift, wire,
  - Leads, control; cable and fittings.
- *Wings,* right and left, solid or panels:
  - Panels, wing,
    - Panels, right and left, upper,
    - Panels, right and left, lower,
    - Tips, extension,
  - Panel, fuselage.
- Ailerons or trailing edge flaps; inter-plane ailerons; warping section; flexing panel or hinged panel. One of these types of lateral balancing devices is generally employed.

Struts,
Overhand struts,
Mast, for aileron or flap,
Cabane,

Wings:
Spars, or beams,
Ribs:
Webbing,
Flanges. upper and lower,
Streamline strips.
Keel, wings (fins),
Wires, lift and drift, and plane fittings.

Chassis, or landing gear:
Struts (chassis),
Axle or axles,
Braces, vertical, V-shaped, diagonal,
Streamline members,
Shock absorbers, and accessories,
Skids,
Wheels: hub, spokes, felloe or felly, and rim.

2. MONOPLANES AND TRIPLANES: differ in trussing from the biplane.

Biplane, pusher type (add or substitute):
Nacelle,
Outriggers,
Propeller.

(Note: In the twin propeller pusher type, a fuselage is often used.)

3. FLYING-BOAT. In this type the wing is attached to the boat hull. The motor is normally installed on engine beds carried between the main plain struts in the center section.

Hull, nose or prow, cockpit, step, deck, tail, motor-pit,
Combination air and water rudder,
Motor stanchion,
Floats, wing tip.

4. SEAPLANE. The seaplane is normally a land craft type, the land chassis being replaced by floats. To meet the very different requirements for water craft, the aerodynamical features of seaplanes differ materially from those of the land planes. In appearance, the differences are slight with the above-mentioned particular.

Main pontoon, or double main floats,
Wing tip floats (not ordinarily employed if two main floats are provided),
Tail float.

5. DIRIGIBLE *(Rigid type Zeppelin)*:
Envelope,
Air space, neutralizing,
Nose and tail,
Tail fins, keels (vertical), stabilizers (horizontal),
Rudders,
Elevators,
Gondolas (or nacelles) forward and aft (one navigating, one engine),
Lookout station and vertical communicating shaft,
Tanks, for water, ballast and fuel,
Framework:
  Annular metal members,
  Longitudinals,
  Angle-irons,
  Cross-braces,
  Angle-braces,
Ballonets,
Armament,
Motors,
Propellers,
Accessories.

6. DIRIGIBLE *(semi-rigid type)*, to include parts of the above, and:
Reinforcing beam,
Gas-bag slings, or suspension cables and patches,
Gondola slings, or suspension cables.

7. DIRIGIBLE *(non-rigid type)*: Same as above, eliminating the rigid features and the reinforcing beam of the semi-rigid type. In the fuselage type dirigible (popularly known as the "Blimp"), add the following:
Ballonets, front and rear,
Air intake manifold,
Blower system:
  Funnel, tube and valves,
Control surfaces and fins,
Fuselages (this unit is similar to an airplane fuselage body).

8. KITE BALLOON:
Gas bag,
Appendix,
Safety valve,
Maneuvering valve,
Safety valve rope,
Maneuvering valve rope,
Ripping panel rope,
Air ballonet,

Ballonet orifice, or intake,
Flexible diaphragm (this device is rarely used),
Air-rudder bag,
Air-rudder bag orifice, or intake,
Horizontal stabilizing planes (this device is rarely used),
Kite tail:
- Tail ropes,
- Tail cones,

Accessories:
- Median line flaps, or suspension patches,
- Suspension cables,
- Slings, or crows-feet,
- Rope webbing,
- Car (or basket),
- Concentrating ring,
- Mooring cable,
- Mooring cable bridle,
- Manometer tube.

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Horizontal stabilizing planes (this device is rarely used),
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- Manometer tube.

PART II

TRAINING IN AVIATION

CHAPTER 1

PERSONNEL AND TRAINING SCHOOLS

While technical and mechanical training and instruction must take precedence in the military air unit, the personnel remains essentially military in character, the individual members being officers and enlisted men, organized into prescribed companies, squadrons, and other units, subject to military law, orders and regulations.

It is not good practice to assign recruits or untrained men to military flying units, but it may become necessary to do so. In the latter event, the recruit must be trained in his purely military duties to an extent necessary to make him a military man, qualified to perform his functions as a part of the military machine. This instruction should be limited to the elements of the work and should include the following:

(1) Infantry Drill Regulations:
- a. School of the soldier,
- b. School of the squad,
- c. School of the company (including principles of extended order, combat and field work, fire discipline, fire control and fire direction).

(2) Field work (practical application of the principles of combat):
- a. General principles of attack and defense,
- b. Patrols,
- c. Principles of reconnaissance,
- d. Messages, reports and field orders.

(3) Physical training:
- a. Setting-up exercises,
- b. Training for field meet.

(4) Signalling:
- a. Visual: semaphore, wigwag, flag, torch and lantern,
- b. Sound: dot and dash, horn,
- c. Mechanical: telegraphy (radio and wire).

(5) Care and use of fire-arms:
- a. Rifle,
- b. Pistol (personnel of air units are armed with both rifle and pistol),
- c. Target practice.

(6) Map reading and sketching.
(7) Loading wagons.
(8) General:
 a. Castrametation; sanitation; personal hygiene and first aid.
 b. Military courtesies and deportment; customs of the service.

For the training of officers and enlisted pilots* of the air service, who have not had previous experience, there should be a course preliminary to the prescribed Officers' Garrison School, to include the following:

Administration:
 a. Army Organization, Military Practice in the Administration and Government of a Company, Field Service Regulations.
 b. Course in Military Aviation, to include:
 (1) Service of Aviation.
 (2) Technological Instruction.
 (3) Science of Aviation.
 (4) Military Aviation.
 (5) Service of Aerostation.†

The personnel of the flying service consists of the Chief of Aeronautics, on duty at the War Department, and his aircraft staff, the aircraft commanders and staffs of the various organized territorial armies, army corps and divisions, as assigned by authority of the War Department, of officers and men of airplane squadrons, kite-balloon squadrons and dirigible units, and of the several aeronautic training schools, bases, depots, and flying stations maintained by the War Department.

The above organization is treated in detail under the subject of *Military Aircraft Units.*

AIRCRAFT STATIONS

Aircraft stations are grouped according to functions, as:

1. (a) Aircraft training schools (aeronautic training schools conducted by the Government); (b) Civilian training schools (aeronautic training schools under governmental supervision).

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*The British system of instruction (3 to 6 months) for pilots includes the following subjects: "Military History, Tactics, Meteorology, Engine Construction (many types), Geography, Compass and Map Reading, Army Organization, Observation of Trenches and Fortifications, Photography, Radio, Artillery Observation and use of Machine Gun, Theory of Flight and a certain amount of drill."

This system is criticized by a British authority who suggests that an improvement should be made "by teaching certain subjects to all and specializing on the remainder."

†The U. S. Army Balloon School has been established at Omaha, Nebraska, for instruction in aerostation.

2. (a) Aircraft parks (stations of aircraft units in the field or with the military forces); (b) Squadron depot units.

3. (a) Aircraft bases (aeronautic arsenals); (b) Aircraft depots (aeronautic supply stations); (c) Aeronautic experimental stations.

(Rules governing the operation of military flying stations other than schools are to be found under PART IV—MILITARY AVIATION.)

Field bases for aircraft in time of peace must be organized to meet the conditions prevailing with reference to location, climate and the duties involved. In case of war, or imminent war, tactical stations with the permanent facilities of aircraft parks, bases or training schools may be found practicable. The nature of aeronautic work is such that every possible convenience and resource should be furnished and employed. The work is *per se* elaborate by virtue of the manifold difficulties to be overcome, and the strict requirement for absolute thoroughness in every detail, and it must be supported in that spirit to produce comprehensive results.

General Order No. 55, War Department, 1916, prescribes: "the country will be divided into three school districts. The commanding officer of the school at San Diego will have general jurisdiction over all the schools in the western department; the commanding officer of the schools of the central part of the country will have jurisdiction over all the schools in the central and southern departments; and the commanding officer of the school in the east will have jurisdiction over all the schools in the eastern department."

Training schools comprise not only the official schools maintained by the military establishment but civilian schools for the training of reserve and national guard officers, under governmental supervision or partial governmental control.

The principles governing the organization of all aircraft training schools is essentially the same.

A simple model is required for flying stations in general.

Such an organization as is outlined hereinafter should prove suitable for a flying school. This proposed organization has no reference to aircraft parks, bases or other aeronautic stations.

Proposed organization for an aircraft training school:

1. The Commandant.
2. Assistant Commandant and Executive Officer.

I. Executive Division.

1. Secretary.
2. The Supply Officer (Aeronautic Supplies).
3. Quartermaster (Military supplies, accounts and records).

II. School Detachment.

1. The enlisted force organized into companies and battalions and properly officered.

III. Technical Division.

1. Technical section.

(a) Courses of lectures, recitations and examinations in aeronautics (*for field officers, administrative officers, pilots, observers and other necessary commissioned personnel).

(1) Aviation (elementary and advanced).†

(2) Aerostation (elementary).

(b) Shop course.

(1) Construction and repair (involving the dismantling and assembling of airplanes and aircraft matériel).

(2) Aero Motors (including dismantling and assembling of aeronautic motors, trouble shooting and adjustments).

(c) Research laboratory.

(1) Aerodynamics.

(2) Radio.

(d) Course for enlisted specialists (to fit enlisted men for their duties as members of airplane crews, motor engineers, gunners, radio operators, carpenters, fabric workers, mechanics, machinists, electricians, chauffeurs, and other necessary personnel).

2. Aviation Training Section.

(a) Practical instruction in over-land flying.

(b) Practical instruction in over-water flying.

3. Engineering and Repair Section.

4. Experimental Flying Section.

5. Machine Shops.

(a) Motor repair shop.

(b) Metal shop.

(c) Wood and fabric shop.

The first function of the military flying school is to produce the highest quality of trained airmen. Everything should be subordinated to this object. The error of training pilots to the exclusion of general training of navigators, observers, administrative, technical and tactical officers and other airmen has become strikingly evident. Aviation schools must become more extensive and scientific, embracing every correlative subject, and extending to the study and practice of aerostation. Military

*This course should cover every subject allied to aviation and aerostation.

†At aerostatic schools the courses should be reversed (1) aerostation (elementary and advanced); (2) aviation (elementary).

aviation schools must inevitably become military aeronautic schools in order to include both aviation and aerostation and cover the entire science of navigating the air. Courses for enlisted men should not be neglected, as all personnel engaged in the practice of aeronautics should not only have a general professional knowledge of the science, but should be specialized in the particular branch to which assigned.

TRAINING IN AVIATION

CHAPTER 2

RULES GOVERNING THE SELECTION AND OPERATION OF AIRCRAFT STATIONS

This subject has particular reference to the selection of suitable landing sites for aircraft and the general rules governing the care and maintenance of the planes in their hangars. The discussion applies to all flying stations, schools or parks in the garrison or in the field.

Flying Fields

Landing fields should be selected by a qualified officer. An experienced pilot should be employed for this purpose. The officer making such a selection should bear in mind the purpose for which the field is to be used. He should be particularly careful in the selection of sites from which elementary flying is to be conducted. The selection of permanent stations for aircraft should be made by a board of qualified officers whenever practicable.

The principal considerations in selecting temporary landing sites are:

1. Sheltered water area for seaplane sites,
2. A firm, dry, level earth for land machines,
3. Possibility of ascending in any direction, with sufficient margin of space, or ample, adjacent fields to enable craft to obtain a safe flying height within which turns for forced landings can be made.
4. Ability to land with ease from any direction.

For permanent fields, other considerations are added. Meteorological conditions are important. It is desirable to obtain a location with such reference to weather conditions as to obtain the maximum number of flying days per year. The influence of the configuration of the earth within the vicinity, in producing wind formations and atmospheric disturbances, must be determined. For training beginners in flying, calm and undisturbed air is necessary. If the normal daily weather conditions are not favorable, flights alone by beginners should be confined to the early hours of the day, at or about dawn, and to the late hours of the afternoon when the air ordinarily becomes comparatively quiet. For advanced flying, however, such ideal conditions are not only unnecessary but may be undesirable, as the finished military airplane pilot must acquire the experience and ability to navigate under all conditions of the atmosphere. When tactical sites are selected, they should be located out of range of hostile fire, whenever possible.

LANDING SITES FOR AIRPLANES

The surface of the ground should be level and firm. The minimum size of a flying field used by the United States Army, for a test of aspirants to the rating of Junior Military Aviator, is an area of 800 feet by 100 feet, assuming an obstacle of 10 feet at one extremity of the long dimension. More common practice is the rule generally followed, which limits the field to an area of about 9 acres, 200 yards square. Due allowance must be made for obstacles. For every yard of height of the obstacle, twelve yards of field depth must be added to the dimensions of the site. This applies to slow machines. Based on an initial site of 200 yards, the following general rules may be taken as an average guide:

For machines having a minimum landing speed exceeding 40 miles per hour add 60 yards.

For machines having a minimum landing speed exceeding 45 miles per hour, add 120 yards.

For machines having a minimum landing speed exceeding 50 miles per hour, add 360 yards.

For machines having a minimum landing speed exceeding 55 miles per hour, and less than 60 miles per hour, add 960 yards.

When the ground is soft or covered with snow, the machine will not run as far on landings as under normal conditions. Hence it would appear that the field selected under these conditions should be smaller. This however, is not true, because the "float-off" is more difficult and the run along the ground lengthened accordingly. These data are given for rising and landing *against* the wind.

Close study of local topography should be made to determine the influence of up and down trends of the air and other prevailing wind formations or disturbances.

In case the slope of the ground is materially greater than ordinary railroad grades, difficulty may ensue. Machines should *not* be landed down grade. The float-off should *not* be made up grade.

Fields of rocks, boulders, brush, high corn or other vegetation should be avoided for forced landings whenever possible. Such neighboring sites materially reduce the value of a field for elementary flying. A machine can be safely landed in cultivated fields, by an experienced pilot, but there is a probability of minor breakage and the machine can be extricated from high growth only with great labor sometimes involving dismantling the craft. Normal and safe landings in soft ground are difficult but not impossible. The chassis of some types of planes are specially designed for this purpose, but the imposed conditions are hard to overcome. Ditches and sharp depressions are dangerous and must be avoided. Occasionally a land plane must alight on the water. The feat is not difficult for a good pilot even when a moderate sea is running, provided the machine is "stalled" into the water from a height of a very few feet. *Such a landing usually entails the complete loss of the craft. When flying fields are situated near bodies of water, the fields should have such reference to the water that a pilot will never be forced to descend in the water in case of motor trouble or failure during the low altitude climb. Fields bordered by poles, wires or trees are not suitable for flying and should not be so employed, except in an emergency. To select such sites for training purposes is to invite disaster. Flying fields should be cleared of all brush, fences, poles, wires, trees, obstructions of every nature removed and chuck-holes, ditches, and hollows in the ground levelled.

Water Landing Areas

The selection of seaplane stations involves the location of a suitable site for hangars on the shore and a properly sheltered water area.

1. Selection of site for seaplane hangars:
   - (a) Location bordering a suitable beach; well-packed sandy soil, level above high water mark. Hangars should be located above high water mark.
   - (b) Beach gently sloping into deep water, gradually attaining a depth of about 5 feet, at or about 125 feet from shore; measured from high water mark.
   - (c) Slope of beach should be steeper for tides exceeding 5 feet variation.
   - (d) Uniform slope of beach is desirable.
2. Water Landing Area:
   - (a) Water area should be so sheltered from winds and currents as to be reasonably smooth at all times.
   - (b) The site to be free from treacherous or dangerous wind formations or air disturbances.

*Life preservers should be carried on all planes flying in the vicinity of bodies of water. A well-doped land plane will float on the water for hours before sinking, provided the planes are double-surfaced. This is standard practice. In case of an attempt to swim ashore from a sinking plane, a flap or aileron, or an inflated tire should be detached from the craft for use in the absence of life preservers.

(c) Water area to be free from treacherous or dangerous water currents. Steady, broad, slow water currents are not particularly serious for seaplane work. Swift, narrow currents, especially if fluctuating in flow are exceeding difficult to overcome and usually dangerous to the aviator and his craft.

(d) The water area must be free from obstructions. It should lie parallel to the shore and the line of hangars, for at least 600 feet beyond each end hangar. The area should be open and free for use to the front (perpendicular to the beach) for about 2,000 feet; this entire area should be "forbidden anchorage."

(e) Water area should be free from shoal water, sea-weed or rocks, at low tide.

IDENTIFICATION OF FIELDS AND AIR ROUTES

Landing sites should bear some identifying mark, visible to airmen at mean altitudes. (Mean altitude as used in this manual is assumed at from 5,000 to 10,000 feet. The term "mean altitude" will be understood to apply to this classification of altitudes.)

Canvas strips are largely employed for the purpose of marking sites. Strips not smaller than 15x3 feet are distinguishable to airmen at 9,000 feet.

Air routes should be indicated by symbols painted on the roofs of buildings or other structures bordering highways of land travel. The roofs of railroad stations and of large houses bordering rail routes should be selected for this purpose owing to the ease with which railroads are followed. Special symbols should be placed at and near junctions and switches, to guide the aviator without possibility of confusion. Warning signs should be displayed at points where dangerous wind formations or air conditions exist. Simple signs and symbols should be used.

The following examples are given:

N. Y. <————————————> Balt.
96 110

This would be read 96 miles to New York, 110 miles to Baltimore and the directions indicated by the two arrows would enable the aerial navigator to orient himself on his map.

X——X T
—

These easily discerned symbols might be used to indicate, respectively, the presence of a dangerous wind formation and the location of a re-supply station or good landing field. In marking positions, the following must be taken into consideration:

a. Good landing fields with wind directions indicated by reliable apparatus, and the site marked by suitable lights at night.

b. Positions of re-supply stations, air routes between principal cities, with directions, distances, and identity of the route. Locations of dangerous prevailing winds or air disturbances.

c. Danger signals of impending storms.

d. Lighting scheme of brilliant lights through certain streets of cities and towns to form symbol figures or letters, visible from above. (At night, practically the only guides are lights. Small villages stand out clearly visible for about 25 miles in slightly hazy weather, at altitudes above 3,000 feet. At or about dusk or dawn, small lighted villages assume the appearance of bodies of water at distances above 25 miles. Great care must be exercised to avoid this confusion. A bright moon overhead may enable a pilot to land safely, but aerodromes should be marked unmistakably.)

e. Aerodromes are marked with canvas strips by day and by flares, bon-fires, searchlights and other lighting devices by night. A general rule is given for indicating the exact direction for approach and the point at which planes are to make contact with the earth. A long strip of canvas is placed at the expected point of contact. Two strips forming a capital T (the outline of an airplane) are placed at the point toward which machines must be steered. Craft are then brought to rest at or before the capital T is reached and pointed in the same direction as the outline of the letter. (This is the conventional signal for marking a landing field.)

The signal is arranged in this manner:

T

—

For night signals, the same arrangement can be used, employing lights.

HANGARS

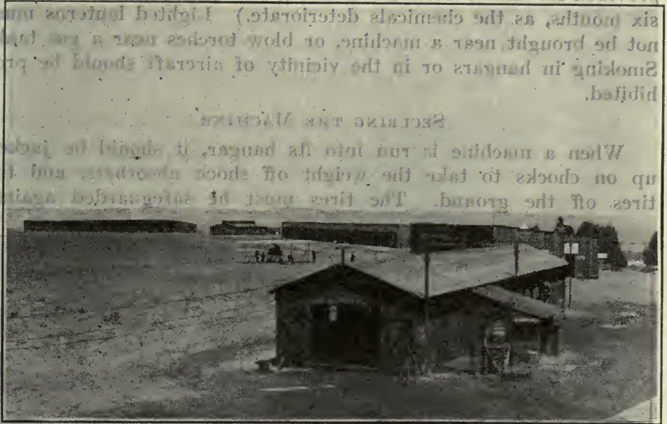
Suitable cover must be provided for aircraft. The equipment is of such a character that it deteriorates rapidly if exposed to the elements.

In the field, tent hangars are provided as a rule. At permanent flying stations, metal, wooden or concrete structures are generally used.

Concrete buildings are normally the most suitable. In very damp climates, however, concrete buildings may not prove satisfactory. In hot climates metal structures are unsuitable. Wooden buildings are to be avoided for housing aircraft matériel, owing to the inflammable nature of aircraft accessories, and the combustible materials used in connection with them.

Hangars must be dry and tight. They should be floored, preferably with concrete or cement. The structure should be impenetrable to dust and sand and provided with effective drainage facilities.

Aircraft units are normally quartered in hangars grouped together. Shops, store-houses and offices should be centrally located.



The shops and storehouses should be centrally located, with reference to hangars

Overhead trolley systems should be installed wherever possible for transferring motors and other heavy loads between hangars, shops and store-houses.

Each machine should have a separate booth or compartment, or be assigned to an individual hangar.

Booths should be kept scrupulously clean at all times. Waste matter, tools, and apparatus must not be left around. Every piece of property stored in the booth should be listed and kept in its proper place when not actually in use. The efficiency and reliability of a crew are surely reflected by the orderliness that prevails in their booth.

If drains are not built in the floor, drip pans should be provided and kept under each motor. Accumulations of oil must be disposed of frequently. Cloths must not be kept near the planes. Cotton waste should not be used around planes. Cheesecloth for cleaning purposes should be cleansed of oil saturations frequently. Metal lined boxes should be provided for the cloths. Metal waste cans must be used for refuse. These cans must be kept outside the buildings. Sand boxes should be kept near each machine and a shovel placed in each box. In case of fire, use pyrene, or sand. It is better to use sand than chemicals in case of small blazes around the plane that are easily handled. Do not put water on an oil or gasoline fire. Water merely causes the fire to spread. Chemical fire extinguishers should be kept in each machine, as a part of the permanent equipment. Large chemical extinguishers should be provided for each booth. (Fire extinguishers must be refilled every six months, as the chemicals deteriorate.) Lighted lanterns must not be brought near a machine, or blow torches near a gas tank. Smoking in hangars or in the vicinity of aircraft should be prohibited.

SECURING THE MACHINE

When a machine is run into its hangar, it should be jacked up on chocks to take the weight off shock absorbers, and the tires off the ground. The tires must be safeguarded against

An ideal training site. Suitable fields along a favorable water area.

exposure to oil drippings or standing in oil. Canvas covers for motors, propellers and cockpit, should be provided and kept on the machine, when it is not in use.

In the event that an airplane must be left in the open for a considerable period or overnight, it should be secured. A sheltered cove, a pocket in the woods, depression in the ground or a site under the lee of a hill should be selected. Canvas strips with attached guy ropes and stakes will be found useful as a part of the equipment of military planes on cross country work. These strips or belts are secured over the planes from the front to the rear, as closely to the fuselage (or center of the lower planes) as possible. The stakes secured to the ends of the ropes are driven well into the ground. The propeller and cockpit covers are adjusted and all metal equipment thoroughly oiled and greased. The machine should be jacked up, on improvised chocks. Ropes attached as guys to the machine must be carefully secured in order not to bring excessive stresses to bear in case a stiff wind blows.

TRAINING IN AVIATION

CHAPTER 3

DUTIES OF CREWS

The basic unit of organization of the air service is the Air Squadron.*

(The details of organization of aircraft squadrons cannot be published at the present time.)

With the idea of undertaking the instruction of this unit with the simplest element and smallest subdivision, the technological instruction of airplane crews in their various duties will first receive consideration.

Some distinction appears necessary between the personnel who man the craft in flight and the personnel who serve the airplane when on the ground, making ordinary repairs, alterations, removals, installations, cleaning and preserving the craft and accessories. The following differentiation is therefore made: (a) Flying Crew and (b) Repair Crew.

Flying Crew

The flying crew of an airplane normally consists of a pilot and observer. One-place planes carry only a pilot; super-planes carry from 3 to 15 men.

The duties of super-plane flying crews are outlined here, as follows:

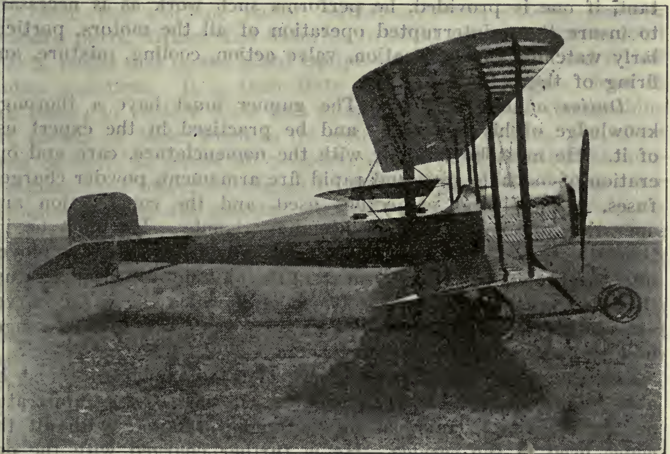
Navigator, observer, pilot, engineer, gunner, and radio operator. The duties of the flying crew (pilot and observer) in the two-place machine are practically the same as given here. In the single-seater type of airplane (usually designated one-place type), the pilot discharges in addition, part of the duties of navigator, observer or gunner, as the case may be.

The flying crew of an airplane always comprises an aviator. An observer is normally carried except in small high-powered, one-place machines designed for strategic reconnaissance flights, and high-speed, single-seater pursuit or "destroyer planes." When the plane mounts machine guns or rapid fire rifles, or carries bombs, one or more gunners are added to the crew. In the larger planes, provision is made for wireless and a radio operator is added. Super-planes ordinarily carry two or more motors (either *pusher* or *tractor*), and auxiliary motors for operating the wireless and starting the main battery of motors. The constant attention of one or more engineers is required on such a machine.

*In the French Army the airplane squadron is designated the Escadrille; in the Italian Army, the Flotilla; in the British Army, like our own, it is called the Squadron; but whatever the name, the unit is essentially the same in all services.

Navigator. The senior officer or non-commissioned officer assigned to the plane is the commander. He may be either the pilot or observer, or an officer specially assigned for the purpose. He must in any case be a trained military flyer to discharge his duties efficiently. The navigator exercises navigating and military control of the entire craft, directs the pilot, radio operator, gunners and engineers.

Duties of Pilot.[1] The pilot is charged with the operation of the craft in flight; the management of power and air controls in flight. He is responsible for repair work and alterations not involving shop work, and the final inspection before the airplane leaves the ground. Before a machine is taken aloft,



This type of plane has a low landing speed and front wheels to take soft ground landings. It carries four persons.

and at once upon return from a flight, he should examine all control leads, wires and cables, especially over pulleys or through fair leads (bent angle tubes), inspect minutely brace wires, fittings, chassis, wheels, control surface hinges, struts and surfaces. If ordered to leave the ground instantly, he should faithfully inspect controls, leads and control surface fittings. No haste can excuse an oversight or neglect of this inspection. The accomplishment of the mission depends upon the control of the machine.

Duties of Observer.[2] In large planes the observer is charged with the navigation of the plane in flight, making observations

[1] See *Flying.*
[2] See *Navigation of the Air.*

CHAPTER 4

CARE OF MATÉRIEL

An airplane cannot be too clean.

This is the first rule to observe in the care of a machine.

All dirt, mud, rust and waste oil must be removed immediately when the plane is returned to its hangar.

In the care, preservation, maintenance and operation of airplane equipment, the following materials are commonly used:

Lubricants: oils and greases;
Preserving materials: paints, enamels and varnishes;
Cleaning materials: soaps and polishes;
Fuel: gasoline; lubricating oils.

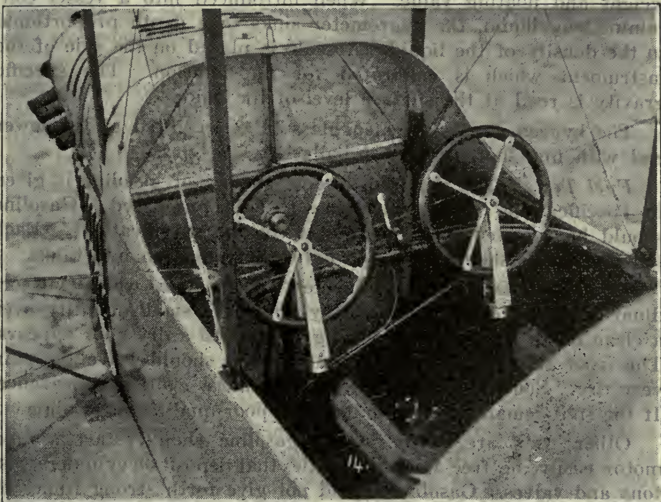
Use of Lubricants, Preserving and Cleaning Materials

Wooden Parts and Fabrics. All the wooden parts of an airplane should be varnished, not painted. Exposed parts should be varnished about once a month. Interior parts must be permanenently protected by a filler of oil or shellac and applications of spar varnish or emaillite. The latter is an excellent preservative for wood. Airplane wood members exposed to excessive moisture and exposed wooden parts of seaplanes, should be treated with two coats of white lead, and one coat of white elastic enamel with proper proportion of lead chromate added.

Fabric must be protected by "doping" with some preparation, such as emaillite or other cellulose base dope, which give the desired properties of waterproofing, air tightness and durability. In cleaning the surfaces of planes, care must be exercised to remove all foreign matter and to avoid bruising or otherwise damaging the cloth or coating. The use of gasoline, for such purpose, should be discouraged. It cuts the coating and takes the life out of dope. Surfaces should be sponged with a weak solution of tepid water and Ivory soap-suds, and dirt, oil and accumulations thoroughly removed employing a fine sponge. After cleaning, the surface is rinsed with clear, cold water, squeezed sparingly from a clean cloth. The surface should then be dried gently with a chamois skin. The practices of scrubbing surfaces and treating with gasoline are useful only as expedients to save time and avoid work. They must be positively forbidden. (The method of cleaning surfaces given here, applies to standard, linen surfaces, treated with a cellulose base dope.)

For cleaning veneer-wood decks, largely used for the section parallel to the fuselage, the same method can be used. These decks should be varnished, and the varnish protected by covers when the plane is on the ground.

Metal Parts. Nickel plated parts should be kept well lacquered. Any satisfactory metal lacquer will serve the purpose. A new coat should be applied at the first sign of rust or corrosion. Metal parts should be painted or enameled about once a month. Fender enamel (Japan Black) is one of the most serviceable preservatives for metal parts. A solution of this material can be prepared by adding turpentine slowly to Japan Black until a thin mixture of the desired consistency is obtained. Aluminum paints are excellent for the preservation of metal parts. Plated parts and brass may be polished.



Cockpit and dual control; training machine

Members of crews should understand thoroughly the proper measures to be taken for the preservation of all parts of the plane. The following uses of preserving materials may be profitably followed. Axles should be coated with heavy bearing oil. Elevator, rudder post, and aileron hinges should be coated with paraffine or wax. The latter is superior. For pulleys, bearing wires and cables (excepting lengths within control posts or tubes), and for turnbuckle threads (coat lightly) yellow cup grease or hard grease should be used. All wires and cables should be kept lightly covered with heavy oil. Castor oil is good but sticky. Slushing oil is excellent for this purpose. For overheating valves in the motor, apply oil-dag.

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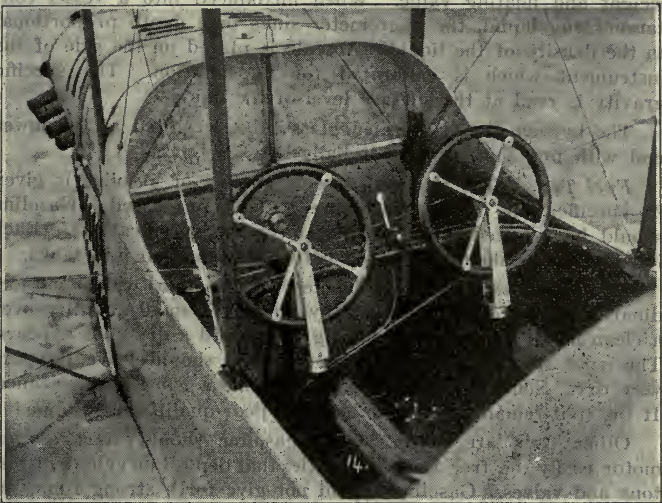

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FUEL

In order to discharge his duties properly, an aircraft attendant must have some knowledge of fuel and lubricants. He must be able to test gasoline and inspect lubricants with intelligence.

Gasoline is the fuel employed in all aeronautic motors at the present time.*

Gasoline is produced by the distillation of crude petroleum. The amount of energy contained in any unit of weight is determined by its specific gravity. Within certain limits, the lower the specific gravity, or density, the greater the amount of energy stored up in a given unit of its weight. The specific gravity is determined by use of an hygrometer, an instrument of definite weight and floating value. When introduced into a vessel containing any liquid, the hygrometer sinks to a depth proportional to the density of the liquid. A scale is placed on the side of the instrument which is calibrated for its flotation. The specific gravity is read at the surface level of the liquid.

The hygrometer is a sealed glass tube, weighted at the lower end with fine shot, to give it ballast.

Fuel Tests. The required specific gravity of gasoline is given in specifications upon which the fuel is purchased. Gasoline should be rejected if it does not meet the specifications. Each lot of gasoline should be tested before introduction into tanks.

Practical Tests. A practial test of gasoline, which will ordinarily prove reliable, is made by pouring a small quantity over a clean hand, immediately blowing on it until a dry spot appears. This spot should be visible promptly and should leave the skin very dry. Sometimes the spot will assume a whitish appearance. If the spot remains oily, it indicates a poor quality of gasoline.

Other tests are given. Good gasoline should start a cold motor easily, be free from impurities that deposit on cylinders, pistons and valves. Gasoline should not give forth strong fumes or odors, either when standing in an open vessel or when exhausted from the motor, after combustion. However, the specific gravity should be checked with an hygrometer to ascertain whether it possesses the required value. (Recent developments prove that the specific gravity has more reference to the volatility than to the contained

*The dismal attempts of man to build craft capable of navigating the air, with consistent failure up to the experimental period of the Wright brothers, were due, in a large number of cases, to insufficient power. Steam, electricity and man-power were all impracticable because the horsepower delivered, in proportion to the weight of power-units, was insufficient to lift itself to say nothing of the weight of sustaining planes, craft, operator and other necessary equipment. The use of naptha was superseded by the more efficient gasoline fuel. The advent of the gasoline motor assured navigation of the air for only minor changes had to be made to provide a light power plant delivering adequate power for flight. Many efforts have been spent to produce a better fuel than gasoline, but to this day there is none better for aeronautic purposes.

energy. This test, however, is the most practicable that can be offered at this time.)

Gasoline should be strained through a chamois skin before placing in tanks. Care must be exercised to place the funnel in perfect contact with metal inlets as static electricity may otherwise be set up, cause a spark, and result in an explosion.

LUBRICANTS

Lubricants for use as protective coats for metal parts and for oiling the moving parts of motors, are obtained from three sources, viz., mineral, animal and vegetable. A few simple rules govern the use of lubricants.

For use as a preventive of rust, the lubricant must be free from water or other compounds that increase oxidation. Mineral oils are generally used for this purpose.

For use in motors, mineral oils are used when the lubricant is supplied through ducts under pressure. Animal and vegetable oils may clog up such a system after several circulations. Animal oils are unsuitable for general use. Sperm and castor oils, however, have the desired properties for high speed lubrication when used in rotary motors.

Mineral oils are classified as (a) light (b) medium and (c) heavy.

Light oils are preferable in forced feed systems of lubrication. Owing to the low degree of viscosity, light oils are more suitable for use in extremely high speed motors.

The medium oils are compromises between the two extreme grades.

Heavy oils are best adapted for general use. The tendency is in the direction of heavier oils for motors. The heavier the oil used, the more favorable the lubrication and the less the oil will be forced into the compression chambers of motors. There is a limit to the degree of heaviness in an oil, at which it will burst the oil gauges under pressure. Heavy oils offer the disadvantages of rendering the starting of the motor very difficult, and of carbonizing rapidly with heavy deposits on the working motor parts exposed to heat (generated by friction and explosions).

Owing to the normally greater heating in air-cooled motors, heavy oils are employed in that type of engine. Most medium powered motors of the water-cooled type employ a medium to heavy oil.

The flash point of oils must never be less than 250 degrees Fahrenheit, as in that case the oil will burn up, in the high heat developed in internal combustion motors. This will cause a loss of lubrication, with costly results. Oil samples should be tested and graded in the supply office of each air squadron. The specific gravity and viscosity should be prescribed in the specifications for oil purchases.

WATER

The use of water in aircraft motors must be regulated with care. Only clean water should be used. Water known to possess impurities should be rejected. Water borne chemicals (in solution) will form boiler scales and clog the cooling system in time.

Water should be drained from the cooling system and removed, at specified times.

GENERAL RULES GOVERNING THE CARE OF MATERIALS

WOODEN PARTS

Wood deteriorates rapidly if exposed to moisture, the action of the sun, oils and dirt.

Wooden parts should be treated and varnished and *kept varnished.* Emaillite or Du Pont solutions, both of which are used extensively for the treatment of airplane fabrics, are excellent preservatives for wood. If the wood is so treated at a place to be covered with fabric, it will discolor the cloth badly. In this case the wooden part should be covered with paper. Interior woodwork of airplanes is ordinarily weatherproofed with these solutions. Exterior woodwork is normally varnished.

Wood is extensively used in airplane construction because it combines desired properties of strength, lightness and reliability to a degree not obtainable from other materials. Wood is superior to metal for general airplane use, if for no other reason than because metal crystallizes under shock and vibration with dangerous possibilities of collapse, while the deterioration of wooden parts is generally apparent.

Defects can and will develop in wooden members if abused or neglected.

Care of wooden parts. All wooden members of airplanes must be observed constantly for such defects as cracks, warping and end checks. Cracks usually indicate improper loading, shocks or exposure to dampness. Warping commonly results from exposure to temperature changes or moisture. End-checks occur when the ends of members are improperly housed or secured.

Wooden members must be kept thoroughly cleaned and covered with a preservative, as described hereinbefore.

Airplane bodies. The interior of the fuselage or nacelle must be cleaned daily. All interior woodwork accessible should be kept varnished. Body struts, spreaders and longerons should be examined for bowing. Small cracks should be filled, taped stoutly and doped. Large cracks constitute sufficient cause to warrant replacing the member. The fuselage or nacelle should be kept covered when the plane is secured. When members are found bowed, cracked or warped out of shape, investigation should be made to ascertain whether all wires or cables concerned have been adjusted for equal tension.

The propeller or tractor screw should be inspected for adjustment and the wooden surface examined for usual wood defects. Hub bolts should be tight and safetied; metal tips secure. The propeller should be covered with its cloth when not in operation. It should never be exposed to the action of the sun when such exposure can be avoided.

Surfaces and Control Surfaces. The standard form of plane consists of two beams, connected by ribs and cross-stayed together by stout wire. They are built to withstand the stresses set up in flight. They will not stand up under rough or careless treatment. Wing collapse in flight is fatal and can be traced in a majority of cases to improper care.

Planes should be handled cautiously. They should be lifted with care. In applying power to lift a wing, take hold directly beneath the front beam. If the surface is installed, take hold at or as near as possible to a strut. In pulling the plane, two or more men should take hold of the corresponding front struts on either side of the body, commencing with the struts nearest the body. The trailing (rear) edge of the lower plane ribs are sometimes broken at or near the wing tips through impact of the wing in a bad landing. Such breakage can be found by placing one hand upon the rear spar and gently working the trailing edge to detect any play. Cracks in covered wings can be detected by slight blows with the hand. To lift the wing for blocking up the wheels, take hold of front beam near the outer front strut, on each side, successively. Bows in a plane indicating bowed spars are usually caused by undue tightening of the flying and landing wires. Ribs should be examined daily, for breakage; interplane struts, for *bowing*.

Control surfaces, rudder, balancing flaps and elevators should be inspected before every flight for signs of wear, warping or breakage. These may be found by the method described for detecting broken ribs.

All wooden brace members should be examined for play. Bolts and metal fittings may cause excessive wear on wooden parts through which they pass.

Oil, grease and gasoline are injurious to untreated, doped or painted woodwork.

METAL PARTS

Metal is extensively used in airplanes. Steel, aluminum and copper are the principal metals used. The airplane attendant must be familiar with every cable, wire, fitting and metal device about his craft.

Metal parts must be kept free from rust and observed constantly for an indication of flaw. Unless it is desired to paint or varnish the metal, protection from weather can best be obtained by coating with grease or oil. Varnish or enamel or other form of coating tends to cover up flaws. Grease rubs off readily, but is the most satisfactory form of protection when properly done. The fixed rule is to cover every metal part with a proper coating or keep it greased faithfully.

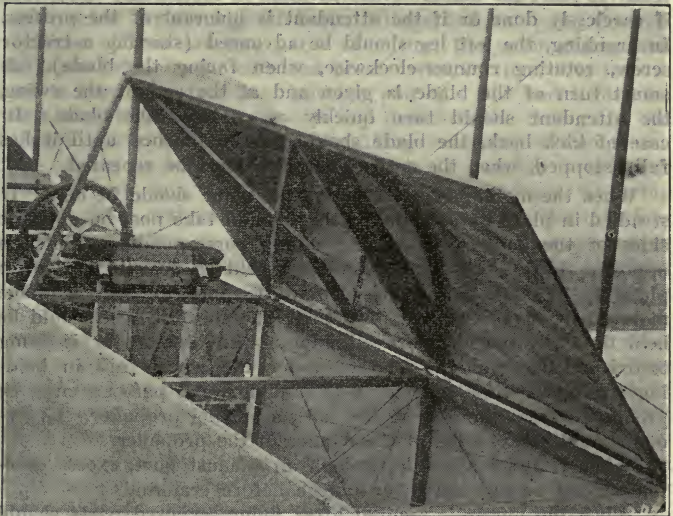
Wire and Cable. Wire and cable if not accessible should be painted and varnished or enamelled. If exposed, it should be protected only by a coating of oil. Such wires and cables should be wiped off at least once a day, inspected and fresh oil applied. A clean cloth is used for wiping dry; an oiled cloth is employed for greasing. An excess of oil is to be avoided, as it will drip on surfaces. Cables or wires should never be pieced together; never united by soldering. Cable when nicked or burred must be replaced immediately. Oil should be cleaned from wire or cable before soldering, using fine emery cloth. Old cable cannot be cleaned properly for soldering; hence the repair of old cable should be prohibited, since imperfect workmanship will result. All cable lengths requiring repair should be strictly replaced by new cable. (NOTE: The distinction between wire and cable will be found under the heading of METALS in the chapter following.)

Miscellaneous Metal Parts. All *bolts* on the machine must be locked firmly by the use of safety wire or a suitable pinning device. *Turnbuckles* must be similarly safetied. It is bad practice to employ the same length of wire for safetying two turnbuckles (in case of double—or parallel—wiring). Each turnbuckle must be safetied individually. Turnbuckles should be inspected for hammer marks, scoring or other indication of straightening or abuse. Turnbuckles that have been deformed must be discarded; those which have been repaired are untrustworthy and dangerous. Threads of turnbuckles are easily stripped. A loose barrel indicates that some of the turnbuckle threads are stripped. Turnbuckles installed in a moving cable or wire must be so adjusted as to avoid interference with fittings, wires or other parts. This is vitally important in control leads, since interference might cause a locking of the leads and result in the fall of the plane. *Cotter pins and safety wire* should never be used after removal. The bending due to removal destroys the strength of these parts. *Wire wheels* must be safeguarded against rust. A proper coating of paint and varnish is the surest preventive. All wires and pipes that rub or vibrate against each other should be separated by tape windings and tape-bound together.

CARE OF THE MOTOR

The following rules for the care of motors, enforced at the Signal Corps Aviation School, should be followed strictly:

The motor should be thoroughly oiled before it is started. Heavy oil should be used on the rocker arms and inlet springs. The oil should be thoroughly spread on the working parts of the rocker arm. The small hole on the rocker arm does not insure lubrication of the working parts. The tap in the gasoline lead, when installed, should be drained daily before starting the motor. When the Schebler carburetor is installed the bowl should be removed daily and examined for presence of water and dirt. On the Zenith carburetor, the four jets should be removed daily and cleaned carefully. The oil should be drained from the sump and



This arrangement permits handy examination of the tail

strained and the sump washed out with gasoline after fifteen hours of flying. (Distillate may be used for this purpose.) Valve clearances should be checked at the conclusion of each five hours of flying. Exhaust ports giving off an excess of oil give warning that the cylinder is receiving too much oil and that the spark plug in that cylinder may become quickly fouled.

When starting a motor equipped with the Schebler carburetor, open throttle wide to prime the motor. When priming is complete, close the throttle for starting. When motor is equipped with a Zenith carburetor, the throttle is kept closed while priming and starting. The butterfly valve in the main air intake must be closed during the operations of priming and starting, in the case of the Zenith carburetor.

Starting the Motor. Before cranking the motor, the magneto ground wire must be in place and switch closed. The propeller (or tractor screw) is rotated several times in order to suck a charge of gas into cylinders. Before the attendant spins the propeller, he calls "safe," the operator in the pilot's seat verifying the safety of the switch, replies "safe." After spinning the blade, the attendant calls "open" and the operator replies "open," opening the switch. The attendant gives the propeller a quick turn, carrying it slightly past a diagonal position. The propeller should not be touched after calling "open" until ready to start the blade. This operation is exceedingly dangerous if carelessly done or if the attendant is ignorant of the process. In cranking, the left leg should be advanced (starting a tractor screw, rotating counter-clockwise, when facing the blade). A smart turn of the blade is given and at the end of the swing, the attendant should turn quickly away from the blade. In case of kick back, the blade should not be touched until it has fully stopped, when the entire operation must be repeated.

When the motor is to be started, the plane should be held. If steadied in place by attendants, they should take post on opposite sides of the body or fuselage, holding corresponding struts on opposite sides. The struts should be held as near to the lower plane as possible. Six men should be able to hold a plane motored by a power plant of 100 H. P. The tail skid should be held down by one or more attendants while the motor is being tested on the ground. Chocks under the wheels aid in holding the plane while the motor is running. All persons must be prohibited from standing in line with a moving propeller. Everyone should be apprised of the danger of the propeller.

When priming a motor through an exhaust port, excess gasoline should be allowed to evaporate before cranking.

When the motor is secured after flying, exposed parts should be coated with a light film of oil, engine compartment cleaned and covers attached.

Fabrics and Rubber

Raw, unbleached linen is the standard material used for covering airplane surfaces at the present time. This cloth is treated with emaillite or Du Pont solutions and varnished. These solutions are standard. The purposes of these solutions, known as "dope," are to protect the linen fabric and to give it certain properties which it would not possess untreated. The result of the several applications of dope is to give the surface a hard, moisture-proof quality, tight as the skin of a drum, when correctly done.

The proper care of fabrics demands careful consideration. Surfaces must be protected from oil and safeguarded against saturation at exposed parts of the airplane, near the motor or beneath greased or oiled parts. Oil soaks through and rots the dope. When the surface becomes covered or even flecked with oil, it should be cleaned immediately as explained hereinbefore.

Holes in the fabric must be patched without delay. A rip or tear in the cloth permits the wind to enter and tear the opening larger. Signs of wear must be sought on surfaces, especially where moving cables or wires rub on the fabric. Such imperfections in arrangement as the latter should not be permitted. All surfaces should be cleaned daily. The top surface of the upper plane must be inspected daily for holes and looseness of fabric. This inspection should be made at the same time that the top deck is inspected for security of bolts, fittings and safetying devices.

Tires. There are two parts of a tire: the outer casing and the inner tube. In the care and preservation of tires, it is important to keep them free from gasoline and oil. Dirt and accumulations must be cleaned from cuts and gashes in the casing and the injured parts filled with a tire-filling solution or compound. Cuts should be vulcanized without delay. If gasoline is used for cleaning out cuts, it should be employed sparingly, applying French chalk and rubbing it well in to counteract the injurious effect of gasoline on rubber. Great care must be exercised in handling valve stems of inner tubes. The stem must be carefully inserted, when adjusting, so that the stem is perfectly centered in its hole. The tires must be kept dry. They should never be allowed to stand in water. When the plane is to stand for some time a dry board should be placed under the wheels. The tires should be kept inflated at the proper pressure for each tube. In hot climates this pressure should be reduced. Spare tires should be habitually carried. Wheels should be observed at each inspection for alignment; when the running gear carries more than two wheels, this is very important. Abnormal wear on a tire may mean axle or distance rod derangement. When brakes are installed on the landing gear of an airplane, they should be used sparingly and lightly, as sudden applications of brakes seriously reduce the life of a tire.

Shock Absorbers. Shock absorbers for airplanes are usually constructed of steel springs or rubber cord. The steel springs are normally incased in a cylinder and act under compression. Rubber cord shock absorbers are laced between the axle and the spreaders or between the axle and a projection on the main chassis strut. This rubber cord device acts under tension. In the case of steel springs, oil protection from moisture is the proper method of preservation. Rubber cords must be protected in the same manner as given for rubber tires. Avoid gasoline and oil drippings and keep free from moisture. In both cases, the weight of the plane should be kept off the shock absorbers whenever possible.

LANDING GEARS

The landing gear consists of the chassis and wheels. The entire apparatus must be inspected before each flight to determine that all bolts, nuts, cotter pins and other connections are secured.

The axles must be examined, wheels inspected for ease of action and lubrication. If ball-bearing wheels are installed, the cones must be kept tight with jam-nuts to avoid tightening and locking the wheel. If ball-bearing wheels are not used, the bronze bushings must be examined frequently for wear and ease of action when greased. Wheels should be inspected daily for loose spokes, weight of plane on the wheels. Loose spokes will cause a side thrust which if very slight may be enough to cause the wheel to collapse. Bolts in the landing gear are subjected to excessive stresses and must be observed daily for looseness and wear. Brace wires must be kept in perfect adjustment.

USE OF THE BLOW TORCH

The cap is removed and gasoline introduced into the reservoir through the filling hole. The reservoir is filled about four-fifths full, leaving the air space for storing air under pressure. The cap is replaced, exercising care that the washer is leak proof to air. A small amount of air is then pumped into the air chamber. The handle of the burner is then turned to the left until a fine jet of gasoline is ejected under air pressure. The hand is then placed over the mouth of the burner, causing the drip pan to fill. When full the burner handle is shut off, contents of drip pan lighted. Just before the contents of pan are burned out, the gasoline jet is turned on slightly, lighted and adjusted. The jet should not be lighted until the burner is thoroughly heated, for in case of incomplete heating, only partial vaporization will result and a stream of lighted liquid gas may shoot 25 or 30 feet from the torch, with dangerous possibilities. The torch burning properly will produce a roaring sound and give forth a bluish flame. As the roaring grows faint, inject more air. If the flame dies, look to the gasoline supply.

To light the torch in a wind, a shelter must be erected to protect the adjustment of heat and flame. The torch should not be lighted in the immediate vicinity of an airplane, gas or oil tanks or reservoirs, neither should a torch be pointed in the direction of machines or tanks. The possibility of a leaking carbureter or gas tank renders the danger of fire always present. Gloves should not be worn in handling a blow torch. In overhead work, care must be exercised to avoid dropping hot solder in the eyes.

The blow torch should never be brought in contact with metal parts. The soldering iron is designed for that purpose.

SOLDERING

The work of airplane crews involves extensive work in replacing cables and wires, repairing metal seams of tanks, and other renewals and installations that entail soldering.

Soldering is the union of two metal parts by applying molten soldering compound to a prepared metal surface and finishing properly.

Uses of soldering are described in the chapter following.

To perform the simple operation of soldering, it is necessary to understand the use of acids for cleaning the materials, the use of soldering irons, applying soldering compound and cleaning the materials after completion of the work.

The Soldering Iron. The iron must be clean, or it will not gather the soldering compound properly, if at all. The four faces of the iron must be smooth, and the point should be tapered fine, in order to guide the molten solder upon the materials, in applying.

To clean the soldering iron, the four faces should be filed down smooth, until every vestige of dirt or pit marks has been effaced. The iron is then tinned. Two methods are used. (a) The point of the iron is introduced into a hole in a piece of sal ammoniac, containing a piece of solder. The heated iron is rubbed in the sal ammoniac until the four faces are tinned. The use of hydrochloric acid is beneficial in this method. (b) The second method consists of rubbing the heated iron faces on a piece of cleaned (acid washed) tin on which are placed solder and acid.

Hydrochloric Acid. This acid is used for all cleaning incident to soldering. The chemically or commercially pure acid is too strong for use in this work. It must be reduced in strength, and this operation is called "cutting" the acid. This cutting is done by adding small pieces of thin sheet zinc to the acid until the amber color of pure acid is changed to the appearance of water. The acid is then ready for use.

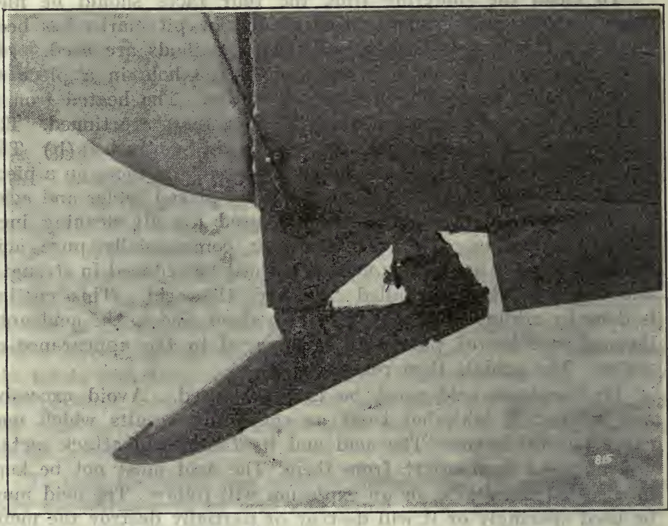
Hydrochloric acid must be carefully used. Avoid excessive use in contact with hot irons as spattering results which may cause painful burns. The acid and its fumes will attack metals and must be kept apart from them. The acid must not be kept in a sealed receptacle, or an explosion will follow. The acid must be used sparingly or it will destroy or partially destroy the metal treated. Acid must be *entirely removed* from metals so cleaned. Cleaning should be done while the metal is heated. The presence of acid on metals can be detected by tasting. Vinegar is sometimes used as a substitute for hydrochloric acid.

Applying the solder. The surface to be treated with solder is cleaned with acid. Blow torch, acid, irons, soldering compound and cleaning materials are made ready. The irons are heated in the blow torch. Two irons should be employed habitually to avoid delays. The solder is applied sparingly to the iron. The point of the iron should deliver a fine thread of solder in the hands of an expert. The solder used should be measured in *drops*, not in "gobs." The job must be *carefully cleaned.* Common ammonia or water is used. The materials are wiped with a cloth, wet in water, wiped again with a cloth saturated with ammonia and finally cleaned by an application of water. Water may be used for the entire operation of cleaning. Test for presence of acid as explained above.

In soldering cables or wires, oil must first be thoroughly cleaned from these materials using fine grade emery cloth for the purpose.

INSPECTION OF AN AIRPLANE BEFORE A FLIGHT

The vital importance of careful and minute inspections of all parts of an airplane prior to flights cannot be too strongly em-



Streamline tail skid. This illustrates the degree to which streamlining has been carried.

phasized. All airplane attendants should be faithfully instructed in the proper methods for making these inspections.

Loss of motor power in flight may not be serious, provided the plane is in perfect order. The failure of some essential part of the airplane to function properly, however, may result in loss of control during a flight with small chance for the best of aviators.

Inspection of the machine should start at a given point. The best rule is to start the inspection at the nose of the fuselage or nacelle, cover all parts of the body and power plane, tail and tail control surfaces, thence to the chassis and running gear, thence to the right wing, thence to the left wing.

The propeller should be checked for balance on the balancing stand before installation. If out of balance it will cause the motor to vibrate excessively and may lead to a serious accident. The test of the propeller or tractor screw installed on the machine, is to ascertain whether the blades "track." The small holes in the end of metal propeller tips should be kept open to insure drainage of water and oil.

The motor is next examined and tested. All nuts and bolts must be safetied and entirely verified for safetying. Motor is tested as outlined hereinbefore and as amplified under the subjects of AERONAUTIC MOTORS, and FLYING.

The cockpit is next inspected, the pilot's and passenger's seats examined for security. Safety or life belts are inspected with *extreme care.* They must be securely attached, show no sign of flaw and function properly for security of fastening, detaching and quick releasing device.

The permanent equipment of the airplane must be checked, including special equipment ordered for the flight. The chief of crew should be furnished with a list of special equipment to be carried and check it before departure. Craft departing over arid territory must be provided with considerable supplies of water and food. Some water and food should be carried on all cross-country flights. Life preservers should be carried for all flights over water. Parachutes may be ordered under certain circumstances. The chief of crew should cause to be installed in the cockpit a typewritten list of all permanent equipment ordered carried in the plane.

Surface controls, leads, control posts and power controls should be thoroughly and minutely inspected. On the first flight after the installation of new control accessories, extraordinary examinations must be made, and exhaustive tests conducted to assure the proper functioning of a part, that the connections have been made correctly and with sufficient strength of unions. Excessive motion in control leads may cause wires or cables to jump guide-grooves, pulleys or wheels thus locking and resulting in fatal loss of control in flight. On the other hand when the leads are too taut, the control may be subjected to strain. Elevator wires should be entirely taut only when in the flying position, to enable free raising and lowering of the elevator.

The aluminum steering wheel (according to the style of control—Curtiss or Dep) may freeze to the axle bolt or to the forks unless an oil duct is provided. With the bolt loose, drill oil hole in top of steering or flap wheel hub. Inspections should include verification of this lubrication. Safety wiring and cotter pins on control surfaces should be visible from pilot's seat when possible. The tail union fittings (in case the plane is equipped with a detachable tail) must be systematically examined before each flight. Loss of one of these attachments means practically certain death to the occupants of the plane in flight.

Running gear, chassis and wheels must be carefully inspected. Wheels must be examined for lubrication. Chassis struts, cables, and devices must be inspected. Minute inspection should follow the lines indicated hereinbefore.

The right and left wings are inspected in order. Struts, fittings, safety wiring, planes, spars, ribs, flaps and attachments, and all accessories of the planes must be examined.

Throughout the plane, bolts, nuts, fittings, cable and wire terminals, turnbuckles, hinges, masts, brace wires, spreaders, struts, and other wooden and metal members and fabric covering must be inspected carefully. The invariable rule in installing bolts is to adjust with the heads on top. Then in case a nut is lost through vibration or other cause, the bolt will not necessarily fall out. Special attention must be given to the inspection of the top surface of the upper plane. This examination requires the use of a ladder. A stand-ladder should be used.

Detection of a leak, water or gasoline, requires instant attention. No machine should be sent out or permitted to go out with water, oil or gas leaks. Loss of water and cooling will cause the motor to burn up. Loss of lubrication will result likewise. Gasoline leaks will in all probability lead to fire in flight and destruction of the plane.

In the care and treatment of an airplane it must be remembered that the machine is only as strong as its weakest fitting. A large factor of safety is useless in the various parts of an airplane, if one vital part is on the verge of collapse or rupture.

This point must be constantly borne in mind. This is particularly so with reference to the observation of cables. Frayed strands must be watched carefully. Each frayed strand reduces the strength of the cable by so much. It is permissible to solder one or possibly two broken strands temporarily. Such lengths should be replaced at the earliest opportunity.

General

Removed, used or discarded parts should be labelled (stamped if possible), and removed or destroyed immediately.

Tools or other weights or materials should not be laid on a plane, even when working about the machine. Men should be forbidden to lean against the planes, struts or other airplane members. Walking on planes should be prohibited, except on the wood-veneer decks, installed alongside the body in some types of planes. This practice is excellent. When the machine is not so fitted, a horse should be placed on each side of the plane (front and rear) and planks laid across, for walking above the planes. Ladders or other objects should not be laid against the airplane.

Gas tanks should be removed from the plane for repair.

After landing or running the motor, care must be exercised to avoid rocking the propeller or tractor screw if the motor is hot.

When weight must be placed on a plane, specially made horses, fitted to the wing curvature must be placed under the surface. These horses are placed from front to rear. They are padded to avoid bruising the surface, and should be placed under a rib at or near the location of an interplane strut.

To secure the machine, it is run into its booth or hangar, placed on chocks to take weight off tires, and after thorough cleaning and inspection by the officer in charge of the craft or its chief of crew, covered and adjusted to cockpit, motor and propeller. A horse should be placed under the tail so that the body is in a horizontal position. This support should be located directly under a vertical brace of the fuselage. The doors should be closed securely and locked. Doors must be kept in perfect working order.

To run the machine out of its booth or hangar, the propeller is placed in a horizontal position. Caution must be employed to avoid striking the wing tips, the top surface or the rudder in emerging into the open. In order to simplify this operation, a line should be painted on the floor marking the exact central line through the exit. When the central line of the fuselage is kept directly over this line it may be run out without danger of misjudging the clearance at wing tips. The tail skid must not be lifted too high.

The posts of the crew for moving and maneuvering the plane on the ground without power are as follows: Chief of Crew in front or at rear of the fuselage or acting as guide man on the tail skid. No. 1 at right, front center strut, No. 2 at left, front center strut, No. 3 guide man on the tail skid, No. 4 at right front strut, No. 5 at left front strut. Other numbers are disposed, when necessary, at corresponding struts, front and rear, on opposite wings, right and left. All men take hold of the strut as near to the lower plane as possible.

LOADING TRUCKS

The general rules, given below, apply to loading the motor transport as well as to aero shipments by rail, boat or other means of carrier.

The main rules to observe are to keep the center of gravity low, avoid overloading and arrange the load in the reverse order, to admit procuring the needed articles first when unloading.

Sufficient personnel should be provided to handle the shipment or load without danger or possible damage.

AERO SHIPMENTS

Airplanes must be prepared for shipment with elaborate care; crates and boxes are provided. The chassis is usually packed in a box crate, complete. The entire motor, having been removed, is secured in the engine box. The fuselage and tail each have separate boxes, as a rule. The control surfaces and wing sections are packed in a box. Great care must be exercised to prevent damage to the fabric or injury to the wooden or metal parts, or fragile devices. All measures for bolting parts into boxes must be provided. The boxes should be serially numbered and carry the gross weight in stencil; invoiced and placed on manifest or bill of lading. The shipment must not be separated. All aero shipments should receive the most careful hauling and handling, and every package of aircraft matériel not only marked "FRAGILE," but so treated.

All aero shipments should be carefully packed in crates or boxes, wrapped or tied.

When packing, great care must be observed to pad all metal parts, and avoid rubbing or scarring of finished wood, metal members or surfaces. Fabric faces should be free from contact with other parts, and surfaces securely fixed in padded racks. Loose wires should be coiled, tied and fixed in position so that they will neither rub against other members nor crush fragile parts by falling around in a box. Motors are either carried installed in the fuselage or in special motor boxes provided with engine beds and other securing devices. In types of biplanes in which the struts slip out and the plane structure collapses, the two surfaces should be protected from each other by an intervening cloth, and all fittings padded to avoid tearing surfaces.

Boxes or crates should be no longer than absolutely necessary, and weight of individual pieces reduced to a minimum. The heaviest materials should be put at the bottom of the box and the lightest on top, to lower the center of gravity and avoid crushing lighter parts.

Preparations should be fully and carefully made before commencing the operation of unpacking aero equipment.

Precautions must be exercised to protect surfaces and fragile parts from cuts, scars and bruises. Cushions, cloths or padded racks should be provided. These should be placed out of the way to receive and protect fabric surfaces and light wooden, metal and other parts and materials.

Unpacking should be done slowly and carefully, removing all nails, bolts, screws, and other securing devices, before attempting to remove a member from a crate, box or other package. No part should be pried or forced in any way. Packing frames, sides and tops of packing cases, should be removed from about fragile equipment rather than removing parts from such cover.

Cable and wire must be handled with extreme care to avoid kinking or bending which result in loss of strength. Metal fittings of all kinds, such as turnbuckles, plates and eye-bolts, wooden and fabric parts must be sorted, checked and stored safely. These parts should be handled a minimum number of times.

Airplane carrier truck

AIRPLANE MOTOR TRANSPORT

Military airplane carrier trucks are usually designed to carry the fuselage of the airplane complete, without removing the chassis or any part of the tail. The wings are removed, struts taken off and collapsed wing sections fitted in racks on the side of the truck.

TRAINING IN AVIATION

CHAPTER 5

WOODS, FABRICS AND METALS

Woods

The kind of wood selected for a given member in airplane construction varies according to the properties and qualities desired. The following rules for selecting wood materials for airplane construction may be taken as an average of the common practice.

Ash: Where the wood surfaces have a bearing. It is tough, flexible wood, and resists sudden stresses. American white and black ash are the lightest and strongest of hardwoods. The white ash is better than the black and airplane constructors generally regard it as the best airplane wood obtainable. The serious defect in *black* ash is its characteristic brittleness.

Bamboo: Used for attaching the tail to main planes where the controls are carried on outriggers (instead of at the end of fuselage tail).

Cedar: Possesses great uniformity. It is abundant and can be procured in large quantities.

Hickory: Used where the loading is unusually heavy. It is an excellent wood, strong, tough and resistant to splitting, but it warps easily, hence must be well varnished to withstand moisture. It is extensively used for skids and chassis struts. White hickory is employed where the loading is excessive and the stresses sudden, as in tail skids.

Maple: Is light and resists splitting. This wood is extensively used in airplanes.

Firwoods: Spruce is a strong, light wood, possessing great flexibility and durability. For its weight it is the strongest wood suitable for airplane use. Spruce is largely employed for struts, ribs and spars of planes. Exhaustive tests made in aeronautical laboratories have proved that Maine and West Virginia white spruces are slightly superior to Oregon red spruce, for compression members. White fir or Baltic spruce is largely used abroad for airplane members of all kinds, but American spruce is preferred. Spruce is an excellent airplane wood because it is light, strong, stiff and does not warp easily. The weakness of spruce is an excessive tendency to split. The ends should be tinned to overcome this fault. The effect of tapering struts, as usually practiced, is to decrease the strength of woods, and especially

NOTE: Spruce members are generally employed at the present time for this purpose.

spruce, which splits easily unless the work is done very carefully. Lamination of struts decreases this danger, hence spruce struts should always be laminated. Good spruce has from 3 to 20 rings to the inch.

Combinations of the above woods are commonly made. For example, the most satisfactory type of airplane engine bed used by the United States Army is composed of alternate laminae of spruce and hickory with maple caps and covered over all with a veneer of maple. Walnut and mahogany are the chief woods used in propeller construction. Other woods suitable for the manufacture of air blades are: baywood, birch, southern poplar and white oak. The desirable properties in propeller woods are: close and uniform grain; toughness; hardness; unusual strength to all kinds of stresses; and resistance to moisture and temperature changes.

Wood must be perfectly seasoned. It should have a clear vertical grain, the plank being cut from the heart-wood, the sap-wood or intervening space on the tree, as specified hereinafter, according to the kind of wood used. Lumber employed in aircraft should be cut between November and April, sawed immediately and seasoned for two years before using. When lumber is sawed green it retains its white, clear appearance, seasons better and is a stronger wood. In some kinds of wood, sap-wood is the more desirable part of the tree; in some, heart-wood is better. Members constructed of spruce, walnut, cedar, mahogany, basswood and poplar should be taken from the heart-wood; of hickory and ash, from the sap-wood; of maple and birch, from the space intervening between the heart-wood and sap-wood. Veneers are used for floors in airplane bodies, and for flooring the planes alongside the fuselage. Veneers are obtained from woods like poplar by means of a special strip knife, which planes the wood in clean strips from the log after it is soaked. In woods like mahogany, veneer is obtained by circular sawing. Veneers are laminated for use as flooring.

"Powder-post" is a form of imperfection caused by the action of insects. Bees attack ash and cause this fungus-like growth, rotting the wood without greatly altering its appearance to any but a lumber expert.

Lumber must be air-dried, *not kiln-dried;* there should be no sign of a flaw; it must be absolutely free from knots, worm-holes, end-checks, sap-pockets, wind-shakes and other defects. Struts, spreaders and such compression members must be straight to avoid danger of collapse from end pressure.

Lamination: Wooden members of airplanes must withstand unusual and excessive stresses. To obtain the maximum strength in wooden parts to meet these conditions, the wood is generally laminated.

Laminating wood is the process of fitting layers or strips one upon another and glueing them firmly together. This gives greater strength and in case one lamina (or strip) breaks, the other laminae remain intact. This not only adds materially to the total structural strength but to the degree of structural safety. Lamination breaks the grain and reduces warping. Strips to be laminated must be very accurately planed so that the surfaces lie true. After glueing they are clamped together and allowed to dry. Skids and struts for the chassis, and struts, spreaders, spars, beams and other members for wings and fuselage, are usually but not always laminated. The number and size of laminae vary with the manufacturer.

Bending: To give wooden members of airplanes a permanent or "set" curve and to relieve bending forces that would otherwise result, two ordinary methods of permanently curving wooden members are employed, the "steam" and the "dry" methods.

First method: The wooden member is brought to the desired degree of moisture by "steam-bending" treatment, and bent to the form in a "jig" or "templet" made for the purpose. The steam must be as dry as possible. Steaming requires from two to six hours. The form must have a greater curvature than required for the permanent set of the completed member. It is left in the form to dry for 12 hours. Earlier removal will result in a partial loss of curvity. In steaming wood, great care must be exercised that the steam is dry, as existence of moisture in excess of amount barely needed to make the structure pliable, permeates the pores, loosens the structure, swells the wood and results in loss of strength. Wood, like metal, has a quality of "temper." In the case of metal, "temper" can be replaced if lost but this cannot be done in the treatment of wood.

Second method: "Dry-bending" of wood is a term used to denote the building up of wood members by means of strips conformed to a templet. This is done as follows: Very thin strips of wood are bent around the templet. If a circular member is being built up, a succession of strips is secured together by splicing the ends for about four inches. In constructing a control wheel, for example, these strips should be carried around for 28 or 30 times, glue being applied each time the strip is laid upon itself. The curvity is made permanent by keeping the cemented member in the templet until the glue has set. German glue, an animal substance, is regarded as the best by airplane constructors.

CONSTRUCTION AND REPAIR

Considerable increase of strength can be given light woods like spruce merely by covering with metal. This system is employed whenever the wooden member is to be subjected to both vertical and horizontal stresses. The member must then be cut in a circular cross-section, the vertical grain laid in the direction of the stress to give maximum strength, and when both horizontal and vertical stresses are expected, the cross-section grain must be laid diagonally. Wooden members are bored out wherever possible to reduce weight, without loss of strength.

Wooden members should not be cut or pieced so that important fibers are ruptured at vital points. Sharp edges of plate fittings in contact with wood members must not be employed. (U. S. Army Specifications.)

Wing Structure. The *average* wood structure of airplane wings may be described as follows: wood members are constructed of spruce, with minor exceptions; the front beam is either a solid or a laminated spruce I-beam; the rear beam, a rectangular (in cross-section) shaped beam, composed of three laminae of spruce, or a spruce box-beam with hardwood plugs at each rib, and at each point upon which fittings or attachments are to be placed. The ribs, webs, streamline strips and other members are of solid or laminated spruce.

Frames of planes are reinforced by cross-stays of solid aviator wire; trailing edges of planes are sometimes formed of a metal rod. The web of a rib is usually bored out to reduce weight. Where a lateral streamline strip must be passed through the web, a notch should not be cut on the upper or lower edge (as is commonly done) since this arrangement materially reduces the strength of a vital member. Round holes instead, should be cut above or below the edge of the webbing and the strip run through it. The web of a rib may be reinforced by small wooden plates, one on either side of the panel, between bored out sections. These plates should cross each other from top to bottom. Any kind of stout wood cut in thin sheets will answer the purpose. This method of bracing the web multiplies the strength of a rib many times. While the rear beam may either be of the solid or I-beam type, a solid type of spar is better adapted to the rear beam because the wing is thinner at that point; the I-beam construction being better adapted to the thicker portion of the wing usually found at or about one third of the distance from the leading edge where (owing to the aerodynamical laws involved) the center of pressure is normally located. The greatest stresses are therefore applied at this point, and the strongest possible spar should be used. The I-beam giving a large vertical cross-section and a small lateral cross-section is the stoutest type of spar that can be used for the purpose.

Wing Structure (Main and auxiliary surfaces). Flanges and ribs should be secured to webs by glue, copper or brass tacks of proper size, at correct spacing, and by loops of Finlayson's 40-lb. waxed shoe thread. The operation is performed by passing the thread completely around outside of flanges, drawn tight at each loop and locked; space between loops, 3 and 5 inches. (U. S. Army Specifications.)

Scarfing. The operation of repairing broken skids or spars is called "scarfing." If the spar is sufficiently wide, a new length may be spliced on. The two pieces to be fitted together must be a perfect fit; the two ends are glued together and clamped until the glue has set. The thickness of glue being uniform, the wooden member is now trimmed down and bolted together on washers, which latter prevent the bolts cutting into the body of the wood. A waxed whipcord lashing is then made around the joint, knotted at each turn and finally glued over. Tape lashings treated with dope are useful. The whipcord is considered better if properly done.

Another method of splicing is to make a diagonal cut across the end of the member of one in ten, measured along the length of the member. Scarfing of laminated members may also be done by cutting down the layers in a series of steps or overlaps. The ends are then dovetailed. Splices having been glued together, clamped until dry, are covered with tape or whipcord, bound tightly, locked at every 5 or 6 turns and doped.

If a laminated member is only partly fractured, the broken laminae (layers) can be replaced by new layers of the same wood. First, the worn or fractured part is cut down (diagonally or in steps) to the necessary depth, provided sufficient layers remain undamaged to which the new layers can be attached. The new layers are then cut and fitted, glued on and clamped to dry. The member is now bolted together on washers and bound with a waxed lashing. Additional strength may be gained, if each layer of wood is secured to the next adjacent layer by using small wood screws. To greatly increase the strength, a plate may be attached and bolted through the member. Sometimes the repaired section or splicing is covered with a sheet of tin, brass or copper.

It is not good practice to repair the damaged wooden parts of an airplane. Repairs to damaged wood members are made on a military machine only by the explicit authority of the proper officer. The general policy is to discard all broken parts except in case of urgent need, unless the damage be slight, or the repairs of the most satisfactory nature.

Wood should be kept in stock in large pieces; small members being sawed off for use as needed. Rapid loss of strength results when wood is stored in small pieces.

Lumber should be stacked in layers, on skids, with supports at frequent intervals. This form of stacking avoids bending and admits of sufficient air circulation to keep the lumber dry.

The wood-shop and lumber storehouse must be kept at an even temperature and dry.

EXTRACTS FROM U. S. ARMY SPECIFICATIONS FOR AIRPLANES

For *seaplanes:* Material should be as far as practicable, spruce, steel and copper alloys. Spruce should be air seasoned for at least two years. All wooden members, except faying surfaces, end grain butts, scarfs and joints, must be protected against moisture by varnish or paraffine.

Laminated wooden parts should not be used for seaplanes (over-water craft) unless positively necessary, and laminated wing rib webs are not acceptable for such craft. Spliced joints are to be avoided.

Scarfed and spliced joints are made as follows: "Shall be liberal and the joint made by using dowels and copper rivets, and bound with Finlayson's 40-lb. waxed shoe thread, each ten turns, locked."

Interior wing and tail wood members should be protected in this manner: Three coats of best spar varnish, butts assembled with varnish or impregnated with paraffine.

All wood members exposed to weather should be treated with two coats of white lead and one coat of white elastic enamel, with proper quantity added of lead chromate.

PROPELLERS

The problem of producing a standard type of propeller, suitable to all classes of flight (that is to say, designed to deliver maximum speed, maximum climb and so on), remains unsolved at this time. The shape of the average model of propeller is therefore a compromise to obtain the best average results, unless the blade is designed specially for a particular class of flying.

Aerodynamically, the effect of propeller shapes upon efficiency of flight under different conditions, follows rules similar to those governing the shapes of plane surfaces. Generally speaking, a plane with a heavy camber is a climbing plane; a plane with a comparatively small camber is a speed plane. Similarly, propellers with a heavy camber or high pitch are designed for climbing, and flat (or low pitch) blades for speed.

The following woods are generally used in the construction of propellers: American and Honduran mahogany, baywood, birch, white oak, and southern poplar.

A propeller must be specially designed as to radus, pitch and form, for the motor to which it is to be attached, to enable the motor to make its proper performance.

When a propeller is driven directly from the main shaft, it turns the same revolutions per minute as the motor and the gyroscopic stresses developed in high speed motors are tremendous. A great deal of propeller trouble experienced in the past was due to an exceedingly high speed propeller. For this reason, it appears conclusive that there should be some reducing gear in the case of high-speed motors to turn the blade at a more favorable, low speed. The most efficient number of revolutions for the motor does not coincide with the most efficient number of revolutions for the propeller. Sometimes the propeller is geared down in order to give the motor a more efficient, higher number of revolutions and the blade a more efficient, lower number of revolutions. When a propeller is to be employed geared down, a greater radius and more pitch is designed than when it is to be mounted on a direct drive shaft.

The propeller swing may be materially shortened by using the three or four bladed types. The trailing edges of blades should not be made so thin as to be frail. Laminations are normally between 3/4 and 1 inch in thickness. Splicing of propellers is not good practice. The laminations should not be spliced.

Government specifications require that the hub thickness shall be measured in axial direction, of: 5 1/2 to 6 1/4 inches for motors from 85 to 115 horsepower; 5 3/4 to 6 3/4 inches for motors from 115 to 150 horsepower.

The most satisfactory propellers are made of wood. Honduran and American mahogany have given excellent results and are entirely suitable. Walnut is extensively used. It must be straight grained, when used for this purpose.

Propeller Construction. The propeller is built up of laminated strips, normally varying in thickness from 5/8 inch to 1 inch. A solid wood propeller warps easily. When exposed to moisture, it does not dry uniformly throughout. This condemns solid wood propellers.

Laminae may be composed of alternate layers of two or more kinds of woods.

The propeller is either fashioned from a templet block of strips, or the individual strips are cut from a pattern.

(a) A solid propeller block is made up consisting of the several laminae cut in a templet and assembled as described under (b). After assembling the layers, the solid block is cut down to the measurements of the blade as follows:

Propeller measurements are checked by laying off points, called "stations," from the hub to both tip extremities, at successive distances, say every six inches; correspondng points on opposite blades, bearing the same exact position with relation to the hub. This check is made both on the top, bottom, and along the sides of each blade, the block being trimmed to meet the measurements.

The other operations are described under (b) which follows:

(b) Each strip is cut from a pattern. The pattern is cut to give the exact outline of its particular strip. A strip is taken from one extremity to the other and includes the hub hole, the position of which is indicated on each pattern. The pattern is laid on the prepared board, which is marked and cut, employing hand saws for the purpose. After all hub holes are bored, the laminae are glued together in the proper order.

The glueing process is of prime importance. The glue is specially prepared to render it insoluble in water. Strips are located successively by the patterns, hot glue applied to both surfaces placed in contact during each operation. Surfaces are clamped together under pressure and the joint heated lightly by means of a small blow torch. After all the strips are laminated, surplus glue is cleaned from the edges.

The drying process requires about twenty-four hours.

The approximate form of the propeller is next shaped. Corners of laminae are cut down to the general form, employing a draw knife and a spoke shave. The blade is now finished by elaborate methods to insure absolute accuracy. Perfect similarity between the two blades of the propeller must be secured. The propeller is swung on a horizontal plane table, pivoted by means of a shaft inserted through the hub hole. Pitch templets are used for working down the faces. The backs are finished by the same device.

The propeller is now sandpapered to a fine finish.

The next operation consists in checking the propeller for true, on a device called the propeller balancing stand. This stand consists of a horizontal shaft, constructed to turn freely. The shaft is inserted through the hub hole, and set into its seat. The propeller should then be so perfectly balanced that it remains in a state of neutral equilibrium, whatever the position in which it is placed.

Finishing the Blade. A base varnish is applied to the wood. When dry the base is covered with several coats of a surface varnish.

Holes for propeller bolts,which secure the blade to its mounting, are bored in the hub by means of a "jig."

The tips of propellers are tinned to protect the wood from flying sand and stone; brass or copper being used for this purpose. Iron or steel cannot be employed as these materials cause injury to the blades. The disposition of metal tips for position and weight must be carefully made. Even the nails that secure this tinning to the blade at opposite ends of a propeller must be disposed at precisely equal radii from the hub center, so delicate is the operation to secure an *exactly even balance of weight.*

†Vibration, due either to the imperfect alignment of the drive

†The best results have not been obtained from propellers because the subject has been insufficiently explored from a structural as well as from an engineering standpoint. The need for better made propellers has been emphasized by the recent failures of propelled aircraft in service, under the influence of hot, dry climate. Mediocre propeller construction fails utterly under field service conditions.

shaft or to imperfect balance of the propeller, is fatal to its efficiency and leads to early breakage.

FABRICS

The following materials are used for covering frames of planes: silk, cotton, calico, linen, and rubberized materials. Raw, unbleached linen has proved the most satisfactory fabric for covering.

Efforts to obtain a surfacing material more suitable or satisfactory than cloth have been made in the direction of wood-veneer, metal sheeting and wood strips. These substances are too rigid and stiff and warp out of shape under climatic influences or abuses. They moreover make the wing structure solid (which is undesirable) and the interior of the plane inaccessible. The latter is not, however, an insurmountable fault. The great differences in weight between cloth and other covering materials dissipates further uncertainty in this matter for the present.

As a fabric for covering planes, silk is the lightest and strongest known, but it is unshrinkable and will not readily conform to the shape of a cambered frame, being inelastic. Raw, unbleached linen has proved the best covering material and is the accepted standard cloth. Materials mentioned above other than linen, have been practically discarded.

Linen fabric for aircraft construction should be made from the finest obtainable flax fibre, properly woven and unbleached. The cloth should be new, free from blemishes or defects due to spinning, weaving or finishing, such as snarls, knots and loose ends. The fabric should be boiled to insure absolute freedom from noncellulose matter; filling agents are prohibited. The cloth must not be calendered ("To press between rollers so as to make smooth, glossy or wavy").

In accordance with U. S. Army Specifications, airplane fabric must be at least 36 inches wide, weight between 3.75 and 4.4 ounces per square yard; woof threads 94 to the square inch; warp yarns 100 to the square inch with a maximum variation of 5 yarns. The strength (tensile) of the woof should not be less than 75 pounds per inch of width. (Tests of textiles as prescribed in Bureau of Standards Circular No. 41.) The fabric should be weaved, spun, wove and webbed straight and even; uniform in number and strength. Heavy linen tape inserted between all tacks and linen cloth should be between ¾ and 1-¼ inches wide and frayed at the sides.

The linen used in aircraft covering is *unbleached,* known as live linen, in contradistinction to dead linen. The latter is white linen, so obtained by treating unbleached linen with chemicals.

COVERING FRAMES

Frame Structure. The plane consists of a front and a rear and perhaps intermediate spars, connected together by beams called ribs. This frame structure is braced by means of diagonal cross-wires. Between the ribs are placed small strips running fore and aft, called "streamline strips" or "nose-strips." The purpose of a "streamline strip" is to give support to the tightened cloth between the ribs and better form to the surface of the structure.

Methods of Covering. There are two methods for attaching cloth to the frames of planes: (a) the diagonal or bias method, (b) the straight (or "longitudinal and lateral") method. The advantage lies with the bias system of covering planes, as this gives greater strength and durability (some authorities claim to as great an extent as 75 per cent), but the straight system is easier to accomplish and entails less waste of material. The cloth is placed diagonally over the frame, the smooth side of the cloth outwards. The bottom of the frame is covered first. Commencing at the forward edge of the plane, the cloth is tacked temporarily, carried to the rear (trailing edge of the plane), and thence across the upper surface to the forward edge. (NOTE: Cloth cannot be joined at the trailing edge of the frame for the reason that the rear edge is usually very light and even temporary tacks might cause damage. Moreover, the trailing edge is frequently made of metal.) The edges may now be tacked together, the cloth having been drawn just taut enough to remove the slack, thus making due allowance for shrinkage which will take place when the weather-proofing solutions are applied.

Cloth is normally placed diagonally on the frames at 45 degrees, in square plane sections; in a direction from inside towards wing tips and from entering to trailing edges. In rectangular sections, the cloth runs approximately from corner to corner unless the section is so broad that the threads and yarn lie at angles materially different from 45 degrees. Strips of linen fabric (not less than 36 inches wide, as a rule) are sewed together to make the cloth wide enough to cover the entire frame. This sewing should be done by machine. A two-needle machine is preferable, employing a double lap device or a double hemmer which makes a two seam, four-ply union (double folding seam) having a lock stitch. This provides the strongest known union for cloth.

Where the cloth meets at each side of the frame, it is doubled under on either edge and sewed together by hand, employing a waxed flax thread and a curved needle, making a so-called bias-bend stitch. The fabric is secured to the ribs by means of sewing; the use of tacks is no longer considered good practice since tacks corrode and eat out the cloth wherever they come in contact. Non-rusting tacks like brass and copper will cut the cloth in time, notwithstanding the use of tape. The faying of cloth at the entering edge may be made by tacking, in which case heavy linen tape should be inserted between the linen and the heads of tacks. If hand sewed (the general rule), edges of cloth must be turned under for one-half inch. Where the cloth is hand sewed to the ribs, a lock stitch must be employed at every turn to avoid raveling in case it is broken. When a seam is hand sewed, the union should be covered by a strip of linen fabric or heavy linen tape attached by "doping-on." Government specifications require that both edges be frayed.

Two kinds of thread are employed, "live" or unbleached and "dead" or bleached. Live thread is stronger but cannot always be secured. When sewing is done by hand it is usual to wax the thread, since it makes a stronger seam. Waxed thread cannot be run through a machine, however. It is undesirable to wax a seam that does not lie directly against the frame so that a strip can be glued on it, as wax interferes with the proper action of the dope, when applied. In other words, wherever wax is employed on the thread, the seam is covered with a doped strip or tape.

In conclusion, emphasis must be laid on the point not to stretch cloth too tightly in covering a frame, since the solutions with which it is to be later treated have the property of greatly shrinking cloth.

Dope, or Fabric Solutions

Several grades of airplane surface solutions are on the market. Emaillite was the first satisfactory fabric preservative and weather-proofing agent introduced. All solutions for treatment of airplane surfaces are called "dope" and will be referred to hereinafter as such. The two principal grades of dope are *cellulose acetate* and *cellulose nitrate.*

Cellulose acetate and acetone are the principal ingredients of emaillite. The characteristic color of this dope is olive-drab. The *cellulose nitrate* dope has proved more durable but is more inflammable. It has a characteristic white color. The *cellulose nitrate* is treated with solvents of methyl-acetone and emyl-acetate. Samples of nitrate dope three years old show more durability than samples of acetate dope six months old, and whereas the latter crumples under the touch of the hand, shells off and cracks easily, the nitrate appears to retain its firm and elastic properties indefinitely.

Nothing short of a blow-torch flame will ignite a surface covered with cellulose acetate; a valuable quality.

Seven coats of the *nitrate dope* are applied. Each coat is allowed to dry which requires about 15 minutes per coat. Sand-papering after each coat is unnecessary since each succeeding coat is a solvent. Care must be exercised to avoid draughts of air or moisture while coating the surfaces, as both tend to discolor the finish, leaving unsightly white streaks or spots. When the seven coats have been applied, they are covered by two coats of varnish. The dope is protection against moisture and preserves the fabric and frame-structure. The varnish is merely an additional protection and gives an excellent, bright finish and appearance to surfaces. Strips of linen are covered with dope and pasted over sewn seams before the surfaces are doped. The effect of dope upon linen strips is practically to cement them to the surface.

Holes in the fabric should be repaired without delay. If the hole is a straight rip, not longer than six inches, it need not be sewed before covering. If the rip is longer or if angular in shape, the torn edges must be sewed together. Before applying a patch, a benzol solvent is used to remove varnish from the area surrounding a tear. Oblong patches with the corners lopped off, and circular patches for small holes, are employed. In putting on the patch, care should be exercised not to allow fresh dope to fall through the hole on to the frame and lower surface, as it will attack the lower surface and blister its finish. If the machine is flown before the patch is thoroughly dry and firmly set (about 24 hours), it will be blown off.

Shellac must not be applied to wood members where it will come in contact with a doped surface as the combination is injurious to materials.

Invisibility of aircraft has been sought through the employment of transparent surface covering. Treatment of cloth surfaces with cellulose acetate produces this effect to some extent. Attempts to use the films formed by dope solutions, for coverings of wing frames, have been made. This substance is too fragile and combustible to justify the practice. A solution of cellulose acetate, employed in the manner given here has been claimed to render an airplane invisible at an altitude of 6000 feet. (Treatment with synthetic resins has been followed by the Germans. This development has been reported a "pronounced success.") The production of reliable, transparent surface covering for employment on war planes, particularly of the tactical type, which operate comparatively at low altitudes, will solve one of the biggest problems in military aviation.

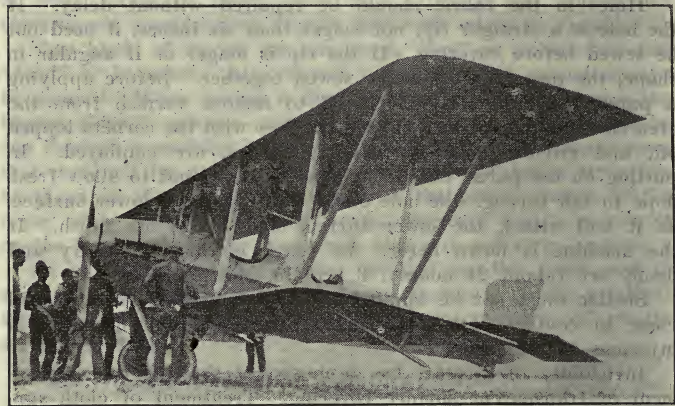
METALS

Metals employed in aircraft construction should be of the highest quality and specially selected, in each case, to obtain the particular physical properties required.

Steels. Many different kinds of steel are produced by variation in structure and composition given the metal, and by heat treating and mechanical methods employed.

The proportions of carbon, phosphorus, sulphur, and other elements contained in a given piece of steel are of prime importance in affecting the qualities. Alloy steels give special properties. Heat treatment of steels provides further variation.

Production of Steel. Steel is manufactured by treating iron. A number of processes have been evolved. The Bessemer process is the principal one. The open hearth and crucible methods are largely used. Materials used in the process regulate the composition of the finished steel. The proportions of carbon, alloys of various kinds, and impurities, such as sulphur, contained in a given piece of steel determine the properties. In general terms,



This machine represents a departure from he usual all-wood machine. Practically all the interior framework is constructed of steel.

a high carbon steel produces a strong, hard steel, but it is brittle and will crack before it will break under a strain. Low or mild carbon steel produces a grade of metal having more or less the opposite qualities of ductility, capable of being drawn out or bent without fracture. The presence of certain impurities results in flaws; others produce tendencies to crack. Steel alloys have special properties in each case.

These properties may be altered or modified after manufacture by heat treating or "tempering" the metal. This consists of "hardening" or "annealing" (softening) the metal.

Heat treating is used largely in the metal shops at airplane stations. Metals are heat treated to obtain special physical properties desired in each case, such as toughness, elasticity and resistance to sudden, alternating and vibrating stresses; in other words shock and crystallization.

Hardening. Metals are heated uniformly to the proper degree and plunged, usually in water or oil. The process may be repeated. For example, the first time, the metal is heated to a cherry red and plunged; then heated to a dull red and plunged. Processes of hardening vary both in degree, number of applications of heat, rate of cooling and with different metals, all these variations designed to produce different qualities. The rule is to obtain uniform cooling, each time so treated.

Properties of Hardened Steel. High tempered steel is materially stronger than annealed steel. The structure is apt to lack uniformity unless the work is carefully done. Hardened metal cannot be machined in the process of manufacturing parts, except by grinding. The qualities found in hardened steel follow generally those given for high carbon steel.

Annealed Steel. This process consists of heating the metal to a cherry red and immersing in ashes or other selected compound; allowing it to cool gradually. This has the effect of "killing" the carbon to a greater or lesser extent.

Qualities of Annealed Steel. It is easily machined. This steel is mild, giving soft properties, high ductility, and uniform structure as a rule. *Annealed* steel can be more relied upon for expected performances than *hardened* steel. Annealed steel is largely used in airplane construction because it is more reliable than hardened steel and because it is more ductile. It is evident that vital metal members should have a maximum strength obtainable, but it is better to have such members bend before breaking under a strain.

Cold Rolled Steel is a form of the metal rolled or flattened under pressure. This steel is a compromise between the hardened and annealed, possessing some of the qualities of both. It is especially suitable for airplane construction and is largely used.

Cold rolled steel must be annealed if plates, sheets or bars are to be bent to any marked extent.

Alloy Steels are selected for the special properties possessed in each case.

Chrome Vanadium Steels, both heat treated and cold rolled, are largely used for fittings and other vital metal parts of airplanes offering excellent qualities for the purpose.

Welding and Brazing

In making up fittings for airplane parts, the steel plates are pinned or bolted together and welded or brazed. Welding is stronger than brazing.

Welding. This process consists of heating two metal pieces to a fused and ductile state and treating with a flux compound. The two pieces united should form a continuous body.

Brazing is the process of joining two pieces of metal by heating with melted brass and a flux. This compound, when properly applied, adheres to the metal and permeates the entire union. Samples cut from metal in cross-section show the quality of the work. The brass in the seams and below the surface shows plainly. Fracture of brazed metal parts caused by strain, and crystallization due to vibration and fatigue of materials, occur first at points at which the brass has not permeated properly. It is of vital importance that brazed fittings on airplanes are of the highest grade workmanship.

Copper and Brass

Copper and brass should be used wherever possible as they do not rust or corrode, and deteriorate through the action of moisture or salt water (in case of seaplanes, brass will respond to corrosive action of salt water and grease). Copper alloy metal is required by the Government for control cable pulleys and pulley parts. These metals should be used for cockpit fittings and instruments as far as possible to avoid placing magnetic materials in vicinity of the compass.

Aluminum is a useful metal in construction where weight can be saved without danger. It is self-protecting against oxidation.

Duralium is a stronger metal than aluminum and possesses similar qualities.

Deterioration of Metals

Four cardinal rules govern the care of metals:

1. Avoid shocks and blows; they lead to rupture.
2. Avoid vibration; it results in crystallization and consequent fracture.
3. Avoid moisture; cover metal with coat of paint, enamel or keep well coated with a film of oil at all times.
4. Avoid heat, except in process of treatment. This includes wide variations in temperature.

Vibration in an airplane should be guarded against as possibly the greatest foe to safety in flight. Vibration is the result of faulty construction or improper adjustment of parts. Loose stays, fittings and connections set up vibration, cause crystallization of metal parts and undue wear to wooden members. Collapse of planes is most frequently due to vibration and this inevitably follows neglect or incompetence in adjustment or handling a plane. A machine must be immediately checked for adjustment upon detection of vibration. Collapse or fracture of parts will result from *fatigued* materials. *Fatigue* is caused by vibratory and other stresses, blows, or deterioration due to age. The objection to metal beams, struts, spars, spreaders, longitudinals and other vital airplane members, rests upon the great susceptibility of metal to crystallization and fatigue.

Steel Plate and Forged Fittings

Fittings are metal devices employed to secure struts, braces, planes, chassis, etc., to other parts of the airplane. They consist usually of plates, sockets or joints in some combination, and may be likened to the hinges that unite a door to its frame, or the nails that attach a board to a box. In fact, all metal devices that secure one part of the airplane to another, are called fittings.

Highly polished surfaces are not given merely for appearance. They stand for good service qualities.

Bolts, pins, plate fittings and turnbuckle ends should be made of chrome vanadium steel (S. A. E. Specifications).

All parts and fittings and forged steel parts and fittings should be heat treated after all bending, by such treatment as will produce the desired grain and toughness and relieve all bending stresses.

Steel parts and members subject to stresses and vibration should be heat treated to obtain highest properties of resistance to alternating and vibratory stresses.

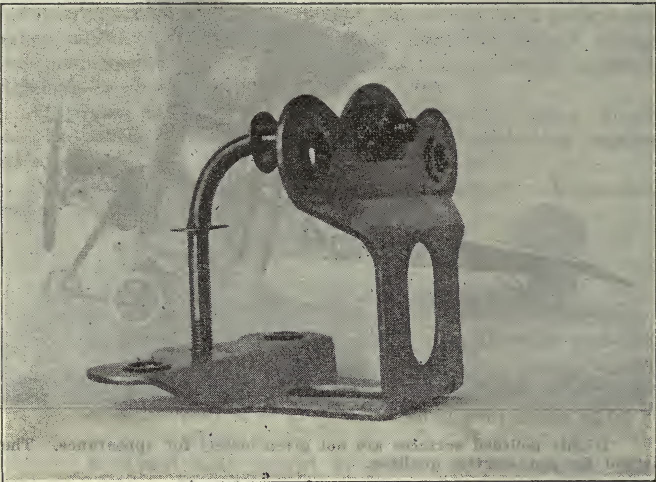
Fittings should never be bent or twisted. Eye-plate and eye-bolt fittings should show no sign of wear or fracture. Aluminum fittings must be watched for cracks, especially after being subjected to heavy strains. When a crack is detected in an aluminum piece, a small hole should be drilled just beyond the end of the crack. This will prevent further splitting.

All sharp edges must be removed from fittings. Eyes cut or punched in fittings should be carefully located with a uniformity of material between location and edge of metal to avoid pulling out.

Taper pins should be drilled and when installed, safetied.

Metal fittings must be greased at all times, unless painted. They should be painted and enameled, however, except on bearing surfaces.

Metal can be protected from the action of salt water by three coats of baking enamel. Steel bolts, pins, nuts and cotter pins should be protected by heavy nickel plating or copper;



High grade steel fitting. (Note finished workmanship.)

covered wires and turnbuckles, by at least two coats of flexible compound. Steel tubing should be thoroughly cleaned, slushed with mineral oil inside and plugged with wood impregnated with paraffine or mineral oil.

Fittings should be the highest grade steel; to save weight in fittings is a dangerous practice.

Metal fittings must be true to form, and free from imperfections or damage. Welding of steel fittings is used wherever possible. When that is impracticable, brazing is employed. Proper heat treatment to restore desired properties is applied in either case.

Wires, cables and fittings must not be kinked or nicked. Pins riveted to fittings should draw both parts close, without crushing the head, which should be of liberal dimensions.

Fittings crystallize, strain and weaken with a constantly decreasing resistance, therefore rapidly become dangerous after deterioration once starts. The fittings of the chassis deteriorate most rapidly. The fittings of the center section of the fuselage (likewise subjected to unusual stresses) must be closely watched for early deterioration.

Springs must be kept free from rust and well lubricated to lengthen life. The weight resting upon springs should be jacked up, when not in use.

Aviator wire must be kept free from kinks and none should be used that has been subjected to severe stress or previously bent. It must be frequently examined for flaws or signs of crystallization. Exposed wires should not be painted but kept carefully coated with grease at all times. Internal wiring (inside the planes or inside the surface of the fuselage) should be freed first from rust or oxidation and then coated with a non-rusting material.

Light colored paints should be used for coating wires. The paint should be enameled or a coat of varnish applied. Whenever two wires (or cables) cross, causing wear, each should be wrapped with insulating tape and the two wrappings bound together.

Cable. Stranded wire or cable should be stretched before installing, all the strands of a uniform twist, and not frayed. Frayed ends should be soldered at once, but it is dangerous to solder broken strands in a *control cable.* It is likewise dangerous to solder up several frayed strands in any kind of cable. When a length of cable is frayed, it must be replaced. Careful and frequent inspections must be made for wear, where a cable passes over pulleys or through fair leads (housing or guide tubes).

Never use a blow torch on a cable, wire or turnbuckle. Heated soldering irons only are used.

The use of aviator wire and stranded wire is as follows:

Stranded wire or cable is used where the single strand wire would be risky. Aviator (or solid, single strand) wire has come into general use for internal bracing of wings and airplane bodies. Cable is used wholly for external bracing wires and control leads, especially where the cable passes through pulleys, fair leads or guide tubes. Cable shows wear by fraying and this provides ample warning. Another warning of strained cable is indicated by the stretching and consequent looseness which precedes rupture. Most machines are now double-wired throughout for safety. Wire does not stretch materially; cable does and this necessitates readjustment after it has been installed a short time. For this reason cable must not be used for internal wires (inside of wings or within fuselage), where they can not be reached without removing the fabric. Aviator wire is not pliable when carried over small pulleys or around sharp bends. For this reason it is not suitable for control wires. Both wire and cable are carefully tested to determine the exact number of pounds it will support without breaking. The various sizes of wire or cable will carry a certain known load with safety. In designing an airplane, the stresses in pounds are accurately computed so that the maximum, normal stress that will be brought to act upon any particular wire is definitely known. The size or gauge of wire to be used in any particular place must be capable of withstanding a strain of at least 7½ to 12 times greater than required. This is called the factor of safety and should not be less than a ratio of from 7½ to 12—to 1, in strength of materials used throughout the machine.

Enclosed wires should be single-strand, high tensile, hard wire. All accessible wires should be of nonflexible, stranded steel cable; control leads should be Roebling's flexible phosphor bronze cable, seven strands of 19 wires each, having a tensile strength in pounds exceeding the requirement. To meet government specifications aviator single-strand wire must have the tensile strength to meet the factor of safety and to undergo these tests: "to be bent at right angles over a radius equal to the diameter of wire, four times each way." Not more than four sizes of wire should be permitted in any one airplane.

Cable should be stretched before making up and fitting, applying a load of about 25 per cent of breaking load, for two or three hours; control leads, before installation, should bear a tensile load of 500 pounds for eight consecutive hours.

Nuts and Bolts. The principal methods of securing nuts and bolts may be listed as given below.

a. Castellated nut fitted with a split pin.
b. Riveting end of bolt, or stud over top of nut.
c. Burring the thread at end of bolt.
d. Split pin through the bolt, provided the nut rests against it, or the intervening space is filled with a check nut bearing against a split pin.
e. Spring or lock washers beneath the nut, but this is not proof against loosening.

The following rules govern the proper care of *bolts*. The threads of bolts, nuts and screws must be true, clean and not worn. The stems of bolts must not be bent. Only new nuts and bolts should be used for renewals. Bolts and nuts must be secured to prevent loosening. Failure to do so has often resulted fatally, and it is likely that many an unexplained accident has been due to this inexcusable neglect.

Turnbuckles. A turnbuckle is a metal device placed in a length of wire or cable to enable adjustment to the desired degree of tension. This device consists of two eye-bolts, each of which screws into a metal tube. The threads at the ends of this tube are cut in opposite directions; this enables tightening or loosening the wires attached to the eye-bolts, to a slight extent. A rigid rule to follow in treatment of turnbuckles is never to subject turnbuckle eyes to heat, as they are carefully tempered. Turnbuckles should be non-rusting. The threads must be perfectly formed and the three working parts must fit accurately. As great loads are brought to bear upon them, the threads must be of unusual strength. The turnbuckle is no stronger than its threads. Turnbuckles are required to have the following minimum strength under tension:

Size No. 1—8,500 lbs.
Size No. 2—4,600 lbs.
Size No. 3—2,100 lbs.
Size No. 4—1,100 lbs.

The rules for adjusting turnbuckles are important.

a. "Turnbuckles must not be worked upon with pliers or other tools."...a special turnbuckle wrench or..."a wire passed through the hole provided in the barrel must be employed, the screws being held by the fingers."

b. "Turnbuckles must not be shortened up to the limit of their screw threads. The wire itself must be shortened, or a new wire fitted."

c. "Turnbuckles must always have at least 3/8 inch of each engaged, and as a rule, must not be covered with tape."

d. "Under no circumstances is it permissible to saw off a portion of a turnbuckle...when a wire becomes too taut, it is conclusive that a measurement is wrong and immediate readjustment needed."

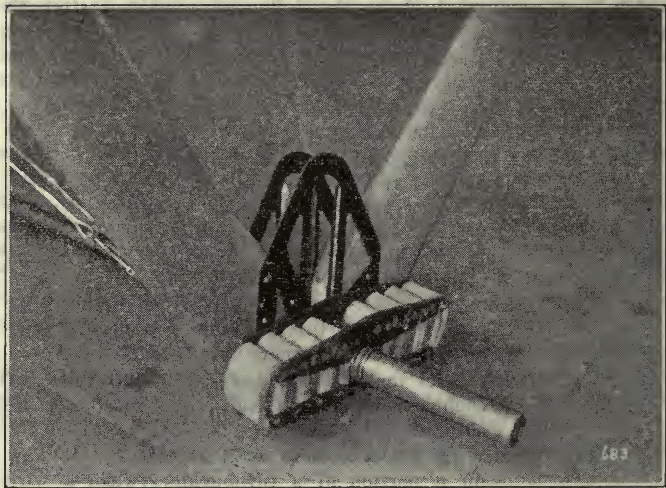
e. Never enlarge the end of a turnbuckle.

After turnbuckles are adjusted, they are *individually* locked by passing a length of steel, soft brass or soft iron wire through the small hole cut in the tube. Each end of this "safety wire" is then bent toward one of the two eye-bolts where it is wrapped firmly through and around the eye of the bolt. This keeps the bolts from turning out of the barrel and the union thus breaking. If the wire or cable to which the turnbuckle is attached requires frequent adjustment, steel wire should be used. If not, soft iron or brass wire should be employed. The best plan is to use the same safety wire once. Turnbuckle safety wiring, 20 gauge semi-hard copper wire is prescribed by government specifications.

NOTE: Aviators, when flying, should note carefully any wires vibrating unduly and cause their immediate readjustment upon landing.

Terminals. A terminal is the fixed loop formed from the end of a wire or cable, by which it is attached to a fitting or turnbuckle. It is made in this manner:

In the case of a *stranded* wire or cable, the ends of strands must always be secured from fraying by the application of a drop of solder. The end of the cable is soldered (sweated) for about seven inches (measured from the end) to harden the cable and make it solid. The cable is then kinked and rounded at a



Details of airplane wheel, shock absorber

point about 3½ inches from the end, and passed through the eye of the turnbuckle. The shoulders there formed are brought close together and the fly-end of the cable should now be about three inches long. This fly-end (free end) is then taped to the long end of the cable for about two inches, using *doubled* copper wire of a very fine gauge. The remaining 1½ inches of the cable are next cut diagonally so that the end will lie along the other length and taper off gradually. The taping is then continued with the copper wire, to the end of the union. The wrapping is next placed in a vise and "cinched" or flattened until the two parallel lengths of wrapping are evened and made symmetrical. The solder is then applied slowly and sparingly to the top side of the wrapping. This insures "sweating" and not merely "tinning." *Sweating* means to *fill* the interior as well as the surface with a uniform soldering free from bubbles.

Tinning is *covering* the surface with a *film* of solder and does not give any substantial strength to the union.

An improvement in turnbuckles replaces the eye-bolt with a conical tube. The cable end is inserted, each strand separated carefully and the ragged end gnarled up. The tube and frayed ends are now filled with liquid solder. The relative value of well-constructed terminals without the use of solder and those in which solder *is* employed, is approximately as 1,900 pounds to 2,500 pounds: breaking strain by actual test.

Cable terminals are weakest at the point where the loop passes through the eye of a turnbuckle or fitting. It breaks first at this point because the strands have a tendency to spread at the turn. This spreading results in strain due to unequal tension on the various strands. Careful inspection of cables at this point should be made frequently. Great care must be observed in installing cables around turns. It is good practice to "sweat" the loop with solder. Saddles or "thimbles" must be used to protect either cable or wire from cutting at the turns.

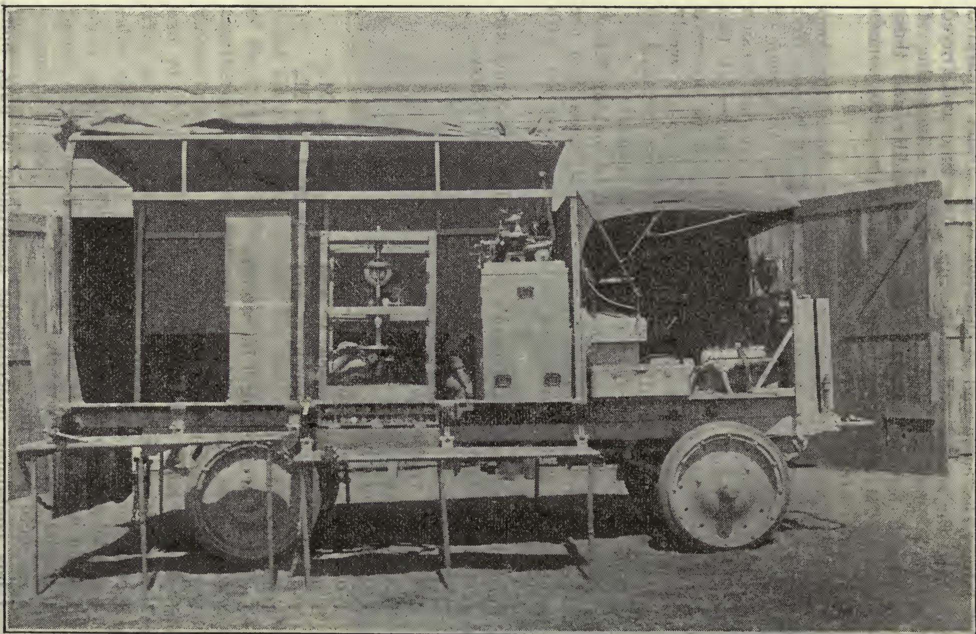
Sleeves (small metal tubes) should be used in making terminals where aviator wire or cable smaller than 3/32nds inch are employed. Small cable cannot be satisfactorily wrapped with fine copper wire.

A tool kit is carried in the pilot's seat of all U. S. Army airplanes, containing highest grade metal spare parts as follows:

- 4 spark plugs,
- 1 lb. (roll) friction tape,
- 1 roll 20 gauge hard-copper wire,
- 1 spark plug wrench,
- 1 one-lb. hatchet with hammer end,
- 1 double open-end wrench, ¼ and 5/16 A. L. A. M.,
- 1 double open-end wrench, ⅜ and 7/16 A. L. A. M.,
- 1 mill file, 10 inch,
- 1 Crescent or Sterling 6 in. wrench,
- 1 Crescent or Sterling 10 in. wrench,
- 1 pr. 6 in. combination pliers,
- 1 pr. 8 in. Klein wire cutters,
- 1 screw driver, 7 inch,
- 1 cold chisel, ½ inch,
- 1 special tool, for tightening turnbuckles,
- 1 spool linen fabric thread with needles,
- 1 special magneto wrench,
- 1 magneto point file,
- 1 box containing miscellaneous assortment of nuts, bolts, cotter-pins, clevis pins, as used in airplane structure.

The weight of the tool kit should not exceed 11 pounds.

A light funnel and a collapsible one-gallon bucket are carried.



Repair truck for air squadron. This unit carries a small lathe, drills, grinders, bench tools, blacksmith equipment and an assortment of stock materials. Such a portable machine shop is an indispensable unit with airplane squadrons.

TRAINING IN AVIATION

CHAPTER 6

ACTION AND ADJUSTMENT OF MATÉRIEL

Features of airplane design and construction are constantly changing.

Design, arrangement and less apparent characteristics of machines improve with every succeeding model, as experiments and practical experience demonstrate improved methods. Thus a great variety of airplane types have come into general use, and it is impracticable to examine and study every type. General features and principles of design and construction have, however, become more or less standardized and may be profitably considered in that light.

Before an analysis of aircraft design can be made, it is necessary to understand some of the technics and theories of aerodynamics universally accepted.

The length, width and height of an airplane are called, respectively, the over-all length, the height, and the span.

The *over-all length* of an airplane is measured from the tip of the nose to the rear-most extremity of the body.

The *height* of a machine is measured from the ground to the top surface at the center section (in dihedrals, at the wing tip), the machine being raised to its flying level.

Span is the distance separating the outermost extremities of the right and left wing tips.

A *wing* is that part of the main plane structure on one side of the central body, or fore-and-aft axis of the machine. Every airplane has a right and left wing regardless of type—monoplane, biplane or triplane.

A *plane* is either the entire upper or lower surface or any part of the main lifting surfaces; auxiliary surfaces are given special names such as elevators, flaps, rudders, fins of all kinds including panels and keels.

Note: The word plane as applied to any lifting surface is a misnomer, as airplane lifting surfaces are never flat but are always curved (or cambered) to obtain the necessary aerodynamical properties. The designation "plane" has enjoyed long usage and better terms such as "deck" and "aerofoil" are scarcely ever employed.

Gap is the distance separating the upper and lower planes of a biplane. A triplane has a double gap and an over-all gap, since there are three planes; the upper, lower and intermediate.

The *chord* of a plane is the distance from the front edge (called the *entering edge*) to the rear edge (called the *trailing edge*).

The relation between the span of a plane and its chord is of prime importance aerodynamically. The span divided by the chord is termed the *aspect ratio*. The measure of the curvature of a plane is called *camber*.

Upper and lower planes are separated by struts and trussed together by means of cross wires. The frames of each plane are likewise trussed by cross wires. The wires *between* the planes are called the *flying* and *landing wires;* the wires *within* the planes, *flying drift* and *landing drift* wires.

Flying wires carry the load in the air and run from the central body at the lower plane to the upper plane in the direction of the wing tips. The landing wires cross the flying wires from upper to lower plane toward the wing tips. There are landing and flying wires along both front and rear spars.

Internal bracing wires are divided as: *flying drift wires,* those from the front spar to rear spar toward wing tip; *landing drift wires* from the rear spar to the front spar toward the wing tip.

These rules apply to either wing.

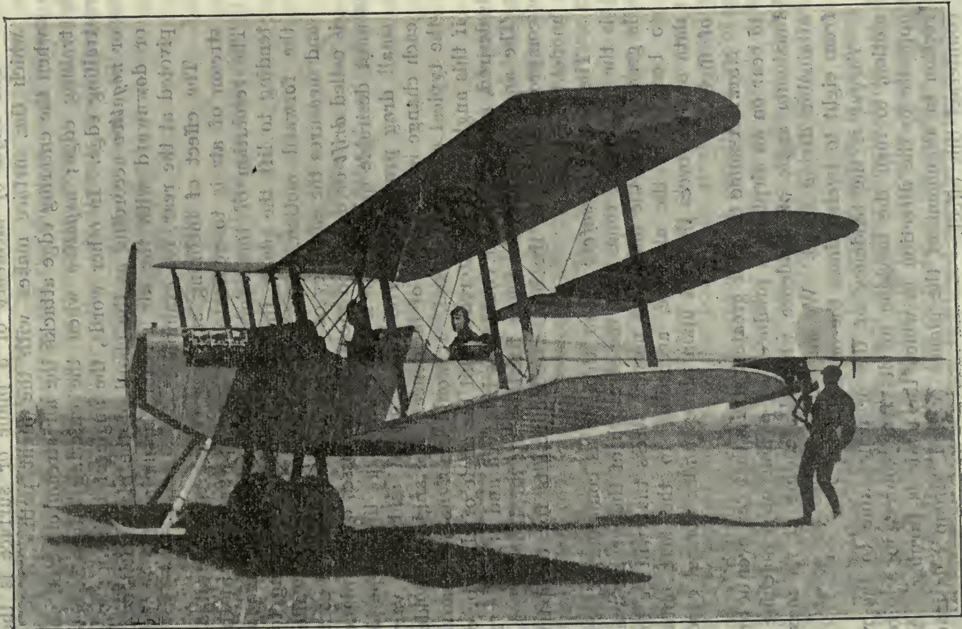
Disposition of Planes

Normally, the planes of a biplane or triplane are disposed vertically, one over the other, upper and lower planes horizontal from wing tip to wing tip, the entering edges of upper and lower planes at right angles to the line of flight.

Planes are said to be staggered when the lower plane is set to the rear of the upper plane (with the machine at its flying level). Triplanes like biplanes may be staggered. The object of staggering planes is to improve the efficiency by reducing "interference" of the lower plane with the upper, which occurs in the normal or vertical arrangement of planes. (This interference is due to deflected currents of air under certain conditions of flight.)

An arrangement by which the right and left wings of an airplane are not horizontal but are inclined equally upward on either side of the central body (fore-and-aft axis) toward the wing tips, is called a *dihedral angle;* when the wing is inclined downwards on either side of the fore-and-aft axis, it is called an *inverted dihedral angle.* (The dihedral and inverted dihedral are common in birds.)

When the right and left wings recede from the center to the wing tips, like the letter "V," the nose pointed forward, it is called a *retreated* or *swept-back* type.



Dihedral angle between wings. Interplane ailerons. Staggered planes.

The objects of dihedral and swept-back types are to produce inherent lateral stability.

The *angle of incidence* of a plane or surface is the angle which the surface makes with the flight path. It is *positive* when the entering edge attacks the air stream elevated above the trailing edge; *negative* when the entering edge is below the trailing edge. In other words, the angle of incidence is *positive* or *negative* according as the chord of the plane inclines upward or downward with the air stream (assuming the chord to be pivoted at the rear, for example).*

The effect of inclining surfaces (front edge elevated) to a stream of air is to generate pressure upward and to the rear. The resolution of these forces gives two factors, one vertical, tending to lift the plane, the other horizontal, tending to resist the forward motion. The vertical component is called *lift,* and measures the efficiency of the plane; the horizontal component is called *drift* or *drag* and measures the losses of the plane. The most desirable qualities in a plane are large lift properties and small drag properties. The values of lift and drag vary with each change in the angle of incidence. The angle of incidence of the typical airplane is fixed. It would be of immense advantage if this angle could be altered to suit the angle of climb or descent desired, as much power could thus be saved and efficiency gained. The angle of incidence when fixed on an airplane represents a compromise to give the best average results for the particular model.†

The *factor of safety* of an airplane as commonly calculated, is the number of times that the strength of the weakest member is greater than the maximum normal stress that will be brought to bear upon the airplane, according to the best obtainable data on the forces that act upon planes under normal conditions of flight.

NOTE: Assume that the greatest stress that can ever be brought to bear on an airplane is produced by pulling up a machine to its maximum angle of incidence when descending at its maximum attainable diving speed. We may thus realize an *actual stress* from eight to twelve times the normal.

Torque is the tendency of the propeller, due to the rotary motion, to turn the machine off its true course, in a direction opposite to the direction in which the blade is turning. A correction in alignment of the planes (called "droop") is made to counteract this effect.

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* Pressure on top of a plane, instead of the normal condition of pressure underneath the surface, results when the angle of incidence is *negative.*

† One prominent type of airplane was built with a movable wing structure but it presented structural difficulties and was unsuccessful.

ADJUSTMENT OF MATERIEL

The adjustment of all the integral parts of an airplane must be made with elaborate care.

Alignment of the fuselage and the shape of main planes and auxiliary surfaces should be properly done in the original construction of the machine; other adjustments must frequently be made by aircraft personnel. The following adjustments are prescribed by the Aviation Section of the U. S. Army:

1. Alignment of landing gear;
2. Alignment of center section;
3. Alignment of entering edge;
4. Alignment of both wings at the same height;
5. Dihedral angle (if any);
6. Alignment of trailing edge;
7. Droop;
8. Tightening and safetying wires;
9. Length of struts; positions of fittings; warp in planes;
10. Alignment of ailerons;
11. Alignment of stabilizer;
12. Alignment of elevator flaps;
13. Alignment of rudder.

(All adjustments should be made with the fuselage horizontal.)

1. *Alignment of landing gear:* the chassis should be aligned with the fuselage supported on saw-horses. Axle or axles should be parallel to lateral (tranverse) axis of machine, center of axle directly under center of fuselage. This is done by marking exact center of fuselage and dropping a plumb bob to axle, adjusting cross wires until the plumb bob is over the center of axis; tightening and safetying the wires.

2. *Alignment of the center section:* the center section comprises the cell formed by the body, body struts, and small wing panel directly over it. (This arrangement permits the use of upper and lower wings having the same dimensions or avoids a union of upper planes over the fuselage center.) In the adjustment of cells between the planes all wires except *landing wires* are loosened.*

In *vertical strut* machines, the center section is adjusted with reference to the engine beds or upper longitudinals, as these members are normally parallel to the propeller shaft or line of thrust, which follow the line of flight of the machine. Each side of the center section panel is aligned parallel to the member used as a base line. The entering edge of the panel is in turn aligned. These adjustments are made by moving the struts, loosening one cross wire, tightening the other, until dimensions check. Then all wires are tightened and safetied.

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* Cross distances are measured between corresponding points on fittings at either end of the wire.

Stagger: In staggered planes, the sizes, shapes and positions of struts and fittings fix the proper amount of stagger. The cross wires on one side of the cell are adjusted until the struts on that side are in their correct positions; wires are adjusted on opposite sides of the cell, until the measurements on both sides correspond. The front cross wires are then adjusted until the cross distances are all identical.

3. *Alignment of entering edge:* Wings may be checked by sighting along the entering edge of the upper plane from a position in prolongation of the wing tip. Any warp or bow in the plane can be seen readily. By loosening or tightening front landing wires, the plane may be straightened so that it lies true with the entering edge of the center section. The lower plane can be straightened in a like manner. The opposite wing should then be straightened.

4. *Alignment of both wings at the same height:* Drop a line from the exact center of the center panel to similar points at the lower extremity of intermediate and outer struts. These distances should be made to correspond by raising or lowering one wing, exercising all care to keep the entering edges of both wings straight and the entire wing structure parallel to the landing gear.

5. *Dihedral:* The checking of a dihedral is accomplished in a manner similar to the preceding adjustment. A tack is placed at each wing tip, at exactly the same distance from the center of the plane. A string is stretched between the two tacks until there is no sag. "A dihedral angle is greater than 90 and less than 180 degrees. A dihedral of 178 degrees (between two wings) means that each wing has been raised one degree. Hence the correction or adjustment of a dihedral of 178 degrees is accomplished: Multiply the natural sine of one degree by the distance from the tack (attached at or near the wing tip) to the exact center of the plane. The result is the inches by which the distance is to be decreased. Both wings should be raised by that amount, keeping the entering edges straight. As each wing is raised, the *landing wires* become shorter and the *flying wires longer,* due to the fact that *bays* are changing from rectangles to rhomboids."

6. *Alignment of trailing edge:* The trailing edge can be made parallel to the entering edge by sighting under the lower plane until both edges appear to coincide or cross. By loosening and tightening the rear landing wires, the trailing edge can be made parallel. The upper plane can be adjusted in a similar manner by adjusting the front landing wires.

"The trailing edges of both wings should be aligned before any droop is given."

7. *Droop:* To correct for the torque of the propeller in screw airplanes, with the blade turning to the right, the angle of in-

cidence of the outer portion of the left wing is slightly increased. The trailing edge is accordingly "drooped" by loosening the outer rear landing wire (from left intermediate strut, rear, upper to left outer strut, rear, lower) until the trailing edge from the intermediate to the outer struts has a droop of about one inch below the normal, for power plants not exceeding 100 H. P.

8. *Tightening and safetying wires:* Wires are tightened to same tension and safetied in the following order: Flying wires to remove all sag, fore-and-aft drift wires (between front and rear struts), drift wires from wings to fuselage and from wings to landing gear. Safety wire is employed to lock the wires as described under WOODS, METALS and FABRICS. Flying and drift wires are tightened to the point that they will carry the load in the air without causing sag in the landing wires. This must be watched by the pilot in flight.

9. *Length of struts; positions of fittings; warp in planes:* Corresponding struts must check to the same identical length, similar fittings occupying similar positions should be spaced the same; in case of warp, each wing should have an equal warp.

10. *Alignment of ailerons:* Flaps should be aligned with their trailing edges. Interplane struts or ailerons should be set in the same plane when neutral. The control leads to the ailerons should be free from back-lash.

11 and 12. *Alignment of stabilizer and elevators:* The stabilizer should be parallel to the main planes. Hold the controls fixed so that the elevators are in prolongation of the stabilizers; the two elevators should rest in the same plane, without back-lash in the control leads. By sighting along the rear edge of the stabilizer and the main plane, *parallel* can be checked.

13. *Alignment of rudder:* Place the wheel post, foot bar or other control device at the mid position, the rudder at neutral and adjust the control wires so that no back-lash remains.

The fuselage of a machine may be checked easily and quickly by running a string or wire from the center of the fuselage at the front to the center of the fuselage at the rear, and drawing perfectly taut. If each pair of cross wires inside, or across the top and bottom panels of the fuselage, do not coincide exactly with the string at the line of intersections, adjustment of wires is necessary.

To attach the main planes to the central body, the fuselage resting upon its chassis is brought to the proper flying level. With the engine beds or longitudinals as a base line, giving the normal line of flight, the machine is put into a horizontal position. The point to bear in mind here is that the wings must be set on the body in such a manner that they will make the specified angle (determined by the designer) with the engine beds or the top longitudinals, which refer to the line of flight directly. This gives the planes the proper angle of incidence. The wings are now fitted to the airplane. Ordinarily, this process is done at the factory, the fittings being adjusted and attached so that the planes can be readily slipped into place, having the correct angle of incidence. If the fittings are not adjusted, special directions for determining the actual chord of the plane must be followed. With this chord known, it may be laid off on the side of the body and the positions of the front and rear beams so located that the fittings, or unions, joining wings to body, will attach to the proper members of the body to carry the load with safety. The angle of incidence of average machines varies between 5 degrees *positive,* and ½ degree *negative,* as permanently set on machines.

WING STRUCTURE

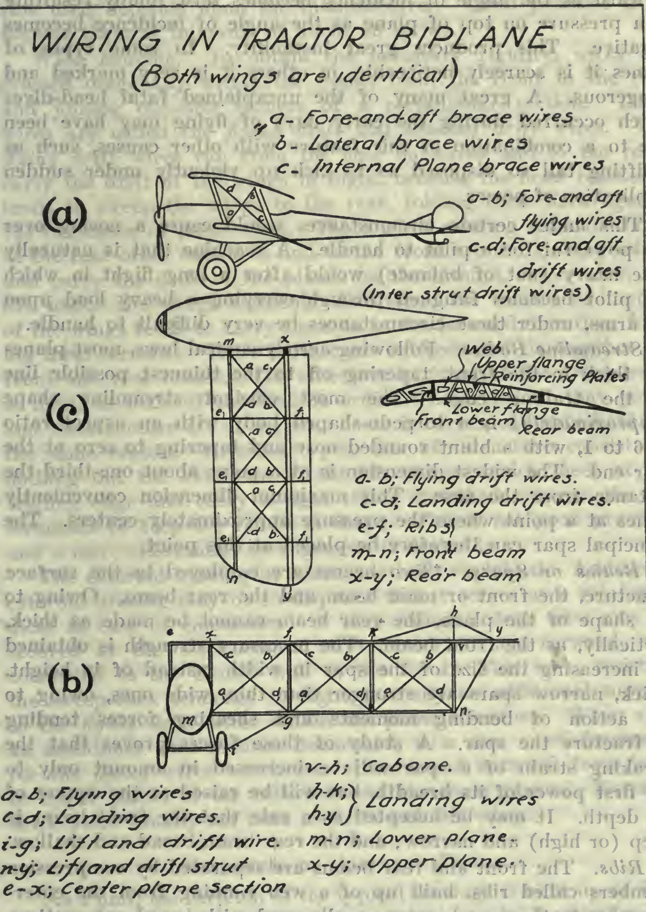
(Planes, more correctly called *decks or aerofoils.*)

The full load of the craft is carried upon the planes in flight. To obtain the necessary strength without making the wing so heavy that it will be out of all proportion to the limitations imposed, is a work of the scientist.

The loading on a plane is determined by dividing the total weight of the craft by the total lifting surface expressed in terms of square feet. If a machine has a lifting surface of 400 square feet, weighs 2,400 pounds fully loaded, the loading per square foot is 6 pounds.

Aerofoils must be given the necessary strength, with a minimum weight, and the shape must be such as will give the greatest amount of efficiency in the work to be done, whether it is designed for speed, climb or weight-carrying, flat glide, etc. Planes are cambered or curved to produce lift that a flat surface would not give; camber varying with each model to produce special desired properties, it is evident that the structure of the plane must in each case be accommodated to the requirements of form. Spars, ribs and other bracing units must be so disposed that they will conform to the aerodynamical shape.

All parts of the plane do not carry the same load in actual practice. Moreover, this load is constantly shifting. For instance, the center of pressure on a cambered plane travels along a certain fore-and-aft distance as the angle of the plane (the angle of incidence) changes in flight. Under normal conditions of flight, this center of pressure remains at a position about one-third from the leading edge of the plane. The ideal wing would be one in which the center of pressure would remain stationary and fixed for all angles; hence engineers are constantly experimenting to produce such a wing, which makes for safety and increased efficiency. As the speed of the plane through the air increases, the center of pressure moves to the rear, in some cases as much as two-thirds of the distance from the leading edge.


WIRING IN TRACTOR BIPLANE
(Both wings are identical)
a- Fore-and-aft brace wires
b- Lateral brace wires
c- Internal Plane brace wires
(a)
a-b; Fore-and aft flying wires
c-d; Fore-and aft drift wires
(Inter strut drift wires)
(c)
Web
Upper flange
Reinforcing Plates
Lower flange
Front beam
Rear beam
a- b; Flying drift wires.
c-d; Landing drift wires.
e-f; Ribs
m-n; Front beam
x-y; Rear beam
(b)
v-h; Cabone.
h-k; h-y Landing wires
m-n; Lower plane.
x-y; Upper plane.
a- b; Flying wires
c-d; Landing wires.
i-g; Lift and drift wire.
n-y; Lift and drift strut
e-x; Center plane section

As the angle of incidence is lowered to the vicinity of zero, the center of pressure travels quickly to the rear, which causes a dangerous diving tendency in some planes, and then quickly forward as the angle of incidence becomes zero, finally resulting in a pressure on top of plane as the angle of incidence becomes negative. This produces great instability. In some types of planes it is scarcely noticeable, in others it is very marked and dangerous. A great many of the unexplained fatal head-dives which occurred during the early days of flying may have been due to a combination of this feature with other causes, such as a lifting tail so disposed as to kick up violently under sudden application of power.

This under certain circumstances would cause a nosing over too powerful for a pilot to handle. A machine that is naturally nose heavy (out of balance) would after a long flight in which the pilot becomes fatigued through carrying a heavy load upon his arms, under these circumstances be very difficult to handle.

Streamline Bodies. Following aerodynamical laws, most planes are thick in the front, tapering off to the thinnest possible line at the trailing edge. The most efficient streamline shape *(approximately)* is a torpedo-shaped body with an aspect ratio of 6 to 1, with a blunt rounded nose and tapering to zero at the rear end. The widest dimension is at a point about one-third the distance from the nose. This maximum dimension conveniently comes at a point where the pressure approximately centers. The principal spar can therefore be placed at this point.

Beams or Spars. *Two beams are employed in the surface structure, the front or main beam and the rear beam. Owing to the shape of the plane, the rear beam cannot be made as thick, vertically, as the front beam. The necessary strength is obtained by increasing the size of the spar in width instead of in height. Thick, narrow spars are stronger than thin, wide ones, owing to the action of bending moments and shearing forces tending to fracture the spar. A study of these forces proves that the breaking strain of a spar will be increased in amount only to the first power of its breadth, but will be raised as the square of its depth. It may be accepted as a rule that the front beam is deep (or high) and narrow; and the rear beam broad and shallow.

Ribs. The front and rear beams are separated by compression members called ribs, built up of a web running from the entering edge to the rear beam normally, and with bored out sections to reduce the weight. A light strip is faced on the web at the entering edge (unless the front beam is placed at that point), which joins the upper and lower flanges of the rib. These flanges are stout wooden strips, secured to the webbing on the top and

* NOTE: Beams are also called spars, but this name is used to designate all heavy supporting members of the plane framework.

bottom. In boring out the web to reduce weight, great care must be exercised to avoid piercing the wood too near the upper or lower edge as this seriously reduces the strength of the member and incurs the risk of easy fracture. The number of ribs used depends upon the manufacturer. Good practice is to dispose them at intervals of about 18 inches.

Wire Bracing. To obtain the necessary rigidity, wires are crossed diagonally within the plane, from the front to the rear and joining opposite corners of a rectangular section. These wires are called the *flying drift* and *landing drift* wires. The *flying drift* wires run from the nose outwards and to the rear; carry the drift of the wings in flight, because the head resistance tends to sweep the wings to the rear, folding them back against the resistance of these wires. Those wires running from the body at the rear beam outwards and to the front are the *landing wires,* and carry the drift of the planes on the ground, since, when the lift under the wings suddenly dissipates, the inertia of motion of the wings tends to carry them on in the forward direction, folding them forward. These wires cross between and tie together the front and rear beams. The structure in front of the front beam is light, as little of the load is ordinarily carried at that point, and the structure aft of the rear beam is correspondingly light for the same reason. In some types, this aft structure consists of nothing but the extension of the rib flanges which meet at the trailing edge and carry a light string stretched between the rib terminals to keep the fabric in shape. This is not good practice, and a more substantial arrangement is desirable.

The external bracing of wires has been explained. Additional external bracing may be so disposed that it serves as a reinforcement in case of emergency. A wire called a *drift wire* may be secured at the intermediate strut, lower fitting, forward, and connected to the chassis well to the front. This wire, resisting the sweep-back tendency in flight, is really an additional support to the *flying drift* wires within the plane structure. When such an additional wire inclines downward, it is also a reinforcement for the *flying* wires which run upward and outward from body to upper plane, in the cells between the main planes. External *drift* wires usually act both as drift and lift wires.

STRUCTURE OF AIRPLANE BODIES

As a unit, the skeleton of the typical fuselage is built up of four solid ash or spruce members, separated by struts (vertical members), and body spars or spreaders (horizontal members), and laced together by cross wires or stays. A front engine plate is normally used, providing fittings for receiving the longitudinals and the engine beds. Another plate is introduced at the rear of the engine compartment, which reinforces the framework rigidly and greatly reduces vibration. The engine beds terminate at the rea fittings on this plate. These plates are made of the highest grade cold rolled steel plate, bored out for lightness and channeled fo strength. To carry out the streamline form of the craft, ligh wooden boards, forming an arch on the top edge and a chord o an arc on the lower edge, are placed with the chord next an across the longitudinals, at regular distances from the nose to th tail. These streamline supports are bored out for lightness. Run ning from front to rear, small, light streamline strips are secure in channels on the arched surface of the supports. The fabri covering the body is attached to this framework and doped.

The wings attach directly to the fuselage. Wing fittings o either side of the body should be bolted through metal tube entering the fuselage and united. Various kinds of fittings ar used for this purpose, however.

The entire airplane is built around this main central body calle the fuselage.

The normal fuselage extends from the nose to the tail.

The single screw type (when the propeller is used for "pull ing" instead of "pushing" it is called a screw) is arranged wit the screw at the nose.

The *Power Plant* consists of one motor and accessorie mounted on properly braced engine beds with the possible excep tion of tanks, instruments and tubing. The power plant occupie the forward or engine compartment. This compartment should b built to possess great strength. The rigidity of the compartmen is of prime importance in reducing vibration, which is the great est foe of aviation. Excessive vibration will quickly shake th best craft to pieces, crystallizing metal parts, loosening member and inevitably leading to a collapse. (The discussion of thi engine compartment construction will be amplified under th subject of AERONAUTIC MOTORS.)

Cockpit. The cockpit for occupants is situated immediatel behind the motor. There are usually two sections or compart ments of the cockpit, except in one-place machines. In some type the pilot occupies the front compartment, but as it is normall located under the canopy of the center panel, with a high cow in front, and with struts, wires and planes to the sides, visio is unfavorable. Situated on or near the center of pressure, th pilot is sitting on the hinge of action, so to speak, and the lo cation is generally undesirable for piloting. The front seat i even worse for observing, and altogether, the forward compart ment offers a most decided disadvantage for military work i the air.

Tails. In military machines which must be dismantled quickl at times, an integral tail (detachable just in rear of the pilot' seat) is desirable. Four unions are fitted to the longitudinal

The arrangement cannot be as strong as one in which the entire fuselage is a unit. Great difficulty is sometimes experienced in obtaining ash members of sufficient length for longitudinals running from nose to tail. Properly spliced material may be used for longitudinals. The tail section of the fuselage carries out the streamline form and at the rear extremity the stabilizing and control surfaces are attached. Usually, an elastic, pivoted tail skid is carried on the base of the rudder post, properly considered as a part of the landing gear.

RUNNING GEAR

(Generally called *chassis*)

The body is mounted on a running gear consisting of chassis and wheels. The normal 3-point bearing type consists of two wheels for forward bearing and a tail skid mounted to the rear and beneath the tail, for rear bearing. The wheels are carried on axles secured to heavy chassis struts by some device that provides the necessary elasticity. Sometimes an auxiliary wheel or wheels are carried out to the front to prevent nosing over when making a rough landing or alighting on soft ground. Four wheel and double wheel types, and skids and wing tip wheels are not generally satisfactory.

CONTROLS

The Rudder. Three independent sets of control surfaces are employed in airplanes. The rudder at the rear, like the rudder on a seacraft, turns the plane around on the ground and in the horizontal plane when flying.

The Balancing Device. The action of rough air which tends to upset a machine and the tendency to skid when turning, necessitate the introduction of some means for balancing the craft and for tilting one wing to get the necessary bank in turning. The latter operation is vital to keep the nose "head on" when circling, as excessive skidding is dangerous. The further discussion of this matter is to be found under the subject of FLYING. Several devices have been introduced to accomplish the same result.

The Warp or Flexing Panel. The warping or flexing plane was the first device adopted to give lateral control. The warp is the most efficient arrangement devised for balancing, but it leads to early fatigue of material and many collapses have ensued.

The Aileron or Interplane Flap. The aileron or interplane flap was next introduced. It is comparatively inefficient, since it offers head resistance, whereas the other devices are streamlined behind the main planes. The interplane aileron is the most direct method of control, however, since it can be balanced at its center of pressure so that the slightest movement will cause positive action.

Trailing Flaps. The trail flaps are distinguished from single action flaps by operating in series. In the single action type the flap on only one side of the machine operates at a time; the other streamlining with the pressure. This type is not deemed suitable; increase of efficiency is not sufficient to compensate for sacrifice of control.

The simplest type of the balancing control is one in which the flap on either wing is elevated while the one at the opposite wing extremity is depressed. Obviously, the wing rises or falls as its flap is elevated or depressed. Single action flaps have a tendency to "slew" the machine toward the low side. With double action flaps the machine will rotate around its fore-and-aft axis with perfect balance, since one wing rises and the other depresses with equal *moments.*

Elevators. The elevators, located at the extremity of the tail, are hinged at the front end, on an axle parallel to the main planes. There are usually two elevators. In case one elevator goes out of control in flight, the other should enable the pilot to reach a landing field without damage, unless it becomes locked out of the streamline flow.

The action of elevators is similar to flaps. By increasing the angle of inclination to the front the elevator gains greater lift. After giving desired degree of ascent, or descent, the elevator is returned to normal. The machine continues flight along the path selected, unless the craft does not fly true. Controls are usually adjusted so that the control post wheel or bar is pulled to the rear to ascend, decreasing the uptilt of the elevator, and by pushing forward on the control to descend, which actuates the elevators in a reverse direction.

Stabilizers. The stabilizers are fixed surfaces designed for shape, area and position to counteract tendencies to nose up or dive. All dead surfaces, such as stabilizers, are called fins. Stabilizers are horizontal fins to increase longitudinal stability; panels are vertical fins, either fusiform or simple curtains, placed between the planes; keels are fins similar to panels. They are located longitudinally *beneath* the lower plane. Fins proper are vertical stabilizers set upon the tail. The common purpose of all fins, panels and keels is to so dispose the lateral surface offered in flight that the machine will tend to resist skidding, side-slip, other loss of control, or unfavorable flying tendencies. It is plain that if the craft has too much side surface below the center of gravity, in the event of a side-slip, the resistance would prevent the bottom from falling faster than the top which is the effect necessary to restore the craft to its upright position. Similarly, if too much side surface is offered between the main planes, in a side-slip the side resistance at this point will overcome the side resistance offered by the tail, and the tail will fall faster than the nose, the situation to be avoided. The use of fins of various kinds, if properly placed, provides almost unlimited possibilities in the control of inherent stability. The general rule is to avoid too much side surface at the nose; too much side surface above the center of gravity of the body is likewise dangerous. Fins placed high above and to the rear of the tail give excellent righting qualities.

*Among all aircraft personnel, the most positive and inflexible rules should prevail as to the exact authority in matters of alterations, removal of equipment and installations on aircraft. Every care should be exercised to differentiate between the work properly belonging to a designer, builder or engineer, and the work or labor of the unskilled. No man whose knowledge and experience are not definitely known, should be entrusted with scientific work or with construction or alterations on aircraft. Blunders, oversights and inexperience are not to be tolerated in flying service.

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* A glaring example of incompetence and ignorance is employed to illustrate this point. A young and inexperienced officer was given the task of building up a machine that had been wrecked. During the course of the assembly he decided to introduce an angle in the plane structure formed by a combination dihedral and inverted-dihedral angle in each wing (a flat V in each wing with the point of the V upwards), which was expected to give unusual properties of stability to the craft. Notwithstanding the wings were built in solid section, in order to obtain the desired angles, he applied the correction by tightening flying wires in one cell and loosening them in another until a distinct bow appeared in each wing. What happened in the first flight can well be imagined. Another officer, with an observer, started on a cross country flight under military instructions that did not permit the pilot to test his machine over the flying station. After travelling 65 miles, a storm was encountered and in the heavy plunging of the craft, the unusual and excessive stresses borne by some of the brace wires caused an extensive ripping out of wires in one wing. The machine went out of control falling end over end for several thousand feet when partial control was gained just before striking the sea, where a landing was effected. One of the officers lost his life before rescue. Such is the importance of restricting all men who work on aircraft matériel and safeguarding flyers from such gross incompetence. Blunders are usually fatal and irreparable in this field of work.

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TRAINING IN AVIATION

CHAPTER 7

MILITARY AIRPLANE TYPES

For military purposes, airplanes may be grouped and classified as follows:

Class I. Military Planes: (generally unarmed; if armed they may be considered under Class II.)

1. Training Machines: a. Primary type, b. Advanced type.
2. Dispatch and miscellaneous types.

Class II. War Planes:

1. Reconnaissance Machines: a. Tactical (short flight type), b. Strategic (long flight type), c. Intermediate Scout type, d. Artillery Fire Control type.
2. Combat planes: a. Destroyer or Pursuit planes, b. Cruiser planes, c. Battle planes (rapid-fire armament), d. Super-battle planes (rapid-fire battery).
3. Bombardment Planes: (armed with bombs; sometimes equipped with machine guns, rapid-fire guns, or both. In the latter case classified as super battle-planes).

If each of the above classes of airplanes were necessarily of a different type, the matters of technical production, training activities, and tactical employment would be rendered complicated and intricate. The supply of such a heterogeneous organization would be hopelessly involved.

In actual practice, the above classified functions demand several types of craft, but in many cases a type of airplane is suited to more than one use. The types of planes on the market afford ample range of qualities to meet the requirements. This simplifies the problem greatly and enables selection of types that give the broadest range of qualifications.

Multiplicity of types should be discouraged for the reasons given herein. Standardization of types and of airplane parts, accessories and equipment are among the most important considerations governing the operation of the flying corps. It is as useless, however, to expect that one or two types will fulfill all the requirements as it is to ignore provision of air units capable of discharging every military function.

The following table gives the general rules governing the selection and disposition of types of airplanes.

TABLE OF MILITARY AIRPLANE TYPES

TYPE	QUALITIES REQUIRED	MILITARY FUNCTIONS
Type "A" PRIMARY TRAINING TYPE % demand = 25	Tractor Biplane. 80 Brake Horsepower. 2-place. Military load, 375 lbs. Radius of Action about 200 miles at full power. Climb = 2,600 ft. /10 min. High Speed = 66 m. p. h. Low Speed = 37 m. p. h. Should have high factor of safety.	For use in training beginners through preliminary and initial stages of flying; for both pilots and observers. Artillery-Fire-control type. Suitable for use as transport for staff officers within lines. Kite-balloon auxiliaries. Interior reconnaissance duty. Night flying.
Type "B" ADVANCED TRAINING TYPE % demand = 20	Tractor Biplane. 100 Brake Horsepower. 2-place. Military load, 400 lbs. Radius of Action about 300 miles at full power. Climb = 3,000 ft. /10 min. High Speed = 75 m. p. h. Low Speed = 43 m. p. h. Should have a high factor of safety.	For use in advanced training of student aviators. Tactical (when carrying radio and additional equipment); Intermediate Reconnaissance. Artillery-Fire-control. Dispatch planes, and transporting staff officers. Interior reconnaissance. Seaplanes: Tactical reconnaissance and artillery fire-control.
Type "C" PURSUIT TYPE (Light-armored) % demand = 21	Tractor Biplane or Triplane. 110 Brake Horsepower. Radius of Action about 315 miles at full power. 1-place. Military load, 200 lbs. Climb = 8,000 ft. /10 min. High Speed = 115 m. p. h. Low Speed = 55 m. p. h. Armament, 1 or 2 machine guns.	Pursuit type, combat plane. NOTE: This type is used for local sentry duty, outpost or station control. It may be used for artillery fire-control and tactical reconnaissance, but its high speed is not favorable for the work. It is especially valuable for offensive operations not involving distant flights. Useful for local coast defense work.

Type "D" CRUISER TYPE (Armor protection for personnel and tanks) % demand = 30	Tractor or Pusher Biplane. 260 Brake Horsepower. Dual motored power plant, 2 or 3-place, Military load, 550-1,100 lbs. Radius of Action about 450-600 miles at full power. Climb = 3,400 ft. /10 min. High Speed = 90 m. p. h. Low Speed = 47 m. p. h. Armament, 1 or more machine or rapid-fire guns of small caliber.	Cruiser type, combat plane. NOTE: This type is employed for patrol and outpost duty both within and outside of lines. Strategic reconnaissance. Convoy duty. Light bombardment plane (if so equipped). Seaplanes: Combat duty, intermediate and strategic reconnaissance. This craft offers the widest range of qualities of the types given in this table.
Type "E" SUPER-PLANE TYPE % demand = 4	Tractor or Pusher or Combination Pusher-Tractor multi-motored Biplane or Triplane. The latter type offers greater advantages. The performances of super-planes vary, as in smaller planes. Generally, super-planes are slower, possess inferior maneuvering qualities, but have increased weight-carrying capacity, radius of action and steadiness in flight. (See text, following pages, for performances of this type.)	Battleplanes; carrying heavy armament, two or more rapid-fire rifles, machine guns, and a load of bombs. This type is manned by a crew of 3 or more men. As many as 20 persons have been carried in these types. The fighting crew of the largest types averages between 7 and 10 men, navigator, pilots, engineers, gunners, radio operator, observers. Super-battle planes are the largest types in use, craft having a wing spread of over 100 feet. Heavy bombardment planes; this type is peculiarly adapted to carrying heavy loads long distances; steadiness in flight is advantageous to accurate work in dropping bombs.
Type "F" MISCELLANEOUS TYPES SOLO TRAINING TYPES	Type A, Pusher Biplane. About 30 H. P. Single-seater (with adjustable throttle). Type B, Pusher Biplane. About 40 H. P. Single-seater. Type C, Pusher Biplane. About 60 H. P. Single-seater. High factor of safety.	Type A, for training beginners in taxying. Type B, for first flights; maximum altitude attainable, about 10-25 feet; *"grass-cutter."* Type C, for training to include pilot's tests.

NOTES ON TYPES

The foregoing classification of planes employed for military purposes shows that a given type may possess qualities that render it suitable for a variety of uses. Versatility of performance should be sought in planes. Experience has proved that the effort to combine a wide range of qualities in one machine may produce a dangerous craft. As a rule, however, types should be chosen and adopted that offer the greatest range of uses. Special features of many types can be profitably abstracted although the type may be generally unsuitable for military work.

The best practice indicates that types of craft used in the air service should be supplied in the following approximate proportion:

Preliminary Training Type	25 %
Advanced Training Type	20 %
Pursuit Type	21 %
Cruiser Type	30 %
Super-plane Type	4 %*
	100 %

For every type of machine it has been found that the maximum radius of action can be obtained when the proper proportion of gross weights is not exceeded for the component units of the airplane. The following table issued by the War Department is given to illustrate this important fact:

For Cruiser Type Airplane (see Table of Military Airplane Types).

		Per cent of total gross weight
1.	Airplane, without power plant, fuel or military load, but including main planes, fuselage, fuel tanks, chassis, control and auxiliary surfaces, etc.	31.0 %
2.	Power plant, 130 H. P., including motor complete (without oil), radiator, water, propeller, etc. ...	31.0 %
3.	Military load, including pilot, observer, instruments, machine guns, ammunition, bombs and racks, radio set, camera, etc.	19.5 %
4.	Fuel load, gasoline and oil for 5 hours' flight at full power	18.5 %
		100.0 %

Under the table, Military Airplane Types, planes not armed are classed *Military Planes* as distinguished from armed *War Planes*. The practice should be adopted of arming every plane that is subjected to the possibility of attack by hostile aircraft.

* Perhaps greatly underestimated.

Machine guns weighing less than 30 pounds should be installed in all craft so exposed. Sometimes reconnaissance planes of the strategic type rely upon speed to avoid combat, thereby saving the weight of machine gun for more indispensable equipment. Other expedients to avoid reduction of weight through arming planes, include the guarding of exposed unarmed machines during their operations by fighting craft, stationed at higher levels. The best practice is to arm all military planes.* Machines armed for defense only should be equipped to fire to the rear.† All war planes, except those of the tactical type should be capable of attaining an altitude of 12,000 feet. In this way, when not engaged at lower heights, they can obtain greater security. All military and war planes should be painted to blend with the background of sky or earth. To obtain this additional protection from attack, the under and side surfaces are painted a sky blue color and the top surfaces are mottled to blend with the earth. Transparent planes are not reliable, either because of inflammability or fragility of surfacing materials used. Non-inflammable materials should be sought in airplanes.

The following established rules should be strictly followed in the construction of military machines in general.

1. Observation: field of view as large as possible to the front and below.
2. Good inherent stability.
3. Covering for crew: inclosed body; armor protection.
4. Dual controls (each must be independent of the other at will). This does not apply to one-place machines.
5. Navigating instruments visible to first and second pilots.
6. All tanks on the same level.‡

General Features. The following improvements in aircraft are immediately needed:

Increased radius of action;

Reduced visibility; materials possessing proper strength, durability and non-inflammability;

Improved precautions against fire;

Silenced armament; invisible powder;

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* Mountings for airplane armament should be installed in the framework of the body. These fixtures should be incorporated in the design of the plane. Loads attached to completed planes, without reference to stresses or strains may lead to dangerous results.

† An excellent arrangement for armament to obtain both fore and aft action is as follows: Pilot seated in front cockpit; observer or gunner in rear cockpit, serving machine gun mounted on a metal ring encircling cockpit. Another machine gun is mounted on the upper plane, giving all-round fire. This piece is operated by means of a system of coördinating levers and sights. The gunner is provided with a revolving seat, which increases his comfort and greatly improves the accuracy of his firing.

‡ One foreign government has adopted the announced policy of favoring manufacturers of types that fulfill the following conditions:

1. Capacity for building immense lots in a brief period of time.
2. Facility of up-keep, and ease of dismounting motor.
3. General dimensions of craft reduced to a minimum.

Muffled motors;

Increased range of speed, particularly in the direction of lower speeds;

Increased stability without cost to controllability.

Monoplanes, Biplanes and Triplanes. The respective merits of the monoplane, biplane, and triplane types of airplanes are well established. Monoplanes are little used except for high speed work. Biplanes are the most commonly used type. Triplanes are rising rapidly in favor, particularly for super-plane models.

Tractor and Pusher Types. The great majority of military and war planes are of the tractor type. This is principally because the tractor type is highly adapted to extraordinary refinement of streamline finish. The location of the motor in the front of the body removes the menace to occupants of being crushed in case of a short fall. The tractor type, while comparatively safe in short falls, cannot be expected to prevent crushing the occupants in a fall from any height over 75 or 100 feet. The rear seat is the safer in the event of a fall. The strength of body structure is all important in a smash. Weak bodies or engine bracing permit the motor to crush through the intervening partition into the front seat. This constitutes the menace to occupants of the front seat, even in a comparatively slight fall. Increased safety can be secured by placing wicker partitions in front of each occupant of the plane. These wicker members should be slung from the body frame or longitudinals being attached well in rear of the occupants.

The pusher type, having the motor at the rear, is used where field of view is required. The type is also useful for disposition of armament to secure the most effective fire to the front.

Twin and Multi-motored Planes. Constructors and military authorities agree in recognizing the value of dual and multi-motored planes. Having more power, other things being equal, a plane will climb more rapidly, fly faster, and carry greater loads, but the increase of carrying capacity is not proportionate to the increase of horsepower. To design craft on this theory without ample power margin is dangerous, however, as the failure of one of the motors might lead to disaster.

Twin motored planes cannot fly on one motor when loaded, without descending slightly and continuously, to maintain sufficient speed. In war zones, such a contingency would render the craft incapable of defense against hostile planes or anti-aircraft batteries and probably unable to reach the safety of its own lines. While this is also true of single motored planes, obviously the probability of perfect functioning is less in the case of a two-motor combination than with a single motor.

Twin motored planes are dangerous to handle on the "float-off," for if one of the motors stops at this time, the machine is thrown off balance. It is difficult for the pilot to recover quickly.

Bombardment planes should be twin or multi-motored.

The use of more than four motors is not considered here.

Multi-motored planes are usually combination pusher-tractor machines. The best practice is to arrange the motors in pairs, two on each side of the fuselage, in column from front to rear. The forward motors each drive a tractor screw, the rear motors each drive a (pusher) propeller. The motors are mounted as close to the fuselage as the swing of the blades will permit. (NOTE: The normal minimum propeller clearance required is 8 inches.) The motors are mounted within a streamline hood to reduce head resistance.

Structural Details of Multi-motored Planes. Bracing of interplane motors is usually accomplished by means of V and inverted V-shaped steel tubing, from the lower and upper surfaces, respectively. When the motor units are placed outside of the fuselage, or nacelle, the space normally occupied by the power plant is available for other uses. One arrangement is to divide the body into three compartments, the center being filled by the gas tanks. A tower structure of streamline form, very narrow in cross-section and approximately the length of the chord of the planes, is employed to carry the right and left wings. The space within this tower is utilized for gravity tanks, which feed the motors. Exits in the body give access to the motors on each side. The lower deck is normally constructed of wood-veneer between body and motor units.

Super-plane Landing Gears. Owing to the extensive loading of motors in the wing sections of multi-motored craft, the bracing to chassis must be more or less elaborate. If the use of a center chassis does not give sufficient strength, carriers must be placed under each motor unit. The landing gear problem in super-planes has always offered many difficulties.

A successful type of super-plane landing gear consists of a large, fixed nose wheel. Four smaller wheels are secured on axles, on each side of the body. A flexible frame carries the transverse axles, separated by spreaders. Heavy spring mounted struts secure body to chassis, and the entire structure is braced by heavy, diagonal thrust members.

Structural Details of Triplanes. Many typical features are introduced into triplanes, especially multiple motored triplanes carrying interplane motors. The design should be such as to facilitate access to the power plants. Upper and lower planes should be in single units to the engine section. Middle planes may terminate at the motors. The lower plane should be covered with durable wood veneer in order that the motor engineers can walk around the power units. Diagonal wiring between planes passes the middle plane at the mid-point between struts and joins the middle plane by means of special fittings. Vertical and horizontal rudders (elevators) are normally balanced in large planes.

Armor. Protective armor should be provided as far as possible, when it can be done without reducing the efficiency of the craft. Effective armor should be provided in the following order of importance:

1. Tanks,
2. Radiators,
3. Pilots,
4. Projectiles,
5. Observers.

General. Powerful bombarding planes, heavily laden with bombs, are not designed to climb rapidly. This type should mount to 6,600 feet in not to exceed 30 minutes; 10,000 feet in not to exceed 50 minutes; have a speed of about 85 m. p. h. at an altitude of 8,000 feet; a range of speed of about 40 % of the maximum speed.

For warplanes it is desirable that dual controls be provided and so installed that the control may be engaged or released by either pilot at will. A very convenient arrangement for gunplanes is obtained by the use of two operators who are trained to alternate the duties of pilot and gunner. Each is provided with a weapon so that fire can be brought to bear, from either the front or rear seat, the operator not engaged in firing, manipulating the controls. Each gun should have an arc of fire of 180 degrees. Bombs should be carried and launched from a horizontal position.

SEAPLANES

Both biplane and triplane types are useful for hydro-airplane work.

Seaplanes are heavier than airplanes of the same type on account of the heavy floats which seaplanes carry.

Seaplanes are used for military functions similar to those discharged by land machines. For coast duty, airplanes may be used for tactical work within gliding distances of the shore. Airplanes are used for pursuit duty along the coast. Superplane types are required for bombardment work over the water. The cruiser type is useful for combat and light bombardment operations. Smaller craft may be employed for artillery fire-control and reconnaissance.

FEATURES OF SEAPLANE TYPES

Seaworthiness. Seaplanes should be capable of rising from the water and running before a wind of 7 miles per hour, fully loaded. An efficient seaplane should rise from smooth water within a brief period of time with its full load. 1 and ½ minutes should be the maximum time consumed in the run. The machine should rise from smooth water in calm air in a run of less than 1,000 feet. The craft should be seaworthy, showing no tendency to capsize on a skidding landing or when running on the surface at high speed, with moderate sea and wind abeam. The seaplane should normally head into the wind when adrift, ride safely on a sea anchor, with the tail out of water, in a wind of 25 miles per hour. The craft should be equipped with bow chocks and cleats for towing or mooring. Propellers should be so disposed that they are not unduly exposed to the action of spray while taxying. Seaplanes must land in a choppy sea, in waves 3 or 4 feet high, crest to trough; without a tendency to porpoise in a calm sea; or in a wind blowing less than 12 miles per hour, when landed from any direction. Water aircraft should be taxied on water, executing figures-of-eight within a rectangle of 1400 feet x 600 feet.

Airworthiness and Flying Qualities. Seaplanes should be subjected to rigorous tests to determine flying qualities. Owing to the great weight of floats, and the large areas of exposed float surfaces it is more difficult to obtain good flying qualities in seaplanes than in airplanes. The weight of floats must be compensated for by reducing the load where it can best be spared. Low centers of side and head resistance must be counterbalanced by high panel-fins or other features of design.

Seaplanes should be required to perform air maneuvers that prove them to be airworthy. Seaplanes should be tested to dive at steep angles, and take steep banks to right and left without loss of altitude. The craft should possess celerity of response to control; proper degree of static and dynamic stability; steadiness in disturbed air under various flying conditions; ability to drive in any desired direction with respect to a wind with a velocity up to 15 miles per hour; ability to land with a 15 mile wind without danger of nosing over; capacity to rise, without danger to floats in a 25 mile wind and land safely in a cross wind of 10 miles.

General Requirements for Seaplanes. Seaplane materials must be protected from water and dampness. All butt ends of wood members must be impregnated against moisture. Spar varnish should be properly applied to all woodwork. All material should be selected with special reference to its resistance to salt water action. Propellers must be especially protected. If tipped with copper metal, drain holes for water should be cut in the tips. Seaplanes should be fitted with attachments on the upper plane, over the center of gravity of the machine, which enable hoisting from the water by means of a crane.

The factor of safety of seaplane parts exposed to deterioration should be very high. This factor should be not less than 7 to 1.

For members not exposed to deterioration, the factor of safety should be 6 to 1.

TESTS (U. S. GOVERNMENT SPECIFICATIONS)

Any or all of the following rules governing the method of conducting performance tests may be enforced at the discretion of the inspectors:

(1) Any or all machines must pass any or all tests to demonstrate guaranteed performances, and to demonstrate that all provisions of specifications have been complied with.

(2) All tests shall be started at approximately sea level.

(3) For all tests power plant and airplane shall be identical in every detail with the arrangement it is proposed to use in practical service.

(4) The same type propeller, the factor of safety of which is satisfactory, shall be used for all tests.

(5) The motor shall not be driven during any performance tests at a speed greater than normal revolutions per minute.

(6) The gasoline used shall be standard automobile gasoline testing not higher than 65° Baume.

(7) The number of officially observed attempts for each performance shall be decided upon by the inspectors at the time of the tests.

(8) For speed tests, machines must be flown at a height of not more than 25 feet for a distance of not less than 900 feet. The original altitude must be maintained over the specified course from start to finish.

(9) The location and length of the course for the speed tests will be decided by the Government.

(10) The period of time for the climb shall start at the instant the wheels leave the ground or the seaplane floats leave the water for flight.

(11) Climbing and speed tests shall be made by a pilot in the employ of the company.

(12) Stop watches, barographs, and other instruments necessary for measuring the speeds and the rate of climb shall be provided by the Government. The fuel and oil shall be supplied by the Government.

(13) The inspectors may at their discretion, prohibit unreasonable delays in performance tests, caused by adjustments in power plants or airplanes which should in the opinion of the inspectors have been made before the date of delivery as guaranteed in the contract.

(14) There shall be an inspection of the machine immediately after any test to show that all parts and connections of the power plant and of the airplane are in good condition.

GENERAL RULES FOR TESTS

(In addition to those cited in the preceding list.)

1. Complete loads should be carried in each test.

2. A registering revolution counter should be used to record the speed of propellers.

3. Horizontal speed should be taken at specified altitudes, regulated by the war altitude at which the machine is expected to fly normally. The speed should normally be taken at 7,000, 10,000 and 13,000 feet successively, for planes to be used in military operations.

Speed on the ground (just off the ground) constitutes an excellent test of good piloting, but is of little value in determining the efficiency of a machine. Uniformity of altitude must be demanded. Descent, however slight, increases the speed. When timing speed tests by direct method, flights should be made in three directions to neutralize wind effect. A second method of measuring the horizontal speed, consists of employing the Venturi tube, or differential registering manometers. Speed over the ground is used to calibrate the instruments. This calibration must always be made to determine that the air pressure instruments are situated in a neutral zone of pressure of suction.

4. Vertical speed or climbing tests should be made to altitude prescribed, as above explained, for horizontal speed tests. Two registering barographs are used for this purpose. The average speed for each 1,000 feet should be determined and plotted on a diagram to show the theoretical maximum attainable altitude. It is good practice to require two separate climbs, on two successive days, the official climb being taken as the mean of all climbs.

5. The angle between the chord of tail surfaces and the line of flight should be measured in flight by a registering linimeter, connected to the elevators.

6. Gliding tests should be made without motive power. Gliding angle should be taken from minimum test altitude. This angle may be determined by direct measurement from the barograph, showing the altitude from which the descent started, the horizontal component being computed on the ground. The glide is made in a straight line. Registering anemometers may be used.

7. Duration flights should be regulated by the designed performances of the plane. The duration flight is normally made at the minimum war altitude of about 5,000 feet. Full power is required. Careful examination of power plant is made on completion of this test.

8. Complete static tests should be made at the factory under the scrutiny of government inspectors. When planes are inverted and loaded to simulate flight loads, inclination of the axes of propellers should be made to allow for resistance due to drift.

The factor of safety to rupture in airplanes should never be less than 5 to 1. Better practice is 7 to 1. Raising the factor of safety reduces the efficiency of the plane. This factor therefore has a well-defined limit.

TRAINING IN AVIATION

CHAPTER 8

AERONAUTIC MOTORS

Without the gasoline engine, navigation of the air would still be unrealized, as far as other forms of power in use today are concerned.

Steam, electricity and man-power have all been applied in the struggle of man to master the task of flight. The internal combustion motor succeeded because it delivered an immense amount of horsepower in proportion to its weight. Gasoline is the fuel universally employed at this time. Efforts to produce a more satisfactory fuel have not resulted fruitfully.

Gasoline motors have been produced in a variety of types. The principal types are the vertical, V-type, rotary, radial and horizontal opposed.

The vertical and V-type have proved most successful in our service and have been adopted as the standard types.

These types may be considered as possessing the following standard features: four and six cylinder vertical types; eight and twelve cylinder V-type. These motors are all of the four-stroke cycle type.

For purposes of instruction, the four cylinder, vertical, four-stroke cycle type is taken as the typical motor.

The Four Cylinder, Vertical, Four-stroke Cycle Tyie Engine

The fundamental principle upon which the operation of the internal combustion motor is based is as follows:

A mixture of gasoline vapor and air is very combustible when confined in a small space and ignited. The reaction is powerful, causing an explosion and expansion which can be converted into motion and power.

An aeronautic motor is an internal combustion engine, differing from those used on the ground, principally in lightness of materials and in the methods employed for utilizing the power delivered, i. e., to drive air propellers.

The object of any motor is to produce power either within itself or in a shaft which will transmit the power wherever necessary. The power is obtained by compressing and exploding gases in an enclosed chamber and converting the force of the explosion to a harnessed motion.

There are four operations necessary in the utilization of power:

a. Generation of power.
b. Conversion to harnessed motion.
c. Transmission.
d. Application.

These mechanical operations may be compared with the manual operations performed in turning a winch. The power of the man represents the exploding charge of gas in the cylinder which forces the piston down its length; the arm represents the connecting rod of the engine which transmits the motion. The hand represents the bearings of the engine; the handle of the winch represents the crankshaft. The windlass corresponds to the flywheel or its equivalent in this comparison.

The Four-stroke Cycle Principle. A study of the action of a gas engine naturally commences with a consideration of the successive functions that take place within a cylinder, by which power is generated.

Suction Stroke. Before the motor can be started, the gas to produce the power must be admitted to the cylinder. The piston moves downwards in the cylinder, the gas is sucked in and this stroke is called the *suction* or *first stroke.*

Compression Stroke. The explosion by which power is generated is more efficient, more power being derived, if the gas is compressed before firing. This is the purpose of the *compression* or *second stroke.*

(This much of the operation must be performed by hand, or by means outside the motor such as a starting device, in order to start the motor.)

Firing, Power or *Explosion Stroke.* The mixture is now ready to be fired. An igniting device timed to spark at the proper instant causes explosion of the gas and the third stroke takes place under the application of power. Hence it is called the *power* or *third stroke.*

Exhaust Stroke. The spent gases must now be expelled from the cylinder before new gas can be admitted to repeat the operation. The piston moves to the top and the cylinder is cleared. This stroke is known as the *exhaust* or *fourth stroke.*

Each of the above individual operations will be called a phase. From these four phases, the motor is known as a 4-phase, 4-stroke or a 4-cycle motor. (The term 4-cycle, although most commonly employed, is a misnomer. The term 4-phase is more correct. The best practice gives the name *four-stroke* cycle.)

WITHOUT A CLEAR CONCEPTION OF THIS PRINCIPLE, IT IS USELESS TO PROCEED FURTHER WITH THIS SUBJECT.

The operations classified here may be expressed in another way.

A charge of gas is admitted to the cylinder and compressed. A spark ignites the gas thus causing an explosion. All means of escape being cut off, the piston, free to move down the interior of the cylinder, gives way under the impulse of the explosion, and moving, transmits motion to the crankshaft by means of a connecting rod joining piston and crankshaft. At one end of the crankshaft is a flywheel, which being a balanced mass, rotates freely when once put into motion, with sufficient "inertia of motion" to carry it around several revolutions without the further application of power. This causes all the working parts to respond and the piston is now carried up and down by the flywheel, which it put into motion. This *counter* force is used to lift the piston, and expel the spent gas. As the piston is drawn to the bottom, a fresh charge of gas is sucked in. There is still sufficient energy to lift the piston to the top of the cylinder, compressing the charge into a small space. Just before, or just as, the piston reaches the top of its stroke, it is again ignited by a spark and this application of power starts the operation all over again.

In connection with this discussion it is apparent that some device must be provided for regulating the admission and expulsion of gases but by such means that the cylinder may be closed tightly while the charge is first compressed and then exploded. Two openings are provided in the cylinder head, called the *intake* and *exhaust* ports. These ports are fitted with valves, operated by mechanical connections with the moving parts of the motor.

NOMENCLATURE OF THE MOTOR

Up to this time the discussion has dealt with a single cylinder. In a four cylinder motor, the cylinders can be so arranged that a different function will be taking place in each of the four cylinders at the same instant; a power stroke can thus be applied to one of the four pistons each time that a piston moves through the length of its cylinder. This renders the action more continuous and uniform.

The general construction of a motor consists of a series of chambers in which gas is exploded. Pistons are fitted within each cylinder, joined by connecting rods to the crankshaft. The crankshaft transmits the motion to the desired place, turns gears which operate auxiliary working parts, assists in oiling and performs a variety of functions. An auxiliary shaft is driven by gears from the crankshaft. This member is called the camshaft. Upon its several cams are mounted rods that actuate the valves, regulating the opening and closing of intake and exhaust ports. A system of devices is provided to carry the liquid gasoline to a mixing chamber, blend the sprayed gasoline with air to form an explosive mixture, deliver this mixture through a valve by which the volume can be controlled, thence through pipes called mani-folds which connect with the cylinders at the intake ports. A ignition system is provided which delivers a spark to each of th cylinders at the proper time. Continued gas explosions and fric tion of running parts, generate great and excessive heat whic must be controlled by lubricating and cooling systems.

The parts of this structure are mounted on, or within, metallic case, called the crank-case, which serves as a combine foundation and house for the assembled motor parts.

While great variety is to be found in design of motors, th principles of construction of all motors are substantially the sam

Motor Units

Cylinders are cast or built up in single units, or cast in pair fours or sixes to make a single unit. Where four or more cylin ders are cast together, it is called "en bloc." In aeronautic moto it is customary to use the built-up type of cylinder constructio although the dual cast and built-up block types (two built-u cylinders frame-welded together), are used. Cylinders are nor mally distinct from the crank-case in aeronautic practice. Hol ing down bolts or rods are used to obtain the necessary rigidit of the cylinder in its seat on the crank-case. The interior wal of the cylinder are machined with great care and accuracy receive the piston. Over the exterior wall is fitted a jacket b means of which water is circulated around the cylinder, for coo ing purposes. In the air cooled type of motor, cooling fins are part of the exterior cylinder walls. The cylinder is provide with one or more intake and exhaust ports. Seats are provide for the valves which close these ports. Valve mechanisms a mounted on the cylinder.

Pistons are hollow metal parts usually of cast iron, steel aluminum alloy. Channels are cut around the outer face of th piston wall. Split rings of cast iron are seated in these channel More rings are used as a rule in slow speed motors than in hig speed motors. The function of the piston is to compress the ga in the explosion chamber and to transmit the power applied it, by the explosion. The closed end of the piston is placed u wards, i. e., towards the explosion chamber. The function of th piston rings is to reduce leakage of gas from the explosio chamber and passage of oil into the explosion chamber. Th piston is fitted to the cylinder with an exact clearance. Th clearance depends upon the type and design of motor. It ma be stated as a general rule that the clearance varies with th designed speed of the motor. In high speed motors it is not desi able to have the small clearance of low speed motor pistons o account of great expansion of the pistons due to unusual frictio and generated heat. (Note: The employment of high speed aeronautic motors promises to increase in the future.)*

Wrist Pins or Gudgeon Pins or Piston Pins. This fitting is placed in the piston to join the latter to the connecting rod, which in turn is connected with the main drive shaft of the motor. The wrist pin is seated in the piston walls. The upper end of the connecting rod is secured to the wrist pin. The wrist pin must be mounted to turn in its seat, or as in more common practice, the connecting rod bearing must be so adjusted on the wrist pin. In either case a bronze bushing is used as a bearing surface. Wrist pins are made of high grade steel, hardened and ground to exact dimensions.

Connecting Rods. This device is a metallic arm. There are two bearings, the upper, connected to the wrist pin; the lower, connected to the crankshaft. The lower bearing usually consists of a split bearing of bronze and babbitt. The bronze is used as a base for the babbitt which is special metal having properties as a bearing surface. The babbitt is carefully scraped for adjustment to an exact clearance. Connecting rods are usually made of dropforged steel in the form of an I-beam.

The *crankshaft* is a bar of high grade steel and is the main drive shaft of the motor. This shaft consists of a bar having the proper number of "U" shaped offset arms, called crank-throws, to accommodate the connecting rods, from each of the several cylinders. The center line bearings are seated in mountings in the crankcase. The number of bearings vary with types of motor. The seats are usually of babbitt or other high anti-friction metal and adjustments must be made with nice exactitude. The crankshaft is usually drilled for oil ducts and hollowed to reduce weight. The member must possess great strength despite this form of construction. A large part of aeronautic motor troubles commence with the crankshaft. If crankshafts are too light they do not possess the required strength, but experience has proved that weight is no criterion of crankshaft suitability. A flywheel may be used in certain types. The weight of flywheel is an important consideration in aero motors, where every piece of material must be reduced in weight as far as possible, consistent with the objects to be attained. Flywheels are useful in reducing inequalities in running, and increasing effective action by tending to counterbalance the dead load of piston parts when not firing.

A system of gears is located at the end of crankshaft opposite the propeller or screw. These gears transmit motion to

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* One authority places the dividing line between high and low pressure engines at about 100 pounds per square inch brake mean effective pressure for engines of the four-stroke cycle type. The pressure of firing is approximately four times the compression pressure. Hence high compression is desirable in increasing power. On the other hand high pressure is wearing on the motor, particularly on valves, valve seats and cylinder walls

a camshaft, oil pump, magneto, instruments and other auxiliary working parts of the motor and accessories. The power is delivered at one end of the crankshaft. The propeller or screw is mounted to drive direct, when secured to the end of the crankshaft. In direct drive motors, flywheels are not ordinarily used. Owing to the fact that the most efficient number of revolutions for the motor is considerably higher than the most efficient number of revolutions for the propeller, it is common practice to introduce reduction gears at the power end of the crankshaft. Reduction gears should be used for motors exceeding 1,400 revolutions per minute. Thrust bearings must be mounted on the drive shaft to which the propeller is attached. This unit is called an *annular and thrust ball-bearing.* If the motor drives a tractor screw (puller type) the thrust bearing is set accordingly. The thrust bearing must be reversed for pusher types, driving a propeller.

The *Crankcase* is a combination foundation and housing for the motor and parts. This vase is constructed of special light metals, usually of an aluminum alloy. It conforms in shape to the arrangements of the type of motor in each case. Generally in aeronautic practice, the crankcase is built in halves. The cylinders are commonly of the single type and distinct from the upper half of the crankcase. The cylinders are bolted down to the crankcase which is provided with bracket extensions or tubular supports that *seat* upon engine beds, for use both when transported in packing boxes and when mounted in airplanes. These supports carry the motor and secure it to its mountings. The bottom of the crankcase is ordinarily employed as a reservoir for the oil used in lubricating the motor.*

Timing Gears. Gear wheels are attached to the crankshaft for the purpose of driving various auxiliary working parts of the motor, such as the valve mechanism, magneto, oil and water pumps, instruments, *et cetera.*

Half-Speed or Camshaft Gear. As two strokes, and therefore two phases, take place in the cylinder (as described hereinbefore) during each revolution, and the cylinder fires but once during four phases, it is evident that the crankshaft makes two revolutions for each complete operation of the valve mechanism. Hence in taking the rotation from the crankshaft to turn the valve mechanism, a reduction gear must be employed which will give the valve mechanism a speed one-half that of the crankshaft. The camshaft gear, of manganese bronze, for example, meshes

* The lowest point of the crankcase in an aeronautic motor should be at the mid-longitudinal point. The oil pump intake should be located at this point. Such an arrangement permits steep climbing and gliding without loss of circulation of oil, i. e., the oil will not uncover the circulating intake as would be the case if the pump were located at one extremity of the crankcase or the sump lowest at one end.

with the crankshaft gear of forged steel. The latter gear has one-half the number of teeth of the camshaft gear wheel. This gives the desired change of speed. (See: Camshaft.)

Idler Gear. The idler gear is a toothed wheel spacer between the crankshaft gear and other shafts seated outside the motor proper. Magneto, pump and other gears may be operated off this gear.

Camshaft. The half-speed shaft or shafts, for operating the valve mechanisms to the several cylinders, is commonly known as the *camshaft,* because it carries on its periphery several irregularly curved collars, or lugs, called cams. A rod called the push-rod, tappet-rod or cam-follower is seated in a cam-follower guide to rest upon its cam; to rise and fall with the turning of the cam. Such a rod actuates the exhaust valve lifting it up and down as it rises and falls on its cam. The intake valve may be opened by suction of the piston. (Both valves are closed by springs.) However, the intake valve, like the exhaust valve, may be actuated by a tappet-rod governed by a cam on the same shaft as the exhaust valve tappet-rod cam or the intake valve system may be operated by a distinct camshaft of its own. It is understood that all the intake or all the exhaust valves operate off the same shaft, in any case. When both valves operate upon the same camshaft, one arrangement is as follows: the tappet-rod runs on the center line of the cam, inside a tube which serves the same purpose for the other valve of a cylinder. This tube rests on an outside cam which is given the form of side rails. This arrangement of combination cams can never be as satisfactory as separate cams and rods for exhaust and intake valves.

NOTE: One criticism of the combination valve mechanism cited here is its complexity. The system is inaccessible to a marked degree and when, in order to give better cooling, the tops of cylinders are not streamlined, the combination system offers more head resistance.)

The following materials are generally used in aeronautic practice. The camshaft is made of open hearth or dropforged steel, with integral cams, case hardened. Five or seven bearings are good practice; bearings should be ground. Bronze bearings are generally used. Aluminum alloy split castings lined with bearing metal bolted together and secured to crankcase are typical of the aero engine most commonly used in our service. Camshafts are drilled to reduce weight.

Valve Mechanism

The valves in aeronautic motors are practically always placed in the head, as this type gives the greatest efficiency. Other types are better suited to automobile practice where noise must be reduced to a minimum. This consideration does not exist in aero motors where it costs power, beyond the advantage of silencing the motor.

Exhaust valve. Tungsten steel is generally used as the material for exhaust valves. This metal has a high resistance to heat, and excessive heats are developed at the exhaust valve.

The valve comprises both the disk and seat. The valve is called a mushroom type, owing to its form of stem and disk. The valve generally opens inwards. The under part of the circumference (towards the stem) is bevelled and ground to fit gas-tight against its seat, which is ground accordingly. The valve operates in a guide and is held firmly in its seat by a specially strong spring. One of the most common troubles with aero motors is from overheating valves, loss of life of springs, with consequent failure to function.

The action of the exhaust valve is as follows: This valve is opened during only one of the four phases of the cycle of operation. This corresponds to one-fourth of a turn of the camshaft. The rise or bulge in the cam which lifts the tappet-rod therefore occupies one-fourth of the perimeter of the cam. Experience has proved that the exhaust valve should open just before the piston reaches the end of the power stroke and close precisely at the top of the exhaust stroke. This adds slightly to the dimensions of the bulge of the cam. As the tappet-rod is lifted by this bulge in the cam, this irregularity is given a curvilinear outline, so that the action will be smooth.

The form and dimensions of the exhaust port must favor rapid and complete expulsion of the spent gases. Aeronautic motors usually exhaust into the open air, as exhaust pipes are mufflers exert a back force that reduces power. Exhaust pipes are not uncommon, however. They are very useful as a precaution against fire, particularly for dirigible work. Exhaust pipes should be used if for no other reason than to carry the oppressive fumes of spent gas out of the airman's face. The employment of mufflers for warplanes may be expected as a logical development.

Intake Valve. Nickel steel is an excellent material for intake valves. As a rule, springs for intake valve mechanism are of the coil type. With the exceptions noted under the discussion of *Camshaft,* the intake valve mechanism operates similarly to the exhaust valve mechanism. The form of the cam, which operates the mechanically controlled type of intake valve mechanism, is of supreme importance. The timing of the intake valve must be exact to derive full power.

Rocker Arms of case hardened dropforgings must be well designed and constructed to withstand the constant hammering to which subjected. This part forms the connection between the tappet-rod and the valve stem. The valve spring maintains the proper pressure to keep the valve seated. The rocker arm transmits this pressure to the tappet-rod and causes it to follow its cam-guide accurately.

Multiple Valves. The use of multiple valves is in the direction of increased reliability just as are double ignition and double carburetion; more general employment of this principle is expected. Unquestionably the problem of securing combined maximum volumetric efficiency and compression can be at least partially solved by resort to multiple valve mechanism.

Spark Plug Seats should be placed with special reference to the flow of gas into the explosion chamber. Advantage should be taken of this flow in locating spark plug seats to derive the greatest possible cleaning effect and to produce the most favorable transmission of the ignition throughout the chamber.

General. It will be noted that the discussion, which commenced with an analysis of the action in a given cylinder, has led through various parts of the motor back to the cylinder. In this discussion it has been taken for granted that fuel was delivered properly to the cylinder and that the spark necessary to explode the charge was created. No discussion has been made of means to overcome the great and excessive heat generated by continued gas explosions and the friction of running parts. It remains, therefore, to consider the subjects of carburetion, ignition, cooling and lubrication.

CARBURETION

Carburetion (as applied to gas engines) is the process of reducing liquid fuel to a vapor and mixing this vapor with the proper proportion of air to form an efficient firing mixture.

Carburetors. The carburetor is a device to accomplish the process defined as carburetion. Numerous carburetors are on the market. The standard type of carburetor performs the following functions, viz.: A float chamber maintains the gasoline at the desired level. A small pipe leads to the jet chamber. A very fine nozzle is fitted to the end of this tube. When the engine is turned or is turning, a partial vacuum is formed by the suction of the pistons through air-tight pipes called manifolds, which connect the carburetor to the cylinders. This partial vacuum sucks the gasoline in a fine spray through the spray nozzle. The suction also draws air in a fine stream through one or more orifices from outside the device. The stream of air is admitted past the head of the nozzle. The gas spray unites with the air to form the desired mixture. Suction performs the entire operation of delivering gas to the cylinders, hence the manifolds must be air tight or the suction will be imperfect and the mixture of gas and air spoiled by admission of air in excess of the required proportion.

The general type of carburetors described here is known as the spray type, and is the commonest form of apparatus for producing gas mixtures. A second type of carburetor must be mentioned in this connection, called the surface type. This form of carburetor is divided into three classes.

1st. Passing air over the surface of gasoline; the air stream carries along a certain proportion of gas vapor by evaporation.

2nd. Wick type, in which a wick stem projects above the liquid fuel level; passing a stream of air over the exposed wick, loaded with the liquid (through capillary action); the air stream carries along a certain proportion of gas vapor formed by evaporation.

3rd. Air is forced through the liquid.

The spray method of carburetion is superior to other methods mentioned for aeronautic work.

Carburetor Auxiliaries. Carburetor adjustments should be placed in airplanes within the reach of the pilot. To obtain the desired proportion of gas vapor and air, the first mixture is made "too rich," that is to say, overloaded with gas. A device is provided to admit a variable volume of air through a series of apertures, as required, until the motor is firing most efficiently. Devices to heat the air are useful under certain weather conditions. In aeronautic practice it is common to employ a large, flexible pipe called a "stove," which is attached to the exhaust pipe. The "stove" is merely an air intake for the carburetor. It must be remembered that planes flying at high altitude generally operate in cold air.

Filters. A screen or filter should be placed between the fuel tank and the carburetor, the purpose of which is to obviate the introduction of solid matter into the carburetor.

Throttle. The throttle is a device which controls the amount, or volume of gas, admitted to the cylinders. This usually takes the form of a valve called a "butterfly valve," a disk mounted on an axle through its diameter.

Manifolds. The gas passes from the carburetor through pipes called manifolds on its way to the cylinders. The manifold is divided into branches built to accommodate the model of motor. Short manifolds are desirable. Sharp bends should be avoided. Lengths of branches must be equal to obtain the same results in all cylinders.

Carburetor Sizes. Motors of different sizes require carburetors of various dimensions according to the power expected. Different speeds require intake apertures of various dimensions. Hence the carburetor size must be regulated by the size of the motor.

IGNITION

The ignition of the mixture in the cylinder at the proper time is obtained by means of a current derived from a magneto and carried to the cylinders through wire leads, each terminating in a spark plug. This device has a break in its circuit, called the "gap." The gap should be wide enough to cause the current to jump and spark. This is the method of firing the mixture by contact with the flame or spark. The gap should not be too great or the current will be interrupted with consequent failure to spark.

Magneto. The principal parts of the magneto are: the magnets and armature around which are wound two coils, the primary and the secondary circuits; a contact breaker, a condenser, a brush, a distributor and a circuit to a spark plug in each cylinder. The magneto turns on carefully timed gears, driven by the motor itself. The function to be performed by the magneto device is to deliver a spark to each cylinder at the proper time by sending a current through the proper circuit.

Many different commercial types of ignition, lighting, starting and generating systems in some combination or other, are on the market. High tension magnetos should be required. Rules for the care of the magneto are simple but supremely important. Keep clean from oil or dirt and protect from moisture. Lubricate with high grade cylinder oil sparingly applied to the working parts.

COOLING

Cooling systems are classified as: a. Water cooling. b. Air cooling.

Water Cooling. A radiator is provided in this system, from which the water is distributed to the various parts to be cooled. Return pipes lead to a manifold which delivers the water to the radiator in a heated condition. The radiator, being a structure of thin, metal tubes, with great, exposed surface area, readily transfers the heat to the surrounding air. Passing back into the circuit, the water continues to make the journeys to the heated parts, conveying the heat back for diffusion.

Water is circulated by one of two principal systems. In one system the circulation is by a pump which derives power from gears connected with moving parts of the motor. The second system is automatic circulation, which depends on the thermo-syphonic principle.

Maximum heating of the motor occurs during a steep climb. To meet this condition, radiators should be so constructed that the cells are not horizontal but are parallel to a tangent to the mean trajectory of climb.

Air Cooling. This system embraces the use of metal fins or cooling plates, radiating from the exterior cylinder walls and other parts where excessive heat generates. These cooling fins absorb the heat of the various parts and diffuse it in the rush of air. A powerful fan should be used in this system as such a device increases the rate and degree of cooling when in flight and is indispensable for cooling when standing still. Air cooled motors offer military advantage over the water cooled type, as the latter are easily damaged and stopped by projectiles.

LUBRICATION

Without proper lubrication a motor will burn up.

Splash System of Lubrication. The oil is poured into the sump (oil reservoir in bottom of the crankcase). As the crankshaft revolves, it picks up oil which is splashed upon the working parts.

Forced Feed System Lubrication. An oil intake pipe is seated in the sump, from which the oil is taken by a gear pump, through pipes, to the main bearings and to one end of the hollow camshaft; through camshaft to all bearings, and to the timing gears. The oil lead to the main bearings continues through crankshaft throws to connecting rod bearings thence through ducts in the connecting rods to the wrist pins. Splash pans with baffle-plates should be provided below the crankshaft returning oil to the sump bottom either by overflow or by pump. The splash pan may be used for splashing oil to wrist pins and cylinder walls.

INSTRUCTION FOR TIMING VALVES AND MAGNETO

(Curtiss Aeronautic Motor Handbook.)

Valve Setting. After grinding and cleaning, both exhaust and inlet valves are set to a clearance of .010, measured just after the inlet valve has closed.

Valve Timing. When the prescribed clearance has been set, the motor should be turned in the direction of rotation. The piston of No. 1 cylinder should be set at exact top dead-center, fully retarded. The camshaft should be turned in the direction of its rotation until the exhaust valve on No. 1 cylinder has just closed. The camshaft gear should then be adjusted so that the keyway of the gear is aligned with the key in the camshaft. The inlet valves will then open at 12° past top center and close at 40° past bottom center. The exhaust valves will open at 45° before bottom center and close exactly on top center.

Magneto Timing. The spark advance lever should be placed at full advance, the gap between breaker points should be .018 inch; spark plug gaps, .023 inch. The adjustment is made to give a firing-time of 30° before top center for all cylinders.

"The motor should be turned in the direction of rotation until the intake valve of No. 1 cylinder closes. Then turn the motor in the same direction until the piston of No. 1 cylinder is on top dead center. Then turn the motor backwards until the piston of No. 1 cylinder is ½ inch from top center. Turn the armature of the magneto in the direction of its rotation (it is the same as that of the crankshaft) until the distributer brush is on No. 1 segment with the breaker points just ready to open. Attach the magneto gear." The same care must be exercised in adjusting the magneto gear as explained for adjusting the camshaft gear.

GENERAL

Accessories. Motors installed in aircraft should whenever possible be provided with self-starters. Starting cranks should be installed in the cockpit. The use of mufflers for warplanes is advantageous. Tachometers, to indicate the number of revolutions per minute, should be a part of the permanent equipment of every installed aero motor.

Life of motor. Under war conditions motors cannot be expected to last longer than 20 to 60 flying hours, depending on the quality of the motor in each case. These motors should then be returned to the reserves or bases for thorough overhauling and employed for instruction flying purposes thereafter. Each airplane in war service should be provided with two and whenever possible three motors of the same model. Motors deteriorate rapidly in the field. Highest grade workmanship cannot be done with the facilities normally prevailing in the theater of operations. For this reason it is better to receive new motors from the bases than to rely upon field repairs. Careful lubrication and protection from dust, dirt and moisture will reduce the motor troubles that otherwise tend to increase in the field. The engine and propeller should be protected by waterproof covers, when the machine is not in use. Elaborate care must be taken to avoid exposure of propellers to the sun, especially in hot climates. In cold or wet weather, the magneto should be protected by a waterproof cover. Packing the magneto with waste is commonly done. When transporting the motor, either boxed or installed in a plane, the motor should be covered carefully to avoid the introduction of dust or dirt. All inlets should be packed.

Housing the Motor. Motors are mounted on specially constructed laminated wood engine beds for installation in planes. The extension brackets or supports of the crankcase are secured to the engine beds by bolts and nuts. The engine beds are rigidly secured in the engine compartment. Usually (always in tractor driven planes) the engine compartment is integral, the engine beds being incorporated into the design of the compartment so that they are permanent fixtures. A convenient arrangement is found in a type of engine compartment which detaches, as a nose from the remainder of the fuselage, carrying with it the complete power plant, less possibly tanks and power controls. This arrangement, however, offers the weakness of a detachable unit and must be carefully observed for indications of looseness and vibration. A better system is to split the engine compartment in two halves, an upper and a lower. The engine can then be lifted from its seat, without interference of other installations. The method of bracing the engine consists ordinarily of light steel tubing, from heel plates (carrying the ends of the engine beds) to the main fittings at strut attachments. Wire trussing is commonly employed. The most satisfactory of installing en-

Details of streamline nose. Housing the motor.

gines consists of a front and a rear engine plate of heavy steel, bored out in grooves and holes to reduce weight and channeled liberally to increase the strength. Heel plates to carry the ends of engine beds are mounted on the engine plates, both fore and aft. Steel tubes may be used to replace most of the wiring, which renders work about the engine difficult. When motors are mounted between the planes, the engine beds are normally carried in heel plates, braced rigidly by large steel tubes. This system does not prevent the use of hoods for streamlining the motor. Hoods should always be used for reducing head resistance. The hood used to cover motors carried outside the central body should be given an efficient streamline form, such as a torpedo shaped body approximately six to one ratio of length to breadth;

the broadest dimension at a point approximately one-third from the leading edge; the nose blunt round, the tail tapering off to a point.

Fire Precautions for Aero Motors. The danger of fire is always present in aero motors. A conflagration in flight is always serious, usually fatal to the occupants of the craft. The best way to combat this menace is to exercise the proper precautions in designing and constructing the craft and motor.

The principal causes of fire are: leakage of gas from tank, tubing or carburetor; explosion in the exhaust ports; back-firing into the carburetor; defects in ignition system. These precautions are of vital importance; neglect of steps to avoid these possible contingencies is criminal in aircraft work.

Tanks under pressure are undesirable. Tanks should be situated well away from the motor, and so placed that the exhaust ports are not in proximity of leaking gas or escaping vapor. In case tanks are pierced, facilities should be at hand for quickly releasing gasoline from the tanks. Baffle plates should be introduced when necessary to intercept the flow of vapor past the motor, as in cases where the tank is placed at the front. However, it is dangerous practice to install tanks in front of the motor.

Ventilation of the hood should be invariably practiced. Louvers should be cut on top, sides and bottom of the hood to force a draught of air through the engine compartment. This will prevent an accumulation of gas vapor, which results from the overflow of the carburetor.

The proper installation of gas leads is vitally important. Faulty installation leads to rupture and leaks, as a consequence of vibration. The tubing should be of large diameter and installed with care to avoid sharp bends. If a sharp bend is unavoidable, a section of copper tubing should be properly bent to the desired angle and inserted in the line. A strainer should be placed in the gas line. Stop-cocks are used to shut off the gas in case the glass level-indicator tube is broken.

Flexible, armored tubing should be invariably used for fuel leads. This material, when of high grade manufacture, is as durable as stiff tubes and avoids the faults inherent in the latter, such as rupture at the bends and fracture under constant vibration.

Electric wiring should be heavily insulated, where proximity to motor and manifolds cannot be avoided.

Caution must be exercised to avoid rupture of gas leads by vibration or blow.

Adjustments. Above mean altitudes (5,000 to 10,000 feet), motor troubles increase with the height. The supply of air to the carburetor diminishes with the air density, which decreases with the altitude. As the proportion of air grows less, richness of mixture results. This can be overcome by introducing inlets between the carburetor and the motor. Such an arrangement is very complicated, however, on account of the great variation which results during the range of speed between running throttled and at full power. The best available data, obtained from extensive governmental tests, indicates that these inlets are necessary, but must be carefully located in the manifold at a point where a strong depression exists. The diameter of the inlet must not be made too large. Such a device must be designed by an engineer. Auxiliary air tanks and cocks may be attached directly to the carburetor in the absence of a permanent device of the above description. The operation consists of admitting more and more air until a point is reached at which the proportion of air cannot be increased by merely enlarging the inlets. The mixture is thereafter kept proportioned by cutting down the admission of gas, but this expedient offers comparatively small range of use. In a climb to *extreme high altitudes* (above 15,000 feet), oxygen must be carried both for pilot and motor. Air intakes to carburetor should be invariably placed outside the engine compartment; oxygen intakes should be airtight between carburetor and oxygen tank.

Motor "Try-out." This term is used to designate the ground test of a motor, which should always be made before a plane leaves the ground. The plane should be anchored or held by attendants. The motor is started, run lightly at first at about 300 R. P. M., until warm. The speed should be increased very gradually when the motor has started cold; moderately when started under any circumstances. A motor should be firing evenly, smoothly, instruments registering cooling, lubrication, engine revolutions, air pressure when pressure tanks are employed, etc. When motor trouble is manifest, instruments indicating to the contrary, the instruments should be examined for calibration. A craft must never be taken into the air until the motor is operating smoothly. To ignore this advice is sooner or later fatal. Adjustments should be made by qualified persons only. All pilots should be qualified to make ordinary motor adjustments, to locate the source of minor troubles and make elementary repairs.

Types of Aero Motors. Of the various types of motors mentioned at the opening of this subject, the vertical, V-type, rotary and radial are in general use. Claims have frequently been made that rotary motors consume an excessive amount of oil and are being discarded. These are denied by manufacturers of that type of motor. Rotary motors have not been generally discarded. Radial motors are represented by several successful products. The vertical and V-types have enjoyed the largest representation of the many types. Motors of less than 100 H. P. are little used at the present except in training machines. The great advances made in aviation up to the present time are due no less to improvements in motor design and construction than to the advances made in airplane features. In the motor field, increase of power has been perhaps the greatest single factor of progress. Better materials; greater convenience in design; added features giving increased flexibility, convenience, simplicity; more finished workmanship; experience incorporated into design, have all brought greater reliability and improved performances for both motors and for planes. Double ignition, double carburetion, and double valves have been adopted in many types, leading to improved performances and reliability. The increase of cylinders in various types has followed the same general rules established in automobile practice. The six cylinder vertical, eight and twelve cylinder V-type motors are standard. No fixed practice can be given for radial and rotary types. One prominent 200 H. P. rotary motor has twenty cylinders.

Large Motors. The weight per horsepower of motor and amount of fuel carried must be kept at a minimum in airplanes. Hence large and very heavy motors require further multiplication of weights in supporting structure sufficiently solid to withstand great stresses in flight and landing. It has been suggested that motor manufacturers must increase "massique" power of motors by increased R. P. M., reduced fuel consumption, and other weights. Fuel may be greatly economized by obtaining a perfect mixture of gas and air at all altitudes. This adjustment should be automatic and progressive. Weights may be greatly reduced by the judicious use of steel and aluminum alloys. Reduction of fuel consumption is the main problem in air cooled motors. A material decrease of fuel consumption constitutes a formidable obstacle to the realization of larger air cooled power plants. Water cooled engines of 300 H. P. have become an established type, but their success has been limited up to the present. The tendency has been to secure great horsepower in super-planes by use of a battery of lighter, less powerful motors, offering great reliability, rather than employing more powerful units. The water cooled motor of 300 H. P. should be perfected before larger power plants are attempted. The motor of greater horsepower requires features not typical to the airplane of the present day, such as transmission system and accessories, each unit that must *per se* add considerable weight.

Motor Instruction. The theoretical training of motor engineers and mechanics must be based on advanced motor textbooks. All airmen, however, should have a correct elementary knowledge of the theory of motors and instruction in practical shopwork, assembling and dismantling motors, trouble shooting and minor repair work.

Conservation of Motor and Fuel in Flight. Airmen soon learn by experience the range of speed of a plane. It is soon found that driving the plane at full power is poor practice. The motor rapidly deteriorates. Pilots should be taught the necessity of habitually driving at no greater revolutions per minute than actually required to fly efficiently or than determined by the conditions of the flight. It must be remembered that the maximum attainable high speed of the plane by no means represents the most efficient speed of the flight unit. This is particularly important in cruising or long distance flights where conservation of fuel is of prime importance to remain aloft a great length of time or cover great distances. The rate of speed governs the length of flight. It is possible for the speed to be too high or too low to obtain the maximum cruising distance possible. Assume that a given motor, developing 100 H. P. at 1400 r. p. m., consumes 1/10 of a gallon of gasoline per horsepower hour. The consumption will then be 10 gallons of gasoline per hour. Suppose that the capacity of the tanks is 20 gallons. Now, if the speed of the plane at full horsepower is 80 miles an hour, ignoring the wind, the limit of the flight will be 2 hours or 160 miles. Suppose, on the other hand, that the plane is driven at a number of revolutions at which the rate of fuel consumption is but one-half that given above and that the speed of the plane is 50 miles an hour. The fuel will then last twice as long, or 4 hours running time, and the distance covered will be 200 miles instead of 160. This illustrates the meaning of "most efficient speed" for it is a fact that the rate of fuel consumption is very much greater at higher speeds than at some lower speed. The explanation is that increase of speed does not advance in direct proportion to expenditure of fuel.

The *most efficient speed* should be known for each plane. A scale of efficient speeds can be worked out for a plane by timing the craft over a measured course, at successively reduced revolutions. The weight of fuel should then be reduced and the determinations repeated. A pilot can thus determine the necessary variation in revolutions of the motor per minute to secure the maximum obtainable cruising distance taking into consideration the loss of weight due to fuel consumption.

GASOLINE

The average calorific value of gasoline per pound varies from 17,000 to 20,000 thermal (heat) units. The energy contained in one British thermal unit is 778 foot pounds of work. Hence, if all the energy contained in a pound of gasoline could be converted, the useful work would be represented by the product of these two factors. Mechanical losses, however, take place in any device for converting the energy of gasoline to useful work; incomplete combustion; large heat losses, due to radiation; incomplete expansion in the conversion, and other ordinary losses, which can be reduced, possibly, but not overcome, leave a comparatively small margin of the total thermal value, obtainable for useful work. This value ordinarily varies from 18% to 22%.

High power with gasoline motors depends primarily upon the mixture of gasoline with air. Disregarding compression and other details of motor operation, and features of motor design and construction, it may be shown that the amount of power obtained from a motor will vary according to the variation in the proportions of gas vapor and air admitted to the motor. The fuel consumption will vary likewise, but as the power curve rises, the fuel economy curve falls, and vice versa. The greater the amount of air in a mixture, the greater the fuel economy but the lesser the power obtained. The proportion of gas in the mixture must be sufficient to give the required power, but fuel economy must not be neglected, as the weight of fuel carried in aircraft must be kept at a mimimum and it is essential to efficiency to get maximum results from the fuel carried. Hence the proportion of gas to air must be primarily kept at the least possible amount. As a secondary consideration in aero motors, excess gas overheats the motor, burns up cylinders, valve mechanisms and other vital parts, throws delicate motor adjustments out of balance and leads to bad deposits in cylinders and exhaust valves. Such is the importance of proper mixture. In aero motors, the normal ratio is about one part of gasoline to 9-18 parts of air. The normal rate of gasoline consumption in aero motors is approximately one-tenth of a gallon per horsepower hour.

Pure gasoline should be demanded for aeronautic use. The practice of diluting with kerosene, introducing low grade oils and napthas are not to be tolerated with aero motors of the present day.

TRAINING IN AVIATION

CHAPTER 9

AERONAUTIC EQUIPMENT

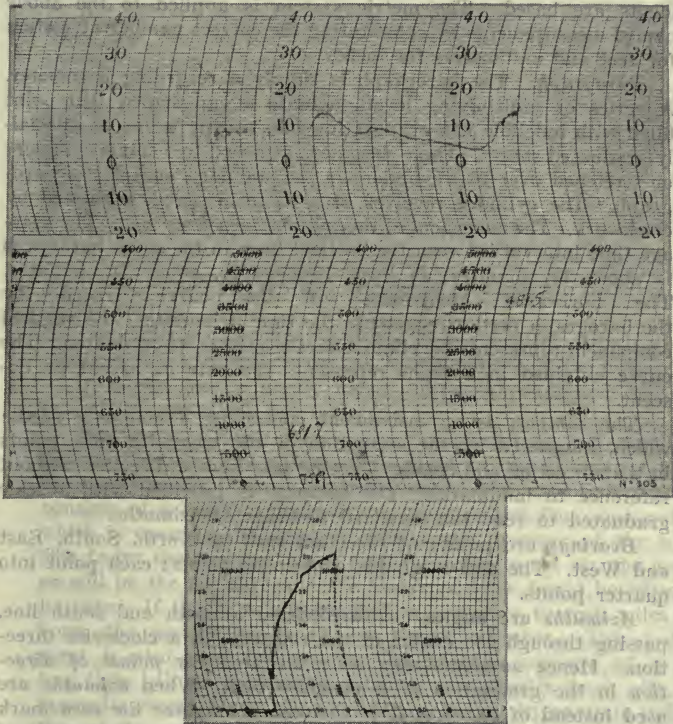
All airmen should have a thorough knowledge of the equipment with which they are called on to work. Aviators must be instructed in the use of navigating and flying instruments; observers in the employment of reconnaissance equipment; gunners in the operation of machine guns, bomb-dropping apparatus; and other flying personnel in the use of special equipment.

Airmen of whatever character should have an elementary understanding of all instruments, aero devices and military apparatus in common use.

INSTRUMENTS

The principal instruments employed in connection with aerial navigation or in flying maneuvers are arranged as follows in the approximate order of their use.

Aneroid Barometer. This instrument is employed for general use in measuring altitude. The actuating element of the aneroid barometer consists of a thin, flat metal cell, from which the air has practically been exhausted. One side of the cell is fastened to the case. A post, to which is attached a strong spring, rises from the other side of the cell. A series of levers, mounted above the spring, are arranged to actuate a needle or pointer, causing it to move radially over a dial, which is calibrated to indicate the atmospheric pressure. An increase in atmospheric pressure forces the thin sides of the vacuum cell closer together, thus actuating the indicating needle. When the atmospheric pressure decreases, the steel spring raises the side of the cell and reverses the motion imparted to the needle. The sides of the vacuum cell are so sensitive that very slight variations in atmospheric pressure cause a rise or fall. As an altitude instrument, the aneroid is constructed on the principle that the atmospheric pressure varies directly with the height above level. It must be understood here that the air decreases regularly in density with the altitude and this density at any point is the value of the atmospheric pressure. Hence the pressure upon the diaphragm of the aneroid barometer is directly proportional to the height. The introduction of a spring on one side of the diaphragm keeps that surface in balance, preventing it from collapsing with the pressure of the air. Figures of altitude, in feet, meters or other desired units of measurement, are indicated on the arc after careful calibration; e. g., 1,000 feet would be marked at the point corresponding to the normal atmospheric density or pressure for that height. This determination is based on measurement from sea level and average weather conditions. When the instrument is employed at a place above sea level or at a time when the weather conditions are not normal (see METEOROLOGY), giving a variation from the normal atmospheric density, the needle will give a false reading.



Thermograph and barograph records. The former records temperature changes; in the latter, every variation in altitude and speed of climb, and the elapsed time are recorded.

For this reason a double scale is usually placed on barometers, one reading the altitude in feet and the other expressing the height in terms of inches of atmospheric pressure.

Before leaving the ground, the needle or height scale (the adjustable arm) should be set at zero. In some types of barometers a marker constitutes the only adjustable device. This marker should then be set opposite the needle before leaving the ground. When reading the altitude in flight, in this case the original reading in feet at the marker must be subtracted from the indicated altitude.

Mercurial Barometer. The average density of the air at sea level is such that a column of mercury 29.9 inches high will be sustained in a U-tube open at one end. This is taken as the standard of air density, upon which all atmospheric measurements are based. The metric system is applied to the above named measurements by substituting the correct number of meters for feet and millimeters for inches.

Barograph. The barograph is simply a recording barometer. A series of multiplying levers actuate a cup-shaped pen point filled with indelible non-evaporating ink, tracing a line on specially graduated sheets. These sheets are attached to a single cylinder; or stretched over two cylinders in the standard pocket size barograph. The cylinder revolves at a uniform speed, regulated by clockwork. The movement of the cylinder measures time. The average time interval between the vertical lines in the small barograph is about 3¾ minutes; in large barographs, about 7½ minutes. The horizontal component of the curve traced by the barograph needle represents the time in minutes; the vertical component represents the climb in feet or meters, as graduated. The curve obtained in a flight represents the rate of ascent or descent.

The *compass* is an instrument containing a magnetic needle which, influenced by the attraction of the magnetic pole, points in that direction and enables steering in a known direction without reference to landmarks. The compass is provided with a scale graduated to read the standard *bearings* or azimuths.

Bearings are points of direction such as North, South, East and West. The dial is graduated into 32 points; each point into quarter points.

Azimuths are angles measured from a north and south line, passing through the center of the compass, in a clockwise direction. Hence *numerals* may be substituted for *points of direction* in the graduation of a compass dial. When *azimuths* are used instead of *bearings* it is customary to place the zero mark at the north point, and to measure all angles from that *point of direction.* In the Coast Artillery Corps, of the Army, the practice is followed of placing the zero at the south point.

The type of compass in which a compass card is suspended in a liquid best meets the requirements of aviation. The liquid tends to damp out oscillations of the needle, which are considerable under the influence of vibration, pitching, yawing and rolling. A solution of distilled water and spirits of wine is generally employed for this purpose. The errors usually encountered in the use of the liquid compass are variation, deviation and collection of air bubbles.

Variation is the error of difference between the true north and the magnetic north. This variation changes with location on the earth.

Deviation is the error introduced by local influences of masses of steel or iron and from the presence of such metals in or about the craft. This error must be balanced by means of compensating metal masses.

Air bubbles seriously reduce the accuracy of the instrument. They can be removed merely by permitting the air to escape through an opened cock.

Tachometer. This is one of the most important instruments employed in flying. The number of revolutions of the motor is a direct indication of the power delivered and may be used as a basis for computing the speed relative to the air. This speed indicates the sustenance of the plane in flight. The tachometer is driven by the motor and registers the number of revolutions per minute at which the motor is turning, at any instant.

The magnetic tachometer consists of a magnetic indicator on the dash, the magnet of which is rotated by a flexible shaft coupled to the engine.

The electric tachometer consists of a generator driven by the engine and electrically connected to an ammeter on the dash.

In either case a needle moves across a graduated arc calibrated in revolutions per minute.

Manometer. Many names such as pitot tube, air speed indicator, pressure gauge, have been given to this instrument. The term manometer is most generally used. The essential principle consists of a liquid contained in a tube, a *lead* from one end of which is open to the front to receive the pressure of the wind. The faster the machine moves with reference to the air, the greater will be the pressure and the higher will the liquid be lifted in its tube. If the tube is graduated in pressures to read miles per hour, the manometer is an air speed indicator. This instrument is also used to measure the internal pressure of a gas bag (kite balloon or dirigible, which are habitually flown with the appendix closed, hence the necessity of having an accurate indication of the pressure at all times in order that it can be released by operating a maneuvering valve, before the danger point is reached). When used for the latter purpose the manometer is graduated in inches, indicating the number of inches of water pressure equivalent to the air or gas pressure within the bag.

Inclinometers are pendulum devices for measuring the inclination of the machine to the vertical. This instrument is useful for measuring both the fore and aft inclination and the transverse balance of the craft. A directional indicator of a light gauze made into conical form is a great assistance to a pilot in avoiding skidding or side-slipping on turns.

Statoscope. This instrument is used mainly for balloon and dirigible work, but it has a use in airplane work. The structure consists of a box, on one face of which is a rubber diaphragm. A rubber tube habitually open leads into the box which is otherwise closed. To the diaphragm is attached a lever arm which transmits motion to a needle, when the diaphragm moves. The needle normally points to a zero, this representing atmospheric pressure. Movement of the needle in a clockwise direction over the arc indicates *ascent;* movement in a counter-clockwise direction indicates *descent.* It is evident that when the rubber tube is open the pressure within the box is the same as the pressure in the outside air. If the instrument is in a craft moving through the air, and it is desired to know the slightest ascent or descent made by the craft, the rubber tube is pinched for a moment. Since no more air can enter the box, the diaphragm will remain unmoved only so long as the outside pressure remains the same as the pressure within the box. The latter remains constant so long as the rubber tube is pinched. The least ascending movement during this time, however, will cause a diminution of the outside pressure, because the atmospheric pressure diminishes with increase of altitude. Hence the diaphragm will yield to the pressure within the box, this pressure remaining constant at the greater pressure of the lower level, while the outside pressure is decreasing so long as the craft continues to rise. The diaphragm yields to the greater internal pressure at a rate of change proportional to the rise into rarer air. The rate of movement of the needle across the arc is an indication of the rate of ascent. The reverse conditions are true of the manner in which the instrument indicates the rate of descent.

Angle of Incidence Indicator. The angle of incidence at which the plane is flying is of prime importance to the scientific pilot. A device employed for this purpose consists of a wind vane pivoted to travel through a vertical arc, and mounted on a box within which gears are seated. The gears transmit the motion of the vane to a pointer, actuated by this system. A scale over which the pointer moves is graduated in degrees. The instrument is usually attached to a strut and shows the angle between the chord of the planes and the flight path. The instrument is attached with reference to the planes; the wind vane follows the path of flight.

Anemometer. A device consisting of four arms, each carrying a cup, open end to the front. The arms turn about a vertical axis. The travel of the cups varies with the speed or pressure of the wind.

Luminous Compounds for Lighting Instruments. The use of electric lights for illuminating instruments for night flying entails complications. Vibration is very severe on the delicate apparatus and the glare oftentimes interferes with the pilot's vision. The introduction of practical luminous paints or compounds, which are applied to the dials of instruments, has apparently solved the problem. The luminous property is derived from radium. The first compounds introduced were faulty and defective. Distinction must be made between these and the radium materials. Radium compounds are practically permanent. The luminous materials are applied as a paint, in which the radium is combined with zinc sulphide. Variations in the quality of zinc sulphide give great diversity in crystal stability and sensitiveness of ray. The criterion of efficiency of luminous paints should be based on a standard of life and luminosity.

Drift Meter. Two types of this device are employed: one which indicates the leeway over the earth by streaking of the objective glass, or by variation of the line of flight from the true normal direction of motion of the craft; the second type consists of the string or pennant device mentioned hereinbefore or of a pendulum which swings over a scale as the craft skids out or side slips. The latter device is strictly an inclinometer. The pennant device is unreliable in the wake of a tractor screw. The visual drift meter depends upon ability to see the earth at all times.

Gauges. Oil gauges must indicate the exact amount of oil contained in the sump of the motor. Oil *pressure*-gauges should indicate in pounds the pressure in the oil system and the rate of flow of the oil. Mechanical gasoline indicators are superior to stand-tube indicators, both for indicating amount present and rate of flow of gasoline. A thermometer should be habitually used for registering the temperature of the radiator.

General. Barometers and barographs should be sensitive and as free as possible from lag. Air speed meters should be free from the effects of accelerations due to flight changes. Pressure types are deemed superior to anemometer types of air speed indicators. Speed instruments should be designed for calibration before each flight. Gyroscopic inclinometers give promise of qualities greatly superior to those of the pendulum type. Angle of incidence indicators should be attached on structures carried to the front of the planes and beyond the locality of influence of the screw or propeller. Statoscopes and manometers must be carefully located on the machine to avoid inaccuracies due to abnormal pressures.

Field Glasses. The types of field glasses most commonly used in this country for observation from aircraft, are the 6-power prismatic and the 4½ Gallilean. This statement, however, must be regarded as general. These two types of glasses were recommended by the student officers of the Field Officers' Course in Aeronautics, at the Signal Corps Aviation School, after completion of a special course of flight training as observers, in which various types of field glasses were employed. The power of glasses used by an observer, must be selected with special reference to *his* vision. For aerial work, the glasses mentioned here should fulfill average requirements.

On account of the vibration felt in most airplanes, and which, however slight, has a noticeable effect on the use of field glasses, most observers prefer the Gallilean lens to the prismatic type of glass.

Generally speaking the higher the power of a glass, the greater the magnification of objectives, but the more noticeable the slightest movement. Glasses of 8, 10 and 12 power are ordinarily too high power for satisfactory use in airplane work.

Prismatic glasses of high power are especially sensitive to vibration or unsteadiness, and this leads the novice to the premature conclusion that prismatic glasses are unsuitable for airplane observation. On the other hand, every effort should be made to accustom observers to the use of prismatic glasses on account of the advantageous stereopticon effects produced.

To overcome the difficulties which arise from vibration and to avoid possible injury, all field glasses used in flight should be provided with rubber eye piece protectors. Good results have been obtained with glasses securely attached to the helmet. This leaves the hands free to perform other work than holding glasses to the eyes. It is important that this practice be adopted whenever possible.

The effective use of field glasses, in observing from aircraft, comes only after long practice. Patience and perseverance alone will yield results.

RULES FOR CHECKING AND PREPARING THE RECORDING BAROGRAPH

It has been stated that the function of a barograph depends upon the atmospheric pressure, based on the assumption that the pressure falls off regularly with the increase of altitude. This is not exactly correct since this varies slightly from normal with location on the earth's surface, with the season of the year and with the weather conditions, such as temperature, density, water vapor suspended in the air and with the force of gravity. Hence the pressure is not a direct indication of height, but is so affected by these variable factors that tables of variation, tabulated for the purpose, must be consulted to obtain accurate results. Computations must be made from these tables to determine the correct setting of altitude instruments or to determine the correctness of records so obtained. The standard tables referred to herein are published by the Smithsonian Institute, Washington.

To Prepare the Barograph for Registration. A barograph sheet is inserted on the drum or rollers of the instrument. This sheet is rectangular; ruled with horizontal lines from bottom to top to mark the successive altitudes from sea level to (usually) 15,000 feet or 5,000 meters. (Note: these two figures do not represent the same altitude.) Special instruments and special barograph sheets must be provided for registering greater heights. Vertical lines, swung on the radius of a circle to correspond to the vertical swing of the needle arm of the instrument, successively mark intervals of time from left to right (usually), graduated in hours, quarter hours, and the least graduation expressed in the eighth part of an hour for large barographs and in the sixteenth part of an hour for small, pocket-size barographs. Small perforations are provided on the sides of the barograph sheet. Special devices enable securing the two edges together and the sheet is thus attached tightly to the drum or around the rollers, according to the type of barograph. A clean pen point, either cup or V-shaped, is attached to the end of needle arm, and filled with special barograph ink, tested for flow to give a continuous, thin line. The clock mechanism should be wound to actuate the drum or roller mechanism which rotates and registers the proper intervals of time. An adjusting key should be next used to set the registering needle on the pressure line corresponding to the barometric pressure existing on the ground at that time. The instrument is now ready for use, either in the air or for testing.

Testing the Barograph. The bell dome is a thick glass vessel which rests on a metal base. The bottom of the glass dome is ground to make a perfect, continuous contact and is sealed air tight by means of a thick heavy lubricant. Air tight tubes lead through the metal base into the cell formed when the glass dome is placed as described here. A mercurial barometer is mounted in this system to record the pressure existing within the glass dome. This mercurial barometer must be corrected for temperature and to correspond with the reading of the master barometer which gives the actual pressure prevailing at the time, and at that place. As the air is exhausted from within the glass dome, it is evident that the density of air will diminish within the cell. Hence if a barograph to be tested has been placed inside, it will go through the same conditions as it meets during a climb for altitude. The mercurial barometer records in inches the pressure within the cell, so that the density of the air can be varied to correspond to successive altitudes by consulting the tables of conversion. For example, if it is desired to know whether the instrument registers correctly at 5,000, 10,000 and 15,000 feet, and if not, what error exists, the air density within the cell is set successively at the exact number of inches to correspond with those altitudes. The barograph should be exposed to each degree of density for a sufficient time to register a horizontal line. The barograph sheets being correctly scaled, any variation from the 5,000, 10,000 and 15,000 feet lines represents the error of the instrument.

The time interval recording device should be checked with an accurate timepiece.

The instrument is now ready for use in recording altitude or duration flights and gives the climb in feet or meters (according to the instrument used), during the specified period of time. Care should be exercised to employ sheets graduated in feet only on instruments designed to register in feet, and sheets graduated in meters only on instruments designed to register in meters.

Instruments registering excessive errors should be turned in for examination and repairs, or discarded. For slight variations in recording, a table can be made and pasted on the instrument, as, for example:

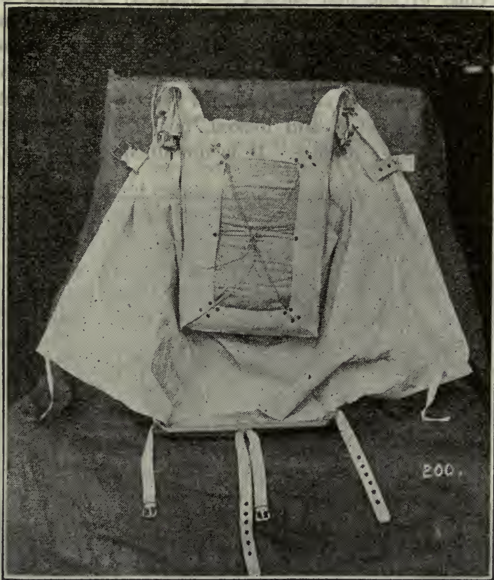
At: 4,000	feet (error)	—150
4,500	....	—75
5,000	....	....
5,500	....	+75
6,000	....	+150

It is arbitrarily assumed that an error of more than 150 feet at 5,000 feet is excessive for general use.

AERO EQUIPMENT AND DEVICES.

Increased comfort should be provided for airmen by the adoption of upholstered seats and heated cockpit whenever practicable. The latter can be done by passing pipes from the exhaust through the cockpit. Comforts require the sacrifice of some efficiency through added weights. It is a question of how much the efficiency of the pilot is thereby increased. Every airman should provide himself with suitable flying clothes.

Flying Uniform. The flying uniform should include a strong padded helmet, a fur-lined combination suit in cold weather, useful at all times for high altitude flights. For flying during warm weather, the service uniform should be sufficient clothing when covered by a leather flying coat. Pockets in the coat should be of generous dimensions so that papers, pencils and other small articles can be easily stuffed in with one hand. These pockets should not have flaps. They should be provided instead with a loose elastic band which keeps the pocket closed. The opening of the pocket should flare to admit easy access. Riding breeches should be worn with boots or puttees. Soft boots of a durable leather are superior to puttees. The latter, when worn, should not be secured by straps. The advantages of boots over shoes rest in the greater warmth of the former and the lesser likelihood of catching on something within the cockpit. Fleece-lined leather gauntlets provide more comfort than unlined leather gloves. Considerable warmth can be gained by wearing pure wool, tight-fitting gloves under the gauntlets. Mittens or fingerless gloves should not be worn for piloting. Goggles of glass are dangerous articles and should be prohibited. Isinglass materials are unsuitable. A grade of celluloid has been recently developed that meets all requirements as material for goggles. Although celluloid goggles cloud with considerable use, requiring frequent renewals,



Parachute pack, designed to be carried on the back like a knapsack. The cover is stoutly secured to the airplane. When the wearer jumps, the chute is wrenched from within its casing and opens by wind pressure.

the low cost of the celluloid renders this type of goggle more reasonable than expensive glass goggles. Goggles should be made of one continuous, transparent sheet of best grade, colorless celluloid, bound by a tubular rubber rim stiffening, curved to fit over the bridge of the nose with comfort. A green, transparent celluloid shade should cover the upper part of the goggle for protection against the rays of the sun. The general shape of the goggles should conform to the shape of the head about the eyes, so that the entire goggle excludes the wind, but small perforations should be provided near the temples to give ventilation and avoid clouding produced by perspiration.

Safety or Life Belts. A safety belt should be installed in every seat of the airplane. This belt should be made of a wide strip of extra heavy webbing, hemp or cloth. Leather deteriorates so rapidly when exposed to the weather that it is dangerous to employ that material for life belts. There should be a quick, detachable release locking the belt over the center of the seat. The two ends of the belt should be securely attached under the seat. The belt must be so placed that the stress when applied rests squarely over the thighs, and so that a quick movement of the hand will instantaneously free the airman. It seems almost trite to mention that no airman should start upon a flight without his safety belt adjusted and locked, but many deceased airmen committed no graver offense. It is not uncommon for a machine

Life pack in operation. Airplane passenger landing by parachute.

to be turned over in flight. Without the life belt adjusted it is plainly impossible for the aviator to remain in his seat, under these circumstances.

Parachutes or Life Packs. It is not general practice to employ parachutes in airplane work. When used, they should be installed in proper receptacles from which they may be quickly released. The harness on the aviator should be secured by stout attachments to the pack, but the installation should be so made that the airman is not burdened by a load directly upon his person. Parachutes should be made of a perfected pattern. The important precaution in the use of parachutes is to air and carefully refold the apparatus daily. This should be proof against failure to function when a drop is made with a reliable parachute.

SIGNAL AND COMMUNICATION DEVICES

Various methods and devices are employed in signalling from aircraft and ground, such as: flight maneuvers, Klaxon horn, electric lamps, Very pistol rockets, flares, smoke bombs, streamers, confetti, message dropping tubes and radio telegraphy and telephony.

Flight Maneuvers. In spotting for artillery fire, it has been found entirely satisfactory to give the battery the proper line of its target by flying directly over the objective on a line of flight connecting firing battery and target. This obviates the need of a special signal for the purpose, but the timing must be exact and the battery commander must know that the signal for "line" is being given. This method of signalling applies to this particular case. Many schemes have been contrived for signalling from airplanes by such flight maneuvers as banking, diving, and performing other variations in the flight path. These are manifestly unsatisfactory.

Klaxon Horn. Sound signals can be heard above the noise of the motor, employing a Klaxon horn, operated by an 8-volt battery in the plane. This signal will carry for a distance of one mile when the airplane is at a height not to exceed 2,000 feet. This form of signalling is too limited for general employment.

Electric Lights. These can be employed only at night. A string of lights should be rigged below the plane for signalling to the ground and on masts for signalling to other aircraft. Used on the ground principally for outlining landing sites at night.

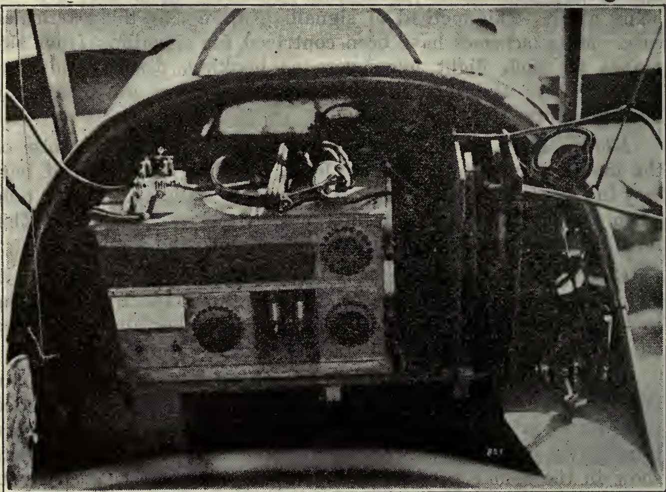
Very Pistol Rockets. These are cartridges, similar to shotgun shells, fired from a special pistol. These cartridges are loaded with different compositions to produce different colored lights, thus giving a range of choice in colors. By day, these colors show in the smoke produced. By night, distinctly colored lights of white, red or green are obtained. They can be seen either by day or by night, both from the air and from the ground, when fired from aircraft or from below. Prearranged codes enable a broad use for this device. Very rockets are visible 3,000 feet overhead, and if the sun is not in the eyes of the observer, the lights can be distinguished a distance of two miles with the naked eye. On clear nights Very lights can be seen and distinguished 6 miles. Special white lights can be seen greater distances at night.

Flares and Smoke Bombs. (See under Night Lighting Devices.)

Streamers and Signal Flags. Red, yellow and blue signal flags have been used on aircraft but their use is very limited. Flags not less than 18 inches square can be seen through field glasses at a distance of one mile, the airplane at a height not exceeding 2,000 feet. Dark and light streamers can be seen at slightly greater distances, with the naked eye. Confetti has been used by releasing different amounts from tubes under pressure; the results have not been particularly good.

Message Tubes. Messages can be dropped from aircraft in weighted tubes or bags, attached to streamers or to a parachute; weighted message blocks, upon which the message is written, have been employed with success.

Radio (wireless) *Telegraphy and Telephony.* The training of personnel for the operation of radio telegraphy or telephony constitutes a special study outside the scope of this book. The



Radio equipment mounted in airplane cockpit

notable achievements of Captain C. C. Culver, U. S. Army, in producing radio apparatus by means of which communication has been established between two airplanes in flight and between aircraft and ground, both through the operation of radio telegraphy and telephony, are believed to be the first entirely successful application of this principle to the problem of communication between aircraft and between aircraft and the ground. The discoveries made by Captain Culver which enable two or more widely separated aircraft to converse freely promise to make the leadership of vast aerial fleets a simplified undertaking. At present the details of radio developments for aeronautic purposes are confidential, in our service.

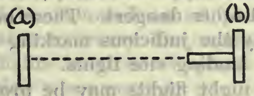
Radio apparatus should be installed on planes whenever the size and carrying capacity permit it, provided the duties of the craft warrant its employment.

In the United States Army, the International Morse Code has been adopted as the General Service Code of the Army for general visual signalling, radio telegraphy and on certain cable lines. The Two-arm Semaphore Code is authorized and the American Morse Code on telegraph and field lines. All three of the above codes will be used by the wireless operators assigned to aero duties and must be familiarized. Special ciphers issued from time to time and the cipher disk issued by the Signal Corps are employed. (See Codes—Appendix "A.")

In sending visual signals, the airplane must be so maneuvered that the persons for whom the message or signal is being sent do not have to look into the sun. It is impossible to read signals when looking into a strong sun. Hence the airplane should be brought as nearly as possible into a position from which the receiver occupies a position between the sun and the plane.

Places where it is desired to have messages dropped should be marked with some specified identification in white canvas strips. Such strips, 6 feet x 1 foot, can be seen from an altitude of 3,000 feet. A prearranged code, employing canvas strips to form letters, will greatly facilitate communication. This system has been perhaps more generally practiced than any other cited herein.

It is common to mark landing places in this manner. The prescribed method is to place a long strip at the point where the machine should touch the earth. Two canvas strips, arranged to form a capital T, should be placed at the point where the machine should be brought to rest. The signal is arranged in this order:

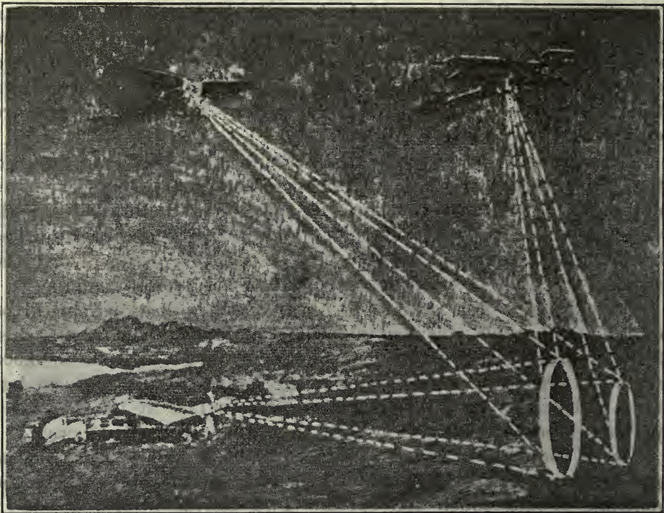


The plane touches the ground at (a), (steering a course to follow the dotted line indicated above) and must be brought to rest at or before reaching the capital T. If these strips are made 15 x 3 feet, it should be possible to distinguish them at war altitudes.

(NOTE: A wide range of reports has been received regarding the height considered safe from anti-aircraft artillery. Undue precaution seems to have actuated many aviators who recommend heights of 12,000 feet and over. The best information indicates that an average altitude for flights in a war zone may be taken at from 8,000 to 9.000 feet. It must be borne in mind, however, that different types of machines must operate at different levels, according to the functions performed. See PART IV, MILITARY AVIATION.

NIGHT LIGHTING DEVICES

Night Lights. Night flying is fraught with all the dangers of navigating the seas along dangerous coast lines, unmarked by beacons, except that the storm waves which menace the aerial pilot are invisible. To winds and currents, always a source of



Night lighting device. The aviator gets his relative position from the appearance of the two rings. The object is to land from such a direction that the smaller light ring is centered within the larger ring.

danger to the airplane near the earth, are added, by night, concealed obstacles and other dangers. These hazards may be almost entirely overcome by the judicious marking of night routes, location of beacon and landing site lights.

Planes used for night flights may be profitably equipped with searchlights and flare rockets for illuminating the ground below. The principal lights employed for marking landing sites may be grouped as follows: the electric arc, the incandescent bulb, the acetylene lamp, flares, rockets and bonfires. Lights must be carried on planes for nocturnal flights to illuminate the instruments, light the ground below and for signalling purposes. Luminous compounds applied to the faces of instruments have largely supplanted the use of a lighting system for this purpose.

Current for the searchlight may be obtained either from an air-driven motor, from the main motor or motors or from an auxiliary motor. It seems undesirable to consume so much of the power of the main motor or motors by deriving current from this source. Moreover, in case the main motor stops, the light fails. An additional motor for this purpose means considerable increase of weight. An air-driven generator insures power while flying, but if the plane is "stalled" or side-slips, the lights fail at the most critical time. If an air-driven generator is provided with means for switching onto the main motor in case of emergency, the best compromise appears offered. The air-driven motor is most favored at the present time. This arrangement saves the weight of the auxiliary motor, additional fuel (which may be scarce in the war zone) and complicated machinery.

Navigation lights should be mounted on planes, as in marine practice; a green light on the right wing tip and a red light on the left wing tip. This practice should be applied to all services of aircraft.

Searchlights. Experience has proved that the silvered mirror searchlight produces the effect of bending the rays back upon the pilot in fogs, mists or even in damp weather. Yellow metallic mirrors do not possess this defect and should be used. Searchlights are of different types, the most common being: electric projector type as generally used on automobiles, the oxy-gasoline projector and the oxy-acetylene type of projector. The automobile electric projector consists of an electric bulb and a mirrored reflector. The oxy-gasoline projector consists of a container charged with a mixture of oxygen and gasoline. This mixture, emitted in a jet and ignited, is directed on an earthen cake to render it incandescent. This light is projected by a powerful yellow, metallic reflector. The system is simple, positive and self-contained. The consumption is small and the light may be operated continuously for a long period of time. The weight of materials and apparatus used are small. The oxy-acetylene projector, similar to the oxy-gasoline type, is notably economical.

Searchlights should be mounted on all planes used for night flights, of sufficient size to carry the equipment. Planes not equipped with searchlights must be supplied with flare rockets. Both should be provided when possible.

It should be remembered that a light which blinds or dazzles the aviator is a source of danger, not of help.

The searchlight is employed as follows: At about 1,500 feet, the light is turned on and the ground searched by playing the light slowly from front to rear and from side to side. Having discovered a landing field, the plane is glided after determining the drift, due to the wind, and making proper allowances (that is selecting the proper direction from which to approach). The observer operates the light. It is very difficult for the pilot to operate the light and fly his craft, hence when flying alone, the pilot must switch off his light at low altitudes, drop flares over the field and trust entirely to this illumination as an aid to effect the landing. Proper lighting of fields from below is certainly to be preferred to the exclusive illumination from the craft.

Flare Rockets. Planes should be equipped with pyrotechnic balls or parachute flares sometimes known as fire balls, flare balls or luminous mines. The distinction between parachute flares and fire or pyrotechnic balls is that the former are designed to fall slowly and illuminate a larger area, while the balls drop swiftly to the earth and illuminate a smaller area with a concentrated illumination. The latter are mainly used for lighting up a hostile position, dazzle the enemy and furnish excellent observation; sometimes superior to day work on account of the lack of effective counter measures. The parachute devices are very satisfactory, lighting the field below while the parachute shields the light from the aviator above. When the plane glides below the flare, reflection is unimportant as far as interference is concerned. A good flare should fall slowly and illuminate an area of about one mile for a period of three or four minutes. The illumination of flares is in the nature of a flood of light, whereas the searchlight projects a concentrated stream of light. The use of flares is not confined to landing operations but is extended to all military night flying, over the theater of operations, involving reconnaissance of hostile positions. In the latter work, flares are indispensable.

The Krupp Flare. This device consists of a tube containing a parachute and a series of explosive and illuminating charges. The charges are arranged to ignite successively and give a prolonged illumination of an area, after the fuse has ignited the first charge, driving the parachute out of the opposite end of the case. This device is unusually effective.

Night Lights for Landing Sites. Night lights, which mark landing sites and indicate the proper direction from which aircraft should approach, are called range lights. *Range lights* are generally mounted to swing with the wind; mounted on trucks so that they can be moved to conform to the wind; arranged to light and occult or extinguish automatically with each change of wind direction; or fixed in position to mark the boundaries of the field.

The variety of methods at present employed in lighting landing sites should be standardized throughout the flying world.

Red flares may be used for illuminating fields or canvas strips. These signals should be moved by hand to a new location for every change of direction of the wind. Rockets and Very lights should be used to attract the attention of aircraft to the spot, when it is apparent that the pilot cannot find the field. Strong or powerful searchlights or acetylene projectors may be used to illuminate sites. These must be carefully trained upon the ground and carefully shaded from the approaching airplane so as to intercept all direct rays or reflections.

Bonfires, if properly shielded; buckets of lighted gasoline; white sheets or strips, illuminated by lanterns or small lights, constitute good substitutes in an emergency. Lights in the vicinity of the flying field should be extinguished, shielded or occulted from overhead view. Dangerous parts of a field should be marked by colored lights.

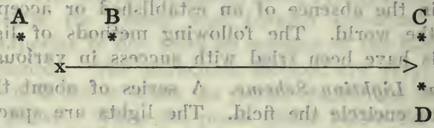
A standard system of lighting should be adopted throughout the service in the absence of an established or accepted system throughout the world. The following methods of lighting permanent fields have been tried with success in various countries.

Triangular Lighting Scheme. A series of about thirty lights are placed to encircle the field. The lights are spaced equally. The circuit is controlled by a sensitive weather vane that swings with the wind, makes proper contacts to illuminate certain lights in the circle. This forms a triangle of lights which indicates location and wind direction to the pilot seeking the landing field. Five lights in the circle of thirty are used to form the triangle. A single light serves as a pointer. Two adjacent lights mark each of the other two points of the triangle. The pilot is expected to enter the field between the double twin-lights and approach the single light. Any light in the circle may become the pointer light as governed by the controller wind vane. All the lights should be placed in special pits in the ground and covered with heavy glass capable of withstanding the weight of the airplane running gear. This system is useful for fields just large enough to meet the requirements.

Twin-light System. A large pit is provided in which a very bright light is placed and covered with heavy plate glass. This light burns continuously when airplanes are expected, being placed in the center of the field, the radius of which is long enough to accommodate the speediest plane that is expected to land there. Four red lights are placed at the cardinal points of the compass. Only one of these lights burns, indicating the direction toward which the wind is blowing, except that in case the wind is blowing between two cardinal points, the two red lights marking the adjacent cardinal points are illuminated. The lighting is regulated by a wind vane, electrically connected to the lights.

Concentric Light Circles. This system has given excellent results. Two illuminated circles are disposed concentrically, one circle having a diameter of about twice that of the smaller. These *light circles* are placed vertically, so that the aviator directly overhead, they would appear as two bars of light. An aviator approaching the circles at an altitude of a few hundred feet would see two circles of light crossing each other. Only when approaching the larger circle with the small circle displayed concentrically, would the plane be at the proper spot to land.

Parallel Lights. With this arrangement of lights, it is expected that the plane will land at some point x opposite the interval between the twin lights A and B (see diagram below), and pointed in the direction of the arrow, as indicated, the plane should come to rest before the line C—D, marked by two lights, is reached. Such a scheme is best used where movable lights are employed.



Outline lights should be so placed on the field, with reference to the wind, that the aviator cannot mistake the field, the line of flight for landing and the wind direction.

The desirable effect to produce in ground lighting, is to throw a strong light toward the horizon and as weak a light as possible towards the zenith. Searchlights must be fitted with lenses and mirrors so arranged that the rays are directed toward the horizon, diminishing in intensity as rapidly as possible to the zenith. For picking up aircraft, as is necessary in searching for hostile aircraft, considerable success has been achieved by means of a revolving reflector projector, employing a striated glass surface placed to intercept the rays and bend them by refraction towards the sky. To locate aircraft at night, by searchlights, is a difficult undertaking requiring elaborate preparations. Flare rockets may be fired from the ground as an aid to airplanes making a landing.

Searchlights equipped with shutters for alternately occulting and illuminating are useful for night signalling employing either the wig-wag or telegraphic codes.

PHOTOGRAPHY AND CINEMATOGRAPHY

Photography. Photography is a subject for specialization. A capable enlisted photographer should be developed in every air unit. Observers, however, should be given a course in photographic work as it forms an important part of reconnaissance duties. Photography should in fact be employed to the fullest possible extent in aerial reconnaissance.

The two principal forms of camera in use at present are the automatic and the so-called pistol camera. Automatic cameras are so devised that the operator having started the instrument, exposures are automatically made at intervals of a few seconds according to the setting of proper regulating attachments. A series of consecutive views are thus obtained over a locality, following the line of sight. A guide line, regulated by the axes of the machine and the action of the mechanism, establishes the line of union for two adjacent exposures. This gives a route picture following the course pursued by the plane during the period of exposures. A scale is computed from the focal angle of the lens and the altitude at which the exposure was made.

The pistol camera is any form of hand camera adapted to principle of a pistol. The operator carries the instrument to be exposed in the manner of firing a pistol. A trigger device actuates the shutter. This instrument is usually arranged to press against the eyes to obtain greater steadiness of aim. This instrument is made use of in the training of aerial gunners. The machine gun is merely a camera device. The machine flies past the pylon or other form of target and "fires" the machine gun, making an exposure and registering the correctness of his aim by the cross lines indicated on the developed picture. Panoramic cameras may be used with profit in aerial reconnaissance.

Provision should be made for developing plates and films immediately upon landing from a reconnaissance flight. This development should be made within 15 minutes. Within a very few minutes after the landing is made, the views should be thrown on a screen by a stereopticon or balloptican lantern and details can thus be magnified and studied. The value of reconnaissance reports amplified by photographs is immeasurable. The important fact to be regarded as preëminent is that the eye of the camera is unfailing and may record details either overlooked by, or invisible to the eye of the best trained and most experienced observer. The telephoto lens has brought great development to the field of aerial photography. Films should be enlarged when unusual detail is required.

Cinematography. The use of moving picture apparatus from airplanes has been exceedingly limited. This field of work adapted to the conditions of reconnaissance work offers unlimited possibilities.

AERO APPARATUS

Stabilizers. Stabilization of planes is obtained through damping out the oscillations, either by means of disposing counteracting surfaces or by means of a device designed to regulate the control surfaces. Persistent efforts have been made to render flying a simple or safe enterprise by creation of a fool-proof method of control, either mechanical or automatic. Attempts to obtain stabilization by use of shifting weights and auxiliary helicopters have been very common but unfruitful and such devices are certainly dangerous in the present state of development of aviation. Inventors should be warned that perhaps no field of human activity offers more peril to the practical experimenter than that of stabilizing planes. Novices are especially prone to delve into the mysteries of stability of flight. That the subject will be fully mastered is to be hoped. It is more probable that the solution rests in greater versatility of wing structure performances, such as variable camber, variable retreat ot wings, variable dihedral, variable surface area and great range of action in varying the angle of incidence.

Inherent stability, obtained by the proper disposition of fixed stabilizing surfaces disposed to produce righting forces in flight, is derived at a cost of controllability, proportional to the degree of stabilization. Automatic stabilization offers perhaps less drag on the machine, since the forces are exerted on the control surfaces, more or less in constant operation by the pilot under any circumstances. The installation of automatic stabilizers naturally adds weight that could be otherwise used for more necessary apparatus.

Two types of automatic stabilizer are discussed briefly here.

The electrical stabilizer depends on a so-called censor device. This device consists of a cube box, having contacts fore and aft and at either side. A specially made ball is seated in this box. This ball is a perfect sphere, the surface a special metal to preserve its shape and give great hardness, conductivity and other desirable properties. When in position there is a small clearance, so that the ball may be free from all contact but that of gravity. In practice, the ball rolls to the lowest point, makes a contact, closes one of the circuits and starts a motor which turns one of the drums on which the control cables are wound. This actuates the control surface affected. The censor device can be adjusted to conform to the flight path of the plane. This type of stabilizer is simple and rugged in construction and action. It should be superior to other established types because it is less apt to get out of order, easier to install, occupies comparatively small space, and is lighter and cheaper to manufacture.

The *gyroscopic* stabilizer operates on the principle that a gyroscope inherently returns to its vertical position when disturbed. This can be seen by studying the behavior of a spinning top. The type of gyro employed for stabilizing airplanes, however, is driven by an electric motor deriving power from a small generator, auxiliary air-driven or internal combustion motor. In the Sperry gyroscopic stabilizer, four gyros are nested in a cardan ring. "Operating in connection with a force impressor system, the ring is maintained in a horizontal position regardless of the movements of the airplane." As the plane moves about the gyro unit under air disturbances, electrical contacts are made which start one of the motors. The motor turns a drum upon which the control cables are wound, actuating the control surface and the plane is brought back to the normal flying position.

Airmen, as a rule, do not favor automatic stabilizers. Inherent stabilization obtained as cited hereinbefore, by proper disposition of centers or axes of gravity, resistance and thrust, is more reliable.

High degree of controllability may be used to compensate for the lack of stabilizing features. Some pilots favor controllability as opposed to stabilization. The highest example of controllability is offered by the pursuit type of airplane in which celerity of response to control is of prime importance to produce a machine that will possess maximum maneuvering qualities.

Automatic stabilizers, when used, must be equipped with a mechanical "cut out" device for use in landing and in case of failure of the stabilizer. One of the chief faults of the automatic stabilizer is that it cannot land the craft. No device used for the purpose at the present time will positively prevent stalling except in a horizontal stream of air, moving at a uniform velocity. Question has also been raised on the ground that it fails to relieve the pilot of all strain, one of its *raisons d'être*. Owing to the lack of reliability and the sudden vagaries to which stabilizers in use at the present time are subject, the pilot cannot afford to divert his attention from the air and power controls.

ARMOR AND ARMAMENT FOR AIRCRAFT

Aircraft armament is classified as:

1. Rapid fire guns, employing explosive projectiles,
2. Rifle or machine guns,
3. Explosive, incendiary or other forms of missiles (bombs), including shell and shrapnel, for use against objectives on the ground.

Rapid fire guns and machine guns are used against hostile aircraft, and against enemy troops on the ground. Bombs are employed against airships, kite balloons and material objectives on the ground. Rifles are of small if any use in aircraft. A machine gun is rated about 16 times the value of a single rifle.

Rapid Fire Guns. Volume of fire and disruptive force must be sought in the use of rapid fire guns, employing explosive shell. A high striking velocity is not very important in explosive shell, for use against aircraft, although high velocity gives greater steadiness to the projectile in its flight. The short range at which aerial gun fire is conducted, eliminates the need of high power guns. Great accuracy of fire is not essential. The detonation of shells nearby, without actual contact with the aircraft structure, is usually sufficient to cause a collapse. Distances cannot be stated in this connection, but the guns usually weigh in the neighborhood of 250 pounds, but a reliable weapon of this type, having a caliber of $1\frac{5}{8}$ inches, has been produced which weighs only 75 pounds. It is not likely that this gun will wear well. However, pieces that would be too light and short-lived for other uses, are entirely suited to aviatic needs where lightness of materials must be sought to the exclusion of ordinary economy. The two-pounder referred to above fires with a muzzle velocity of 1,200 feet per second. The balanced or non-recoil rapid fire piece is made both in the two-pounder and in the 3-inch guns. The gun is loaded in the center, between two barrels. The projectile is inserted in one barrel, a load of fine shot in the second barrel and the powder charge placed in the chamber between the two. When the piece is fired, the shot are discharged in one direction, the projectile in the opposite direction and the two forces tend to balance; the difference is the recoil, which is slight. The shot spread within a short distance. Three-inch guns have been used with success in airplanes. It must be remembered that the ordinary types of 3-inch guns, such as are used in the field artillery or in the defense of mine fields, are many times too heavy for installation in aircraft. The problem is altogether different for another thing. In aerial combat, it may be mentioned here, the antagonists close in to short ranges. Most of the fighting is done at less than 100 yards range. This is habitually true when the weapons employed are machine guns. Reduced ranges are also used in the operation of rapid fire armament. Even at these short distances the hostile plane is a bewilderingly uncertain and elusive target. These conditions are entirely favorable for the use of 3-inch guns, employing a very light projectile and low powder charges, which give a low muzzle velocity but set up a minimum of internal stresses and admit the use of very light short guns. One type of 3-inch aircraft gun fires a twelve-pound projectile at the low initial velocity of 1,100 F. S. Rapid fire guns larger than one-pounders are used only on the largest planes having an enormous carrying capacity.

Machine Guns. In aerial combat the action between two or more craft is brief. Rapidity of fire is therefore of prime importance. The unfavorable nature of the targets and the difficulties of operating weapons render accuracy of fire an almost unattainable condition. This must not be taken to mean that a reasonable accuracy of fire cannot be achieved by a diligent and well-trained gunner. A very slight difference in gunnery between two opposing airmen will usually present the difference between defeat and victory. The degree of accuracy compassable, however, is limited, hence the importance of delivering volume of fire. High controllability is essential. Lightness is imperative. The machine gun offers the highest rate of fire with the other required features to provide the most suitable weapon for aircraft use.

Lewis Machine Gun. This weapon, the invention of Colonel Isaac N. Lewis of the United States Army, is the standard aircraft weapon of the present day. The gun is admirably adapted to airplane work on account of its extremely light weight and its simplicity of action.

Descriptive Data on the Lewis Gun. This piece is primarily notable for its simplicity. It consists of sixty-two working parts. It is an air-cooled device, weighing from twenty-five to thirty pounds with the necessary mountings for an airplane. The gun is easily transported by one man. It can be fired instantaneously from any position, mount or cover. It withstands sustained fire without changing barrels or other parts of the mechanism. The cooling system consists of fixed parts. A cylindrical jacket of aluminum "having deeply cut longitudinal grooves throughout its length and circumference is encased in a thin steel casing," the muzzle end extending with a reduced diameter beyond the jacket and barrel. The jacket and casing constitute the entire cooling system and together form the radiator. To the end of the barrel within the casing is screwed a specially shaped mouthpiece which so influences the blast that the ejector action is aided by syphoning cool air through the radiator grooves. (NOTE: The radiator is removed for airplane use, as a rule, on account of the ample cooling produced by the normal air blast in flight.)

The extension casing beyond the muzzle prolongs the action of the gas on the bullet, after the latter leaves the muzzle, thereby accelerating velocity in spite of the loss of a portion of the gas, consumed to operate the working parts of the gun. The recoil of the piece is practically negligible, due to the manner of trapping the gas to reduce powder blast friction.

The automatic action is described by the manufacturer as follows: "The gun is operated automatically by trapping a small portion of the live powder gases before the bullet leaves the muzzle and causing this portion of the gas to impinge against the head of a free moving piston which is driven back against the force of a spring and returned to its position by the spring when the force of the gases is spent." The piston unlocks the breech bolt, ejects the empty shell into a bag, feeds a new cartridge into the chamber, relocks the bolt and fires the piece. This operation is performed by pulling the trigger on one bullet and continues as long as the trigger is held down. Single shots are possible by pulling and releasing the trigger quickly. In the same way, two, three or any number of shots may be fired at will. The magazine capacity is forty-seven cartridges. Four seconds are required to change magazines under favorable circumstances. When a new magazine is inserted, the charging handle is pulled to the rear and released, arming the gun for action.

The aircraft attachment is simple and installed with the following accessories: (1) mounting standard, a circular base with an upright portion; called (2) mounting yoke pillar; joined to

(3) mounting yoke; by means of (4) hinge pin. The mounting yoke receives the machine gun approximately at the balance of the piece.

Machine Gun Mountings. The usual method of mounting the machine gun on the single seater is to secure the weapon rigidly upon the upper plane. The mount consists of a front pivot and a rear universal joint, which enables the pilot to swing the piece to the rear and downwards when it is necessary to change magazines. When the gun is "in battery," it is held rigidly in a position parallel to the longitudinal axis of the plane. Front and rear sights are so placed that the pilot can sight upon an adversary by pointing the plane, fire being directed to the front and true to the line of flight. The piece is operated by an attachment on the steering wheel or control post, connected to the trigger of the gun by a wire or lever device. A battery of two or more guns may be located on the upper plane in a similar manner. In two-place and larger types of planes, gunners operate the machine guns under more favorable conditions. The practice is sometimes followed of mounting the machine gun to fire over the hood and through the blade of the tractor screw. This can be done in two ways. Either each discharge of the gun must be synchronized with the rotary action of the screw to fire a shot only when the turning blades are not covered by the gun, or the screw must be armored to deflect those bullets which strike the blades. In the first case the timing of the gun is obtained either by means of electrical action which successively "makes and breaks" a circuit, or by mechanical devices which arrest the firing action during the time that the blade covers the line of fire. This arrangement is complicated at best. The method of armoring the blades is generally more favored. A triangular-shaped steel plate, of about two-fifths inch thickness, is secured by special fittings to the blade so as to cover the line of fire of the machine gun. Small channels are cut into this plate, leading to right and left. These assist in deflecting the bullets that strike the armor plate. The gun must be fixed to have a constant line of fire, adjusted to position with reference to the plates, or *vice versa.* About five per cent of the bullets are lost in this system but it is more satisfactory than by timing to fire through the revolving blades, although the rocking effect on the blade is extremely undesirable. In two-place and larger planes, machine guns are mounted with special reference to the functions to be performed by the craft and the kind of fighting to be expected. Permanent mounts are provided for machine gun or rapid fire armament upon the frame of the body. Mountings should, in any case, be incorporated into the design of the craft and placed with particular regard to the stresses exerted by pieces in action. The gunner should be protected from the wind blast by a transparent protector plate, whenever practicable.

Anti-aircraft armament is considered under MILITARY AVIATION. (See COMBAT.)

Bombs. Missiles for offensive operations from aircraft are classified as follows:

(a) High explosive shell bombs, detonated by direct action, or percussion fuse. The weight varies, in general practice, from 15 to 100 lbs. (For use against material objectives.)

(b) High explosive shrapnel bombs, or shell, detonated by time or percussion fuse. (Shrapnel may be used by gun planes in pursuit of routed forces. Modern shrapnel is generally a combination projectile, for use as shell in percussion fire.)

(c) Hand grenades.

(d) Fire (or incendiary) bombs:

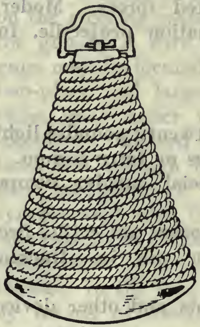
1. Gasoline; weight from ten to twenty pounds; lighted by fuse, Very cartridges or ferro-cerium.
2. Composition; filled with special burning compositions.
3. Anti-airship rockets; special rocket projectiles fired from a special gun; for use in attacking airships and kite balloons.
4. Flare rockets, parachute lights and other devices for illuminating areas.
5. Asphyxiating bombs, for use against personnel.

(e) Smoke bombs, for signalling, or for concealment of craft when seeking escape.

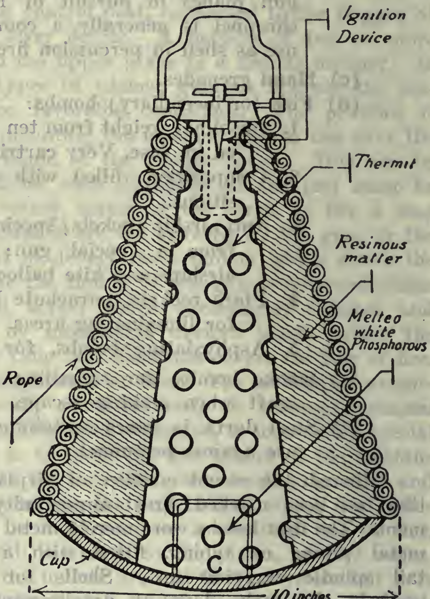
(f) Steel darts, in boxes containing from 150 to 200; for use against personnel.

Although the recent advance of airplane missiles and projectiles has been marked, great opportunity remains for improvement. The first bombs were merely metal cases of large diameter, metal piping or tubing, fitted with a rounded nose and a tail spindle carrying fins. Shells for field guns were also used in the early days of development. Modern bombs are specially designed to carry the proper amount of explosive and fitted with well constructed tails, fuses, primers and other parts. The bomb consists of a case, properly shaped for ballistic efficiency and containing an explosive, a detonator, a booster charge, a primer, a fuse, perhaps an auxiliary arming or safety device, usually in the form of a safety pin and wind wheel, a tail and fins. The bomb should, whatever the type, be so devised that it will not "arm" without an appreciable drop, but the arming ratio must be sufficiently sensitive to act positively upon a reasonably short fall.

Safety Devices for Bombs. There should be three safety devices on all bombs used for aircraft work, viz. (a) safety pin (b) wind wheel and (c) compression spring, resistance split ring, or other fuse device. The safety pin must be pulled before placing the bomb in the release cradle or compressed air tube, according to the method of releasing. The wind wheel should be threaded to unscrew in a flight of not less than seventy-five feet, unlocking the plunger and arming the fuse. A compression spring or split ring yields under the impact of the missile against the ground. This allows the plunger to pierce the primer. The primer ignites the booster charge which explodes the detonator and the latter fires the main charge of explosive. Great



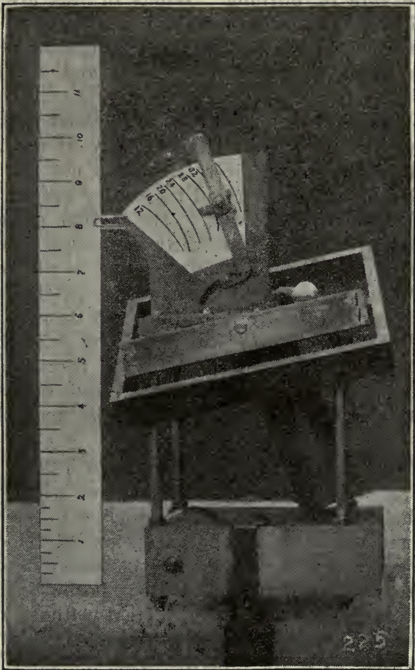
Sketch A
Appearance of an
Incendiary Bomb



Section of Incendiary Bomb.

precaution must be exercised to set all safety devices properly, certainly to avoid an explosion near the plane when the bomb is released or an explosion from jar when a landing is made with *disruptant* explosives aboard.

Torpedo Bomb. This missile is designed to avoid the usual fault of aero missiles which have the tendency to bury too deeply before detonation. To prepare the missile, the time fuse is set to the distance between the craft and objective. The fall of the first fifty feet fires the auxiliary primer by the action of the nose pin wheel. The flame travels along a rope powder composition. When this is entirely burned away a plunger is forced into its seat and the booster charge encircles the detonator. This move-



Bomb-dropping fire control apparatus, mounted on gimble bearings. The speed scale and altitude chart are shown.

ment also carries a primer down upon a firing pin and the flame travels along time element to detonator which explodes and detonates main charge. A percussion device is provided. The bomb weighs about 100 pounds.

Incendiary Bombs. Incendiary bombs usually depend upon gasoline to effect the conflagration, but special burning compositions have been introduced and used with more or less success. A simple and satisfactory form of incendiary bomb may be described as follows: It consists of a tank containing gasoline and a powder charge container. The tank is mounted on the shaft of an arrow. When the point of the arrow strikes or is arrested in flight, the momentum of the heavy tank carries it onwards, the action setting into high motion a toothed wheel which rotates against a fixed ferro-cérium brush. This friction generates a stream of hot sparks which ignite the spilled gasoline. The charge of powder is also ignited, exploding and increasing the rate of burning. Wings or fins are adjusted to the arrow spindle, in order to maintain steadiness of flight. Two barbs are attached to the arrow for use against airships. The barbs are designed to arrest the arrow and set off the fuse devices.

Bomb Dropping. If an object is released from a moving body it will move forward with the velocity of the body. When a bomb is released from an aircraft, it does not fall vertically to the ground but describes a curved trajectory (flight path) in the direction followed by the craft. The action of gravity pulls the bomb downwards with a constantly increasing acceleration, and while the horizontal velocity decreases, due to air resistance and disturbances, the vertical velocity increases as the square of the time (t^2). In order to score a hit by bomb dropping, these various factors must be known exactly. The trajectory (curved flight path) can then be determined with precision, reduced to some practical method for application and adjusted to conform to certain rules of gunnery whereby accurate aiming is attained.

The parabolic trajectory described by a falling bomb varies with velocity of the craft and the height from which thrown. The greater the height and speed, the farther will the missile carry to the front (to the point at which its forward velocity is wholly spent; at this point, the velocity of the bomb becomes entirely vertical). An airship can stand still or hover against the wind directly over its objective and drop bombs without respect to the height or time factors. The horizontal component of the trajectory increases with the speed. This effect is reduced, as has been cited, by air resistances and disturbances, but such effect can be modified by adopting efficiently shaped bombs, fitted with effective tail fins to obviate tumbling and damp out oscillations, and by releasing the bombs in a horizontal position to a considerable extent by propelling the bomb from a compressed air tube.

From the above, it is evident that the greater the initial velocity and height at which released, the greater must be the distance in advance of the target at which the bomb is released. With certain ballistic tests and computations, based on a missile of known weight and form, it is possible to construct a table of heights and velocities, to give the time in seconds at which the bomb must be released in advance of the target. For convenience this time factor is reduced to angular measure so that a telescopic sight can be set at a computed angle, corrected for all influences, and the bomb released when the target appears in the field of the lens.

The height is determined by the aneroid barometer. The speed is obtained by reading the angle to a selected objective before the objective is reached. The time elapsing between the first sight and the second sight when passing vertically over the objective can be reduced to speed if the height and angle are known. The speed and height known, the angle for setting the telescope for actual bomb dropping can be quickly obtained from computed tables. The telescope is then set at that angle. The plane approaches the target along such a flight path that it is drifting straight over the objective. When the target appears on the cross wires of the sight, the bomb is released. Accuracy in bomb dropping depends upon the teamwork developed between aviator and gunner. Since the direction of drift must be adjusted so that the flight path of the airplane crosses the target center with great exactitude, and since this line of drift is determined by the steering of the craft, as much depends upon the aviator as upon the gunner. Inaccuracies caused by variable air conditions and errors in the determination of speed should be corrected in subsequent rounds. Hence the gunner having released his bomb should spot for accuracy of fire.

The practice of dropping bombs has been improved upon by the introduction of the compressed air tube for projecting bombs. The launching device for dropping bombs usually consists of a simple cradle.

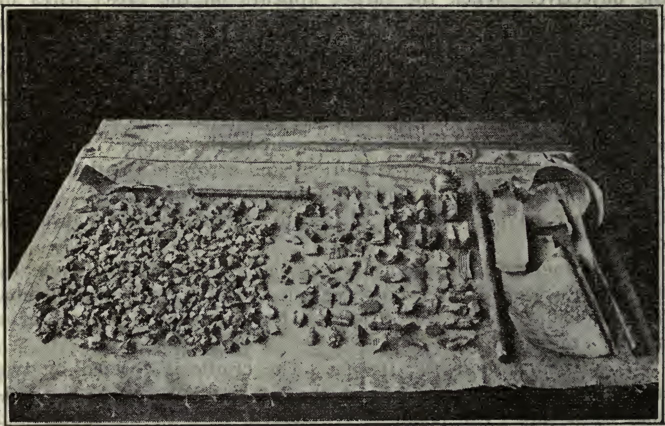
Launching Cradle for Bombs. The cradle is formed by two sets of metal fingers, hinged at the top and secured at the bottom by a pin. The bomb is introduced, nose to the front, and released by pulling the pin. Precaution must be exercised, in locating the cradle, to anticipate the possibility of the bomb coming into contact with any part of the craft when released. In the interests of economy, wireless and photographic apparatus installed in airplanes should be demountable and replacable by bomb-dropping equipment.

Bomb Carriers. Bombs are carried in racks or cases called clusters. Clusters usually consist of groups of six or more bombs.

Steel Darts. These are slender, pointed spindles. The tail is spiralled to produce a rotary motion and steadiness in flight. Darts are packed in boxes of 150 or 200, generally, and an entire box is emptied at a time.

These weapons are directed against massed troops and released according to the rules governing bomb dropping. The bombs scatter and cover a rather large area in a long fall. At a height of about 5,000 feet a dart has been known to strike a horseman on the skull and penetrating the full length of his body, enter the body of the animal he rode. Darts are very uneconomical, however, and scarcely worth the weight forfeited to carry them.

Armor. One-eighth or five thirty-second inch armor plate is generally used on airplanes operating at altitudes of not less than 7,000 feet; one-eighth inch armor weighs about 10 pounds to the square foot. Armor on airplanes is mounted in sheets, in turrets and in shields. The proper disposition of armor depends mainly upon the type of the plane, which usually regulates the average altitude at which the plane must be flown. Type also determines the weight margin available for armor protection. The



Fragmentation of a fifty-pound bomb

altitude at which the plane is to habitually operate, the resistance of the metal used, and the particular kind of fire to be met, regulate the thickness of metal required. The important conception of the use of armor protection is this: Ineffective armor is worse than no armor; if not proof against fire, it merely serves as an aid to fragmentation, and increases the destructive effect of the fire. It is better to have a small amount of adequate protection than a large amount of armor of insufficient thickness, since every portion of the vitals so protected makes the plane a stronger war craft. On account of the dangers of light armor, and the losses of flying efficiency in some direction for every pound of weight added, armor protection is rarely ever sought, except against fire from the ground. This protection takes the form of floor plates beneath the motor, tanks and passengers. When armor protection is furnished against adversaries in air fighting, the shield or turret is usually adopted. The latter requires an excessive amount of material. The shield should be so arranged that it can be lowered when not in use to give protection from below. The shield should then be mounted on a universal point with means for rotating the apparatus during a combat. The objection to any kind of cover for protection during the aerial combat rests upon the fact that ranges are point blank as a rule, hence adequate armor would add excessive weights. Overhead armor is not to be considered at the present time. Owing to the limitations imposed on weights in airplanes, armor protection for plane surfaces, control structures, struts, braces and such parts, however important, is out of the question. It is imperative, however, to give these parts such construction as will not be severed or crushed by ordinary fragmentation or small arms fire. Duplication of parts should be resorted to in order to increase the factor of safety, in this respect.

The target presented by the plane to the observation of hostile gunners is small at mean and high altitudes, but the vital target which must ordinarily be struck fairly to cause material damage is much smaller by comparison. Suppose, for example, the target presented by the full area of the airplane is 250 square feet, and the vital part, composed of the motor, tanks and cockpit is 25 square feet. It is readily seen by scrutinizing an airplane flying several thousand feet high that a target of 25 square feet at such an altitude is a mere speck in space. This constitutes only one of the enormous difficulties of anti-aircraft gunnery. Hence a plane with vitals protected from a chance hit, flies at proper altitudes with a reasonable degree of security from gun fire.

Armor for Low Altitude Operations: The rôle of the airplane in warfare is offensive—not defensive. Armoring planes for offensive operations at altitudes below 1,000 feet is no longer impracticable. Heavy gun planes for pursuit of forces either demoralized or on the verge of rout are an essential part of the properly equipped air forces. These planes might perform but one such flight during an entire war, but when the need comes the demand is imperative and immediate. Armor, proof against rifle and machine gun fire at short ranges, is indispensable for this class of work. Artillery fire cannot be met defensively in the present stage of development of the airplane. The airplane here enjoys superiority of field of view, but it must elude hostile artillery by quick maneuvering and high speed. In a rolling or hilly country the plane would pass swiftly out of range and the low altitude would operate strongly in its favor.

PART III

THE SCIENCE OF AVIATION

CHAPTER I

METEOROLOGY

No aviator can be a good pilot without an elementary knowledge of meteorology. Experience brings this knowledge, but without proper theoretical instruction misconceptions are formed that may prove fatal.

All airmen sooner or later acquire a wholesome respect for the air and its behavior. Haphazard flying without regard to weather conditions can lead but to one end for the airman who is so injudicious. Scientific application of all the laws governing flight, including meteorology and navigation of the air, constitutes the greatest safeguard the airman can attain.

Meteorology is "the science of the atmosphere and its phenomena."

Characteristics of the air. The air is a gaseous fluid that behaves like water, seeking the lowest level and flowing toward the spot where the lowest pressure exists. The air is composed of about 21% of oxygen and 79% of nitrogen. There are also contained a slight quantity of ozone, carbonic acid gas and water vapor in suspension. The water vapor varies in amount with the temperature.

The envelope of air surrounding the earth has often been compared to the ocean on account of the fact that the air is a fluid having most of the physical properties of water, except that air is about 1,600 times lighter than water. The weight of air is, however, a matter not to be ignored, for at the bottom of the aerial ocean we are supporting a considerable weight in the form of a column of air over our heads. The atmosphere is at least 50 miles deep and may exist in a very light state as high as 200 miles. One-half of all the weight of the air is below 3 miles, measured upwards from the earth. Usually the temperature of the air decreases at the rate of approximately one degree for every 287 feet of altitude, or in round numbers, about three degrees for each 1,000 feet of altitude. This general rule must not be taken too literally. In fact, in meteorology the rules are generally the best approximations based on years of study and observations. Hence reliance must not be placed upon regular decrease of temperature with the altitude. This varies in different localities and at different seasons of the year. Commencing at sea level, the air becomes thinner with the altitude. In other words, the density, like the temperature, decreases with the altitude, although this is subject to variation under different influences.

Variation in density is caused by temperature and pressure. Temperature affects the density of the air since heated air expands, cooled air contracts; in either case there is less or more air contained in the same space than is normal. Pressure affects the density of the air because the deeper the body of air above a spot the greater the density at the bottom. Still air gets into motion in the following manner: Assume that day is just breaking. The air is in a state of rest and of a uniform temperature. The sun rises and the rays fall upon and heat the earth. The earth does not absorb the heat uniformly. Some portions are bare and some are covered with forest, brush, grass and so on. It is apparent that the bare spots will overheat and that the forests will underheat, relatively. A column of heated and (since it is expanding under the heat) ascending air will rise over the bare spot to the upper regions, diminishing the pressure in that locality, and the surrounding cooler air which has not diminished in pressure will fill in the space vacated at the bottom. The cycle has started, and the air is in motion. These ascending columns are manifested by heat waves over the land, glassy streaks upon the water and sometimes by certain cloud formations.

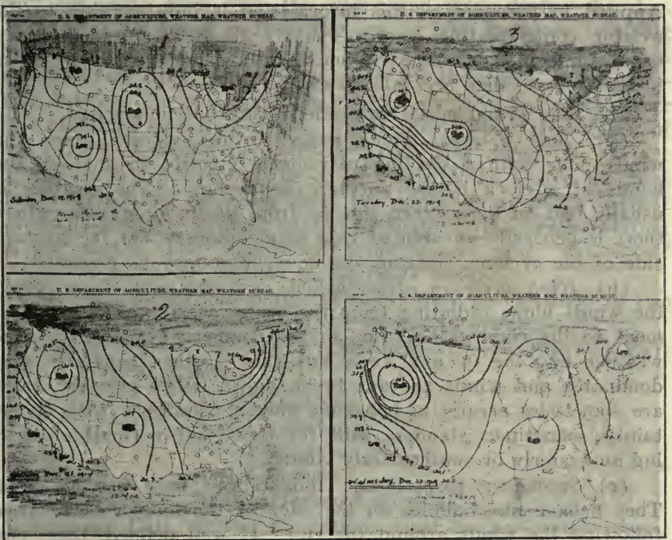
The effect of unequal pressures in the atmosphere is to produce aerial elevations and depressions, and aerial mountains and valleys are formed. Like water, air seeks to fill the depressions and the aerial mountains start flowing at once directly toward the aerial valleys. The aerial mountain is called a "high pressure area" and the aerial valley is called a "low pressure area."

Air does not flow in a *straight line* toward its destination. The surface air meets many obstacles in its path, such as mountain peaks, forests and other irregularities on the surface of the earth, which deflect the air, setting up aerial disturbances in many forms. At the same time, the earth is revolving on its axis from west to east, and this throws the streams of air off the true course, and deviates all flowing air to the right in the northern hemisphere, and to the left in the southern hemisphere.

The direction of flow of the air from the *high* to the *low pressure area* takes up a circling or spiralling course, and instead of flowing *straight* into the depression, flows around the edge in spirals like a tub of water pouring into an outlet. This effect is modified by ground-friction, which tends to reduce the deviating effect of the rotary motion of the earth upon the winds by tending to carry the air with it.

THE WEATHER MAP

Pressure Areas. Atmospheric pressure is the basis upon which the weather is predicted, and the first step in making up the weather map is accomplished by reading the pressure existing at the same instant at a number of stations scattered over a large area of country. Pressure areas are thus located; some are "high pressure" and some are "low pressure" areas. When these



Weather maps—Showing the progress of pressure areas

areas are mapped for several days they are found to be moving at varying speeds in a general easterly direction over the earth, occasionally toward the north or south, rarely ever toward the west excepting tropical hurricanes. Pressure areas appear to follow certain approximate lanes. They rarely ever stand still. They are shown on the weather map by rings within rings, and the outline in each case indicates the formation and location at the specified time. The rings on the weather map are like contours on a topographical map, each ring representing a line of equal pressure, corresponding to the height of the aerial mountain at that point. These pressure or weather contours are given the special name of *isobars*. The *isobars* indicate the locations of both high and low pressure areas. These areas are usually hundreds of miles in diameter. When the diameter of a low pressure area, also called a *cyclone area,* becomes unusually small the "pressure gradient" is said to be "steep," and the weather changes are sudden and violent; in fact the force of a cyclone is measured by the steepness of the pressure gradient and the velocity of the wind which the gradient determines. The winds flow spirally around the pressure areas, so it is evident that they flow very nearly parallel to the *isobars;* hence by consulting the weather map it is simple to note the general direction of the wind. Applied to aeronautics, this information is indispensable to the aviator contemplating a cross-country flight. The *isobars* are usually irregular in shape. When there are indentations or kinks in the *isobars,* they are called *secondary* formations.

The four grand aerial formations may be summarized:

(a) *Low pressure areas,* called CYCLONES, into which the winds pour with a circling movement opposite to that of the hands of a clock in the northern hemisphere. The weather is usually bad on the eastern side or front of the depression where there is generally an area of rain or cloudiness. On the western side of the cyclone, clearing, cooler weather may be expected.

(b) *High pressure areas,* called ANTI-CYCLONES, from which the winds blow, radiating from the center with a circling movement to the right (clockwise) in the northern hemisphere. The weather may be of any kind, but fair weather generally predominates and winds are apt to be light. High pressure areas are sometimes erratic in behavior, moving slowly or with uncertainty; sometimes standing still for days, but normally following an easterly or southeasterly course.

(c) *Secondary formations.* Indentations in a cyclone area. They behave like bubbles on the edge of the low pressure area, following the winds around the rim. If well defined, they may become small CYCLONE areas in themselves, and in this case, the weather is more severe than when the indentations are not very well defined.

(d) *Wedge formations,* a peculiar V-shaped formation, which occurs sometimes between two CYCLONE AREAS. They usually carry good weather but are of short duration, being followed closely by another CYCLONE area.

There are three classes of meteorological phenomena: *Aerial,* including winds, cyclones and so on; *aqueous,* such as clouds, fog and rain; *luminous,* such as lightning, the *aurora borealis* and others.

Winds. The action of the wind can be anticipated to a large extent from its habitual behavior. The average all year round wind in the United States is about 11 miles per hour. The wind is stronger by day than by night on the surface of the earth. Generally speaking, the velocity of the wind increases with the altitude. Normally it increases rapidly in the first 1,000 feet, but above that height the change is uncertain and may increase or decrease. Over the sea the wind has a higher velocity than over the land. On the coast, the wind comes up in the morning, increases to noon and dies gradually to a calm at dusk. During the night this "coastal" wind flows from the land to the sea. This exchange of air is accompanied by a return stratum, at a height of 500 feet or above, and does not extend to sea for more than fifteen or twenty miles. The reason for this is that the air is more heated over the earth than over the water and rises during the day. The cooler air flows in from the sea to take its place. During the night, the sea does not cool as rapidly as the land and the reverse cycle takes place. Owing to the difference of temperature between the polar and the torrid regions of the earth, there is a continual exchange of air, which affects about two-thirds of the earth's circumference. These winds flow along the surface of the earth approaching the equator where the heated air rises and flows toward the poles along the upper strata of air. These winds do not flow straight north and south, owing to the rotation of the earth. They are called *trade winds.* The "monsoons," typical of India, are similar to the *trade winds.*

All wind formations or disturbances may be classified in two groups, the *vertical group* and the *horizontal group.*

Formations in each group: (classification U. S. Weather Bureau). Vertical group:

Aerial fountains,
Aerial cataracts,
Aerial cascades,
Aerial breakers,
Eddies (forward portion).

(All vertical formations must be horizontal formations at or near the ground, for it is evident that a current approaching the earth must be deflected.)

Horizontal group:

Wind layers,
Wind billows,
Wind gusts and eddies (central part),
Aerial torrents.

Aerial fountain.

This formation usually occurs "during warm weather, over barren soil, especially over conical hills." They are troublesome, but not dangerous as a rule. Their presence is sometimes indicated by turbulent cumulus clouds at the top.

Aerial cataract.

There are two kinds of *aerial cataracts:* the "free-air" and the "surface" cataract. The first is the reverse of the fountain. It becomes dangerously rapid only in thunder-storms. The "surface" cataract is formed by the flow over a bluff or cliff of a body of heavy, cold or snow-laden air. These winds, called "*aerial torrents*" are usually formed at high altitudes, and the cataract is developed by the flow of the aerial torrent down a steep, barren slope. The formation where the heavy air flows over a precipice is similar to a waterfall. It is exceedingly dangerous to attempt a landing in such a disturbance.

Aerial cascade.

This is a formation caused by the winds following the surface contours of the earth in great bounding falls like the water cascades. They are not dangerous if the aviator remains above the treacherous eddies and counter-currents which form below the main flowing stream.

Aerial breakers.

These are choppy winds that behave in a manner similar to ocean breakers. They are as dangerous to aircraft as the ocean breakers are to seacraft. Aerial breakers are caused by strong cross currents and their proximity is revealed by corrugated, pitted or cross-lined clouds of very beautiful effect.

Wind eddies (vertical effect).

Wind eddies form under the brows of hills. The wind seems to describe a circle in the vertical plane. The front and rear travel *vertically*. The intermediate part flows horizontally. An airplane should avoid the pocket under a hill, but once in it, should head in and land parallel to the side of the hill.

NOTE: The above description of the wind eddy is a good illustration of the manner in which vertical winds become horizontal near the earth.

Wind layers.

This formation is a member of the horizontal group. The layers are superimposed masses of air moving in different directions and at different velocities. Passing from one stratum of air into another might result in momentary loss of buoyancy if the airplane enters a layer moving in the "same horizontal direction and with the same velocity." As the pilot instinctively points down with the first sign of loss of buoyancy and changes the direction of the machine with reference to the air, it is not thought that this formation is ordinarily dangerous. Wind layers should be anticipated when the weather is growing foul.

Wind billows.

Wind billows correspond to the waves on the ocean. They occur at the surface between two wind layers. They cause rough travelling but are not considered serious.

Wind gusts; wind eddies.

Fluctuations in the velocity of the wind near the surface of the earth are called *wind gusts*. They make a landing or a "take-off" exceedingly precarious. As these gusts vary in intensity with the mean velocity of the wind, the altitude of flight should, if for no other reason, be influenced thereby. Wind eddies have been described under the vertical group. As they are circles of wind in the vertical plane, they have both a horizontal and a vertical direction. This does not mean that they do not act in a horizontal plane, which is indeed a natural formation when a stream of air strikes the side of a cove, for example. Eddies occur on the windward and lee sides of hills and other elevations. The lee eddy is the stronger of the two.

Aerial torrents.

The aerial torrent is a body of air that is colder than the surrounding air or laden with snow or moisture; hence being heavier, it pours downward with great velocity. It is formed at cold altitudes, as a rule, and develops high speed down open valleys or barren slopes.

Dangerous wind formations can only be avoided by studying their characteristics and behavior and applying the knowledge gained. Various cloud formations are caused by the behavior of the air. A careful study of the clouds, which reveal weather conditions to a great extent, is therefore of first importance to military aviators, who cannot choose the weather in which to fly. With an intelligent understanding and application of the principles of meteorology, the pilot can usually anticipate abnormal conditions which make flying perilous. The periods before and following storms are critical.

In cross-country flying the topography should be carefully studied, wind directions and velocities determined and predictions of wind formations based thereon. The season, geographical position and diurnal changes in the atmosphere should be regularly considered in making the most common daily flights. A pilot will in this way cultivate the habit of coördinating his knowledge of meteorology with the principles of flying in a scientific manner.

Successful aviators owe their long, unbroken success and avoidance of mishaps to scientific flying. Without knowledge of the air, a pilot may become a clever aerial jockey but he will inevitably come to grief.

Cloud formation. (International System of Classification: taken from publication by the U. S. Weather Bureau.) Clouds are classified according to the altitude at which they habitually float. There are five cloud levels, viz., the cirrus, the cirro-cumulus, the alto-cumulus, the cumulus and the stratus.

Cloud Chart (Weather Bureau Bulletin).

1. (a) *Cirrus.* Detached clouds of delicate and fibrous appearance, often showing a feather-like structure, generally of a whitish color. (These are the highest clouds considered.)

(b) *Cirro-stratus.* A thin, whitish sheet of cirrus clouds.

2. *Cirro-cumulus.* Mackerel sky. Small globular masses of white flakes without shadows, or showing very light shadows, arranged in groups and often in lines.

3. (a) *Alto-stratus.* A thick sheet of a gray or bluish color, sometimes forming a compact mass of dark gray color and fibrous structure.

   (b) *Alto-cumulus.* Largish globular masses, white or grayish, partly shaded, arranged in groups or lines and often so closely packed that their edges appear confused.

4. (a) *Strato-cumulus.* Large globular masses or rolls of dark clouds, often covering the whole sky, especially in winter.

   (b) *Cumulus.* Wool pack clouds. Thick clouds of which the upper surfaces are dome-shaped and which exhibit protuberances; the base is horizontal.

   (c) *Cumulo-nimbus.* Thunder cloud. Shower cloud; heavy masses of cloud rising in the form of mountains, turrets or anvils, generally surmounted by a sheet or screen of fibrous appearance (false cirrus) and having at its base a mass of cloud similar to nimbus.

5. (a) *Nimbus.* Rain clouds. A thick layer of dark clouds without shape and with ragged edges from which rain or snow usually falls.

   (b) *Stratus.* A uniform layer of cloud resembling a fog but not resting on the ground.

It is seen from the above that clouds possess characteristics typical of the altitude in which they exist. This may be explained by the fact that the altitude of a cloud is an approximate indication of its density. Some increase or decrease of altitude is produced by up and down trends of air. Clouds are formed directly from temperature causes and show that precipitation is taking place. Their shapes are visible representations of the wind formations. The composition of cloud is merely moisture in suspension. The lighter the cloud, the higher it will ascend. Temperature changes, the density of the air in the locality, local and general currents, the amount of water vapor present or forming, all combine to produce a variety of cloud formations. A rip or tear in a cloud indicates the presence of a current of air. Even unbroken clouds indicate a smooth, even flow of air. Ragged, broken formations indicate presence and the behavior of wind currents and should be treated by the aviator as a code of weather signals.

The cirrus clouds are perhaps the most characteristic of clouds, although they take the most varied shapes. These clouds appear commonly at altitudes of 30,000 feet and more. They are very delicately formed, as a rule, consisting of light flocculent masses or isolated tufts, and thin, curling filaments, sometimes in rich or delicate hues but generally of a white color. The stratus variety of the cirrus class of clouds sometimes cover the sky completely, in formations like a tangled web, or more or less continuously of milky color. The mackerel sky is the lowest of the cirri class.

The alto-stratus is an intermediate cloud between the cirri and the cumulus. Its average altitude is about one-half that of the cirro-stratus.

The alto-cumulus cloud is a very irregular formation, having the appearance of small waves, which become larger and more compact at the center of the group. The cross lines in different directions indicate the presence of strong cross currents. The cumulo-nimbus is the typical thunder cloud. These clouds emit local showers, occasionally hail, of more or less violence. They should be studiously avoided by the aviator. "The front of thunder clouds of wide extent frequently presents the form of a large are spread over a portion of a uniformly brighter sky." The so-called wool pack clouds are indicative of the "diurnal ascensional movement" of heated air (aerial fountain). They dissipate when the aerial fountain ceases to rise.

Nimbus and stratus clouds belong to the lower levels. The nimbus are rain clouds. They yield steady rain or snow as a rule. Rifts in nimbus clouds almost always reveal a stratus cloud of the alto or cirrus variety. Under the action of strong, choppy winds, the nimbus breaks up into small, loose clouds called fracto-nimbus. This formation is known among mariners as "scud." The true stratus cloud takes the form of mists, fogs or solid clouds. They usually hang low over the earth, above 500 feet. Solid clouds like the stratus, the typical overcast-weather cloud, act as an insulator or blanket over the earth, preventing both radiation of heat and dissipation of cold. An overcast night is usually a warm night. An overcast morning is ordinarily chilly and damp. Fliers penetrating stratus cloud need expect no difficulty but nimbus and cumulus clouds must be entered with caution.

THE SCIENCE OF AVIATION

CHAPTER 2

NAVIGATION OF THE AIR

The following instruments are commonly used in aerial navigation:

The compass, for steering a course by a map;
The aneroid barometer, for indicating the altitude;
The barograph, for recording the variations in height and the elapsed time of the flight;
The pitot tube, air speed indicator or manometer, for indicating the speed relative to the air;
The tachometer, for indicating the revolutions of the motor per minute;
The inclinometer, for measuring the angular oscillations of the plane in a given direction;
The angle of incidence indicator, for indicating the flight angle of the planes, i. e., relative to the flight path;
Drift meter, to indicate the leeway of the craft;
Maps and holders.

For military journeys in aircraft involving reconnaissance, combat, bomb-dropping or artillery fire-control operations, special apparatus must be carried according to the nature of the work expected. Observers, however, should habitually carry the following articles: sharpened pencils, note-paper (preferably pads, indorsement size, sheets bradded together to avoid loss in flight), watch, field-glasses and dispatch cases. Cameras and photographic equipment should conform to the requirements of the flight.

Preparation for the Flight

Weather Maps. The weather maps for several days preceding should be displayed on a special bulletin board at the flying stations. An individual should be detailed in charge of the weather data, for specialization, if the services of a representative of the Weather Bureau cannot be procured. It should be the duty of the weather agent to collect the reports, study the meteorological situation, locate storm and doubtful areas, predict movements of the pressure areas, establish the localities where dangerous wind formations are prevalent. A bulletin should be posted twice daily of the local and general weather situation and special bulletins prepared for special flights. All flying stations should be periodically supplied with data from the nearest weather bureau station. Arrangements should be made immediately that the flying station is established to receive this information and intelligence of special or unusual weather conditions.

In preparing for a flight, high and low pressure areas must be located and expected movements noted. After a careful study of the weather maps and determination of probable wind directions and magnitudes, a detailed prediction should be made of wind formations for all points along the route. Conclusions should be influenced by the season, geographical location and established diurnal variations of the weather. Cloud effects should be studied in particular connection with the weather map for that day. All weather deductions should be noted on the margin of the topographical map prepared for the flight.

With a scientific grasp of the whole situation, the probable success of the flight will be greatly increased.*

Topographical Maps. A topographical map for a cross-country flight should be arranged with a view to greatest convenience in flight. A map having a scale of from two to four miles to the inch, has been found to be most satisfactory for military purposes. The first steps are to mount the map and construct the proper scale if one is not shown satisfactorily on the map. A margin should be left on both sides of a route map whenever feasible. Notes, reminders, observations, comments and other data can be entered on this margin for convenient reference during the flight.

As a part of the work performed in the headquarters of an air squadron, route and area maps should be prepared in advance, so that immediately orders for a flight are issued, the squadron or company commander can instantly obtain the proper maps for use in connection with his study of the situation.† Blank orders to pilots and observers can be filled in without delay, aircraft and flying crews quickly named, papers attached and immediately put into the observers' hands, and verbal instructions given, all within a few minutes. If this work cannot be prepared in advance, the course is plotted on the maps upon receipt of orders for the flight. It is convenient to set off on each "route line" the mile, five or ten mile marks. These marks may be called "mile posts." If the map is to be pasted or tacked to a board, the route will be on one sheet, a very desirable arrangement. If it is to be placed on a roller case, the route must be run down the center line, necessitating cutting the map into sections. These sections are then pasted together in one straight line. When depending upon it for compass courses, this method should only be used

*Pilots at flying stations should be required to render daily reports on flying conditions and currents should be systematically charted over topographical features of the adjacent country, with a view to providing tables of reference for common use.

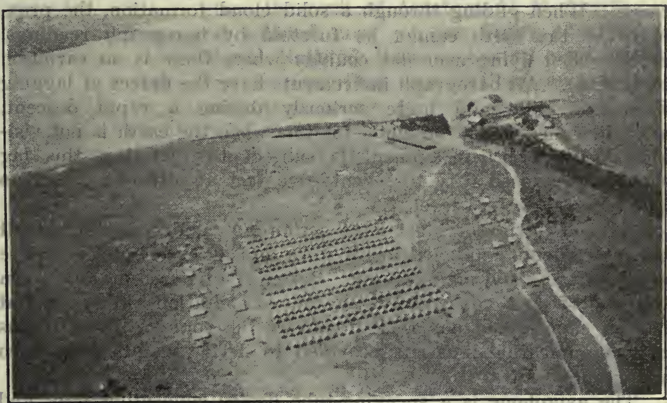
† In military flights over the theater of operations, no papers should be carried in a plane that would be of value to the enemy if captured. Military flights in time of peace should conform to the expected war practices.

by an experienced aerial navigator, as it easily leads to error. A handy method is to cut the map into equal rectangles, paste on cardboard sections and attach them to a large sheet of cloth. They can then be folded into a book form, a convenient arrangement when placed in a rack holder in front of the pilot. This obviates the necessity of arranging zig-zag lines of the course along one straight line, a system that is very confusing unless the navigator has had considerable practice. Route maps can be placed on a roller-case more conveniently. Area maps which are too broad for the roller-case can be placed on a large flat board holder, or arranged in rectangles as given above. In any event, *a margin should be left on one side of the map;* on both sides, whenever possible, especially if a return flight is contemplated over the same route. Compass bearing should be determined for each change of direction (called "legs") and corrected for geographical position. The corrected compass course is the magnetic course. These data should be carefully entered on the proper leg. The altitude to be maintained must next be considered. If in time of war, the altitude must be gauged or influenced by the effective vertical range of hostile fire. Other considerations now enter, such as gliding range, mountains to be crossed and distances between landing sites. Well-known landmarks and landing sites should be marked and notes made, together with small detailed sketches of such *guide-points.* All these above mentioned data must be entered in the margin of the map. Each note or sketch should be connected with the point affected by an arrow.

Navigation in Flight. Upon taking the air, the following principles of navigation are involved. The navigator must note the wind drift carefully. To take the true course, the machine is so headed that the compass reads the magnetic course. A distant object is selected on the magnetic course, and the craft is so steered with reference to the wind that the drift carries the machine directly over the objective. The angular difference between the two courses is the angular value of the wind drift.

Time is an important factor in aerial navigation. Computation of the elapsed time between two points, the intervening distance being known, gives the speed. The speed should be checked frequently, always between *guide-points* and between *mile-posts.* Variations in speed indicate slight (expected) increase of speed for loss of weight by reason of fuel consumption; disturbing wind formations, which may accelerate but usually reduce the speed; and change in magnitude and direction of the wind, indicated by variation in speed along the true course. (NOTE. Such variation is suggested by change in the compass reading, found necessary to keep the machine on the correct course to the objective. The altitude is an important feature of the flight. Wind sometimes decreases but usually increases with the altitude; certain conditions like the flow of the sea air landwards during the day are attended by an exchange of the upper air flowing back to sea at some altitude, and these counter winds must be anticipated in selecting the altitude for flights to be made along coast lines.)

Landmarks. The principle guide-points selected by the aviator should be objects visible at great distances. Bodies of water are usually visible at considerable distances. Lakes, bays and large rivers are satisfactory objectives. A winding river should not be followed as this involves loss of time; the course should be established between well-defined objects near or along the



Appearance of the earth from 4,000 feet

shore. Water courses are ordinarily the most satisfactory features of a map and easiest to follow. Towns and cities are usually found by following valleys, water courses, railroads or highways. Railroads are excellent guides, as they are easily followed, but branches and spurs are apt to be misleading unless carefully watched. Small sketches of towns and cities are useful, if drawn in the margin on the map and connected by an arrow to the proper point. Roads and highways are excellent guides, but to distinguish selected highways is difficult in a well-developed country, even to one familiar with the topography of the land. Forests, if small and isolated, constitute good guide-points. Elevations are not satisfactory unless very high, as they fade into the flat tone of the earth from normal altitudes.

Reckonings. One of the greatest sources of danger encountered in cross-country flying is the possibility of getting lost over the clouds particularly in the vicinity of a large body of water or desert. For short periods of time a compass course may be steered by bearings reckoned during an elapsed time, knowing a speed and proper angular allowance to be made for wind drift. Steering with reference to a mountain peak projecting above the clouds is satisfactory only when two peaks are clearly visible, enabling the aviator to steer a true course "for line." Otherwise, changes in the wind might drift the machine in a circle without any indication of the error.

Every precaution should be taken in descending through clouds in mountainous, hilly or wooded country. Always seek an opening through which to glide, so the earth below is visible at all times, thus avoiding the possibility of striking objects in case the clouds are low lying over the earth, covering mountain or hill crests. When gliding through a solid cloud formation, the proximity of the earth cannot be foretold by barograph readings, except when flying over flat country where there is no variation in altitude. All barograph instruments have the defect of lagging during a glide and quite seriously during a rapid descent, and allowance should be made for this when the earth is not visible. While every instrument is subject to variation, this lag should not exceed fifty to seventy-five feet at altitudes less than 1,000 feet above sea-level.

A good navigator must have a thorough understanding of all the instruments employed in his work and an excellent knowledge of topography and map-reading. Better results are obtained when the pilot is not concerned with the computations involved, but has an experienced navigator to direct the course. Some means of communication must be provided to derive results from such an arrangement.

The aviaphone is a speaking-tube device connecting pilot and passenger. It is adjusted by means of a telephone head set.

NOTE: The following notes and sketches should be entered in the margin of all topographical maps:

Prominent landmarks, with both notes and sketches; air-line distances; compass courses (corrected for geographical position); course distances; landing sites with complete data for locating them; elevations; wind formations to be expected; altitude necessary at certain points; data on the weather, gradient pressures, direction and magnitude of the wind.

THE SCIENCE OF AVIATION

CHAPTER 3

FLYING

In our service, candidates for instruction in aviation are selected from the following sources:

Officers of the line of the Army,
Enlisted men of the Aviation Section of the Signal Corps,
Civilian aviators, employed as Instructors,
Civilian aviators, employed to perform flying duties and given the rank of Aviators, U. S. Army,
Officers and enlisted men* of the Signal Officers and Signal Enlisted Reserve Corps, after passing certain prescribed examinations, undergoing a prescribed course of instruction and successfully completing specified tests.

Determination of fitness for detail of officers and men of the regular army, eligible for such assignment, is based on prescribed physical examination. Selection of civilians for appointment is based on mental and physical examinations, issued by the War Department from time to time. This information is furnished by the Adjutant General of the Army upon request.

Physical Requirements. Airmen should be physically perfect. This is especially so in the case of pilots. Hence the importance of certain physical requirements for airmen is recognized in practically every flying corps in the world. The examination of candidates consists of established medical tests to prove the condition of the senses of sight, hearing and the so-called sense of balance; the condition of the nervous, circulatory, respiratory and digestive systems; and the aspirants' temperament. In one service, certain shock tests are prescribed, which are accepted as infallible proof of the candidate's nervous condition. These tests are generally regarded as excellent indications of the candidate's probable aptitude. A blood pressure meter is attached to his limb. A pistol is fired without warning to the candidate, and the meter registers the variation in blood pressure, set up by the shock to his system.

Stages of Practical Flying. The undertaking of teaching men to fly presents no radical departure from the principles that govern the general science of education. There are certain definite and well-established stages in the flying course.

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*The Signal Enlisted Reserve Corps practically exists only for the assignment of those officially undergoing training for qualification as reserve officers.

These are divided into:

Practical flying,

a. Preparatory stage,
b. Preliminary stage,
c. Elementary stage,
d. Advanced.

To understand this classification clearly, it will be necessary to study the various flying stages as applied to each of the three well-established methods of instruction. It may be stated in general terms, however, that instruction in flying, up to the point where the pupil takes hold of the controls in free flight (off the ground), may be conveniently designated as the preparatory stage. When the pupil is permitted to take the machine up alone on a flight involving quarter, half or full turns, he has concluded the second period of his training, which may be known as the preliminary stage. From this point to the completion of his pilot's tests, the aviator is undergoing elementary training. From the *pilot's* to the *qualification* tests as a junior military aviator, the work may be described as advanced. Varied and specialized training in the art of advanced flying, as proposed hereinafter, including instruction in the duties of airmen other than pilots, should constitute a special postgraduate course.

Each of the above stages should be subdivided into steps and each successive air maneuver should mark a definite, progressive and logical advance in the course.

Instructors. The candidates should be divided into classes of not more than six each. Such a class should have a special instructor who should have charge of their entire flying instruction throughout the course. Should the instructor report unfavorably upon the progress of a pupil, the latter should be transferred to another class and before final adverse recommendation in the matter, the pupil should be given a fair test under the observation of a senior or chief instructor. Great caution should be exercised to prevent abuse of the more or less absolute authority that must be vested in flying instructors. On the other hand, the responsibility for loss of life must rest upon the instructor who permits an altogether unsuited pupil to continue flying. It must be borne strictly in mind, however, that many of the most skillful aviators have been discouragingly slow to acquire the knack of piloting. There is a marked distinction between unsuitability and slowness of perception, or physical awkwardness. Flying instructors should be selected from well-educated candidates of superior mental attainments, excellent judgment and clean moral character. The instructor in flying must be fair-minded and impartial to perform his important duties justly and efficiently.

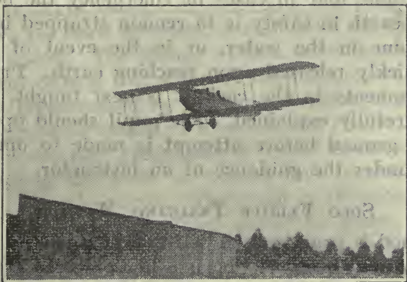
A chief instructor should be selected with special reference to his expert knowledge of aviation and practical and theoretical flying. He should if possible be a man of mature years and judgment.

PRACTICAL FLYING

There are three methods generally employed for instruction in practical flying, viz:

1. *Solo* or "grass-cutting" method;
2. *Dual* method;
3. *Combination solo* and *dual* method.

Regardless of the method selected, the preparatory instruction should embrace the following features. The pupil is first taught the nomenclature of the plane upon which he is to receive first instruction. The functions of the various units of the machine



Taking unnecessary chances. Gliding over buildings for landing with insufficient clearance.

must be explained carefully. The pupil is then taught how to inspect the craft, start the propeller, test the motor, make minor engine adjustments, set and read instruments and operate other essential equipment.

Inspection of the Plane (See Care of Matériel). The pupil should be conducted around the plane, the most important members pointed out, such as fittings, brace and control wires, landing gear, control hinges and fittings, power controls, safety belt and propeller. He is taught how to take his seat, adjust the safety belt and test the motor.

Testing the Motor. Some motors have air and gas adjustments in the cockpit. This is desirable. If a starter or crank is placed in the cockpit, the pilot can start his motor without assistance. The pupil is taught how to start the motor by means of starter device, by the crank and by spinning the propeller. He is instructed how to place the crew, in order to hold the machine, while the motor is being tested. He starts the motor slowly. If it is cold, the motor should be run lightly, speeding up gradually to 300 or 400 R. P. M. for about thirty seconds then to 600, 900 and 1,200 revolutions for like periods. The motor must not be run wide open on the ground, except for the purpose of testing the mixture, firing or other adjustments. It should be throttled down without delay when the test is made, as the motor heats rapidly owing to inefficient cooling, and excessive vibration results when running on the ground. The carburetor should be adjusted for quick throttling, quick impulse and rapid acceleration of power. These adjustments are taught the pupil.

Safety Belt. The pupil must understand the use of the safety belt. No device on an airplane is more important. It is not especially difficult to recover an overturned machine if at a safe altitude, provided the occupants are strapped in. All airmen should be taught that in cases of emergency the best chance of reaching the earth in safety is to remain strapped in. If landing a land machine in the water, or in the event of fire, the belt should be quickly released upon reaching earth. Practical use of all the instruments in the cockpit is next taught. All controls should be carefully explained. The pupil should operate all controls on the ground before attempt is made to operate them in flight, even under the guidance of an instructor.

Solo Flight Training Method

This method is practically a self-training course. The airplane for preparatory solo instruction is a low-powered craft with small supporting surface. It is not intended for use off the ground. A special small surfaced plane motored by a 30 H. P. engine is usually employed. It may be described as an ordinary machine with a stop on the throttle limiting the number of revolutions. The pupil is caused to sit in the operator's seat of the airplane and is taught the three controls, consisting of the rudder, the elevators and the balancing planes. The pupil is then taught to steer the airplane around on the ground, by means of the air rudder. This is called "taxying" and is an important part of the work. Taxying is done on a straightaway course, a broad, flat, hard path, which should be at least two hundred feet wide and extend for a mile or two. When the novice has acquired skill at taxying in an airplane that has insufficient power to *float off* the ground, he is advanced to an underpowered machine that will float off for short distances. The lift obtained in this plane is regulated by the throttle. A device limits the admission of gas to the motor, hence the power delivered to carry the plane up. Great care must be exercised to avoid giving the pupil more throttle than he can handle. Such a mistake would probably be fatal. When the beginner has mastered the first control, the rudder, for steering to right and left, he is ready to leave the ground. On the second machine, just barely enough throttle is adjusted to enable the plane to leave the ground for a height of about two feet. The lack of flotation causes the plane to sink gently back on the ground. This operation requires the use of the elevator. The pupil is instructed to use all air controls gently, particularly the elevator. With a little practice the beginner is soon skimming over the ground for short "hops" of 100 to 200 feet and handling the balancing planes with accuracy. When the knack and science of balancing are mastered, the pupil is permitted to advance a foot or so at a time, until he is flying straightaway at a height of 10 to 20 feet, and making several landings and *take-offs* on each trip. The beginner is now advanced to another type, and when he has gradually attained an altitude of 50 feet in his flights, it is safe for him to undertake very slight curves along the course. From these curves, he advances to quarter, half and full circles, as increasing altitudes are attained. During the turns, commencing with the first slight change of direction, the plane is *banked up* slightly more for each decrease or radius of the turn or for each increase of speed. The theory of this technique should be thoroughly taught during this stage of the instruction, and the *banking-up* must be increased by barely perceptible degrees, or an accident will probably result. From full, flat circles, both right and left, the beginner now progresses to broad figures-of-eight, gradually diminishing the radii of circles, and increasing the degree of *bank* to moderate circles. The pupil is advanced from straight and spiral glides *with throttled power* to glides without power, known as the *vol plane*. Accuracy in landing on a mark and landing to come to rest over a mark are then attained, and the novice is ready to undergo his pilot's tests. Upon completion of these elementary tests, the pilot commences the course of flying that is expected to qualify him for expert aviator's tests.

DUAL FLIGHT TRAINING METHOD

In this system both the preparatory and preliminary stages are covered under the personal flying direction and control of a flight instructor. The dual differs from the solo method in that the first flying instruction takes place in the air. Landings and *float-offs* come later. The machine should be a moderate or slow speed machine with a safe range of speed. Machines having large supporting surfaces (large surfaces so as to give slow landing speed) and moderate power are generally used. The craft must be provided with dual controls, in order that either the instructor or the pupil can control the craft. At first, the pupil merely observes the operations of the instructor. The beginner is taught to gauge his speed and flotation for horizontal, climbing, banking and gliding flight, by the air pressure against his face and body, the celerity of response to the controls, the resistance of the controls to motion and the "feel" of the machine. The first flights are designed to give the pupil the *feel of the air*.

Cautiously, the operation and personal management of controls are taught. Straight, horizontal flight is the first air work undertaken and as in the solo method, this is followed by broad, flat turns and quarter, half and full circles, right and left; simple, normal landings and *float-offs;* and balancing the plane in flight. The air work up to this time should be performed in favorable, calm air. The instruction should now embrace turns and banking in disturbed air; climbing and gliding; straight and moderate spiral glides; straight and spiral *vol*

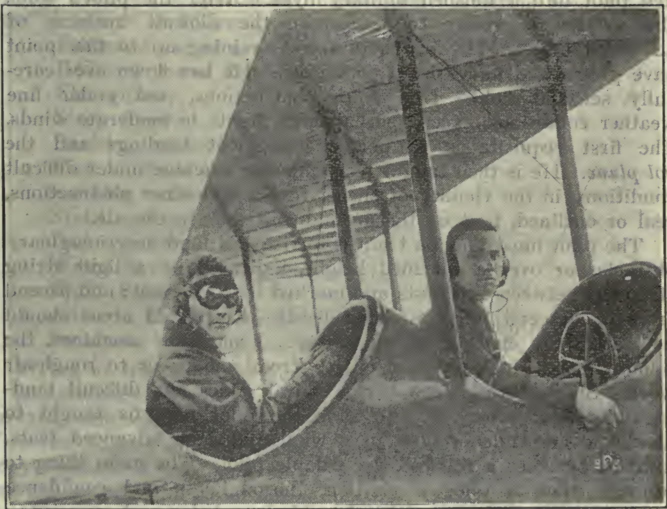
Dual control training model

planes. The different landings are taught at the proper time: the *normal, slow-speed, pancake* and *stall* landings, and wind landings including the *normal, slide* and *banked* landings.

As the air work progresses, the instructor gradually turns the controls over to the pupil. The instructor reserves the power controls until the beginner has mastered the air controls. Taxying or maneuvering the craft on the ground and distance judgment are taught, and the pupil is ready to take the air alone.

When flying alone, the pupil should be required to report to his instructor for explicit, detailed instructions before ascending. Upon return from a flight, the student aviator should report for correction of errors observed. Instructions governing student or practice flights should specify the flight course to be followed, or impose a restriction to a definite area, and the particular flight maneuvers to be performed. The altitude should also be prescribed, especially when several machines are operating. The flight levels of all machines in the air should be controlled by orders given prior to flight, regardless of the nature of the flights. Certain lanes should be set aside for students. Landing lanes should be assigned especially for the use of instruction machines. The latter should always have the right of way, when recognized. Rules of the air should be adopted at each flying station. All military flying stations should operate on a standard set of rules of the air. These several precautions will aid in avoiding interference and in reducing the danger of collisions in the air.

The first flight made alone, in the *dual* course, should be restricted to horizontal flight, making *getaways* and *landings* on a straight course. This flight should be made as elementary as



Pilot and pupil wearing aviaphone for communication in flight

possible and designed to give the beginner confidence in himself. This should be followed by more advanced flights, adding circles to right and left, straight glides and moderate climbs.

With practice the radii of circles should be decreased, and degree of *bank* increased successively making large and moderate figures-of-eight. The next step should be to combine the turns with glides and thus advance to spiral glides. Landings are made with a dead motor, both from straight and spiral glides. During all these flights, the aspirant should be closely watched from an observation tower, where each flight maneuver can be detected. Performances should be carefully separated and marked. Those seriously at fault should be corrected by actual flight with the instructor.

The airman is now ready to undergo his pilot's tests.

Combination Solo and Dual Method

This system is a combination of the *solo* and *dual* methods, which is designed to establish the self-reliance produced by the solo method, and to eliminate any errors that the student has instinctively developed. This is unquestionably the best training course, when time permits.

Expert or Military Aviator Course

Certain general methods are followed in developing the qualified pilot into a finished military flyer. After the pilot's tests, the aviator is ready to undertake the difficult business of advanced flying. His instruction and training up to this point have progressed under ideal conditions. He has flown over carefully selected fields, free from obstructions, and under fine weather conditions, except perhaps for flights in moderate winds. The first requisite is to perfect judgment landings and the *vol plane.* He is then taught to handle the machine under difficult conditions, in the vicinity of sheds, fences and other obstructions, real or outlined, first on the ground and then in the air.

The pilot must now be trained to rise and land over imaginary obstacles or over a specified height, indicated by a light string stretched between two posts and marked by a pennant; and ascend from or descend into restricted fields. Restricted areas should be marked by chalk lines for safety. From slow machines, the pilot passes to high-powered craft; from smooth-air to rough-air work. Sharp turns, steep banks, spiral glides and difficult landings are next practiced. In time the pilot may be taught to handle a side-slide landing in a wind and such advanced feats, until he becomes a reliable, dependable pilot. The main thing to impress upon a pilot is caution, thoroughness and confidence in his abilities only proportional to his knowledge and experience.

The pilot should now take an elementary observer's course, consisting of progressive flights, at increasing altitudes, and under varying conditions of visibility from clear weather to foul. Visibility tests both with the naked eye and field glasses of various powers should be made, and followed by instruction flights in sketching, reconnaissance and navigation of the air.

The aviator is now ready to make short cross-country flights in preparation for junior military aviator's tests, which complete his training as a military pilot.

After an aviator has reached this stage, he is qualified to undergo instruction in another type of machine. Daily practice brings perfection, but should not lack a specified plan of development, leading up to advanced flights in altitude, endurance and cross-country work. After the aviator has mastered this class of flying, he may further be developed by training on various types of craft, monoplanes, biplanes, high-speed machines, battle-planes, and super-planes. Special work should now be undertaken in *aerial acrobatics* and piloting of high-speed *pursuit* planes. All expert aviators should be required to attain an altitude of not less than 12,000 feet, remain in flight for 4 hours and cover 200 miles, cross country.

The postgraduate course in flying with the exception of progressive instruction in new types of craft, should embrace only flying of an advanced character. The advanced work is classified by the Training Department of the Army Aviation School into special phases as follows:

Excessive use of controls;
Reduced power flights;
Flat glides;
Steep climb;
Banking up to 90°;
Fast landings and get-aways;
Landing across wind;
Stalls, side-slips, tail-slides, loops;
Bad weather; rain;
Water flying (hydro and boat);
Night flying;
Altitude flights; duration flights; cross-country flights;
Passenger carrying and low flying.

Flying at this juncture becomes purely military in character. A postgraduate course of study and practical work should be pursued, embracing the elements of aeronautic engineering; use of meteorological and aeronautic instruments; advanced meteorology; practical reconnaissance; spotting artillery fire; bomb dropping; principles of aerial combat; wireless telegraphy; gunnery; strategic and tactical employment and administrative control of the air squadron, and such other professional studies as are necessary to make the pilot an efficient, finished military aviator.

AIR MANEUVERS

Instruction and training in flying should embrace both practical and theoretical work. The latter should be taught in class-room, employing charts and blackboard work as a part of the lectures. One of the gravest mistakes made in the early days of aviation was the tendency to discredit the value of theoretical work. This was due largely to the fact that most aviators were neither scientific nor technical men and consequently disparaged any departures from the purely practical side of the work. It is now evident that most of the accidents in aviation are due to ignorance. Without proper study and instruction the most skillful aviator will ignorantly defy the science of aviation.

Air maneuvers should be classified, listed and treated in phases, each phase being indicated by diagrammatic sketches on a blackboard. The following air maneuvers should be most carefully treated.

CLASSIFICATION OF FLIGHT MANEUVERS

Training Department, Army Aviation School

Figures of eight; landing for a mark. Landings as follows: from a turn of 180 degrees, from a spiral of 360 degrees, coming to rest over a mark; from a turn of 90 degrees, from a turn of 180 degrees, from a spiral glide of 360 degrees, same landings for mark repeated but with a dead motor. Climbs: around restricted area and out of restricted area. Landings for mark: from 2,000 feet straight glide; from 2,000 feet, spiral glide (changing direction of spiral); from 2,500 feet, one straight glide and one spiral glide (changing direction of spiral); from 3,000 feet one straight glide and one spiral glide (changing direction of spiral). Landings, for mark with dead motor: from 2,000 feet, one straight glide and one spiral glide (changing direction of spiral); from 2,500 feet, one straight glide and one spiral glide (changing direction of spiral); from 3,000 feet, one straight glide and one spiral glide (changing direction of the spiral). Landings in restricted fields: flights under throttled power; skimming the ground; figures-of-eight in restricted areas; landings over obstacles; cross-country flights.

The above air maneuvers, arranged in a progressive order are given as an example of a method for arranging air maneuvers, that can be profitably followed in the flying course.

One of the most common faults of aviators is the tendency to allow the altitude to increase rapidly without notice. The height must therefore be watched constantly in military flying, where uniformity of altitude is generally important. In bomb-dropping and in taking aerial photos, especially in automatic photography involving exposures at successive intervals, it is of prime importance to maintain a uniformly horizontal flight path.

Machines having an excess of power, climb rapidly at low angles of attack. If speed is desired (within limits), the angle of incidence is reduced to keep from climbing. When negative angles are necessary to avoid climbing, it represents a great waste of power, hence it is better to ease off on the throttle and reduce the power applied, to maintain positive angles of incidence without climbing.

Landings. The various landings, with respect to the attitude of planes to, and relation of the running gear with the ground, may be classified as follows:

(a) *Normal:* the planes are given an angle, such that the lift gives the lowest possible flying speed; all points of support touch the ground simultaneously.

(b) *Slow-speed:* a landing with positive *attitude,* such as to produce a slight *braking effect;* in three or four wheel running gears, the rear wheels make contact before the front wheels touch the ground; in two wheel landing gears, the tail drops appreciably below the horizontal, or normal flying position, in making contact.

(c) *Pancake:* this landing may be expressed as squatting the machine upon the ground. It is accomplished by dropping the machine on all points of support simultaneously, from a height

The occupants generally escape unhurt in minor accidents, when using the tractor type

of two or three feet. This landing is frequently confused with the *slow-speed* or *stall* landings. Pancake landings rack a machine and should not be used when avoidable.

(d) *Stall:* this landing covers a wide range of conditions. If attempted at too great a height (this refers to a very few feet) the machine may nose over into a negative landing (front *wheeler*) with disastrous results; or the machine may settle heavily upon the tail with equally dire consequences. The *stall* landing is effected by giving the planes an excessively positive attitude with insufficient power to ascend, or by gliding so flatly that the machine entirely loses its sustentation. In the former case the effect produced is to create a sudden and unusual braking force. In the latter case, the result is inevitably, loss of control. The proper procedure to effect a stall landing is to level off about five feet above the ground and increase the attitude very gradually and proportionally as the speed diminishes. A *stall* landing must be handled with great care, and should be employed only by an expert or in a grave emergency, such as when a landing must be effected in an unusually restricted area, or when landing a land machine in the water. In the latter case, the tail must touch the water before any other part of the craft makes contact, but this contact must not be attempted at an excessively high landing speed; say not over 45 miles an hour.

(e) *Negative,* or *nose landing:* also called "front-wheeler" by aviators. This landing is dangerous and should be avoided.

Immediately after making contact, some pilots employ the trick of *nosing the machine forward* to avoid bouncing or porpoising. This resort displays a lack of skill on the part of the aviator. A skillful pilot depends upon correct judgment and accurate estimation of speed, distance, drift, buoyancy, configurations of the earth and other factors to obtain smooth landings. Nosing the machine over to obtain the appearance of a smooth landing has the effect of causing the running gear to follow the configurations of the earth. It involves a serious risk because the machine will somersault if it strikes an object of sufficient size or encounters soft ground. While this is not necessarily fatal to the occupants of a strongly built tractor biplane, it means more or less partial destruction to the craft.

Wind landings. These may be grouped conveniently, viz.:

(a) *Normal:* the machine is headed into wind while *leveling off;* this neutralizes the wind drift. Just before making contact, head up the field in direction fixed by the limits of the field, so that the wheels are running true with the ground.

(b) *Slide landing:* the wings are inclined very moderately, so that one wing tip is lower than the other; no rudder is used; the low wing towards the wind, the machine slides towards the low side at a rate fixed by the degree of inclination of the wings. The side-slip into the wind neutralizes the wind drift, when the proper degree of bank is given. Contact must be made when sufficient speed remains to give positive control action; the plane must be leveled up as the lower wheel touches the ground.

(c) *Banked landing:* the machine is brought in for a landing, making a very broad, flat circular turn, with the center of the curved path towards the wind. The direction of the plane, at the point of contact, is straightened to a path, tangent to the circle.

Slide and banked landings are for advanced flying. Beginners should be prohibited from undertaking these difficult maneuvers. Wind landings should be avoided whenever possible, by landing head into the wind.

Air sickness usually results from high altitude flights, and manifests itself in the form of dizziness, headache and faint spells. This sickness may also come from long flights in rough air, or exposure to unusual or sudden temperature and pressure changes.

These ill effects are not merely temporary but are more or less permanent, according to medical authorities. The consequences may be avoided by the employment of oxygen tanks for high altitude flights and by restraining pilots from venturing to great altitudes too frequently. Above 13,000 to 14,000 feet, oxygen tanks should invariably be carried. To neglect this precaution is dangerous.

General. The most important precept to establish in the minds of aviation students is *caution.* Thoroughness and patience are essential to success. One can never hope to make a good aviator without confidence, but confidence disproportionate to abilities proved by knowledge and experience and attested by results, is the menace that has finally destroyed many a promising flying career.

A feeling of security and confidence grows with each flight made and as knowledge is gained, until the pilot comes to regard his daily air work as a normal, natural occupation. Flying should, however, never lose its tang, even to the veteran airman. Such performances as steep, vertical dives, vertical spirals and loops are useful in the education of a flyer, but should not be encouraged as a regular diet. These advanced maneuvers should be restricted by competent regulation.

The technique of flying or piloting cannot be acquired from a book. Self-instruction is dangerous. Theoretical study should be applied under the strict regulation of competent instructors.

Flying must be taught scientifically. The pupil must be instructed in every branch of the work to derive full benefit and attain maximum results. The attempt to develop pilots to depend wholly upon the sense of "feel" is a most reprehensible policy and fraught with grave probabilities. Every advantage should be taken of the advances of science. Class work should not be neglected, and should include lectures, conferences, study and recitations. This refers especially in this connection to the instruction in *Flying.*

[illegible]

speed; [illegible] not over 10 miles an hour.

[illegible]

accurate estimation of speed, distance, drift [illegible]

[illegible]

[illegible] speed remains at [illegible] must be landed up on the lower wheel [illegible] the ground.

(c) *Banked landing.* The [illegible] is brought in for a landing, making a [illegible] banked, [illegible] circular turn, [illegible] the [illegible] of the curved path towards the wind. The direction of the [illegible] at the point of contact is straightened to a path tangent to the circle.

Slide and banked landings are for advanced flyers. Beginners should be prohibited from undertaking these difficult maneuvers. Wind landings should be avoided wherever possible by turning head into the wind.

[illegible] sickness [illegible] from high altitude [illegible] and manifests itself in the form of dizziness, headache and [illegible]. This sickness may also come from long flights in rough air or exposure to unusual or sudden temperature and pressure changes.

PART IV
MILITARY AVIATION

CHAPTER 1

THE AIR SERVICE IN WAR

The service of aircraft is indispensable to the success of modern arms.

Under the critical test of war, the air service has exercised a revolutionary influence upon strategy and tactics.

Success in war is based on a proper coördination of all the component parts of the military and naval forces. The air service is one of the essential elements of the army and navy and perfect coördination is imperative between the air service and the other arms which it serves, or which it aids in serving.

The structure of the air service is based on the successful types of aircraft produced by the science of aeronautics. These are the *airplane,* the *kite balloon* and the *dirigible.* *Each of these types is produced in a variety of models, designed to perform different kinds of aerial duties, and are organized into properly balanced air units which are assigned to various elements of the military forces and to the fleet.

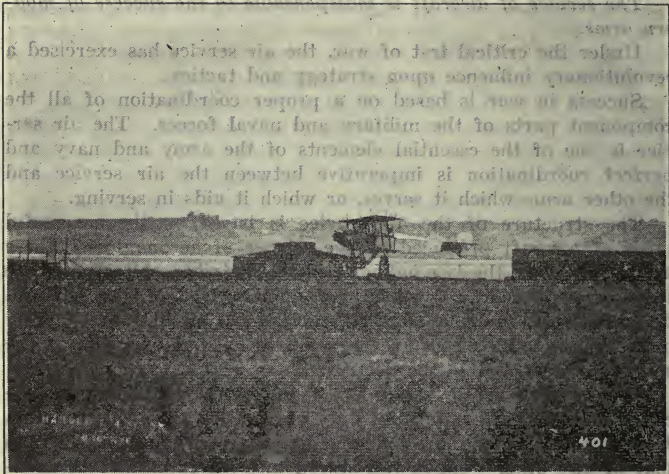
War Functions of Aircraft. The service of reconnaissance constitutes the most important duty of aircraft, since this function has possibly exerted more influence upon strategy and tactics than that of any other weapon introduced into warfare since the cannon and musket. The control of artillery by means of aircraft service is closely associated with the service of reconnaissance, and has proved of inestimable value by serving to vastly increase the efficiency of artillery fire methods of warfare where preponderance, or *efficacy of artillery fire,* is tantamount to victory. The use of aircraft for bomb dropping is chiefly valuable for striking the enemy in vital points, beyond the range of the artillery. The power to maintain the services of reconnaissance, fire-control, bombardment by aircraft, and other war functions of the air service, depends upon the capacity to protect unarmed and non-fighting craft and the ability to blind the enemy by destroying or obstructing his air service. Control of the air is therefore of paramount importance. Combat aircraft are also used for other purposes than fighting aircraft, when desirable; such as for offensive action against enemy forces on the ground. The

*See Classification of Aircraft.

measure of success with which combat functions are discharged by air units, bears directly upon the effectiveness of the air service and indirectly upon the entire military situation.

Types of Aircraft. In considering the type of aircraft most useful to perform a given duty, two prime factors enter: (a) air qualities of the craft, (b) transportation required.

At the present stage of development, the airplane is the most efficient type of aircraft. It is not only versatile in the air (successful types having been produced to perform practically every character of air work demanded), but it is comparatively small, light of



Swift, fast-climbing *destroyers* leave the ground in hot pursuit upon the appearance of hostile aircraft

weight, and easily maneuvered in the air and on the ground alike. An airplane can be prepared for flight within a few hours, requiring the services of a relatively small crew, whereas the dirigible and kite balloon have serious limitations in the air, are difficult to handle on the ground, requiring large crews and perhaps more complicated technical apparatus and accessories. The problem of housing gas bags is a formidable one. Whereas the airplane is highly *mobile* both in the air and on the ground, being easily and quickly placed on its truck carrier and moved along the road when necessary, this is not true of lighter-than-air craft. The kite balloon is a stationary or captive craft.* It is therefore immobile in the air, except for slight changes which can be made by moving

*A captive balloon always swings with the wind.

the winch truck about the field, or by shifting the mooring pulley. The dirigible possesses many desirable qualities common to the airplane, and many superior qualities, but it offers neither the speed nor the maneuvering qualities which render the airplane so efficient. On the ground, the kite balloon and the dirigible must be regarded as transportable rather than mobile apparatus, on account of the complicated operations and extensive technical equipment involved in inflation and deflation of envelopes. But the kite balloon and the dirigible have their special uses which the airplane cannot discharge.†

ORGANIZATION OF THE AIR SERVICE

Aircraft Units. The organization, equipment, control, and operation of tactical and administrative units of the air service, designed to meet military requirements, have been chiefly influenced by the limitations of aircraft, but it is the fact that types of aircraft produced to meet the demands of military necessity have given satisfactory results. The principal demand of aircraft has been for increased performances to discharge the four major functions of reconnaissance, fire-control, bombardment, and combat. Auxiliary military uses of aircraft comprise such functions as dispatch carrying, transporting supplies, messenger and mail service, passenger carrying, and others. These uses are practically the same, with certain well-established variations, both for the military and naval service. Except in special cases, types of aircraft are assigned to auxiliary or secondary functions which are useful for major duties.

The Airplane Squadron. An airplane squadron usually consists of planes of one type and the unit designed for one of the four major duties. Compound or mixed squadrons comprise more than one type of airplane. This practice, a measure of economy, has been largely abandoned with the increase of aerial navies to large proportions. Reconnaissance and combat squadrons are sometimes organized as compound squadrons. A compound reconnaissance squadron, for example, might comprise one group of ***strategic,*** or long range cruising planes, one group of ***intermediate*** type planes, and one group of *tactical,* or short flight type planes. A compound combat squadron usually consists of one group of pursuit type planes and one group of cruiser planes, a powerful fighting type similar in flying qualities to the strategic reconnaissance type. Planes assigned to artillery fire-control duty are generally of the tactical reconnaissance type. The strength and composition of a fire-control unit should conform to the organization of the artillery command to which assigned. Bombardment squadrons should consist of planes of one type, since it is

(†Except in a general way, lighter-than-air craft are not treated in this book, and then only to establish the relation between them and the airplane, since the study of light-than-air craft belongs to the subject of aerostation as distinguished from aviation.)

desirable that these craft fly as a unit. This type is essentially a weight carrier, having a broad cruising radius. Bombardment squadrons are generally equipped with very large planes or super-plane types which provide a broad margin of useful lift. Battle-planes are super-planes possessing the flying qualities of the type described as most useful for bombardment operations. By dispensing with the weight of bombs, powerful armament may be added to make this a formidable fighting craft. Battle-planes have generally been used up to this time for convoying bombardment planes. A broader use exists for these craft and they should be assigned to special units for major fighting operations, rather than attached individually, as has been the practice.

It is apparent that the formation of compound squadrons should be avoided, when possible. Units should comprise planes, all of which possess the same qualities of climbing power, speed, and maneuvering properties, to operate satisfactorily as a unit in flight.

The assignment of airplane squadrons is regulated by the strategic and tactical situations, by the aerial phases of the war, and by other considerations, given hereinafter.

The Balloon Squadron. This unit consists of four companies, each manning one kite-type or station balloon, and a headquarters. All kite balloons used are as far as possible of one type. Fifteen thousand, and twenty-five thousand cubic foot kite balloons are useful for low altitude work, carrying light loads, both for use with field and naval forces. Small, one-place types are used in naval work, having a capacity of 15,000 cubic feet. Service types for the Army are generally two-place 35,000 or 45,000 cubic feet. The size of the kite balloon is determined by the weight of passengers, instruments, and other equipment that it is necessary to carry. Special super-kite balloons are designed to carry two baskets, one for the observers and one from which an operator can serve a machine gun. Communication is by phone to the ground below, when the balloon is aloft. The balloon squadron is helpless without its transportation. This comprises about 23 trucks and trailers for each balloon. These vehicles include a winch truck, a number of trucks designed to carry gas cylinders, hydrogen generators, supply carriers, and other special trucks. The balloon squadron should be assigned to the division and army corps, to permanent fortifications, and important stations exposed to air attack. An airplane squadron should be attached to the balloon squadron for its defense in the air. Anti-aircraft batteries should be assigned for defensive measures.

Dirigible Units. Airships should be organized into squadrons or assigned to independent sections. Dirigibles are most satisfactorily used at the present time for coast patrol and off-shore operations. They are better adapted for cruising over large water areas than seaplanes. Dirigibles should be assigned to permanent fortifications, especially to the coast artillery defense. In the field, dirigibles should be used to supplement the airplane service.

AERIAL PHASES OF WARFARE

Aerial warfare may be classified for convenience under the following phases:

1st Phase Preliminary or phase of mobilization.
2nd Phase Strategic or phase of concentration.
3rd Phase Tactical or phase of contact.

PRELIMINARY PHASE

Success of the air service throughout the war that follows, depends in a large measure upon the successes achieved in the initial brushes with hostile aircraft. This period offers the most favorable opportunity for gaining and securing ascendency and control of the air. The contest for supremacy should therefore be carried into enemy territory upon the outbreak of hostilities, provided the enemy is within reach by means of aircraft. *It is easier to seize an opportunity than to regain a lost one.*

This presumes constant readiness for action, which is the criterion of efficiency of the air service. A weak, vacillating, bureaucratically controlled flying corps will approach a state of war timidly or without that spirit of boldness and confidence which is inseparably linked with command of the air. Such a force will be whipped by a dashing, enterprising opponent before the preliminary phase comes to a close. A defeated air force regains the air with enormous difficulties. Ascendency over the enemy under such conditions offers almost insuperable obstacles, if he pursues his initial advantage, as must be presumed. Success in war is a corollary of preparation and training for war. The air service must always be ready for war. In the preparation and training of the air service for war, the following essentials govern the conditions of readiness and effectiveness, when hostilities commence: a. a definite policy, b. a progressive spirit, c. the required strength in highly trained and specialized personnel, d. adequate and efficient matériel, e. suitable organizations trained in the art and practices established by the best precedents of aerial warfare.

General Principles of the Preliminary Phase. This term is used for convenience to designate a period which may intervene between the outbreak of hostilities and the occupation of well-defined theaters of war. The concentration of aircraft forces for offensive action is not necessarily restricted by the difficulties surrounding mobilization and concentration of military forces on the earth or on the sea. During this phase, the action of aircraft is general in character. Aircraft of broad cruising radii are employed. Dirigibles may prove more useful than airplanes.

In the case of an overseas or distant enemy, every advantage should be taken of advanced air bases near the hostile territory. With the possession of such bases insured by the required military and naval strength, strong aircraft forces should be maintained for raids and observation flights against enemy bases and other vital objectives. Bombardment, combat, and reconnaissance squadrons should be detailed to prosecute a vigorous and aggressive campaign. Reconnaissance craft should reconnoiter the enemy dispositions, mobilization points, arsenals, depots, navy yards, docks, shipping, rail lines, bridges, and other communications. Roving and special combat squadrons should take the initiative and drive the enemy from the air. He must be literally overwhelmed; his aerial eyes blinded by the destruction of his aircraft; his dispositions reported and checked, both by aircraft action and counter dispositions on the ground and sea; his movements impeded by an overpowering air offensive directed against the ground forces.

Supremacy of the Air. This condition implies supreme control of the air over hostile as well as above occupied territory. It insures unrestricted power of maneuver to the air fleet, as vital to the success of aerial operations as to the favorable outcome of military operations on the ground. The effect of aerial ascendency on field operations is to increase the power of maneuver of the field forces. Unrestricted power of maneuver presupposes victory, whether it be in the air or on the ground.

The struggle for complete mastery of the air should be opened boldly and without delay. If it does not exist at the commencement of hostilities, it must be fought for; if it does exist, it should be maintained. In the event that the enemy has no air service or a comparatively weak air force, he should not be permitted to enter the air. His bases should be patrolled ceaselessly and vigilantly. Daring attacks at low altitudes should be made over the enemy's flying fields if he attempts to put craft into the air. Combat should be sought at every opportunity, but superiority of numbers should be employed, for no principle of aerial tactics is more important. A thorough and alert patrol will minimize the enemy's successful air ventures. This object should be gained at all costs, but nothing short of complete destruction of enemy aircraft should be accepted as the standard to be attained. In aerial warfare, comprehensive results are obtained only by the use of overwhelming numbers of aircraft. The air offensive should be launched in terms of brigades, divisions, and superfleets of airplanes. The enemy must be deluged by a vast horde of winged cavalry; smothered by a torrent of aerial artillery; overpowered by preponderance of numbers; mastered by superiority of personnel and equipment. With blinded aerial eyes, an army, however otherwise superior, is incapable of directing its strength with intelligence.

STRATEGIC PHASE

Until concentration, the regulation of the air service should be exercised by the *service of the interior,* decentralized under territorial commanders as in time of peace. When theaters of war are established, the necessary quota of aircraft are assigned to the field forces. The problem of controlling the vast aircraft organization required by modern warfare, involves a definite and tangible relation to the scheme of military operations on the ground. Concentration follows mobilization and service of the theater of operations is established. (Par. 247, F. S. R.)

The duties of the air service may now be discussed under the following classification:

1. Air forces assigned to the *service of the interior.*
2. Air forces assigned to the *service of the theater of operations:*
   a. Air units assigned to the *zone of the line of communications;*
   b. Air units assigned to the *zone of the advance.*

Service of the Interior. The air forces of the interior, whether in war or in peace, include the administrative, technical, supply, training, and tactical functions of the air service; the disposition of the personnel and matériel, the service of home defense, and aerial activities not related to or remote from operations in the theaters of war.*

Service of the Theater of Operations. Aircraft units, depots, and bases are established at concentration camps, ports of embarkation, and debarkation, and in both zones of the theater of operations. Aircraft for permanent duty at ports of embarkation and debarkation should be furnished by the Army; aircraft to accompany convoys on the water should be provided by the Navy. The assignment of aircraft within the theater of operation is governed by the character of the operations and affected by the changes in the strategic and tactical situations. The theater of operations is divided into the *zone of communications* and *zone of the advance.* Reconnaissance, bombardment, fire-control, and combat airplane squadrons with their individual depot units are assigned to the *line of communications* and to the *zone of the advance,* in such numbers as the situation demands. The control of all aircraft forces should be vested in general headquarters, during the strategic phase. Airplane units may be assigned to army corps during this phase, but would rarely be assigned to divisions or brigades, with the exception of fire-control planes attached to artillery units. Kite balloon squadrons are essentially army corps units, but are useful chiefly in contact operations (tactical phase).

*"The function of the service of the interior in time of war is to supply the commander of the field forces with the means necessary for the accomplishment of his mission." (Par. 250, F.S.R.)

The Aircraft Commander. An officer of the air service is assigned to each command to which aircraft are attached. He is the technical adviser of the general commanding, on all matters pertaining to the aerial service within the command. The aircraft commander (designated as the aviation officer, when activities of the air service are limited to airplane operations), should be assisted by an aeronautic staff, consisting of such officers as the conditions require. The aircraft officer assigns aircraft bases, parks, and squadron depots. He directs the services of supply, maintenance, and administration, technical functions, and aerial operations.

Aircraft Stations. The following designations are generally given to the stations of aircraft troops in the field:

a. *Aircraft base* (devoted to the reception and repair of damaged materials).
b. *Aircraft depot* (storage and shipping point).
c. *Aircraft park* (a station of aircraft units).
d. *Squadron depot unit* (reserve supply unit of a squadron).

Aircraft bases and depots should normally be located in the zone of communications, but may be pushed into the zone of operations when circumstances warrant; such as, when there is little danger of a forced withdrawal; when the enemy is inferior; or the supply of aircraft inadequate, necessitating the employment of repaired materials at the front. Aircraft parks are located throughout the theater of operations, as the *zone of communications* must provide for its own air defense in addition to its function of furnishing a channel for the maintenance of aircraft forces in the *zone of the advance.*

Aircraft Bases. One or more aircraft bases are ordinarily maintained well to the rear, on a main line of communications to the front. Here general aircraft matériel, planes, airships, balloons, and accessories, are received through the proper channels of supply from the service of the interior, and made ready for service at the front. Damaged or unserviceable aircraft matériel, motors, aircraft, and accessories are returned to the aircraft base from the front for proper disposition. Suitable machine and repair shops, storehouses, and other facilities are provided for dismantling matériel, making necessary repairs, replacals, adjustments, and for assembling. Materials are carefully sorted, defective parts being discarded and replaced by serviceable equipment; only perfect matériel should be returned to the front, other serviceable equipment being forwarded to training bases as a rule. Aircraft bases are generally established for technical and supply purposes only, but are sometimes used as camps for the formation of new units.

Aircraft Depots. These are storage points for the reception, protection, care, and shipment of supplies to aircraft bases and to aircraft units. Storehouses, hangars, and other facilities should be provided for housing property. Aircraft depots should be so located as to be accessible to the main line of communications, preferably at the base of supplies, at intermediate or advance bases. The depot should constitute a source of supply for squadron depot units.

Aircraft Parks. Stations of aircraft units in the field are assigned by the aircraft commander of the zone. This assignment is regulated by strategic and tactical considerations, discussed hereinafter.

Squadron Depot Units. Under the present organization of the Aviation Section of the Army, each airplane squadron is provided with a depot unit. Depot units for balloon squadrons have not been authorized at present, but are under consideration. It is contemplated that these depots remain behind when the squadron moves into the field, depot units being moved wherever necessary. They should constitute the connecting link between aircraft depots and the squadrons or aircraft parks at the front. Their movements must conform to those of their respective squadrons, but it is probable that the most desirable location for squadron depot units will be at or near *rendezvous, refilling,* or *distributing points* on the line of communications. Personnel for the squadron should be furnished by training bases, supplies from aircraft bases and depots. These stations may be located either in the *service of the interior* or in the *theater of operations.*

GENERAL PRINCIPLES OF THE STRATEGIC PHASE

The Air Service in Operations. The chief objects of the air service are:

a. To destroy the hostile aircraft forces;

b. To provide efficient air service for the forces served.

The means employed in the struggle for supremacy of the air constitute aerial tactics. The methods involved to provide adequate air service for the military forces are inseparably linked with the principles governing military operations on the ground.

Aircraft Screens. Defense of field forces against hostile aircraft is insured by effective aerial screens formed by the aircraft units. During the strategic phase, this screen is formed far to the front and flanks of the advancing forces, and consists of a number of aircraft units and other aerial groups, guarded on the ground by proper mobile forces of cavalry and automobile batteries. Whether strategic or tactical, the aerial screen is formed by cruiser and pursuit types of combat planes, operating both for offensive and defensive purposes. Normally, reconnaissance and fire-control planes and kite balloons operate at the lower levels of the screen, covered by the anti-aircraft artillery and protected by the combat planes at the higher levels. Combat and reconnaissance planes may comprise the only types of aircraft employed in the *strategic screen.* Combat planes should prevent all enemy craft from penetrating the screen. Cruiser (combat) planes are assigned to patrol a certain *lane* at a fixed altitude. Pursuit planes are stationed in readiness on the ground, to ascend against enemy craft that may appear. They are also used for patrol work or on short cruises. Observation and searchlight stations and anti-aircraft batteries form an essential element of the aircraft screen. The efficiency of the screen depends upon the availability of sufficient planes to maintain continuity of observation, continuous readiness for pursuit, and perfect coördination between air and ground forces. Ordinarily aircraft must be employed in considerable numbers to carry out this scheme. The use of light radio sets on all planes operating in the screen, is of the highest importance in maintaining the integrity of the scheme. Hostile aircraft are sought outside the screen and destroyed when encountered. From four to six planes in a group are sent out on a patrol. Patrols are employed over friendly territory when the enemy craft cannot be wholly arrested, by the combat planes and supporting anti-aircraft artillery of the screen. Interior patrolling should not be neglected simply because no enemy plane is known to have penetrated the screen. If one lone air scout succeeds in passing the aerial barrier, the best laid plans may be wrecked as a result of his reconnaissance, even if incomplete. Patrols over the enemy's territory should systematically cover his flying fields and aircraft bases. These stations should be regularly raided by fleets of bombardment craft. The contest for mastery of the air should take the form of an air offensive outside the aerial screen; within the screen, defensive measures must be unfailing to be effective.

Aircraft and Independent Cavalry. The front and flanks of forces advancing to contact are covered by a protecting screen of highly mobile forces of motorcycle and automobile scouts and batteries, and cavalry units, known as the independent cavalry. The employment of aircraft has exerted a revolutionary influence upon the functions of independent cavalry. Aircraft can accomplish practically everything formerly required of the independent cavalry, and can accomplish these duties more rapidly, more thoroughly in most cases, and more economically. The reconnaissance functions of the independent cavalry are now restricted to the collection of detailed information beyond the capacity of airplane observation.

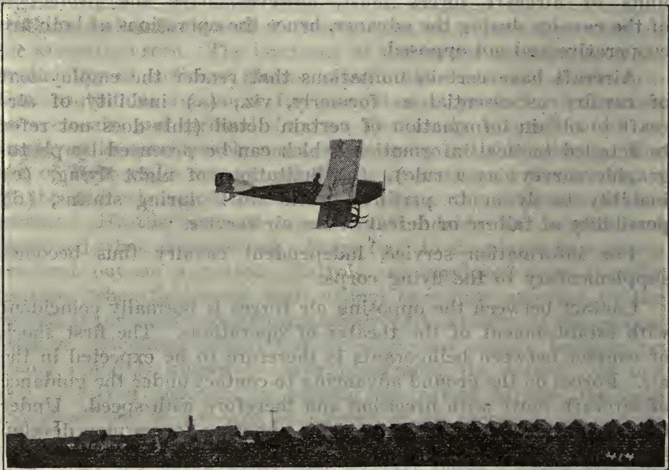
Aircraft forces are arrested in the advance, only by an effective aircraft screen. Cavalry on the other hand are stopped by obstacles on the earth which block its further progress. Hence aircraft must always be used and become the prime service for information and reconnaissance. Aircraft actually increase the effectiveness of independent cavalry as a ground barrier, by guiding the latter to quick contact, and under the most favorable conditions, relieving it of the strain of uncertainty and of much of the drain on its forces caused by dispersion of considerable strength in the form of reconnoitering patrols. But this is not apt to prove true, unless a liberal quota of aircraft is supplied. The ground units of aircraft forces must, however, have the protection of the cavalry during the advance, hence the operations of both are coöperative and not opposed.

Aircraft have certain limitations that render the employment of cavalry as essential as formerly, viz., (a) inability of aircraft to obtain information of certain detail (this does not refer to detailed tactical information, which can be procured by photographic surveys as a rule), (b) limitations of night flying, (c) inability to fly or to perform useful work during storms, (d) possibility of failure or defeat of the air service.

For information service, independent cavalry thus becomes supplementary to the flying corps.

Contact between the opposing air forces is normally coincident with establishment of the theater of operations. The first shock of contact between belligerants is therefore to be expected in the air. Forces on the ground advancing to contact under the guidance of aircraft, move with precision and therefore with speed. Under these conditions, contact between the opposing forces may develop so rapidly that the independent cavalry will be able to perform little screening or reconnoitering. The duties of the independent cavalry in that case merge with the functions of the advance cavalry. The main brunt of the first shock on the ground will then fall upon advance cavalry units. At this juncture, when the strategic phase draws to a close and the tactical phase opens, the movements of the advance cavalry must be largely regulated by the movements of the strategic aerial screen to the front.

Strategic Reconnaissance by Aircraft. Combat and reconnaissance are the principal duties of aircraft during the strategic phase. Efficient aerial reconnaissance should relieve the cavalry of all major reconnaissance operations. Cavalry and infantry reconnoitering detachments, when used, should be restricted to minute and detailed searches and examinations. (This does not apply to *battle reconnaissance,* which must never be neglected by forces approaching contact on the ground, without regard to reconnaissance performed by other units; to those engaged in security operations; or in obtaining information affecting dispositions.) An efficient air service should relieve the ground forces of considerable strain and render surprise—by forces of sufficient size to constitute a serious menace—an impossibility. No large body of troops should be pushed out to the front without the guidance and safeguard of aircraft. Such a course exhibits poor generalship, in view of the established military functions of the air service. Armies no longer have to grope and fight in darkness and uncertainty respecting the enemy's movements. To do so, either through failure to provide aircraft or sufficient numbers of aircraft, is to invite disaster, surprise, ambuscade, superior con-



Surprise attack at low altitudes may be launched with such swiftness that counter action is ineffective

centration, and possibly rout or annihilation. Surprise or ambuscade by large bodies of the enemy is inexcusable. Such failures indicate either an inadequate or an inefficient air service or improper use and disposition of the air forces at hand.

TACTICAL PHASE

The third or tactical phase is the period of contact between the hostile forces. The tactical phase will be considered under:

a. Zones of operations.

b. Contact operations.

Zones of Operations mark the transition from the strategic to the tactical phase. The hostile forces are approaching contact. The strategic screen drives forward pushing back or overwhelming the enemy screens. The ground forces advance; cavalry action develops. The main forces take up a formation of parallel columns. Every disposition is made to effect rapid deployment before entering the zone of hostile artillery fire. A reassignment of the aircraft forces should be made to facilitate the formation of the *tactical screen* and the retirement of the *strategic screen.*

CONTACT OPERATIONS

Assignment of Aircraft Forces. Accessibility to the zone or sector in which flying operations are expected, is the prime consideration in the assignment of air forces. Bases and depots are however located with more reference to transportation. Aircraft parks are established under the direction of the immediate aircraft commander. Squadrons are assigned to corps and divisions and in some cases to brigades, during contact. Roving combat squadrons are sometimes employed in operations, but this arrangement leads to complications and disorganization. All units intended for flying operations in advance of the aerial screen should be stationed as close to the front as possible. Some reconnaissance units are kept near general headquarters at all times, in order that staff officers can be sent out as observers. Such units are used not only for reconnaissance over enemy territory but for interior reconnaissance, in observing the progress of various bodies of troops, or in checking the developments of an action. During the strategic phase and during the first part of the tactical phase, when contact is incomplete, the majority of the active airplane units should be stationed at or near the position of the aerial screen. Artillery fire-control units are used only at points of contact, when hostile forces are within artillery range. Bombardment and special service air squadrons should be assigned to and controlled by the supreme commander. In general, when tactical operations are well defined, large aircraft reserves of squadrons, wings, regiments, brigades, divisions, and fleets of airplanes should be found attached to general headquarters; combat and bombardment wings and regiments to army headquarters; reconnaissance wings to army corps, and fire-control squadrons to divisions.

In the location of air units and in the assignment of aircraft parks, it must be borne in mind that dispersion means loss of power and control. The high mobility of the airplane must not be destroyed by locating aircraft parks farther to the rear, or more distant from the expected area of activities than absolutely necessary.

During the tactical phase when hostile forces face each other in deadlock, central flying stations may be established to advantage; units being assigned to aircraft sectors rather than to tactical units. Stations may be established in each sector and the control regulated by territorial command instead of by tactical units. This system naturally involves the building up of a more or less elaborate flying station in each case, but it offers superior facilities. However, a rapid change in the tactical situation may necessitate a temporary retirement and result in the loss of large amounts of materials, which is not so apt to be the case when major establishments are placed in a secondary line or well to the rear.

The Tactical Screen. When contact is imminent and the advance cavalry retires from its position in front of the main body, a second aerial barrier is formed. This is called the tactical aircraft screen. The duties of this element are more detailed than those of the strategic screen, entailing reconnaissance of a minute character and comprising all the military functions of which aircraft are capable. The strategic screen is dissolved after formation of the tactical screen.

The duties of the tactical aircraft screen are to protect the ground forces from hostile aerial observation, offensive action, and raids; to gather all the required information concerning the enemy's strength, dispositions, distribution, and probable intentions, and to guard against surprise and deception. So far as the military situation is concerned, the complete achievement of these objects is the criterion of an effective air service.

An effective aircraft screen necessitates the continuous night and day patrol of aircraft along the barrier line so formed; the endless searching of observation stations employing powerful searchlights at night; the constant readiness of anti-aircraft batteries. Groups of airplanes are employed at specified altitudes.

For military purposes, altitudes may be classified as:

Below 5,000 feet, low altitude.
5,000-10,000 feet, mean altitude.
Above 10,000 feet, high altitude.

Patrols are normally assigned at mean or high altitudes, but this is regulated by the proximity and effectiveness of hostile anti-aircraft artillery. The forward position of the aircraft screen is generally limited to the hostile outposts. Hence the advance or retreat of the aircraft screen exerts a material influence upon the field it protects.

A consideration of the tactical aircraft screen should be divided as follows:

a. The exterior or hostile zone.
b. The tactical aircraft line.
c. The interior zone.

The *tactical aircraft screen* is at or near the line of contact between the hostile forces. It is regulated in its movements by the advance or retreat of the ground forces and by the condition of ascendency of the contending air forces, but the governing principle should be to maintain the screen over hostile territory. A secondary line should be maintained about 5,000 yards in rear of the front, consisting of *station* balloons.

In the tactical screen, combat airplanes patrol at high altitudes to be safe from anti-aircraft artillery and from which the non-fighting craft operating below may be the better observed and protected. At mean or low altitudes and at a safe distance in rear of the lines, reconnaissance planes and artillery fire-control planes go about the work of gathering information and directing artillery fire.

An aircraft screen must be continuous to be effective. This does not mean that an unbroken line of aircraft cruise across the entire front. Aircraft forces like field forces should operate within supporting distances of each other. Observation must be positive, detection of invading forces unfailing, and pursuit relentless to maintain the integrity of the screen. This scheme contemplates the use of aircraft in vast numbers. Aircraft must be provided, in fact, in hundreds and in thousands and used liberally to render proper returns. Decisive results are obtained only by the offensive. Aggressiveness wins battles. Persistent and relentless aggressiveness wins campaigns. These principles, which govern operations on the ground, where only two dimensions are to be searched in seeking contact with the enemy, possess a magnified value and importance in aerial operations, where there are three dimensions of space to sweep; clouds which conceal without impeding an enemy; treacherous wind formations to combat.

The Exterior Zone. The success of the offensive under these conditions depends upon preponderance in numbers and efficiency of aircraft, superiority in training and equipment, and perfect morale. The offensive should be carried into the exterior zone to prevent the enemy enjoying the fruits of air service. The purposes of the air offensive are to clear the air of hostile craft, to completely blind the enemy, and to carry the attack into hostile territory at an angle from which the ground forces are as vulnerable as upon a flank; namely, from the air.

All air operations in the exterior zone should be controlled by the supreme commander. The immediate front may be divided into convenient sectors, in advance of which aircraft commanded by subordinate commanders would not normally operate. Strategic reconnaissance flights, bomb raids, and combat patrols should be directed from general headquarters. Owing to the limited load-carrying qualities of the most suitable types available for these functions, numbers must be used to accomplish decisive results. For bombardment and gun raids directed against positions and personnel, large units of planes, which may be designated as *wings, brigades, divisions,* or *fleets,* should be used. Combat units should be employed systematically; assigned patrol areas or specific pursuit duty. From four to six planes are sent out in a group for patrol or pursuit. They should be machines of one type with respect to flying and fighting qualities. Heavy gun planes should be used in large groups for offensive action against troops on the ground, either for independent aircraft action or as *contact patrols* in coöperation with ground forces during an attack. Such planes should be heavily armored and armed with rapid-fire and machine guns.

It is evident that the types of aircraft found most useful during the strategic phase generally possess as much value during the tactical phase, owing to the need for continued employment of aircraft on distant cruises over enemy territory.

The Interior Zone. Air defenses should be provided within the lines to meet the most formidable invasions possible, in case the aircraft screen is broken. This system should comprise groups of airplane parks and supporting anti-aircraft artillery batteries. These elements should be located to protect vital points or positions exposed to attack, or placed with reference to usual lanes of air travel. Lookout stations equipped with every facility to detect the approach of aircraft should be established. Combat planes stand ready to take the air instantly upon advice of the whereabouts of a hostile machine. In this way hostile air forces may be pursued by a superior force. It is imperative that a hostile plane be brought down before he regains his territory with valuable information. The seemingly insuperable task of detecting the presence of all invaders, at all altitudes, will largely dissipate if a comprehensive lookout system, detector stations, and microphone towers are adopted. It must be remembered that to do effective reconnaissance, under existing conditions, aircraft must descend to an altitude from which they may be detected. An efficient system of radio communication between stations and pursuing planes will best facilitate running down invaders.

Under *Zones of Operations,* hereinbefore, it was shown that the typical formation of forces advancing to the attack is in a series of parallel columns. It is of paramount and vital importance that these columns advance directly upon the assigned objectives, each column within supporting distance of the adjacent column or columns. The initial deployment into this formation to extend the front and diminish the depth to proper dimensions, can be best regulated by observing airplanes under the control of the supreme commander. These craft should be of the tactical type, equipped with radio and the observer should preferably be a staff officer detailed from the headquarters under which operating.

Offensive Action of Aircraft Against Objectives on the Ground

Airplanes must be used in such numbers as to give the necessary *shock action,* whether produced by volume of gun fire, weight or destructive effect of bombs, or other weapons. The growth of the air service of leading nations warrants the expectation that aircraft must be provided in thousands to discharge all the duties which they can perform efficiently. Airplanes especially should be used in vast fleets for offensive action, owing to the nature of the craft, for, all other things being equal, the results achieved by the airplane rise in direct proportion to the numbers employed. As a fourth arm for offensive action against the ground forces, the airplane has a definite function. When the hostile troops are in disorderly retreat gun-planes should be used to spread the rout by daring attacks from low altitudes of a few hundred feet. Special planes armored for low altitude work should be provided for this purpose. A similar type of plane is also useful for coöperation with the ground forces in powerful drives, when the hostile position has been blasted by mining and artillery fire. Planes are useful in bringing fire to bear upon the personnel occupying intrenchments, which are defiladed from direct and possibly from indirect fire. The proper coöperative use of airplanes in the charge should under favorable circumstances, be highly fruitful in carrying a position with minimum infantry losses.

INFLUENCE OF THE AIR SERVICE ON TACTICS AND STRATEGY

The advent of aircraft into warfare has exercised a decisive influence upon tactics and materially altered the principles of strategy theretofore prevailing.

The chief effect of aircraft service upon land warfare has been to dispel the "fog of war," and to penetrate the veil of uncertainty that formerly concealed grand movements. Since aircraft reconnaissance almost infallibly reveals concentrations of ground forces, the accepted rules of tactics and strategy have necessarily been reconstructed to meet the changed conditions. Aircraft have become the *eyes of the artillery,* enabling these weapons to search out their targets with unerring accuracy, facilitating the use of all calibers of armament alike, and making possible the use of gun fire on a prodigious scale. The function of bomb dropping has served to increase the range of offensive armament, limited only by the cruising radius of aircraft. The creation of the super gun-plane has brought about the realization of aerial cavalry for launching swift air drives, charges, and raids against the enemy, practically at any chosen point. Hence reconnaissance, artillery fire-control, bombardment, and combat functions, and other auxiliary uses of aircraft, have each entered into the science of modern warfare to produce powerful individual and collective influences upon the conduct of operations.

Relations of the Air Service to the Military Forces. In military operations, the employment of aircraft for the purposes outlined here, has the effect of reducing the *power of maneuver* of field forces; of minimizing the probability of blunder; of eliminating the surprise attack and rendering complete victory more dependent upon preponderance of force, represented by superior training, superior methods, superiority of personnel, equipment, and resources with which to maintain preponderance indefinitely. These conditions are to be regarded as normal and prevail when the opposing air forces are each capable of effective work. This, then, is the vital importance of gaining mastery of the air.

It is no longer possible to cover the concentration of great masses of troops, in the face of an active and enterprising hostile air service, except by means of an effective aircraft screen combined with superior air work over the *exterior zone,* which should absolutely prevent the approach of hostile aircraft within observing distance of the screen. This ideal state is difficult if not impossible of complete attainment for it is evident that movements on the earth are quickly and easily discovered and one lone air scout may succeed in eluding the most vigilant patrol. Even minor operations cannot escape detection under ordinary conditions. The result is that each adversary, apprised of practically every hostile development, meets concentrations move for move. Such conditions lead to deadlock and stalemate.

Certain limitations, however, are imposed on the power of the overhead service to affect the military situation. Concealment of troops, positions, and movements from aircraft observation, is possible when local in character; when confined to a small area; when covered by forest areas or restricted to cities or towns providing good overhead cover; when movements are accomplished by unlighted train service by night; when the air service is inadequate or inefficient; when the air service is incapable of conducting effective night operations; or when in any of the varied conditions of field service artifice is employed to deceive the air scout.

The effect of aerial observation upon military operations, is minimized when the tactical situation on the ground is unfavorable; such as when a movement is so far under way that it cannot be arrested to take advantage of information furnished by the air service; when insufficient time is available to make use of information gathered; when the enemy enjoys surpassing concentrating powers, by reason of higher marching abilities, superior transportation facilities or interior lines; when the friendly troops are out of hand.

Unrestricted power of maneuver presupposes victorious action. It is in this particular that aircraft service has seriously curtailed the principles of military tactics and strategy; mainly through elimination of the surprise attack as a normal condition of warfare, and *within limits* rendering ultimate victory more directly dependent upon preponderance of force, than upon brilliant generalship.

The most striking effect of these influences has been to make warfare a tedious field siege operation, by virtue of the restrictions imposed upon the power of maneuver.

Tactical and Strategic Value of Aircraft. Generally speaking, the success or failure of a local operation is of no more than tactical importance and effect. A tactical operation in a local area, may however, have a decided bearing on the situation at a distant part of the line, or in some distant theater of operations, hence become of strategic importance. "Combats of large forces are composed of a number of local combats" (F. S. R. 154). Combats of strategic importance may consist of a number of engagements of no more than tactical importance in each case. Strategy, the science of directing grand military movements, had up to the advent of aircraft into warfare, been largely based on the darkness and obscurity that prevailed behind the lines as far as the opposing forces were concerned. The use of aircraft has served to lift this veil, giving eyes to the general and to his artillery. The use of gigantic fleets of raiders to penetrate hostile territory by going *over the lines,* instead of through them, offers unlimited possibilities to increase the scope both of strategy and tactics. Offensively and defensively, aircraft have broadened the range of military operations, bringing victory with supremacy of the air and disaster to the side whose air forces fail or are defeated.

THE CAPTIVE BALLOON

The streamline, captive balloon, commonly known as the kite balloon, has proved to be an invaluable craft for the performance of certain kinds of aerial duties. As lookout, scout, and fire-control station, the captive balloon is superior in many respects to the airplane, owing primarily to the high rate of speed at which the slowest moving airplane must travel to sustain itself in the air. This is not conducive to careful and deliberate observation. On the other hand, the captive balloon is stationary and the car is generally steady. It moreover offers the advantage of easy communication by phone between the observer and the ground. While the target or objective may be examined at leisure from the car of a captive, the field of view is fixed, whereas the airplane can be maneuvered with respect to its objective and obtain views from various angles, and this is a decided advantage. For spotting artillery fire, the kite balloon is superior to other forms of aerial craft. Kite balloons are especially valuable for use in coast, field, or other fixed fortifications. This type is also useful afloat. When used in the field, the balloon is anchored about 5,000 yards in the rear of the fighting line (generally 3,000-10,000 yards) and flown at an altitude of about 2,500 to 3,000 feet. It is vulnerable to airplane attack and should be protected both by planes and by anti-aircraft guns which should be attached to the balloon company for the purpose. When assigned to positions, the balloon unit should be favored by every possible provision to facilitate its safety from hostile fire, airplane attack, and capture in case of quick retirements. With its transportation the unit can move about 10 miles an hour on the road. Laying out and inflating the balloon requires about 1 hour. The balloon will ascend to its flying altitude in about 10 to 15 minutes. These considerations make the balloon unit more transportable than mobile. When especially attached to mobile artillery units, these facts should be regarded and the balloon assigned to artillery forces having the same qualities of mobility. For example, the balloon should be assigned to heavy field howitzers rather than to light mobile armament. Airplanes should coöperate with the balloon units by detecting, identifying, and photographing their targets, positions, and areas.

THE DIRIGIBLE

For military purposes, the dirigible has special uses, but it lacks the versatility of the airplane. Difficulties of housing the dirigible, handling it near the ground, its repair and maintenance; its vulnerability and great size, which invite easy attack from airplanes and anti-aircraft guns alike, render it more useful for special projects. When used with the field forces, dirigibles should be operated from permanent stations, equipped with gas plants and provided with suitable hangars. Over-land flights should be restricted to night work. Airships are useful in the field for patrol work in rear of the aircraft screen. They are invaluable for coast patrol in connection with the defensive operations of the coast artillery. For work with the fleet, the dirigible is at present the superior type of aircraft, but large airships are limited in range of flights by cruising radius measured from the shore. In off-shore operations of the fleet, the dirigible is supreme. Over the sea, the floating positions of hostile armament are easily detected and avoided.

The rigid type of airship is superior to the semi-rigid and non-rigid types. The latter has been developed to a high state of efficiency, however, and is capable of long cruises over the sea. The doubtful value of seaplanes in a heavy sea and the ability of the airship to keep station with the fleet, render the insurance of dirigibles necessary.

COAST DEFENSE AIR SERVICE

Aircraft units assigned to the coast defenses and coast patrol service constitute a link between the air service of the land and naval forces. All three established types of aircraft are useful with the coast defenses. Land craft should be attached to the mobile troops, or coast artillery supports, consisting of such reconnaissance, fire-control, bombardment, and combat airplanes as the situation demands. Station balloons may be assigned to these field forces, but should invariably constitute part of the aerial equipment of coast fortifications. It is thought at present that the proper quota is one balloon for each battle command, each fort command, and each fire command. Combat and reconnaissance planes are required for protection against hostile aircraft and for supplementing the observation work of kite balloons, respectively. Scouting to seawards may be done by seaplanes, but dirigible service is superior for this purpose. It is probable that the dirigible performs its maximum service with the seacoast defenses having easy access to protected hangars and supply stations and performing its tactical functions well within cruising radius from the shores. For offensive and defensive action against hostile aircraft, mobile and permanent anti-aircraft batteries should be provided. Airplanes may be used instead of kite balloons, but the latter should be regarded as best suited to the character of work performed by the coast artillery, for reconnaissance, and fire-control duties. For tactical duties, all reconnaissance aircraft should be controlled by the coast defense commander; fire-control units should be directed by the battle, fort, and fire or mine commanders.

The service of seaplanes, dirigibles, and balloons involves extensive aeronautical stations. These should be permanent and grouped as far as possible under an *aviation* or *aircraft* officer, attached to the staff of the coast defense commander. Kite balloon hangars should, when possible, be located at least 5,000 yards from the nearest channel from which hostile fire might be brought to bear. Captive balloons are generally raised about 5,000 yards in rear of the line of batteries, for many tactical reasons. Seaplane and dirigible hangars should be placed with special reference to the waterways and the open seas over which they are to operate. Owing to the inaccessibility of many seacoast defenses, mobile aircraft bases or parks should be located with due regard to shipping and transportation facilities.

NAVAL AIR SERVICE

The effect of the air service upon naval tactics and strategy has been to reduce the power of maneuver of the fleets. With the aid of aircraft service, the sea may be policed by a superior naval force; effective blockades maintained at will, commerce destroyed, the submarine menace combated, and control of the sea facilitated. The fighting qualities of two opposing fleets being equal, victory will fall to the one gaining aerial ascendency.

The naval air service may be considered under the following headings:

1. Aerial service of yards and bases.
2. Coastwise patrol.
3. Air operations in the open seas.

Aerial Service of Yards and Bases. The assignment of aircraft to navy yards and bases is governed by the principles affecting the defense of positions. Protection of yards and bases is provided by the fleet on the high seas, and generally by coast defenses. Each of these elements is provided with aerial service, hence the need for aircraft defense at navy yards is ordinarily slight. Anti-aircraft batteries should be mounted and aircraft assigned according to the special requirements of the local defense problem. Combat planes only are necessary. Listening towers, microphone detectors, searchlights, anti-aircraft guns, and planes constitute proper defensive equipment for these stations. Airplanes, rather than seaplanes, should be used when possible, owing to the greater efficiency of the former as fighting craft. It is expected that air protection will be furnished by aircraft on duty with the fleet, supplemented by aircraft in the coast defenses, and that raids will be intercepted by air units with the mobile army supports of the coast artillery. This normal arrangement does not operate where navy yards or other stations are removed from the protection of the coast defenses. These conditions assume perfect coöperation between the naval, coast defense, and coast artillery support elements and proper coördination of duties and activities.

Coast Patrol. The maintenance of an adequate air patrol is imperative along the maritime frontier. This service is under the Coast Guard Service of the Treasury Department, in time of peace. In time of war, this control passes to the Navy Department. The coastwise patrol should be organized and assigned to contiguous zones which cover the entire sea front of the nation, except that the zones immediately in front of seacoast defenses should be assigned to the coast artillery air units. In time of war, reconnaissance patrols should be made to protect shipping and harbors from submarine raids; to halt and examine merchant vessels; to convoy vessels; to give warning of the approach of hostile warships; and to keep the coast defenses advised of the presence of friendly and hostile vessels. The dirigible is best adapted to the long cruises involved in coast patrol flights, but seaplanes are useful.

Air Operations in the Open Seas. The functions of reconnaissance, fire-control, bombardment and combat aircraft, as outlined for the air service on land, apply in principle to those craft as used in naval operations. With the fleet, aircraft relieve the naval commander of all the strain that accompanies the lack of information. The probability of miscarriage of plans, due to the uncertainty of intelligence that prevailed before the introduction of naval aircraft, has vanished. Air scouting at sea possesses a positive value it does not enjoy over the land. Objects are easily detected on the surface of the water. Flying conditions are generally better over the sea, as the air is smoother than over the land, and this in part compensates for the lower standard of efficiency of seaplanes, which are essentially heavier and have more air resistance than airplanes. Aircraft at sea are invaluable for the pursuit of merchantmen; aiding in the enforcement of an effective blockade; for the detection of hostile submarines; for offensive operations against enemy seacraft; for convoy duty; for bombardment raids; spotting artillery fire; protecting seacraft from surprise; performing reconnaissance duties of all descriptions; and for messenger and passenger carrying. Aircraft reconnaissance with the naval forces perhaps offers greater difficulties than land reconnaissance, since the theater of operations is generally larger than on land, battle formations more elastic, and the nature of grand operations more mobile. The principal duty of the air scouts is to locate the enemy and guide the fleet to the objective; furnishing safeguard against surprise; positive information of the enemy's formations, dispositions, and movements.

The difficulties of transporting, housing, and supplying aircraft at sea are manifold, and tend to diminish the results that should be achieved by the use of sufficient numbers. Seaplanes have great difficulty in leaving the water in heavy seas; dirigibles are generally too large to be housed on board vessels, and must not be employed beyond cruising range of the shores. Balloons are awkward to handle on board ships, unless the latter are specially constructed for the purpose.

Hangar Ships for Aircraft. One of the chief problems confronting the naval air service is the provision of suitable mother ships for housing aircraft with the fleet. Great obstacles are offered in the present methods of handling seaplanes. The planes are kept on shipboard. Space being limited, wings are normally removed when the plane is stored on the ship. When a seaplane is ordered to ascend, the wings are adjusted and the craft lowered into the water. Upon its return, this long process must be reversed. In a heavy sea, planes cannot get up sufficient speed to lift off the water. Landing in high seas is dangerous. Launching devices are now used for sending seaplanes into the air, but this does not overcome the landing difficulties. Hangar ships should be specially built to meet requirements. Special types have not appeared yet, but it is expected that this development will follow. An aircraft hangar ship should have an extensive launching and landing deck; hangar space for housing aircraft; machine, metal, wood, and fabric shops for repair work; and ample storage facilities for supplies of aircraft matériel and accessories. Balloons and dirigibles are best carried in vessels having large cradles built in the holds by removing the decks. Only small dirigibles can be carried in this way.

AIR POWER

The time has arrived when preponderance of military power on land, or command of the sea, can no longer be maintained without a superior air service. Mastery of the air may be unavailing without adequate military and naval strength, but control on the ground and sea cannot be complete without domination of the air. Control of the air, purchased through the provision of an air service vastly superior to the opposing aircraft forces, is the cheapest, most direct route to the advantages that lead to and culminate in victory. The influences exerted by a few hundred aircraft, as exemplified in warfare, may be magnified almost directly in proportion to the size and efficiency of the aircraft forces.

It has been said that "of all weapons produced by war, the airplane is the most efficient; it protects, it destroys, it fights; it is the super-spy, the super-scout, the super-belligerent." And yet the balloon and the dirigible have uses which the airplane cannot discharge as efficiently, and in some cases not at all. Hence the aerial fleet should be properly balanced, each unit devised to meet the demand.

An army is a crawling thing that arrives at the end of its usefulness when it comes to the sea. A navy is a floating thing that is limited in its radius of action by the shores of the land. An air service on the contrary knows no limitations of travel. It is equally at home on the land or sea and yet its real home is in the air above. It thus furnishes the last link of the strategic and tactical chain that binds the army and navy into a united and coöperative fighting unit. Neither armies nor navies should ever lose their potential fighting strength through the introduction of aircraft but inability to meet the enemy on equal terms in the air, where superiority is so potent and overwhelming, will result in inevitable defeat.

MILITARY AVIATION

CHAPTER 2

MILITARY AIRCRAFT UNITS

To accomplish the comprehensive and elaborate program, demanded by existing conditions, the aircraft forces of a nation should be organized into an independent arm of the service.

For technical purposes within the Army and Navy, the autonomy should be complete. For administrative and tactical functions, the air service should serve under the direct control of the General Staffs of the Army and Navy. Experimental, research, and training work should be united in the military and naval services.

The chart on the following page gives the existing organization of the air service of the Army.

The Chief Signal Officer of the Army is the head of the Army air service. The Aviation Section is divided according to G. O. 55, W. D., 1916, as follows:

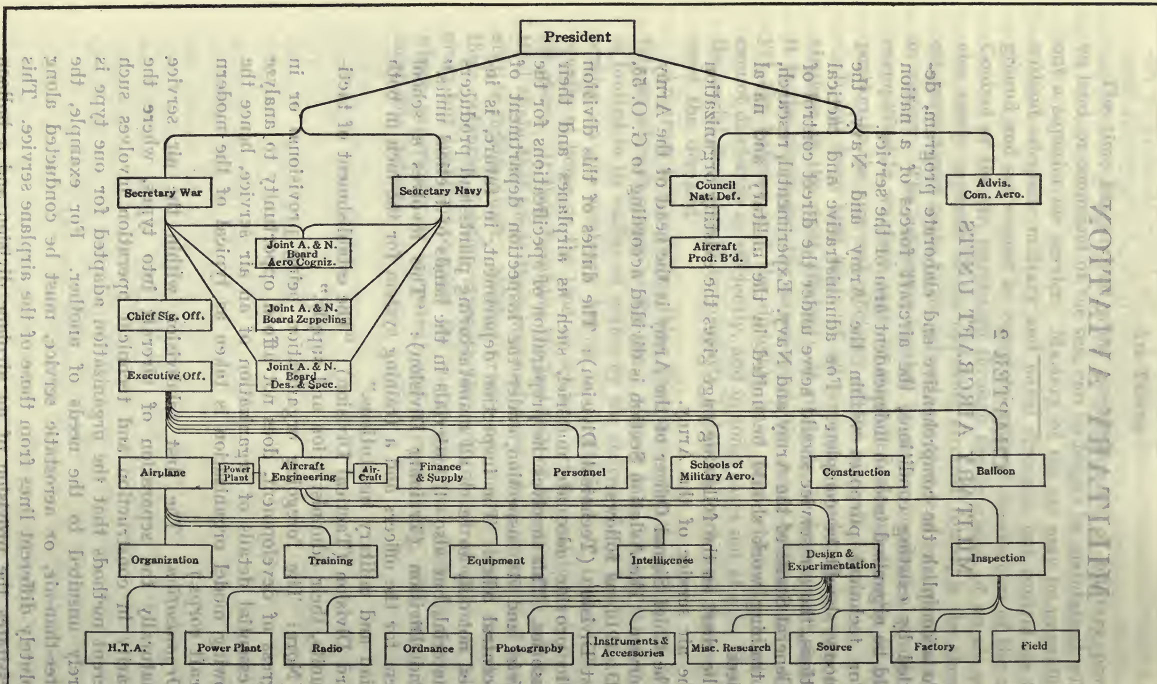
1st Division (Technical Division): The duties of this division are to provide adequate matériel, such as airplanes and their accessories. This involves the preparation of specifications for the *matériel* and its inspection under the inspection department of the central office. The inspection department, in future, is intended not only to reach all manufacturing plants and producers of material, but also all materials in the hands of tactical units."

2nd Division (Training Division): "This involves a school system for the officers and a training system for the men in both civilian and military institutions."

3rd Division (Tactical Division): "The establishment of tactical units, their administration and supply."

(NOTE: The foregoing organization being provisional or in progress of development, does not afford opportunity to analyze the essential details of organization of an air service, hence the following model organization is taken as typical of the modern aircraft corps.)

Organization. The first subdivision within the air service is naturally the separation of aircraft into types, where the disparity in construction and technical operation involves such different methods that the organization adapted for one type is entirely unsuited to the needs of another. For example, the lighter-than-air, or aerostatic service, must be conducted along absolutely different lines from those of the airplane service. This necessitates the provision of an airplane division and a balloon division, separate and distinct, but under the command of the



ORGANIZATION CHART

chief of the aeronautics, for technical, supply, training, and organization functions. On the other hand, when aviatic units are put into the field and brought under the control of military commanders, the entire air service should be a homogeneous organization, coördinated to work in the common cause of providing efficient air service, for this is the *raison-d'être* of the aircraft corps. Hence for technical, supply, and training functions and for the organization and development of new units, the two major elements of the aircraft corps should be separated; but for tactical purposes, united. This arrangement should produce maximum efficiency, provided *aeronautic* officers commanding both heavier and lighter-than-air units, are trained and experienced in both *aviation* and *aerostation.*

It is essential that training, technical, and supply functions be provided for both heavier- and lighter-than-air divisions and appropriate activities grouped under these heads. The following table may serve to tabulate the essential activities of the aircraft corps.

CHIEF OF AERONAUTICS

I. AVIATIC DIVISION

A. *Training Section.*
- 1. Organization.
- 2. New Units.
- 3. Training Schools:
  - a. Military,
  - b. Civilian.
- 4. Personnel.

B. *Technical Section.*
- 1. Aircraft Engineering.
  - a. Equipment: ordnance; engineer; quartermaster; aircraft.
  - b. Design and experimentation: experimental engineering; airplanes; *power plants; ordnance; *photography; *instruments; accessories.
  - c. Construction: source; factory; field.

C. *Supply Section.*
- 1. Finance.
- 2. Supply.

II. AEROSTATIC DIVISION

A. *Training Section.*
- 1. Balloons.
- 2. Dirigibles.
- 3. Organizations.
- 4. New Units.

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* Collaboration between Aviatic and Aerostatic Divisions.

5. Training Schools:
    a. Military.
    b. Civilian.
6. Personnel.

B. *Technical Section.*
1. Aircraft Engineering.
    a. Equipment; ordnance; engineer; quartermaster; aircraft.
    b. Design and experimentation: experimental engineering; balloons; dirigibles including power plants*; photograhy*; instruments*; accessories.
    c. Construction: source; factory; field.

C. *Supply Section.*
1. Finance.
2. Supply.

III. TACTICAL DIVISION

(Airplane, Balloon, and Dirigible)

A. *Department of Air Units.*
1. *Combat Section.* Orders; movements; disposition of forces; tactical operations; war diaries and records.
2. *Administrative Section.*
    a. Organization; supply of personnel; supply of matériel; correspondence.
    b. Department *Aircraft* or *Aviation* Officers.
    c. Aircraft Stations.
3. *Intelligence Section.*
    a. Foreign data.
    b. Domestic progress and aircraft industry.
    c. Aeronautic library.
    d. Gathering and distributing war data.
    e. Professional bulletins and textbooks.

The training section should exercise general jurisdiction over all training schools, maintained by the flying corps. This may be done either directly or through the aircraft officers assigned to each department. The latter is favored in our service. The training section should supervise instruction and training courses, prescribe methods and rules governing civilian and military training schools for airmen.

The technical section should be subdivided into departments which control the adoption of matériel, types, and fixtures of all aircraft and accessories. This section should prepare specifications for matériel, place orders, superintend and inspect all aircraft construction, and accept or reject aircraft and accessories; conduct flying tests and all manner of experimental work. The

*Collaboration between Aviatic and Aerostatic Divisions.

functions of this section should embrace supervision of all matériel in service; the services of maintenance, repair, and alterations; and direct the operation of experimental stations and aircraft arsenals or bases at which shops are maintained.

The tactical division (under which both *aviatic* and *aerostatic* organizations should be controlled for garrison or field service) should exercise general supervision of the administration of tactical units, through department aircraft officers and aircraft commanders with field forces. These functions may be conveniently discharged through a department of air units; thence the channels of direction should lead through the above named aircraft officers, to aircraft forces, airplane, balloon, and dirigible squadrons; to aircraft bases, depots, parks, and other stations and detachments.

Aircraft or aviation officers assigned to direct the operations within territorial departments or with field forces, should be assisted by such officers as are found necessary in the discharge of their duties. These assistants should consist of competent aviatic and aerostatic officers; engineer, and supply officers; inspectors and other aids. The following illustrates one method of apportioning duties:

Aircraft Commander

1st Division

1 Personnel Officer and Aid,
1 Supply Officer,
1 Engineer Officer,
1 Inspector.

2nd Division

1 Aviation Officer,
1 Aerostation Officer,
1 Director of Bases and Parks.

3rd Division

1 Director of Aviatic Training,
1 Director of Aerostatic Training.

Aviation Officers. The present practice is to assign aviation officers to the staffs of department commanders and commanders of field forces, to which aircraft are assigned. The growth of the air service to include large forces of aerostatic units, balloons and dirigible squadrons, imposes the need for trained *aircraft* officers, that is to say officers who by virtue of experience and other qualifications are suitable to exercise direct supervision over both heavier- and lighter-than-air craft. The practice has been adopted by leading nations of designating the aircraft officer at general headquarters in the field, as the *aircraft commander.*

The aircraft commander should be the technical adviser of his commander on all matters pertaining to the air service, within the command. The former should be the commander of all aircraft troops, stations, and aeronautic units, and control the distribution and assignment of all air units in the command. He should be charged with the entire administration of the aircraft forces, including the technical, supply, training, and tactical functions. He should suggest policies and measures for the conduct of the aerial warfare and be made directly responsible for the proper use of the aerial arm, to secure mastery of the air and render efficient air service to the field forces. He should have complete control of the personnel assigned to the command, the power to appoint the commanding officers of aircraft stations and units, and to regulate the transfers and assignments of officers and men. The aircraft commander should be charged with the supervision of a field weather bureau for collection and distribution of meteorological data, in the absence of an established meteorological system. His headquarters should include an office for gathering and issuing aeronautic data and information. He should direct the aerial operations, and control the various services performed by the aircraft forces.

Department aviation officers should direct the aircraft units which do not ordinarily form a part of the field forces. He should direct the training of pilots and observers, and his office should serve as a channel for all administrative matters not handled directly between the aircraft forces and the Chief of Aeronautics.

Subordinate aircraft officers perform duties similar to those prescribed for their superiors. The commander of an aircraft company, squadron, wing, etc., is charged with the entire control and management of his unit, subject to the orders of his superiors and to the regulations which govern the flying corps. His duties include the administrative, technical, supply, training, and tactical functions.

Aircraft Stations. In time of peace, technical, training, and supply stations should be located with reference to the needs of the air service. The sites for elementary training schools should be selected with climatic considerations uppermost. Supply stations should be situated with due regard to geographical location and shipping facilities. Technical, experimental, and research stations should be situated near the center of the aircraft industry, in a locality where climatic conditions are good throughout the year, and at or near large shipping centers with excellent local transportation facilities. Such stations should preferably be located within easy travel of the headquarters of the aircraft corps. Tactical units of the air service are assigned to garrisons for coast defenses for service with troops, and to field forces in maneuvers or in hostilities. In time of peace, every disposition should be made for readiness and quick action upon outbreak of hostilities. Aircraft units should therefore be stationed at strategic points along the borders, inland or maritime frontiers, and at points having shipping advantages.

The present allowance of aircraft to the mobile army is three squadrons to each army corps. This quota, however, is provisional and will inevitably vary with the exigencies arising in warfare.

Aircraft Forces in the Field. The allotment of airplane forces should be based on the strategic and tactical situations, both on the ground and in the aerial campaign. This presumes due consideration of the strength and disposition of hostile aircraft forces; provision of effective, defensive aircraft screens, interior and exterior patrols; having due regard to the balance of strength between opposing aircraft forces, with a view to pushing a continuous offensive to attain or maintain complete mastery of the air; and taking into account the requirements of the military situation on the ground, providing adequate air service for the ground forces at all times, and air offensives to support ground offensives. Aircraft are rarely ever attached to units smaller than divisions. Combat and bombardment squadrons and wings may be assigned to army headquarters, reconnaissance squadrons to army corps headquarters, and fire-control forces to divisions. Special aircraft forces should be attached to general headquarters. Other considerations affect the disposition of captive balloon and dirigible companies and squadrons; such as the terrain in local areas; the activity of hostile airplanes; adaptability to methods of warfare developed; and the nature of the operations. The concentration of balloon forces will vary almost directly with the concentration of heavy artillery. In trench or stationary warfare, *station* balloons offer greatest usefulness. In open field operations, however, balloon units should be utilized to the fullest possible extent. Their adaptability to the latter kind of warfare will depend upon the degree of mobility given balloon organizations. The present normal quota is one squadron of four balloon companies (each company serves one balloon) and one headquarters and depot company to each army corps. Assigned to sectors of the front, balloon units should never comprise less than four balloons to the front occupied by each army corps, and should when possible be stronger; in some cases the allotment may be as high as sixteen balloons or four squadrons to the army corps. Dirigible squadrons are assigned in accordance with the needs. They are used to supplement the airplane service on land, being of especial value for night operations or for air work behind the lines. Dirigibles are of greatest value over the sea. The allotment should be made to fulfill the prevailing requirements.

Field Forces. Under ordinary conditions of warfare, the army corps may be taken as the typical unit upon which to regulate the assignment of aircraft in the field. In practically all armies the army corps varies in strength between 20,000 and 30,000 men. Against a well-matched enemy the front occupied by this force in action is placed at a maximum of about five miles. In the attack or defense of important positions local concentrations may vastly exceed this number. The problem confronting the aircraft commander is to allot sufficient forces to each unit or sector of the line without wasting his strength. The front occupied by an army corps may be taken roughly at 8,000 yards. The army corps should be required to maintain its aircraft screen across this front. This screen should consist of the following elements:

1. The patrol planes, at high altitudes.
2. Reconnaissance and fire-control planes, at mean altitudes.
3. Station balloons for reconnaissance and fire-control duties at low altitudes.
4. Pursuit planes held in readiness on the ground.
5. Anti-aircraft artillery.
6. Observation stations, lookout towers, and detector posts.

Patrol Planes. The number of combat planes necessary to maintain an effective patrol across a front of 8,000 yards must of necessity vary with the local and general situations. A group of six planes should constitute an effective patrol, providing a combat plane to the mile, with a reserve of two planes to engage possible invaders. Three reliefs of six combat planes each should be able to furnish a patrol for a period of one-half day, of twelve hours, providing patrol flights of four hours each. If the three reliefs are furnished by one squadron of twenty-four planes, there would remain a reserve of six planes in constant readiness for flight. A squadron should not be employed on this arduous duty continuously, hence the necessity for perhaps two squadrons for this purpose. One of these squadrons may be used for patrolling to the front of the screen, but this duty is considered more severe than patrolling over friendly territory owing to the greater hazards entailed in invading hostile areas; exposure to anti-aircraft artillery; to capture, in case of motor failure; and other considerations. The altitudes at which this patrol is maintained must vary with the conditions of warfare. The present practice is to operate combat patrols at from 9,000 up, according to circumstances.

Reconnaissance. Reconnaissance squadrons are used in the aircraft screen for all manner of duties, such as observation of movements, both friendly and hostile, fire-control, and photography. The reconnoitering planes should also be used in coöperation with station balloons, identifying and photographing targets which appear indistinct to the latter, and otherwise assisting the balloon observers. Reconnaissance planes should operate at altitudes (usually) above 8,000 feet.

Pursuit Planes for Station Duty. The small, high speed pursuit type is best suited for station duty. When hostile aircraft are sighted, generally a group of from two to six planes should be sent out in speedy chase. A group of six planes constitutes the most suitable unit, providing due strength without loss of mobility or control. In sending out pursuit groups, however, effort should always be made to provide a force superior to the pursued. These rules apply equally to searching patrols beyond the lines.

Anti-aircraft Artillery. In general it has been found that the best results are obtained by the sheaf fire from a group of four guns constituting a battery. These guns are arranged to form a square, each side of the square being about 200 feet. Groups are mutually supporting when about 1,000 yards apart. To provide a single line of anti-aircraft guns to cover a front of 8,000 yards, it is necessary to have nine groups of batteries in the screen (thirty-six guns) when the corps is acting alone. If the corps is acting with adjacent or contiguous units, so equipped, eight groups may be employed on the front and the remaining group placed in reserve. The anti-aircraft artillery should be held responsible for the integrity of the screen to an altitude of 7,500 feet.

Groups of anti-aircraft artillery should be placed in reserve on the flanks of the position occupied by an army corps, acting alone. When an army corps acts as part of an army, supplementary groups should be placed at or near corps headquarters and in reserve.

The type of anti-aircraft artillery used with field forces should be mobile. Mobile anti-aircraft artillery consists of two classes: (a) Very light, rapid-fire, mobile units mounted on motor trucks; (b) Heavier, high power guns, provided with more deliberate and accurate means for fire-control. The latter may be tractor-drawn or transported on caterpiller trucks. The lighter armament is more suitable for the aerial screen where mobility and rapidity of fire are paramount. High power guns are required in rear of the lines, for protection of definite sites and for reaching higher altitudes at points where patrolling combat planes cannot be relied upon to furnish the opposition. The first line of guns should be very near the front in order to keep the hostile craft at a safe distance from the screen. Guns in the rear must be given more cover. Ample time will usually be available during which to make extensive preparations to this end. The guns on the immediate front must be highly mobile, to advance and retire quickly with the ebb and flow of the daily tide of war. Fixed mounts for anti-aircraft guns consist simply of a small block of concrete which can be transported with the guns. Fixed mounts are used chiefly for the air defense of cities and permanent stations. Fortresses and fixed emplacements should be so protected. Fixed mounts are worth employing whenever possible.

Observation Stations. Observation stations should be established along the front in sufficient numbers to insure that the entire front will be covered. These stations should fulfill the following conditions: Situated on elevated sites, enjoying the vantage of a broad command of the sky; equipped with special microphone detectors for making known the presence of airplanes by the hum of the motors, when other noises do not interfere; equipped with searchlights for night work; manned by trained personnel supplied with high power glasses and telescopes for searching the skies; other facilities to insure thoroughness and continuity of observation. These stations should work in coöperation with the anti-aircraft artillery and pursuit planes. Radio stations should be established for communication with airplanes in flight. Fire-control apparatus should be employed for range finding and fire adjustment on hostile aircraft.

General. In order to obtain proper coördination, observation stations and anti-aircraft artillery should be placed under the control of the aircraft corps. The closest coöperation should exist between the ground and aircraft elements, under any arrangement adopted.

Aircraft Parks. The stations of air units in the field, or when otherwise serving with military forces, are generally called aircraft parks. The sites for such stations are located in time of peace in accordance with the rules governing the selection of aircraft fields. The requirements for landing sites prevail under all circumstances. If suitable fields do not exist at the desired places, they should be prepared. Aircraft parks at the front should be located within twenty miles of the front. During the strategic phase, these stations may have to be changed daily. On the other hand, especially during the tactical phase, some of the flying fields may be occupied indefinitely. When stationed within twenty miles of the front, only slight loss of cruising radius results. The stations should be removed from main roads and if possible from the neighborhood of depots and hospitals. Roads leading to the front are usually choked with long trains of supply trucks, ambulances, and troops. The confusion, interference and effect of witnessing the procession of wounded are not desirable.

The units assigned to one aircraft park should, whenever possible, be limited to those under one commander in order to avoid conflict of authority. Squadron commanders should not be interfered with in the control of their squadrons. Under no circumstances should they be interfered with in the tactical control of their units. Whether a squadron should be assigned a field of its own is a question to be decided in each case. Landing sites shared by more than one unit offer great advantages. Consolidation should result in better improvement of landing sites, and sharing shops and depots may be advantageous by giving improved facilities.

In addition to the tactical and aeronautic considerations governing the selection of flying fields, the rules of castrametation must be followed. Locations for camping sites should be chosen with reference to communications, accessibility, sanitation, comfort, space, wood, water, and drainage. Rail and motor transportation should be provided. Electric power is desirable.

It is desirable to keep a unit in one locality of the theater of operations whenever possible, as the airmen become accustomed to the terrain, and the quality of work to be performed is improved accordingly.

Night flying in the theater of operations should be expected as a matter of common occurrence. Owing to the greater uniformity of temperature, the air is much better for flying at night than during the hours of daylight. There is also less interference from the enemy. The visibility of the airplane is slight at very low heights, and effective firing from the ground and interference of hostile planes are practically negligible. Radio work and signalling are more effective by night. Estimation of ranges, correction of artillery fire, and bomb dropping are practicable and effective work can be done. Reconnaissance is possible with the aid of illumination devices. In some cases projectors are used; in others, flare-balls or rockets are preferable. Patrolling at night by airplanes, however, is an uncertain undertaking. Dirigibles should be employed as far as possible. Planes held in readiness are sent in pursuit of invaders. Combat at night offers great, but not insuperable difficulties. For airplanes, the principal danger of night flying is encountered in landing. Lighting must be provided flying fields for night flying.

Night Illumination. Landing lights for night flying should be furnished each aircraft squadron, mounted on automobiles for service work, when the squadron is called upon to perform night flying in the field. The apparatus includes a motor generator set, with searchlight, controlled electrically by means of a weathercock to swing with the wind and so convey to the aviator above, information as to the exact wind direction.

Special rules must be followed to avoid betraying the position to hostile aircraft. Lights should be kept occulted until aircraft overhead signal identity, or a system adopted, such that the lights convey no information to hostile airmen. When friendly craft overhead signal, the illuminations are turned on. Special projectors are employed to illuminate the landing field clearly. (See under INSTRUMENTS.)

AIR SQUADRONS, DIRIGIBLE, AND BALLOON UNITS

Duties of Squadron Commanders. These are generally governed by orders, instructions, and practices of the air service. They are similar to those outlined for superior aircraft officers.

The duties of the airplane squadron commander are divided into the administrative, supply, training, technical, and tactical. He is charged with the efficiency and readiness of his command for active service at all times. As the commander of a technical unit, the effectiveness of which depends primarily upon excellence of organization, and specialization of personnel he must be a trained technical man, a capable commander, and have a thorough knowledge of the administrative system of the air service. Upon his qualities as an instructor, depend the proper advanced training of observers, gunners, motor engineers, radio operators, and other specialized airmen, as well as the efficient instruction of the entire personnel. He should have a thorough knowledge of the tactical operation of his unit, the aerial tactics of combat, and the employment of the squadron in its military function of reconnaissance, bomb dropping, artillery fire-control, as the case may be.

Administrative. The squadron is the smallest administrative aircraft organization. For convenience, the unit is divided into twelve flying sections, each under a captain or lieutenant. The squadron is the appropriate command of a major. For tactical purposes, four or six planes may constitute a squad or group. For administration, the squadron commander should exercise control and supervision of the preparation and rendition of estimates and requisitions, for supplies of all kinds and classes; correspondence, records, reports, and returns; care and accountability of squadron and other government property, and the disbursement of the squadron fund.

Supply. The squadron commander is assisted by a supply officer whose particular duties include the preparation of estimates and requisitions for all manner of equipment: clothing, equipage, subsistence, arms, ammunition, aircraft *matériel,* accessories, and supplies of all kinds. He is charged with the reception of supplies; housing, issuing, expending, and accounting for all property; keeping of proper accounts, records, reports, and returns for the same. His duties cover the use of property supplied by all departments. It is not good practice, however, to burden a supply officer with quartermaster duties when avoidable; certainly not at large aero stations.

Training. The training of squadron personnel includes instruction in the duties, practices, and regulations pertaining to squadron and section commanders, staff officers, aviators, observers, gunners, motor engineers, radio operators, chauffeurs, airplane mechanicians, mechanics in the motor, machine, metal, wood, and fabric shops, and any other personnel assigned. The work should be divided into officers' and enlisted men's courses. An elementary course for airmen should be formed, similar to the prescribed officers' garrison school course in the army. Instruction courses for airmen should be made continuous, from elementary to advanced subjects. Promotion and advancement should be made on the records made by airmen in their practical and theoretical work. The failure of an officer or enlisted man as a pilot does not preclude his usefulness in some other capacity. The inability of the squadron commander to employ an airman should result in transfer of the latter to another squadron before final action is taken in relieving the aviator.

Airmen when graduated from flying schools should be used on the reserve, interior, or lines of communication, to get the necessary experience before being sent to the front.

Technical. The highly technical nature of the flying unit requires the services of competent technical men. Each air squadron should be furnished with an engineer officer, who should whenever possible, be a graduate aeronautic engineer. The effort to train aeronautic engineers at training schools is a waste of time. Men who show special qualifications for such work should be sought, however, and developed at technical schools. A qualified officer should be furnished each squadron and aircraft station for duty as engineer officer. He should have charge of the various shops or repair sections, and all repairs, alterations, renovations, dismantling, and assembling should be done under his direction.

Tactical. The tactical duties of the squadron officers are divided between the squadron commander and his officers.

To discuss the tactical functions of the air squadron, the organization must be examined first.*

The basis of organization of airplane units is the squadron.

It consists of a headquarters, supply section, shop facilities for metal, wood, and fabric work, a truck train of airplane carriers, supply and fuel trucks, and twelve flying sections, to each of which is assigned one airplane and certain specified personnel and matériel. These squadrons may be divided into groups, independent in airplanes, personnel, and transport to carry such spare parts and supplies as to be self-supporting if detached for short periods of time. Each squadron is officered and manned by the required aviators, observers, and crews for the planes, machinists, mechanicians, chauffeurs, clerks, and orderlies.

Squadrons are organized for a specific character of aerial duty, such as combat, bombardment, reconnaissance, and artillery fire-control squadrons. The distinctive features of one type of

* The tactical control of air units refers not only to *tactical command* but to *tactical control in flight.* A discussion of the latter is found under COMBAT.

squadron are found in the number and type of planes, the class of personnel assigned, and the description of equipment and accessories employed.

It is important that units which are to operate as such, must consist of planes of a type, i. e., those having the same qualities of climbing power, speed, and maneuvering capacity. Compound squadrons may be used whenever the groups are designed to act independently, provided the groups are homogeneous in types.

The squadron commander selects landing sites when so directed. When assigned to station, he establishes camp, improves landing sites, and immediately puts his unit in order to take the air. Tactical flights should be directed by the aircraft commander. Practice and test flights should be restricted to a certain area. The squadron commander should conduct his test flights without interference with tactical flights of other units.

Orders directing tactical flights should be issued by the aircraft commander whenever practicable in "Orders of the Day." Special flights are directed from the same source. *Orders of the Day* are routine and should be issued from aircraft headquarters on the day preceding. The hour at which these orders can be issued will depend upon the hour at which the reports of daily operations are received from the various squadron commanders. Daily reports of losses and developments should be communicated to aircraft headquarters at the earliest possible moment. Whether these reports shall be submitted as events occur, as learned, or consolidated for the day will depend upon the system adopted. In case routine reports are submitted at specified hours, exceptional achievements or mishaps should be reported without delay.

Routine flights and convoy duty should be divided between the combat squadrons as the latter are particularly disagreeable to airmen. The duty of convoying over hostile lines is exceedingly dangerous, monotonous, and tiresome and does not offer the same opportunities as combat duty over the lines, where the outcome can be watched and full credit obtained for victory.*

A daily bulletin of aerial operations should be furnished each squadron commander.

In general practice, the following rules are well established. The squadron commander is charged with carrying out the flights directed by the aircraft commander. He designates the planes to participate, arranges the details of the flight, issues the maps and special orders involved, transmits, or in their absence, specifies the mission and tactical orders. He orders the hours of departure

* One cardinal rule followed in the employment of all types of squadrons, combats, bombardment, or fire-control, requires all aircraft to assist in reconnaissance regardless of the nature of their normal duties. Likewise every craft is expected to assist other friendly craft to the fullest possible extent, without, however, relinquishing its regular duties. This must be regulated by the mission in each case.

of patrols, of reliefs, and names the pilots, gunners, observers, passengers, and other personnel. If observers are not assigned by higher authority, they should be detailed by the squadron commander. The observers deal directly with the squadron commander in that case. The assignment of observers to a given machine is advantageous. The mutual confidence established between pilot and observer by constant association, should be encouraged. Whenever observers and pilots are congenial, this arrangement should be adopted. An airman does better work when he has faith in his pilot.

Reports of flights should be forwarded to the chief of staff, or to the aircraft commander immediately upon landing, after accomplishing a mission.

Reports of movements of the squadron transport should be submitted to the aircraft commander daily.

Reports of expenditure of important supplies, losses of equipment, accessories, and other aircraft property should be submitted to the aircraft commander. The bulk of expenditures should be made on the certificate of a squadron commander.

In addition to the instructional, disciplinary, and tactical duties of section commanders, they should be charged with the care, maintenance, and minor repairs to planes and motors.

When losses have been unusually heavy, reports of serviceable planes may have to be rendered twice daily in order that rearrangement of schedules can be made without delay.*

Planes should be reported unserviceable which require repairs that cannot be made within a reasonable period of time. This is regulated by orders from the aircraft commander based upon conditions existing in the theater of operations. If roads, rivers, or rail lines are choked with reinforcements and supplies and the situation perilous, transportation problems might make it advisable to perform extensive repair work at aircraft parks.

The formation of new squadrons at aircraft parks in the theater of operations, should not be attempted except under the most pressing circumstances.

Squadrons and other units of aircraft should be distinctively marked.

Each airplane should bear a flying corps serial number and its number in the squadron. It should be marked under the planes, on the sides of the body and rudder with the national aircraft emblem. The aircraft emblem of the United States air service, both military and naval, consists of a white five pointed star, having

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* The flying life of planes has been satisfactory in warfare. The average useful life in warfare, barring mishaps, has been about 65 hours of actual flying. Planes of mediocre construction and workmanship and those that are overloaded show signs of deterioration after 15 hours' flying, and these deteriorate very rapidly after that time.

a red center; the whole painted on a blue disk. This emblem is applied on the lower surface of each wing of an airplane and upon the under surface of the nose of a balloon.

Based on the developments of aviation in warfare, the following table illustrates, in a general way, the organization of different types of aircraft squadrons, accommodated to the prescribed reconnaissance aero squadron, U. S. Army.

AIRPLANE COMBAT SQUADRON (Compound)

1st Group 6 sections; comprising 6 pursuit type airplanes.
6 sections; comprising 6 cruiser type airplanes.
2nd Group 12 airplanes in reserve.
19 officers; 154 enlisted men.

Transportation: 23 motor trucks, 24 trailers, 2 repair trucks, 6 motorcycles, 154 rifles, 173 pistols, 12 machine guns.

NOTE: The compound squadron has lost favor, except for special uses. The usual policy is to organize a combat squadron to consist entirely of pursuit or cruiser type planes.

In the reconnaissance, fire-control, and bombardment types of squadrons, the appropriate types of planes are substituted. Reconnaissance squadrons are sometimes organized as compound units.

AIRPLANE RECONNAISSANCE SQUADRON (Compound)

1st Group 4 sections; comprising 4 strategic type reconnaissance airplanes (probably bi-motored).
2nd Group 4 sections; comprising 4 intermediate type reconnaissance airplanes.
3rd group 4 sections; comprising 4 tactical type reconnaissance airplanes.

Personnel and transportation as given under Combat Squadron.

NOTE: The *intermediate* type is not recognized as established, although its functions are definite and the type extensively used. The tendency is to eliminate as many types as possible by selecting planes having improved qualities and capable of discharging several functions.

Battle-planes are sometimes attached to bombardment units. These should be organized into squadrons for special employment in offensive operations, particularly for use against troops on the ground. This will necessitate an altogether different organization table for personnel, transportation, and equipment, from other types of squadrons discussed hereinbefore.

BALLOON SQUADRON
(For assignment to army corps.)

4 companies; comprising four 35,000 cubic feet kite type or cylindrical captive balloons.
1 headquarters, supply, and depot company.
28 officers; 416 enlisted men.

Transportation: 5 motor cars, 11 motor trucks, 5 winch trucks, 46 gas cylinder trucks, 5 fuel trucks, 8 hydrogen gas generator trucks, 1 repair shop truck, 25 trailers, 10 motorcycles, 416 rifles, 444 pistols.

DIRIGIBLE SQUADRON

(The organization of dirigible squadrons has not been announced in this country.)

The following organization of a dirigible squadron is suggested, conformed to the practice in the Balloon Division of the Aviation Section, United States Army, with respect to Balloon Squadrons.

4 companies or sections; comprising 4 non-rigid dirigibles, 60,000 to 75,000 cubic feet.*

1 headquarters, supply, and depot company.

20 officers; 488 enlisted men.

Transportation: (about) 100 trucks and 25 trailers; 10 motorcycles; 488 rifles, 508 pistols.

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*The rigid type of dirigible is not adapted to mobile organization.

CHAPTER 3

COMBAT

The combat function of the aircraft forces is to secure mastery of the air. This presumes that the air over occupied territory be cleared and kept free of hostile machines, and enemy territory invaded at all hazards, maintaining a degree of superiority over opposing aircraft throughout all spheres of operations, aerial and military. Supremacy in the air implies complete dominance of the aerial situation, the military forces freed from hostile aircraft observations, raids, or offensive action, and given effective, coöperative aircraft offensive action; friendly aircraft enjoying immunity from interference of hostile aircraft.

This program involves an immense force of aircraft, engaged on a variety of combat operations. These may be divided for convenience into the following:

(a) Patrols:
  Interior.
  Exterior.
  Aircraft screen.
(b) Pursuit and aerial fighting.
(c) Aircraft fleet operations.
(d) Bombardment raids.
(e) Convoy duty.
(f) Combat with lighter-than-air craft.

Patrols. Patrolling is performed by single planes or by groups or flights (small bodies of aircraft operating together in flight). It appears that the most satisfactory results are obtained by sending out groups of four to six combat planes on a patrol, although groups of ten and sixteen planes have been employed with marked success. Larger units have been used. A single plane should be sent out for patrol duty only in an emergency, unless other combat planes are within supporting distance. It is important that the combat unit should consist of planes of one type, or those having the same qualities of climbing power, speed, and maneuvering ability. Cruiser planes and pursuit machines are both useful for patrol duty, but the latter is essentially a short range type and is superior for station duty on the ground, rising to attack upon the approach of hostile aircraft.

Patrols should be maintained constantly. This involves reliefs. Owing to many limitations imposed by the difficulties of night flying and by flight in storms, the maintenance of continuous patrol is an ideal situation to be sought. For night work, combat dirigibles should be used to supplement the airplane service.

Invasion of hostile territory involves patrols over specified areas, journeys far into enemy country, routine and roving search for all classes of enemy aircraft. Combat should be sought at every opportunity. The fighting group should possess sufficient strength to meet superior forces with a fair chance of winning a fight. Increase in the size of units beyond a certain point results in loss of mobility and control. The installation of radio giving free communication between the planes of a group in flight, should enable the employment of large units.

Owing to the third plane of direction and to the ever present lack of complete stability, maneuvers and operations by a group of planes in flight are essentially more complicated than upon the ground or on the sea. Without radio equipment, the unit must proceed according to a prearranged plan. The undertaking is similar to patrols by ground scouts. Every pilot and observer in the unit must know prior to departure his mission, the route to be followed, where friendly and hostile forces are to be expected, both on the ground and in the air, the course to be pursued upon meeting the enemy under certain well-established conditions, where to reassemble in case of dispersion or scattering, and other such details.

The formations employed in maneuvering aircraft units are matters of drill regulations and tactics, which like all military operations must be adjusted to the conditions as encountered. It may be said that the formations adopted should favor the types of aircraft employed. For example, in the *pusher* type of airplane the most favorable vision is obtained dead ahead, while in the *tractor* type of airplane the most favorable vision is had to the flanks. Flight at the same approximate level should be sought. Columns, lines, echelon formations each offer advantages and disadvantages. Actual drill should be practiced with the types concerned, until the aviators of a group cultivate the necessary teamwork.

Sentinel Duty. Patrol planes assigned to the aircraft screen are given special missions, but the routine work consists in observing the reconnaissance, fire-control, photographic, and other special service planes operating at a lower level, and frustrating all attempts to interrupt them at their work. The plane must be kept to its assigned lane or patrol post and contact maintained with other combat planes patrolling adjoining posts. Patrolling is done at slow speeds. Upon the appearance of hostile aircraft, full speed is put on. Combat planes within supporting distance close in for attack. When one or more planes leave post for pursuit, neighboring combat planes should be on the alert to extend their patrols until the appearance of reinforcements from the ground to replace the craft withdrawn. Combat planes should be on the alert to defend station balloons from attack. Owing to the low altitudes at which these operate, and the high altitudes at which combat planes operate (station balloons, 2500-3000 feet; combat planes about 10,000 feet), the defense of kite balloons must be provided by frustrating the enemy's attempt to penetrate the screen at high levels, rather than by diving at the attack, if the balloon is to be saved. Defense at the lower levels should be provided by aircraft guns and possibly by swift, fast-climbing pursuit planes stationed on the ground in waiting.

Contact patrols should be furnished by battle-plane units for low altitude work in coöperation with the ground forces in assaults. These planes operate at heights of a few hundred feet and perform both offensive and reconnaissance duties.

Patrols inside the line should be maintained to supplement the work of the exterior patrols and of the aircraft screen.*

Planes operating in groups, squadrons, or larger units, leave the ground independently and assemble over a selected site at a certain altitude.

Aerial Fighting. Combat planes are designed to fight. Combat personnel should be prepared to fight aircraft of all types. The tactical principles involved in a combat between two planes differ materially from those which affect combat between an airplane and a dirigible. The various flight maneuvers and tactical principles involved should be studied by airmen in anticipation of any combination that may be met in aerial combat.

There are three phases of aerial combat:

1. Maneuvering for position.
2. Delivering the blow.
3. Culmination of the encounter:
   (a) Successful escape if worsted.
   (b) Destruction of the opponent if he is injured or seeks to escape.

When a hostile airplane is encountered, the aviator should be guided by two elementary tactical rules: to get into such a position that fire can be readily brought to bear on the enemy while denying him the opportunity to return the fire; and to reach a relative position that offers the best field of fire. The two opponents circle and dive, each endeavoring to reach the most favorable position above, below, in rear, in advance, or in prolongation of the enemy's wings; a choice depending upon the types of planes involved, the disposition of the enemy's planes, the location of his crew, armament, and other considerations. All these things are seen at a glance. It may be apparent that the opponent is badly disconcerted from the mere behavior of his craft. Ability

*All aircraft are charged with reconnaissance, regardless of what duties they perform in flight.

to obtain the advantage of position depends upon the relative flying qualities of the two craft, and the airmanship of the two pilots. The important flying qualities of an airplane in contest are speed, climb, and celerity of response to control. The most advantageous position will vary for every combination of opponents; for example, a different position must be taken up by the *tractor* with reference to an opponent in a *pusher* type, than would be the case if tractor meets tractor.

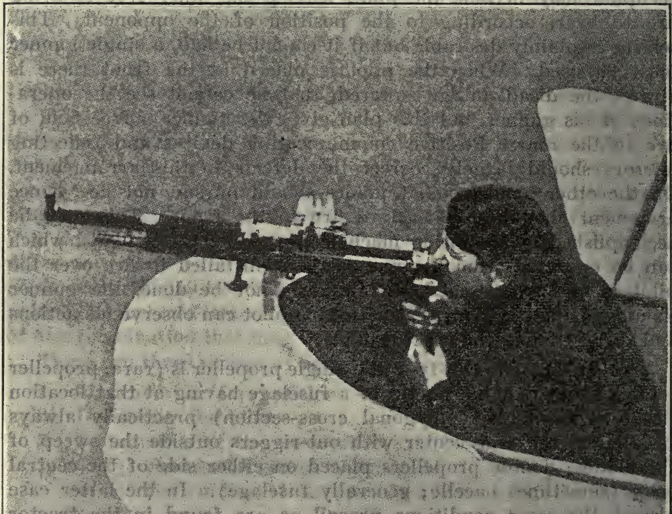
Tractor Type. In the tractor type, it is assumed that machine guns are mounted both fore and aft. The armament should be so arranged, and the craft provided with dual controls, so that either occupant may become the pilot, leaving the other free to bring fire to bear, according to the position of the opponent. This scheme is plainly desirable but if it cannot be had, a single gunner must be used. When the pilot is placed at the front there is always the disadvantage suffered, that he cannot see the operations of his gunner, but this plan gives the gunner a free field of fire to the rear. Positive communicating devices and reflecting mirrors should largely correct the defects in this arrangement. On the other hand, combat planes should pursue, not flee, hence armament should be placed to fire to the front. This may be accomplished by mounting machine guns on the top plane, which can be operated from the rear seat, or installed to fire over the pilot in the front seat.* If these cannot be done, the gunner should occupy the front seat where his pilot can observe his actions and direct the machine accordingly.

Pusher Type. In this type the single propeller is (rare: propeller rotates around the perimeter of a fuselage having at that location either a circular or polygonal cross-section) practically always situated at the rear center with out-riggers outside the sweep of the blades; double propellers placed on either side of the central body (sometimes nacelle; generally fuselage). In the latter case almost the same conditions prevail as are found in the tractor type. With the single propeller pusher type, firing to the rear is subject to interference of the blades. The pusher type enjoys the advantage in a pursuit, but it suffers when measured with the best features of the tractor type, because the latter is generally

*One of the chief difficulties experienced in arranging armament on airplanes has been to obtain a field of fire through tractor screw. This was first overcome by timing the machine gun so that it would fire only when the muzzle of the gun pointed through a space between the rotating blades of the screw. This involved an intricate electrical or mechanical timing device coupled to the motor, and this did not always function properly, resulting in many demolished screws (propellers) and forced landings. To protect the blade in case of such failure, a metal sheathing was placed over the blade at the proper location. It was then found that this sheathing could be given sufficient strength and thickness to deflect bullets that did not pass through the spaces between the turning blades. The timing device was then discarded and the machine gun fired through the blade without regard to rotation. It is estimated that about five per cent of the bullets fired are lost by the latter arrangement.

a more efficient craft, speedier and otherwise superior, on account of better streamlining. The gunner in the pusher type is seated well forward, giving extensive fields of fire laterally and vertically. The *pusher* is favored over the *tractor*, as a fighter, by many experienced airmen. The type naturally lends itself to the requirements for heavy, rapid-fire gun-planes. Both types have distinct uses.

Special Features of Combat Craft. Whatever the type of fighting craft, every possible necessity, convenience, and comfort should be introduced to favor the occupants and render the craft more effective as a fighter. Stability is a desirable feature in the



Machine gun mounted in nacelle of *pusher* type airplane

fighting plane, as it enables free use of weapons with minimum attention to flight. Inherent stability is obtained by means of surfaces which reduce controllability. Automatic stability adds heavy devices and their weight can be more profitably used for other purposes, especially as this form of stability is none too reliable. Ease of aiming should always be sought in arranging the armament, in protecting the gunner or gunners from wind blast, and in providing suitable types of gun mountings. Gun rests should be fitted with elbow cushions, and seats rendered comfortable to reduce the fatigue of airmen who must commonly occupy them for three or four hours on a flight. Rotary turrets and movable shields should be provided when possible. It has been suggested that duplicate tanks, thicker armor, and a cockpit warmed by pipes leading from the exhaust be considered in the design of combat planes, but an accumulation of conveniences, at the cost of overloading the craft and reducing its capabilities, must be avoided.

Aerial Tactics. There are four recognized formations for aerial combat:

1. Flying parallel.
2. Pursuit.
3. Circling or enveloping attack.
4. Spiral dive attack.

Flying Parallel. No advantage accrues to either of two contestants passing each other in opposite directions, unless one gunner is armed with a piece which must be aimed from the shoulder, in which case it is desirable to pass on the right side, unless the gunner is left-handed. Care should be taken by the pilot to take a position that favors his gunner, particularly when engaged in a running parallel fight. When worsted, outmatched, or placed at other disadvantage, a machine should seek to escape, or to better its position. Superior tactics are necessary; a vertical drop enabling an attack from below, or when over friendly territory a dive to safety might improve the position.* A respite from the attack may be had by a quick dive under the enemy's wings. In the attack from above or from below this is obviously the advantage to seek, fire being brought to bear on the enemy while he is unable to return it until he can change his position. Such an effort must be anticipated and frustrated. Meanwhile a steady stream of machine gun fire should find a vital spot, wounding or killing the crew, piercing a gas tank, severing an essential strut or brace, shattering a propeller, or through some other damage bringing the fight to a successful conclusion.

The advantage of lower level or command of elevation depends upon the types and relative flying qualities of the craft engaged. A pusher type in which a nacelle is situated at the front carrying the gunner in the nose, should be attacked from the rear and generally from below. A fuselage type should be attacked, as a rule, from the flank and below favoring a position slightly to the front. The lower position generally interposes the enemy's wings and landing gear or his tail between the two contestants, interfering with the enemy's fire. Parasol types should be attacked from above and to the front for the reasons set forth here, as in

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*This emphasizes the importance of sending only superior craft to operate over hostile areas. These must be able to outmaneuver all enemy craft encountered, and prevent their escape by diving to the protection of ground forces. Otherwise the quarry will be discovered in vain, and after all, the combat function of aircraft employed against aircraft is to deliver the death blow.

this type, pilot and gunner are usually blanketed under the planes. It is probable that fire directed downward does not possess the accuracy of fire directed upwards, as in the former case the gunner ordinarily has to leave his seat in order to obtain a good firing position. On the other hand the higher position can always be converted into power and acceleration of speed. Vision is also better, looking downwards. So the upper command offers many advantages. When the hostile plane is constructed with the center, upper panel cut away, great care must be exercised to avoid getting into the upper position.

When planes are armored, this protection is placed on the under surface of the parts protected, hence protection from fire below can be enjoyed from the superior position. This is not true in the case of light armor, for unless the armor plate is impenetrable at battle sight ranges it is a source of danger, serving only to splinter the bullet and cause more damage.

In choosing a position above or below, front or rear, or on a flank, the opponents' dispositions should be quickly noted and a decision instantly made. It is generally better to follow up a poor plan well than to pursue a good plan poorly. Keenness of perception, quick and unfaltering judgment, steadiness, determination, and relentlessness are the qualities that win air battles, given efficient aircraft and highly trained experienced personnel.

Pursuit. To overtake an enemy airplane, superior speed is necessary if he seeks to escape. When aerial ascendency is obtained over the enemy, it may become difficult to engage his aircraft in combat. Speedier craft are required.

When a hostile plane is discovered, planes at higher levels may gain great acceleration of speed in the descent. Pursuit planes sent up from the ground must possess powerful speed and climbing qualities to come up with enemy craft before they have passed or or are lost to view. If the enemy turns to fight the problem is simplified. If not the pursuit should generally be maintained until it is certain that he cannot be overtaken, or (when the chase leads over hostile territory) until the limits of the cruising radius demand a return. When the pursued is overtaken, fire should be opened when within range. Effort should be made from the start to take the upper or lower level according to the situation.

A pursued aviator, on the contrary, should fly directly towards the sun, when possible, as the blinding glare not only affords a good opportunity to escape, but makes his plane a poor objective for the enemy and the latter craft an excellent target.*

*The Germans have devised a gas bomb for use when hard pressed. It throws out a great pall of black smoke, enshrouding the plane or airship from the hostile view. Another type of smoke bomb employed throws out a volume of mist-like gas having the appearance of a cloud.

Clouds and haze will in some cases save a hard pressed pilot. Only as a last resort should the pursued abandon his mission by diving to safety, or when over enemy country, diving for short drops to gain sufficient speed for quick maneuvering. Wind disturbances may distract the attention of the pursuer, but these cannot be relied upon. Slowing down quickly causes the pursuer to pass, and may be used to completely alter the situation. This trick necessitates a quick drop at the same time, otherwise the machine becomes an excellent target or might be rammed.

Circling or Enveloping Attack. The contestants circling around each other, naturally bank up. This offers an advantage to types from which favorable angles of fire are obtainable overhead, for in the encircling attack the machines engaged are banked away from the circle, with the upper planes inclined toward the center. When two or more planes close in on an inferior force, great caution must be exercised to avoid bringing friendly units into the line of fire. The enemy will undoubtedly seek to dive out of the trap, but the attackers must endeavor to "ride him off."

This formation is more or less the natural consequence of an attack by superior forces. The overmatched either seeks escape by diving or by sharp changes of direction. If his escape is cut off from below, he will naturally seek the most favorable opening. Meeting an opponent with superior forces wherever he turns if he cannot escape in straightaway flight, the pursuit naturally develops into a circling attack. The formation favors concentration of fire.

Spiral Dive Attack. This method of attack had been extensively practiced with good results. The attack is favored for surprise, as it is difficult to perceive aircraft at higher levels, comparatively, whereas craft at lower levels stand out prominently. Hence the attack usually takes the assailed unawares, and is delivered swiftly, the attacker diving upon his prey and spiralling in the descent with his enemy at the center of the cone of flight. This is subject to great variation, for the attack may be delivered in a straight glide or dive. A steady stream of fire should be directed against the hostile aircraft during the descent. This form of attack is generally practiced by high speed, one-place pursuit type planes, equipped with machine guns aimed by pointing the plane.

Fire Action of Aircraft. The offensive value of an airplane depends upon the kind, number, and arrangement of weapons. Ease of firing position is highly important. High speed and heavy wind pressure make aiming difficult. A fast moving target offers a poor target. Firing ranges must be short. Most effective work is done at less than 200 yards. To fire at longer ranges is generally to waste ammunition. The angle of the sun is important and should be considered in taking position. When facing the full glare of the sun, the gunner is handicapped if not power-less to sight his weapon. Allowance must be made for relative speed of the airplane and the gunner's objective, and for the time of flight of the projectile. In an aerial combat, good judgment in selecting the angle of lead may mean the difference between success and failure.* "When firing on another airplane governed by orders, instructions, and practices of the air service, moving in the opposite direction, the angle of lead will be six to one, more or less, a considerably greater allowance than is known in any other branch of gunnery. With the highest muzzle velocity and the slowest moving aircraft the angle of lead under these conditions is about 1 in 15. The angle of lead given by a pigeon shot when the bird is flying fast across the *line of sight* is about 1 in 20, and even here the demand . . . is for higher . . . velocity." A plane under fire should follow an irregular course. This does not imply that a plane under fire can avoid the fire directed against it, but the effect of maneuvers that interrupt the regularity of the course is to greatly affect the accuracy of the enemy's fire. If fighting at the same time, these maneuvers react upon the accuracy of fire directed from the plane. Stress should be laid upon the dangers of flying broadside to, head or tail on, to the firing gun or guns. The conditions encountered in aerial combat require close-up fighting. Expert airmanship is essential to avoid collisions, for in some cases air pilots have established under strict necessity the precedent of flying within ten feet of an antagonist, in order to bring him down.

Combined Tactical Operations. Combats between individual aircraft should prove rare in properly conducted aerial campaigns. Aircraft habitually operate in groups, the strength and composition determined by the mission and other considerations. Airplanes operating alone should be restricted to areas within which support of other airplanes may be enjoyed.

Aircraft Fleet Operations. Tactical exercises should be commonly conducted by organized aircraft units to develop teamwork essential in warfare.

The commander of an aircraft unit should have a definite plan of action before he leads his command from the ground. All the personnel in his command should be acquainted with the details of his scheme. When a hostile air fleet is sighted, the commander should lead his forces into action without hesitation or uncertainty, well fortified with the consciousness that each of his airmen is prepared for the fray, aware of the course to be pursued, the objects to be accomplished, and the means to those ends. All plans of action are subject to modification, however. An estimate of the situation must be made when the enemy is detected, taking into consideration his strength, disposition, and probable intentions. There is no time to cogitate under the circumstances.

*Lanchester.

Either fight or flee. The decision should be made to fight whenever there are the slightest prospects of success.

Tactical Discussion. Assume that a group of six planes meets a hostile force of eight combat machines. The commander sizes up the situation. The enemy's planes are of a similar type, his armament is apparently the same, the only visible difference in fighting strength between the two opposing forces lies in the enemy's superiority of numbers. The theory has come to be accepted, that ". . . . . the fighting strength of a force may be broadly defined as proportional to the square of its numerical strength multiplied by the fighting value of its individual units."* Hence, the fighting value of the two forces may be represented as follows:

Enemy forces, eight planes, $8^2 = 64$
Friendly forces, six planes, $6^2 = 36$

Superiority of the enemy 28

But suppose that by superior tactics, the enemy's force of eight planes can be split, his formation broken up so that one-half of the force can be dealt with at a time. The fighting values may then be expressed:

Friendly forces, six planes, $6^2 = 36$
Enemy forces, eight planes, $4^2 + 4^2 = 32$

Superiority of the friendly forces, 4

This represents the only chance of defeating the enemy. But this is purely a mathematical process and does not take into consideration differences in leadership, gunnery, maneuvering, morale, all unknown or uncertain quantities before the test of combat. Disparity of gunnery, armament, defensive qualities, superiority of types of aircraft, and other matériel and equipment, are best learned by the outcome of evenly matched encounters. Mere confidence that superiority over the enemy does exist and unwavering determination to drive the enemy from the air, are positive factors in overcoming slight disadvantages and in favorably affecting the issue. Leaders of flights should be guided by these sound principles.

Too much stress cannot be laid on the importance of superiority in numbers. All other things being equal, the side possessing superiority of aircraft should be victorious. Add to this, superiority of personnel and equipment and with a dashing aerial campaign, the air service should achieve complete mastery of the air.

General Principles. The various factors that affect the outcome of all aerial combats are: maneuvering qualities, celerity

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* Lanchester's theory of concentration.

of control, speed, climbing ability, strength and arrangement of armament, numerical strength, skill, and morale of pilots and gunners.

Aircraft Fleet Operations. Full enjoyment of the air service is not to be had without proper coöperative offensive action launched against the hostile ground forces as a part of the general military program. This contemplates the use of powerful battle-planes in large forces: wings, brigades, and divisions, for overhead action in conjunction with assaults delivered by the ground forces; for active participation in following up a retreat; and for actual air offensives directed against the enemy's positions, perhaps far behind his lines. Offensive action may be profitably employed against massed troops, trenches, fortifications, and other objectives of a military character. Slow, heavily armored planes *(contact patrols)*, armed with rapid-fire rifles, should be used at favorable opportunities, to go forward with the assaulting lines on the earth. These units should not only assist in clearing a hostile position by bomb dropping and gun fire, but should perform thorough reconnaissance.* In the pursuit of defeated forces, especially those on the verge of a rout, aircraft designed for low altitude work may be profitably employed for offensive action at altitudes of a few hundred feet.

At present, it is possible for aircraft proof-armored against rifle fire to fly at low altitudes, above the range of guns (not howitzers) and below the range of anti-aircraft guns. Airplanes for low altitudes (except those designed for coöperation with infantry in the attack, and which should be very slow machines) should be high speed craft, as the great speed renders any fire directed against them exceedingly inaccurate.

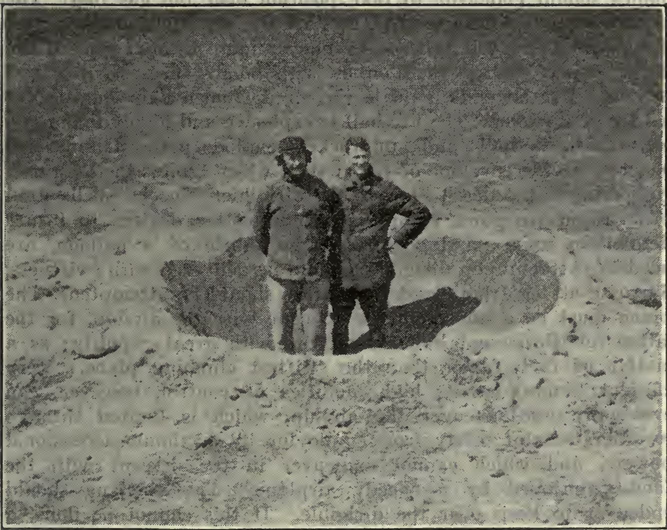
The employment on airplanes of rapid-fire rifles, as large as 3 inch, weighing less than one-half of the field piece of that caliber, is an established fact. Guns of this size are adapted only for use on super battle-planes.† The use of wooden breechblocks, which blow out to the rear when fired, dispenses with the hydraulic cylinders for taking up the recoil.

Bombardment Raids. One of the most important functions of the air service in warfare is the conduct of bombing raids against the enemy. These are generally directed against important objectives, such as munition plants, arsenals, lines of communications, trains, convoys, field works, and trenches. Because of the nature of the work, aircraft bombardments are more commonly aimed at material objectives than against troops, but to

*Flying out toward the advanced positions at low heights, and back with the information, which is dropped in weighted message tubes.

† The largest super-planes are capable of lifting in the neighborhood of 4 tons. Such a plane has the following approximate dimensions, and features: Wing, spread, 175 feet; length of body, 100 feet; gap, 25 feet, horse power, 1,200.

neglect favorable opportunities for launching this form of attack against the ground forces is to discard one of the most effective weapons placed in the hands of a commander. In bomb dropping, intensity of destruction is obtained by the use of great fleets. The practice of carrying lighter loads efficiently in an increased fleet of bombardment planes is better than overloading a small number of aircraft. Troops, masses, supports, and reserves offer excellent targets for the bombardment plane. Columns on the



Crater of fifty-pound bomb

march constitute good targets. Bomb raids may be advantageously employed in concert with heavy attacks on intrenchments. The success of an aircraft bombardment against troops, culminating in a rout, may be advantageously followed by an attack of battle-planes armed with machine guns and rapid-fire rifles.

Convoy Duty. Combat planes, detailed to accompany non-fighting types of airplanes or dirigibles, generally leave the ground individually and assemble with the unit at a prearranged altitude and over a predetermined site. Heavy planes and slow climbers should leave the ground first, and the swifter planes in such order that all will reach the designated assembly place at about the same time. In convoying slow bombardment planes, requiring 30 or 40 minutes to attain the necessary altitude, combat planes may leave considerably later, unless protection must be furnished immediately. Combat planes should remain outside the assembled fleet formation. Best observation of the convoy is had by taking post above and on the flanks of the fleet. Fighting planes should also fly at the head and tail of the formation, and in general maintain *advance, flank,* and *rear guard* elements.

Combat between Airplanes and Lighter-than-air Craft. The armament on dirigibles is generally carried in the gondolas. In the rigid type of airship, machine guns are also mounted on the roof. As the heavier armament is carried below, attacking planes should endeavor to take position over the gas bag. The machine gun operator on the roof of the airship should be first disabled. After this is done by one or more combat planes, the dirigible may be attacked either with bombs, fire-balls, or gun rockets. The latter is a projectile, fired from a light gun, in the nature of a rocket. The fire-ball is explosive and highly inflammable. Both fire-balls and gun rockets explode upon striking and penetrating the envelope of the airship, which ignites the hydrogen gas. This is the death blow to the dirigible. Special shells fired from rapid-fire guns, equipped with sensitive devices to insure detonation upon passing through the fabric of a balloon, are needed. Attack upon dirigibles should be delivered with swiftness. Surprise attack from cloud formations should be attempted. The plane must be a quick climber to cope with the airship, for the latter can throw out ballast and rise with great rapidity; as a matter of fact, faster than the swiftest climbing plane. Very efficient planes, having high qualities of control, however, can eventually out-maneuver the airship, which is limited through considerations of safety from employing its maximum ascensional powers, and which cannot maneuver in the descent with the facility enjoyed by a speedy airplane. The airplane should endeavor to keep over the dirigible. If this cannot be done, a dive to safety should be made. If the airship mounts tail guns, the dive should be made past the nose of the ship when possible, as this avoids exposure to the broadside of guns mounted in the gondolas. When directing bombs or rockets against the airship, the airplane should maintain a safe distance to avoid destruction in case the dirigible explodes.*

Attack upon captive balloons follows the methods practiced in attacking dirigibles. Station balloons are sometimes armed with machine guns and these must be treated with care. This equipment is usually restricted to very large station balloons and to those carrying twin cars. Anchored balloons are generally protected by anti-aircraft artillery, and aircraft are expected to lend assistance in their defense.

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*It is stated on reliable authority that at a distance of 300 feet another aircraft is safe from the explosion of a dirigible.

War Altitude. The rules given herein for regulating the altitude must be regarded as only approximate. The altitude for any flight should be influenced by atmospheric conditions and governed by tactical and other military considerations. Altitudes should be regulated from time to time according to the activities of hostile aircraft, anti-aircraft artillery, and the nature of work performed. As effective results constitute the only final answer to all questions confronting the air service, war altitudes must be determined and regulated by the work in hand, the requirements, and the experience gained from practice. Craft must be prepared to fly low when necessary, although seriously exposed to hostile fire and aircraft attack. However, to squander aircraft by ill advised efforts to achieve the impossible is condemnable.

In general, altitudes may be classified as follows:

Divisions of Altitude	*Height*	*Class of Flying*
Low	To 5000 feet 300-2000 feet	Heavily armed battle-planes for use in conjunction with the ground forces, or for offensive action against hostile ground objectives.
	2500-3000 feet	Kite balloons. Planes engaged in night operations. Bombardment and other raids. Photographic planes. Planes on interior reconnaissance or other duties *within the lines.*
Mean	5000-10,000 feet	Tactical, photographic, and artillery fire-control planes, Combat planes. Bombardment planes on raids.
High	10,000 and above	Combat planes in the aircraft screen. Planes returning from missions or otherwise seeking to avoid hostile aircraft.

Conquest of the Air. This condition is best indicated by the relative number of air duels fought over friendly and enemy territory. The effect of aerial ascendency is undoubtedly felt by the airmen of the victorious side and this is reflected in the morale of the air forces. The personnel of a defeated air service ventures from the home fields with timidity, their offensive operations marked by a diminishing radius of action, until finally they demonstrate their condition by refusing all combat, unless it is actually forced upon them. Gradually the enemy craft will disappear except over his own flying fields, probably with the exception of cruiser and pursuit planes on guard over important posts, say under the protection of anti-aircraft batteries. The enemy raids will eventually cease. His strategic reconnaissance will likewise suffer. At this point the overpowering superiority of control of the air will become strikingly evident. The enemy, deprived of information concerning the movements of vast bodies of troops throughout the theater of operations, will be subjected to strategic disadvantages that will annul the remaining value of his air service as a *defensive weapon.* Other things being equal, no military force can expect to fight a winning fight, while laboring under such a tremendous handicap.

MILITARY AVIATION

CHAPTER 4

RECONNAISSANCE

"Reconnaissance is the military term used to designate the work of troops or individuals when gathering information in the field." (Field Service Regulations.) Aerial reconnaissance is divided into (a) preparatory (b) strategic and (c) tactical, corresponding in a general sense to the three phases of aerial warfare. "In reconnaissance work, airplanes have proved very useful, not only in service behind the lines for movement and concentration of troops but also for inspecting reserve depots and other far distant sites of military character."*

The service af aerial reconnaissance has grown up around a variety of uses. In the modern sense, it includes strategic and tactical duties, reconnaissance of artillery positions, and control of artillery fire from aircraft. These comprise a detailed study of the technique of military reconnaissance.

The training of observers involves an elaborate program. The candidate should be selected with reference to his special fitness for the work. He must be a man of unusually keen perception, highly developed powers of observation, natural, inherent thoroughness. In addition to an extensive military education he should possess an excellent physique and perfect vision. The aerial observer must have a thorough knowledge of topography, map making and map reading, and understand the operation of all instruments used in his work.

In super-planes carrying large flying crews, the navigator usually discharges these important duties; in one-place types, the aviator performs reconnaissance duties. Normally the observer has no other duties, except, possibly, to operate a machine gun when attacked.

Types of Reconnaissance Craft

The technique of aerial reconnaissance includes the principles governing the employment of aircraft in war.

Aircraft reconnaissance has developed three general types of planes. The *strategic* type, having great fuel capacity to give broad cruising radius and speed. This type is sometimes a single-seater, since the work is of a very general nature and can be performed by the pilot alone. The two-place (usually twin-motored), broad cruising radius machine has grown into high favor, as a

*Report of MILITARY OBSERVER.

strategic type scouting plane. It appears probable that this type will become the standard scout plane. The *intermediate* scout type has reduced fuel capacity but must carry an observer and wireless equipment; both fuel and speed are modified. The *tactical* scout type is a low-speed machine provided with every facility for detailed and accurate work. This type is used for short scouting flights, controlling artillery fire, and reconnoitering artillery positions; it is especially useful for night work, having a low mean speed, which enables slow flying and landings on comparatively small sites at safe speeds for difficult night landings.

Reconnaissance machines are organized into reconnaissance squadrons but normally fly alone or in pairs.

Orders for reconnaissance are generally transmitted by the chief of staff or aircraft officer (on the commander's staff), to the squadron commander. General situations and missions are outlined to the squadron commander and he orders the flight, in detail. For obvious reasons, personnel should be named by roster; aircraft are selected on a basis of (a) radius of action; (b) equipment; (c) readiness for flight; (d) reliability of power plant.

Preparatory Reconnaissance

The term *preparatory reconnaissance* is introduced to cover a class of work performed by aircraft that has not heretofore been possible by other means. This form of reconnaissance takes place upon the outbreak of hostilities and usually at great distances over land or over seas; perhaps before a theater or theaters of operations are defined or established. The missions of air scouts will be to determine enemy's dispositions, the locations of his mobilization points, his depots and munition plants. These operations will usually be accompanied by offensive action from fleets of aircraft directed against all vital objectives of a military nature.

There is no directional limitation to the operation of aircraft. The air lanes reach out in all directions to include the three dimensions of space and this sea of air is so immense and boundless that aircraft can sail the skies under the protecting vastness of the element, unless opposed by an overwhelming air service.

In warfare, prior to the advent of aircraft, a belligerent could not reach out behind the enemy's line to spy out his dispositions, except by the unsatisfactory means of the secret service, or by actual penetration in force. War was conducted by blind antagonists. Aircraft reconnaissance supplied this deficiency.

After mobilization, concentrations are made and theaters of operations established. The hostile forces should be located at the earliest possible moment. If the movements are made by train, rail lines should be broken and enemy communications interrupted relentlessly. If the concentration is made by shipping, transport fleets, docks, and harbor bases must be raided incessantly, and all the while these offensive operations are in progress, every military development must be observed and reported. This plan will result in extensive aerial fighting and fierce contest for supremacy of the air, but that is a matter for special tactical study in connection with the general military employment of the air service, and a discussion of the service of reconnaissance must be based on the hypothesis that freedom of the air exists. *Strategic reconnaissance* may be conducted by mounted and foot troops, as well as by aircraft, throughout the theater of operations. The best results are produced by close coöperation between all these elements. Aircraft of great cruising radius are employed. An efficient, modern flying service should relieve the cavalry of all strain and most of the difficult scouting work, and should render surprise to the independent cavalry (cavalry in advance of and screening the main forces) an impossibility. *No body of troops should be pushed out to the front without the guidance and safeguard of aircraft. Surprise and ambuscade of modern armies by large enemy bodies is inexcusable.*

STRATEGIC RECONNAISSANCE

The reconnaissance functions of aircraft include the services of security and information. Airplanes, airships, and station balloons are each useful in the performance of these duties.

When one-place strategic type reconnaissance planes are used, the pilot discharges the observer's duties. It must be remembered that the objectives are large ones and accumulation of details left to the cavalry.

The enemy aircraft screen and cavalry masses will probably be the first hostile forces encountered. Behind this screen the concentration or movements of large bodies will be observed. Concentrations are usually made behind natural obstacles to lend greater security, hence aircraft and cavalry screens should be expected at such places. Constant reconnaissance enables the commander to follow all hostile movements and developments within his own lines, and the complex problem of war becomes a simple, but scientific game.

Large bodies are always sought, but the presence of smaller bodies is not to be ignored, as they may afford indications of larger bodies. The enemy's cavalry masses should be carefully watched, as an aid to discovering his intentions. Channels of supply, rail lines, rivers, and roads used by motor transport, should be continuously watched. These sources offer valuable information and often disclose the enemy's intentions. Objectives being large, the air scout should seek main bodies, lines of communications, bases, and depots. Rivers and bridges should be observed. Station balloons may prove useful for this duty. Airplanes so employed should visit bridges every three or four hours.

Large bodies cannot cross and clear in that time. Aircraft bases should be located. Aircraft parks usually indicate the proximity of headquarters, balloon stations, the presence of major caliber artillery; and both generally indicate the presence of large bodies.

Upon discovering a body of troops, "determine exact location, whether marching, in camp, or deployed; strength and arms of the service represented." Ascertain the tactical disposition of the troops, whether a main body, outpost, advance, rear or flank guard covering troops, or cavalry screen.

Once an enemy force is located, observation should be maintained constantly. A cardinal rule in aerial scouting is never to lose the position of a body of troops once located. It may be necessary at times to maintain a continuous patrol or relays in reconnoitering a hostile force, successively sending up planes at specific intervals of time. This will only be required in rare cases. Reconnoitering craft can be sent up at intervals of several hours and yet keep in touch with the unit. These principles also relate to tactical reconnaissance. Reconnoitering craft should never make side excursions, unless the change of situation positively demands it.

TACTICAL RECONNAISSANCE

Tactical reconnaissance is carried out in the immediate proximity of the enemy and is performed during contact between hostile forces.

Two types of airplane, the *tactical* and the *intermediate,* are generally used for tactical scouting. The intermediate has been used for bridging the gap, so to speak, between the two classes of reconnaissance craft, the strategic, and the tactical types. The uses of photography, possibly cinematography, extensive map making and compilation of notes, require a double seated machine, an observer, and radio equipment in both types. The essential differences have been outlined under CLASSIFICATION OF AIRCRAFT. Tactical reconnaissance by airplane is used both in attack and defense. While extended in nature, it involves careful, possibly minute examinations of terrain and hostile forces, but not of small localities and detachments. In constant operations, detailed observations should be performed by low altitude armored planes and by station balloon observers, whenever possible.

Field Service Regulations (1911) states: "Tactical reconnaissance by *aeroplane* is . . . designed to discover turning and enveloping movements, the position and strength of the enemy's general reserve, artillery positions, and movements of cavalry, also from the movement of combat or field trains behind an enemy's positions, information may be gained as to whether certain parts of the line are now being weakened or strengthened, or whether a retreat is contemplated."

Tactical reconnaissance is divided into *battle* and *protective*.

Battle reconnaissance comprises the aerial work performed with a view to putting every obtainable fragment of information into the commander's hands, thereby enabling him to study the situation, and form his estimate and decision. He is also kept advised of every development during the course of the action or contact operations.

Protective reconnaissance pertains to the service of security; that is, it "embraces all those measures taken by a command to protect itself from observation, annoyance, or surprise by the enemy."

BATTLE RECONNAISSANCE

The information sought in this class of reconnaissance pertains to every change in the enemy's tactical dispositions and distributions. The various trench lines, fighting, support, and reserve lines must be determined. The location of batteries and calibers, lines of communications, depots, aircraft field bases and parks, and of terrain features, constitute the aids, as it were, to tactical reconnaissance. Bodies of troops in the battle area are usually so concentrated that they can be picked up readily by observing or photographic aircraft. Signs of activity in the hostile lines, such as departure or arrival of troops indicating a weakening or reinforcement of the position, movements of truck trains and artillery, possibly first betray the enemy's intentions.

PROTECTIVE RECONNAISSANCE

In a retreat, aircraft play possibly their most valuable rôle, for at this time, especially if troops are harried or broken, a heavy attack from an unexpected quarter, delivered with great facility through the informative functions of aircraft, generally turns a withdrawal into a precipitate retirement and retreat into rout. Hence aircraft, especially planes, should be very active during a retirement to give the greatest possible protection to their columns.

In the pursuit, to obtain maximum results, the natural preponderance of force, morale, or other advantage on the ground, must be accompanied by an equal superiority in the air and aircraft employed accordingly.

The surest way of protecting the ground forces is to keep the enemy under constant surveillance.

Aircraft patrols should work in relays to maintain continued observations of an objective. When a shortage of airplanes exists and this cannot be done, a body once located may be observed at regular and frequent intervals, the airplane remaining aloft only for brief observations. Continuous or sustained patrols may be performed by lighter-than-air craft. Aircraft are especially useful in reporting the movements of friendly troops, there being no better method for the commander to keep his units under complete control. An intelligent use of aircraft by the commander reduces large field operations to a simple checkerboard game, and the developments of gigantic war problems are simplified, accordingly.

INDICATIONS OF THE ENEMY

Reconnaissance of positions may be grouped under three heads:

1st Reconnaissance of marching columns.
2nd Reconnaissance of intrenchments and deployed forces.
3rd Reconnaissance of camps and bivouacs.

COLUMNS

When a hostile force is discovered, the following data should be obtained:

(a) Determine whether foot, mounted, artillery, or wagon trains are present.

(b) Note the head and foot of each class of troops and compute the road space.

(c) Ascertain head and foot of main body and note all open spaces in the column, being especially careful to avoid confusing the advance, flank, and rear guards with the main body.

(d) Obtain the exact location of troops on the map employed; identification of the road; direction and rate of march.

In computing the strength, great care must be exercised not to confuse motor, wagon, or artillery transport with the combat troops. Count all foot troops as combat troops. Note unusual dispersion and gaps in the column. If the altitude required is such that it is impossible to determine direction and rate of march at once, leave the locality and return within a short time when a second determination of position will reveal these data. A second check is desirable as any temporary dispositions made to deceive the air scout may be disclosed. Loss of time in an effort to conceal position of aircraft is a mistake. In clear weather it is impossible to hide from view at war altitudes or heights from which satisfactory results can be obtained. In misty weather, no advantage accrues from hiding, except to dart quickly in and out of the cloud banks. When under fire, however, an irregular course should be steered in an effort to reduce the enemy's accuracy of fire.

Wagon tracks in the average soil are distinguishable at a safe flying height; hence fields scored by artillery tracks will lead to the utter confusion of an inexperienced observer, who will find the roads marked on his map, lost in a network of tracks; every wagon track makes a new road. In snow, tracks and tramped areas are plainly visible at war altitudes.

Field trains indicate the presence of large commands. Field train parks should be especially noted.

MILITARY TACTICS OF DEPLOYMENT AND DEPTH

Positions. In computing the size of an intrenched force on the first or fighting line, estimate one man per yard of trace of the trench line.

The rules governing the degree of deployment of engaged forces consider:

(1) The initial deployment.

(2) The developing deployment.

The strength of a force and extent of front occupied are variable quantities. Depth is more important than front when the initial deployment is made. Depth in this sense refers to the supports and reserves in rear of the fighting lines, and applies to foot troops. During the opening phases of contact, artillery is kept in rear of the first lines and cavalry retires to the flanks.

In our service, the regiment consists of three battalions, and the brigade, division, and army corps normally of three next lower units, each; but the next higher unit in each case can only hold twice the same line, even though three times as large, owing to the need of holding out adequate reserves.

In operations against a well-matched enemy force, a division is restricted in its initial deployment to a front of one and one-half to two miles; greater deployment results in loss of strength. An army corps of three divisions is likewise restricted to a front of four to five miles. The resistance and fighting effectiveness of the enemy in their local contests constitute the best gauge of his measure of deployment.

In the reconnaissance of positions, observers should gather the following data: the trace of field works; the depth, including the reserve; dispositions and distribution of forces; movements in rear of the lines; the location of flanks, lines of communication, batteries, aircraft sites, and headquarters; noting all activities in the area under surveillance.

Trench lines should be photographed and reconnaissance of positions covered in great detail. Ordinarily, this applies to tactical reconnaissance. Unless the enemy is demoralized, shaken, lacks strength or morale, or has retired so rapidly that contact cannot be maintained, or some such unusual conditions prevail, intrenching takes place actually or practically in contact. Every development in the construction of intrenchments should be observed, as trenches may be later given overhead cover and rendered difficult to detect.

Ranges of burst for the various gun calibers are useful to know, if the firing battery can be located. Heavy calibers indicate the presence of large bodies of troops. Field artillery rarely

(EXTRACT: "ROAD AND CAMP SPACES"—FIELD SERVICE REGULATIONS)

Units	War Strength, in round numbers		Vehicles, including guns	Length of Columns			Contracted Camping Space (troops and trains)	
	Men	Animals (horses and mules)		Organizations, including combat trains	Field trains without distance	Ammunition, supply, sanitary, and engineer trains	Yards	Approximate number of acres
Divisions:								
Infantry	22,000	7,500	900	10.3 mi.	11.8 mi.	3.6 mi.	....	180
Cavalry	10,000	12,000	500	8.0	9.5	1.5	....	150
Brigades:								
Infantry	5,500	520	67	1.7	2.0	....	....	19
Artillery	2,300	2,300	257	2.6	2.9	....	....	18
				Yards	*Yards*	*Yards*		
Field Artillery, Light, regiment	1,150	1,150	128	2,240	2,500	....	240x300	14.7
Signal Troops, aero squadron (including landing place 150x350 yards)	172	....	24	*415—645	....	....	175x350	12.5
Balloon Squadron (including inflation and maneuvering field)	450	....	104	*860—2,430	....	....	....	....
Trains:								
Infantry divisions—								
Ammunition	260	750	162	....	....	2,440	75x380	5.8
Supply	190	630	126	....	....	2,000	80x380	6.2
Cavalry divisions—								
Ammunition	60	140	33	....	....	500	30x200	1.2
Supply	220	860	75	....	....	1,200	80x280	4.6

"This table is based upon the road spaces occupied by troops at war strength, infantry in column of squads, cavalry in column of fours, artillery and trains in single column.

"The spaces differ but little from the requirements of drill regulations. On the march, after a command is straightened out on the road, elongations always take place. In calculating the length of a column further allowance must therefore be made, in accordance with circumstances; sometimes as much as 25 per cent.

"For approximate calculations, assume 1,600 meters—1 mile; 5 miles—8 kilometers; the number of acres in a rectangular tract—the product of one-seventieth of the length in yards, by one-seventieth of the width in yards."

It is difficult to obtain information concerning forces in cantonments, troops billeted in dwellings, or quartered in other structures. The presence of transport, artillery, and other activities, probably constitute the best sources of information procurable when scouting over sites of this character.

The size and strength of enemy units and road, camp, and position spaces occupied, are published in bulletins by the intelligence bureau, upon outbreak of hostilities. The above data can therefore be used only as a reference.

*Motor transport at closed and extended route distances. (At a halt, usually 5 yards; at speeds less than 10 m. p. h., about 15 yards; at greater speeds, 50 yards between trucks.)

ever fires at ranges over 6,500 yards. Medium caliber, heavy artillery rarely fires over 8,500 yards. The introduction of heavier guns and howitzers has served to enormously increase these ranges.

ORDERS FOR MILITARY FLIGHTS

Orders for flights should be issued by the Chief of Staff, the Aircraft Commander, or Squadron Commander, in that order. Orders for flights issued by the Chief of Staff or Aircraft Commander should be written when possible.

Two forms should be provided: (a) ORDERS FOR FLIGHT; (b) REPORT OF FLIGHT.

(a) *Orders for Flight:* Orders stating the serial tactical number of the flight; the unit to participate; assigning the airplane or airplanes and designating the personnel; time and itinerary; all information which it is desirable to give the aviator concerning the enemy forces, friendly troops, and the commander's plans, and the mission to be performed. The place, time, and method, where, when, and how, the message or report will be delivered, should be stated in exact terms. Orders should be issued as early as possible before the flight, in order that pilot and observer may study the situation.

(b) *Report of Flight:* (Always submitted by the observer.) The report handed in upon completion of a military flight should give the following information:

Report of reconnaissance (combat, bombing, etc.) flight; to whom submitted, where, and time at which rendered; serial number of flight. Reference should be made to the map or maps used. The body of the report should chronicle the reconnaissance in paragraphs, headed with the hour and minute of each observation, and complete data covering the formation, composition, dispositions, distribution, and location of the objective, at the instant of observation. The course of flight should be given in this form: COURSE: HAMPTON—JOHNSTOWN—JERKWATER GAP—VALLEY RIDGE—RETURNED ALONG STATE HIGHWAY TO HAMPTON. Ascended 8:50 A. M. Landed 10:28 A. M. Special Remarks: Plane struck by shrapnel fragments. (The report should be signed by the observer.)

Reports should be submitted on prepared forms and accompanied by notes, maps, sketches, and other data, gathered or prepared during the flight. Reports should be prepared with elaborate care. In cases, a verbal report may be submitted, where speed is required, but the written report should be rendered later.

General. Observers should remember that they are not *general officers* or commanders. All facts should be reported. Any information not essentially fact, such as deductions or opinions, should be reported, but so specified.

Reconnaissance planes, when armed, do not fight unless absolutely necessary. When returning with important information, safety should be found by flying at high altitudes, escape from attack or pursuit being sought by flight, or by stratagem. (See Combat.)

The position of the observer in front of the pilot is a satisfactory arrangement, as the pilot can thus watch the observer's signals. Hovering over a given objective is accomplished by various air maneuvers designed to avoid interference with view caused by the disposition of planes, struts, body, and other parts. Sharp banks, steep spirals, flying over an oval, circular, or figure-of-eight course may have to be resorted to, in order to obtain prolonged observation. The skilled pilot must apply considerable study to this feature in order to favor maximum visibility and sustained observation.

WATER AREAS

The reconnaissance of water areas involves new principles of observation. It is often necessary to ascertain the outline of a channel and the depth of water alongside of docks, the position of shoal water, submarine fields, or the presence of shipping. Deep water presents a striking contrast to shallow water. The colors of water vary from a light yellow or green in the shallows to a dark green or deep blue (approaching a black) for extremely deep water. The nature of the bottom materially affects the appearance of the water. Vegetation on the bottom darkens the effect. Color effects also vary with the angle and intensity of the sun rays. It is impossible to observe, looking into the glare of the sun reflected on the water.

AIRCRAFT CONTROL OF ARTILLERY FIRE

The aircraft position finding service may be divided as follows:

1. Reconnaissance of positions:
   - (a) Hostile locations.
   - (b) Friendly positions.
   - (c) Preliminary ranging data.
   - (d) Signalling and communication.
2. Fire Control:
   - (a) Correction of trial shots, for line, range and fuse (burst).
   - (b) Correction of trial shots for height of burst and deflection.
   - (c) Corrections of inaccuracy in course of firing.

RECONNAISSANCE OF ARTILLERY POSITIONS

The location and distribution of field and heavy (mobile) artillery is made by the commander upon the recommendation of the senior artillery commander.

The senior artillery commander assigns regiments to certain areas or sectors. He may even assign smaller units when circumstances warrant. The battalions of an artillery regiment are assigned to positions, areas, or sectors by the regimental commander, or the battalion commander, who in turn assigns the batteries to positions, imposing such restrictions as may be necessary in the emplacement of guns to secure defilade.

Extract (from Drill Regulations for Field Artillery), "Important considerations in the choice of a position are:

(1) Obtaining range not much greater than 3,000 yards (longer for heavy artillery).
(2) Securing large field of fire.
(3) Concealment from view.
(4) Facility of movement to the front, flanks, and rear.
(5) Proximity of good cover for teams (or motor vehicles).
(6) Favorable conditions for re-supply of ammunition."

The above ideal conditions may never be encountered in actual practice but they should always be sought with special reference to the particular needs in each case.

When aircraft are available for artillery use, many difficulties involved in selecting suitable sites for observation stations on the ground are eliminated. While the use of observing stations will be continued, they may be regarded as the emergency system of field artillery fire. For light armament high mobility is of prime importance; hence aircraft employed in conjunction with artillery units must be operated with dispatch. Special air units should be assigned to the artillery and placed under the direct control of the artillery commander. For field artillery the airplane is most useful; for heavy artillery the station balloon is superior.

The information required in aircraft reconnaissance for artillery should include, "the enemy's locations and dispositions," examination of terrain involving photography of positions. Special attention must be paid to communications to the front, rear, and flanks of the positions selected to fulfill the requirements. Automatic photographic apparatus should be carried on the airplane when traversing the line of fire (from the battery position to the objective), and the photograph plates should be delivered without delay for immediate development and use. Additional machines should be employed for the fire-control work to follow the reconnaissance of positions (both enemy and friendly), and for the occupation of a position by the artillery unit.

In addition to the above requirements, movements of the enemy and friendly forces must be noted and reported instantly by wireless, since any such movement involving a change of the situation might render the position valueless.

Information acquired, together with notes, sketches, and photographic prints should be handed to the reconnaissance officer of the artillery unit immediately upon landing.

Decisions as to the qualifications of positions are not made by the air scout, unless a qualified artilleryman is detailed for the purpose. Complete data on the existing situation are desired without expressions of opinions or reconnaissance, unless especially directed.

One of the principal duties of aircraft in connection with reconnaissance is the disclosure of screened targets and discovery of the enemy's batteries, his strength, and dispositions. Reference has been made herein to the detection of hostile artillery by identification of the size of the shell or shrapnel burst or detonation, and determining the location of the firing gun with reference to the range.

Great care must be exercised to avoid deception by dummy batteries and trenches. This artifice and the general introduction of camouflage (overhead cover) for field batteries has increased the difficulties. Aircraft reconnaissance for artillery has proved indispensable in warfare and this system of controlling artillery fire has virtually superseded all other methods.

The reconnaissance functions of aircraft in connection with the artillery, include the services both of security and information. Airplanes and station balloons are each useful in the performance of these duties. Airships may be of value under certain conditions.

ARTILLERY FIRE-CONTROL

Control of artillery fire by aircraft is distinctly separated from reconnaissance, as a field for use of aircraft. Owing, however, to its close relation with tactical (battle) reconnaissance, it is included to a great extent, under the broad general discussion of reconnaissance.

An experienced aviator may be able to control the fire directed against three separate targets in one flight.

Correction is usually made for line, range, and fuse, in that order. Attempts should not be made to signal corrections for all three at the same time. Single shots are generally used for the first correction. When the firing is heavy, salvos must be fired in order to identify the trial shots. From the air, observations for *line* and *range* are easily made, but for fuse, with difficulty. The *patterns* of shrapnel burst are difficult to measure with respect to *fuse.*

A method of fire-control that has been extensively used consists in dropping a signal bomb, which marks the target. The artillery then opens fire on the spot so marked. The observer corrects *overs* and *shorts* with reference to the signal smoke. Another method has been practiced as follows: Two observers on the ground, stationed at different positions, take three observations each on the fire-control plane, which makes a broad, circular flight around the target as a center. The center of the observations locates the target. This method has proved of some value for use in emergencies.

As a general rule it may be stated that aircraft should be assigned to artillery units on a basis of mobility. For observation of artillery fire, the station balloon has proved the best fire-control agent; the observer is in direct wire communication with the artillery unit. Observation within the limited field of view is better than from the airplane. The balloon, however, is a very clumsy craft and cannot be moved as rapidly as light batteries. Hence airplanes are better adapted for coöperation with mobile armament, the balloon being restricted to use with transportable heavy batteries.

The problem of communication from aircraft to ground and between aircraft, recently accomplished by the introduction of an improved radio apparatus, promises to remove the limitations of communication that have existed up to the present time. A successful wireless telephone is also in possession of the Aviation Section.

For use in fire-control, the airplane has been as successful with ship batteries as with land batteries and as successful in connection with seacoast armament as with field batteries.

PHOTOGRAPHY

Photography forms one of the most useful and important function of aircraft reconnaissance. Photography may be relied upon to produce results that cannot be achieved by the human eye. The camera should be used to supply details not visible to observers; to verify important observations; for enlargements of details not otherwise obtainable; to supplement hasty observations made under fire or when the activity of anti-aircraft artillery drives reconnaissance planes to levels from which observation is difficult or unsatisfactory. When the hostile aircraft screen cannot be pierced, photographs may be taken of positions well to the front and the views enlarged. (The height being known by the barograph, the focal angle of the camera determined, photographed distances may be computed.) Photography also gives a permanent record which is valuable not only in studying a situation for the time being, but for preserving an accurate record for all time. Prints may be developed within a few minutes after the plane alights.

Special photographic planes should be employed for tactical reconnaissance. (See AERONAUTIC EQUIPMENT.)

TRAINING OF OBSERVERS

Observers are provided from various sources. For special operations reconnaissance of artillery positions, a trained artillery officer should be so employed; for observation of infantry dispositions, an infantry officer used; for inspection of bridges and demolitions, an engineer officer; for strategic and tactical dispositions, a staff officer.

All observers should be selected from trained military men. This material should be of the highest quality insured by a careful process of elimination.

Candidates should be carefully chosen. Tests should be conducted to demonstrate the alertness of the student. The instructor takes a class into a room where many different articles are laid upon a table, the candidates make a mental note of all they see, within so many seconds. This operation is repeated several times and following each inspection the pupils are required to write down a list of the articles noted. Thus begins the process of elimination of those who are unsuited. The course should include road sketching, instruction in map-reading, navigation of the air, meteorology, and reconnaissance. Failure in the least degree should result in elimination. The practical course should include a study on the ground of such features as elevation, roads suitable for infantry and artillery, bridges, positions for, and location of, trenches, and other military features.

OBSERVERS' FLYING COURSE

1. First series of flights (Clear weather):
   - A—Visibility Tests (naked eye).
   - B—Use of Field Glasses (choice).
   - *C—Identification of known objectives, comparison of sizes of objects of known dimensions.
2. Second series of flights: In low broken cloud formations. (Least altitude 1,500 feet.)
   - A—Flying just below clouds. (Repeat observations of first flight.)
   - B—Flying just within mist. (Repeat observations of first flight.)
   - C—Flying over broken clouds—observing through holes in the cloud roof. (Repeat observations of first flight.)
3. Third series of flights: Altitude not less than 5,000 feet.
   - A—Taking an incomplete map; sketch in all buildings and structures at given cross road.
   - B—Fill in roads, trails, bridges, and docks within a given area.
   - C—Check up errors with a corrected map after landing.

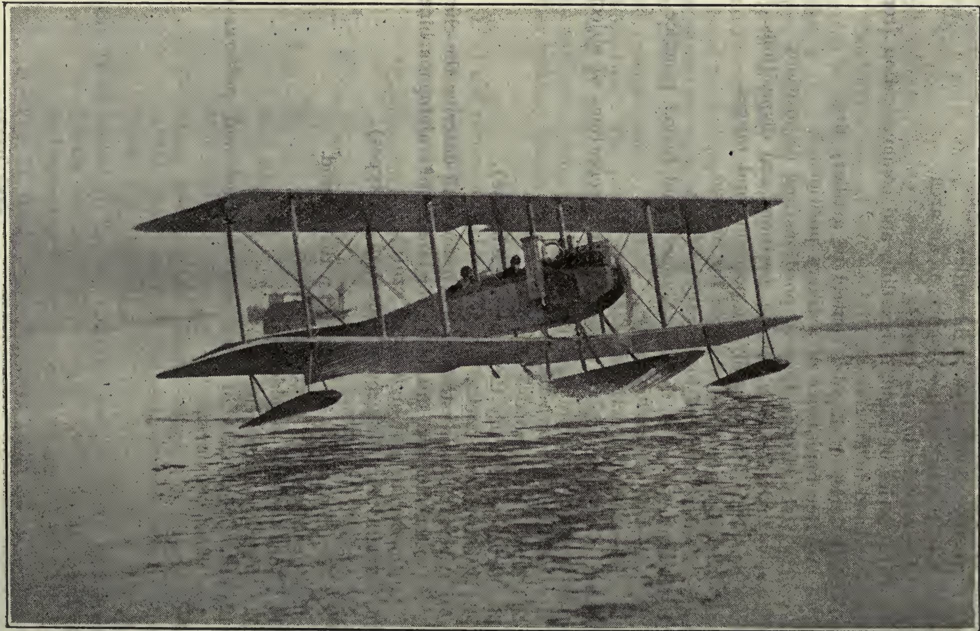
(These tests to be repeated at 6,000 and 8,000 feet.)

* These tests to be repeated at 1,500, 2,000, and 3,000 feet.

4. Fourth series of flights; reconnaissance problems (9,000-10,000 feet).
   - A—Photographic flights.
   - B—Reconnaissance flight orders.
   - C—Military reconnaissance of an area.
   - D—Submission of reports.
5. Fifth series of flights: signalling and communication from and to ground.
6. Sixth series of flights: control of artillery fire.
   - A—Reconnaissance of artillery positions:
     - 1st Hostile forces; positions and dispositions.
     - 2nd Friendly forces; positions and dispositions.
     - 3rd Photography of positions and ranges.
   - B—Ranging of trial shots for bracket.
   - C—Correction of inaccuracies of fire.
7. Seventh series of flights: Gunnery and target practice.
   - A—Use of machine gun.
   - B—Target practice in flight.

NOTE: Chronicle visibility and relative proportions of objects in following order:

1. Buildings (known dimensions).
2. Trails, lanes, roads.
3. Bridges (identify the type in each case).
4. Wharves and docks.
5. Aircraft sites (estimate dimensions and describe the characteristics and suitability for landing of training machines, moderate and high speed craft).
6. Aircraft on the ground (identify the types).
7. Identify trenches.
8. Identify groups of persons on the ground.
9. Identify autos, wagons, artillery.
10. Identify gun emplacements.
11. Identify mine fields.
12. Identify bursts of shell and shrapnel and *patterns* of shrapnel burst.



Coast defense seaplane. (Note: single pontoon and wing tip floats, dihedral between lower wings, cutaway in upper center panel for overhead view.)

MILITARY AVIATION

CHAPTER 5

COAST DEFENSE AND NAVAL AIR SERVICE

The following elements of the coast defense forces must be considered in apportioning aircraft:

Coast Defense Elements:

1. Artillery District Defense.
2. Railroad artillery.
3. Coast artillery supports.
4. Seacoast Fortifications.
   a. Coast defense command.
   b. Battle and fort commands.
   c. Mobile gun defenses.
   d. Fixed armament.
   e. Mine fields.
   f. Obstacles:
      (1) Land obstacles.
      (2) Water obstacles.

The allotment of aircraft forces to coast defenses depends upon the situation in each defense; such as, the locality, number, and position of forts, the composition and distribution of units, and the organization of the fixed, mobile, and movable elements for local and general use along the coast line.

Aircraft for seacost defense is intended for the following purposes:

1. Strategic reconnaissance to seawards, tactical reconnaissance in battle, distant bombardment, reconnaissance in force, run-by, raid on mine fields, etc.

2. Artillery fire-control for all rapid-fire, intermediate and major armament.

3. Combat to destroy all hostile aircraft, prevent enemy aircraft from reconnoitering positions, or conduct offensive operations against coast defense areas, to protect mine fields and prevent countermining.

4. To provide efficient air service to the railroad artillery and to the coast artillery supports.

The assignment of air units to the coast artillery defenses should be based on the local problem in each case; to the railroad artillery, on the conditions involved in the defense of the coast line; to the coast artillery supports, as regulated by the requirements of mobile forces.

Coast Defense Aircraft. In coast defense, both land and water craft are required. Airplanes, dirigibles, and station balloons are suitable and necessary types. The assignment of aircraft to coast defenses may be made upon a permanent basis. Dirigibles and strategic airplanes should be provided to perform strategic reconnaissance and distant aircraft offensive-defensive action against hostile fleets and their aircraft. Dirigibles should prove better adapted to this use, and in fact are the ideal craft for distant scouting over the sea. Combat seaplanes should be used for distant fighting operations. Tactical reconnaissance planes will be required for coöperative operations with the balloon service, which should constitute the chief aircraft element of the seacoast fortifications. Airplanes and balloons are both useful for work in connection with railroad units of the coast defense system. Aircraft should be allotted to the coast artillery supports in accordance with the rules governing their assignment to the mobile forces, and in conformity with the particular defense scheme adopted.

COAST DEFENSE ELEMENTS

Artillery District Aircraft Units. Aircraft should be assigned to the Artillery District Commander in sufficient numbers to carry out the approved scheme of defense for his command. This should contemplate the entire defense of his district and involve the control of all elements assigned to it. For this purpose aircraft of the coast patrol should be assigned coast artillery district commanders, upon outbreak of hostilities, and his aircraft forces further augmented as necessary to establish and maintain an aircraft screen over that part of the coast line within his command. These forces should consist of strategic type aircraft for offensive and reconnaissance operations to seawards, of patrol reconnaissance units assigned to sectors, and of combat units, employed on station or patrol duty according to the activity of enemy aircraft. Airplane squadrons, wings, regiments, brigades, divisions, and fleets should be assigned somewhat as provided general headquarters in the field.

Seacoast Railroad Artillery. This element which naturally comes under the control of the district commander must be provided with a proper quota of fire-control aircraft. Station balloons should generally prove useful with train artillery. Facilities for carrying the balloon, its technical equipment, and supplies will always be available when used in connection with train artillery. One balloon should be sufficient to direct the fire of all the artillery units that can be profitably used in one train. One car should be equipped as a generation plant, with facilities for rapid inflation, one car devoted to carrying the balloon winch and supplies, and a flat car suitably rigged to carry the inflated balloon, and its nurses.† The balloon may generally be raised from its car. If wires, cuts, or other objects interfere, the balloon may be run to a dead man, sunk in a neighboring field, and controlled from the winch on the car. If the train is required to move through tunnels which will not accommodate the balloon, it may be quickly deflated, the gas being transferred to nurses of a small diameter, and practically as quickly replaced in the balloon. Airplanes may be used in coöperation with railroad artillery units. These should be employed to fly from place to place rather than to rely upon the railroad for transportation facilities. The tactical value of the airplane as a fire-control agent, is perhaps secondary to the station balloon service, but the plane is essential for identification of targets not plain to the balloon. This is more true of the use of station balloons in land warfare, where the principal targets are carefully defiladed by the enemy. On the seacoast, this condition is not encountered when operating against hostile vessels.

Coast Artillery Supports. The rules laid down, governing the conduct and tactical employment of the air service in connection with mobile forces, apply equally to aircraft forces assigned to coast artillery supports.

Seacoast Fortifications. All airplanes assigned to a coast defense should be controlled by the coast defense commander. Dirigibles should be furnished as the prime craft for reconnaissance to seawards; airplanes and seaplanes principally for combat functions. Station balloons should be used for local observation and fire-control functions. Balloon units must be allotted in sufficient number to provide effective fire-control for all the artillery elements. Each battle, fort, and fire or mine command should have one balloon assigned for its use. In many cases a balloon may serve satisfactorily a fort and one or more fire commands. The functions performed under the battle and fort commanders should be mainly observation; balloons assigned to fire and mine commanders, fire-control duties. In practice these functions are more or less combined. The balloon observers are expected to furnish all information required for the service of armament, fixed, movable, or mobile, for mine fields, and for the protection of water and land obstacles.

COAST DEFENSE AIR SERVICE

The coast artillery air units are divided tactically into:

1. The dirigible service.
2. The seaplane service.
3. The airplane service.
4. The balloon service.

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†Small fabric gas containers, having capacities of from 1,000 to 2,500 cubic feet.

The Dirigible Service. Dirigibles of the rigid or non-rigid types are useful for distant strategic cruises. All dirigibles should carry equipment for conducting careful reconnaissance at great distances while in radio communication with the base. The tactical value of the dirigible has been more derogated through prejudice than through its own limitations. The chief weakness is its susceptibility to destruction by reason of its inflammable cargo of gas. Airplanes, having in some cases higher maneuvering qualities, are dangerous foes of the dirigible, for it is possible to completely destroy the latter by scoring a single hit, with the proper kind of projectile or missile. Anti-aircraft guns, moreover, find a favorably large target in the dirigible. On the other hand the airship, especially one of the rigid type, armed on the roof with machine guns can generally hold its own with the airplane. Dirigibles do not encounter the difficult conditions over the sea, that are met with in over-land flight. Seaplanes are not as efficient as land planes, owing to the great weight of pontoons, and other considerations affecting the design of water flying craft. Lurking anti-aircraft guns are easily avoided over the water. Moreover the development of the seaplane has not kept pace with improvements in the land plane.*

Owing to the difficulty experienced in getting seaplanes off the water in a rough sea, there are times when entire reliance must be placed in the dirigible service. At other times the ability of the airship to *stand by,* or *keep station,* with the fleet in operations, or near the hostile naval forces, while the seaplane must be constantly traveling to *keep afloat,* render the service of dirigibles superior to that by seaplanes.† Dirigibles are especially useful in seacoast patrol, in searching for submarines, and in locating mine fields, for convoy duty and for use in maintain-

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*A detailed consideration of the dirigible and station balloon entails a lengthy study of AEROSTATION. Only so much of the general principles governing the military operations of lighter-than-air craft as is essential to an understanding of aviation, are treated herein.

†The airship is capable of doing practically everything demanded of the airplane or seaplane and although defective in some particulars, has certain advantages over the airplane that should not be overlooked. It can drift silently in the sky without power; provides a steadier platform for gunfire, bomb dropping, reconnaissance, or sketching, and for the use of photographic or fire-control instruments. An accident to the machinery does not, as with the plane, necessitate landing with the prospect of capture if over hostile areas, or loss if far out in the sea. The dirigible is awkward near the ground and sometimes requires aid from below in landing. It presents a large target while the airplane presents a small one. (This disparity is not as great as formerly. Some super-plane types measure nearly 200 feet from wing tip to wing tip and about 30 feet in over-all height. Small non-rigid, two-place and three-place fuselage-type dirigibles measure less than this in length and about the same in master diameter.) The dirigible enjoys great advantage over the plane in the matter of cruising radius, and the former can remain aloft for days at a time. Its vertical speed is very rapid in an emergency with the release of ballast and with the assistance of its elevators. The dirigible may suffer great handicap in maneuvering ability, through moisture deposits from clouds or high fog, which form a coating of considerable weight and a serious burden upon the gas bag.

ing harbor patrols, stopping and searching merchantmen, conducting distant reconnaissance flights, and carrying offensive operations beyond the range of seaplanes.

The Airplane Service with the Coast Defenses. The principles governing the technical, tactical, supply, and administrative functions of the air service, as employed in connection with the other military forces, prevail in the use of aircraft with the coast defenses, with certain modifications.

The aircraft stations should for economy be consolidated as far as possible within the defenses. An aeronautic officer should be designated to command the air units within the defenses whenever possible. The seaplane and airplane stations should be located on the same site when possible. The seaplane hangars should be located parallel to an interior, protected water area, and removed from the range of hostile fire, delivered against the defenses. The land hangars should be situated in a field adjacent to this site, in order that both units may use the shops and other facilities in common. Dirigible units should likewise be located with reference to station balloon units, the sites for which are more or less fixed. Gas generation plants, hangars, and other facilities should be shared.

THE SEAPLANE SERVICE

The *military functions* of *sea aircraft* differ greatly from those of land aircraft. Certain fundamental principles affecting the use of aircraft over the sea should be considered, in order to examine their established functions with understanding.

At present, aircraft motors are not sufficiently reliable to depend upon long ventures from the shore lines, except under the observations of ships. It may be safely assumed that to venture farther than 200 miles from the shore without the coöperation of vessels is to invite probable loss at sea. This applies where reliance is placed on single or twin motors. (If a single motored plane suffers loss of power, a landing must be made. If a twin motored plane loses the power of one motor, the other motor will probably deliver only enough power to maintain a descending flight.) The sea presents a landing place practically everywhere the water flows. Flying conditions over the water are generally better than over the land. The air is smoother, i. e., it is less broken by cross-currents and other disturbances. (See METEROLOGY.) One notable exception to this rule is found offshore in the proximity of rugged mountains, when a land breeze of considerable magnitude may cause rough flying conditions in the neighborhood. The nature of seaplane work necessitates a much heavier, stronger craft than would be used to perform the same kind of duties over the land. The efficiency of seaplanes is not only reduced by the limitations imposed on design, but by the difficulties of getting on and leaving the sea, especially in rough water.

Combat. Aerial fighting over water will have an altogether different character than that conducted over the land. This is primarily due to the differences between the types involved, the heavier seaplanes being less active in maneuvering than land craft. Contact with landcraft should be avoided near shore, as the land fighter generally possesses great advantage over the seaplane in celerity of maneuver. For operations against enemy vessels, special torpedo planes may be used with considerable effect. Gunplanes are useful against submarines and armed merchantmen. Combat between seaplanes will be comparatively protracted, engagements being fought with less movement in the vertical plane, less circling and diving. Greater reliance must be placed on accuracy of fire, superiority of armament and *service of the piece.*

Reconnaissance. Strategic reconnaissance over the sea by seaplanes does not possess the range obtained in land flights. Tactical reconnaissance may be regarded as generally satisfactory.

As a rule objectives on the water are more readily seen than on land. Submarines are easily detected. Reconnaissance seaplanes are used to locate submarines and guide patrol boats to the spot. Mines may be visible when the light is favorable. Photography is done under ideal conditions. Visibility suffers at times owing to unfavorable reflections from the water.

Artillery fire-control is in some respects simplified in overwater work. Targets are more easily identified, splashes are very distinct, and measurements easily determined. Reference points and fixed positions are rarely to be found, however, and the situation is constantly shifting.

Bomb Dropping. This function loses some of its value, on account of the nature of the targets. Ships armed with anti-aircraft guns should be approached cautiously. Smaller vessels, except destroyers, are seldom armed with anti-aircraft guns. Bombardment planes may be used with effect against submarines, discovered at a halt, either floating or submerged. When floating at a halt or in motion, the bombardment plane dives to a low height and conducts the usual bomb-dropping operations. When the submarine is submerged and halted, the bomb plane lands and lowers a mine against the submarine, which is electrically discharged.

The Station Balloon Service (see THE AIR SERVICE IN WAR).

NAVAL AVIATION

In fleet operations the aircraft forces are carried on capital and scout ships as a rule. Special hangar ships are sometimes used.

In operations within cruising radius from the shore for dirigibles the latter should always be employed, as the most efficient type of sea aircraft.

The proper quota of aircraft for naval vessels must, like aircraft requirements of land forces, vary with the situation, but the following constitutes normal practice: Two seaplanes and one captive balloon for each capital ship; four seaplanes for each scout ship; one dirigible for each division of the fleet.

For naval aircraft bases: Eight airplanes or seaplanes; one station balloon; and one dirigible each. For each advance base unit: Twelve airplanes or seaplanes; one station balloon; and one dirigible.

NAVAL AIRCRAFT OPERATIONS

The aerial operations of the navy may be classified as:

a. High sea operations.

b. Coastwise operations.

The navy constitutes the first line of defense. In case the naval forces lose control of the seas, their operations are more or less restricted to waterways dominated by shore defenses. When hostile naval forces break through the naval defense and endeavor to force a landing, defensive and offensive functions pass to the control of the army.

High Sea Operations. The aircraft forces with the fleet should be employed to afford effective reconnaissance; offensive operations against the hostile forces, sea as well as aircraft units; protection of naval units which they serve; intercommunication between units of the fleet; transport of officers and limited amounts of matériel; observation of friendly units out of view of the fleet. *Commerce destroying* is a function of aircraft. Patrols and convoys by aircraft should be used.

The screening of movements of the fleet is a prime duty of the seaplane service. Effective reconnaissance yielding complete information about the enemy should constitute the principal duty of dirigibles. The latter should be supplemented in this work by the seaplane service. In the absence either of dirigibles or seaplanes, the other type must discharge both functions. Whenever possible, dirigibles "pilot ahead" of the seaplane units. The closest coöperation should exist between these two types of craft. The dirigible performs detailed and distant work; the seaplane, brief or short flights, duties of a general nature, offensive operations, and protection for the naval and aircraft forces.

When the opposing fleets approach, dirigible scouts far to the front are expected to detect the hostile scout ships, destroyers, and patrol boats, light cruisers, capital ships, and auxiliaries. This information should be wirelessed in. As contact nears and the dirigible scouts fall back, seaplane units should go forward to protect the former. Full information should be furnished concerning the enemy's strength and dispositions. As the battle develops, formations, maneuvers, and all other useful information should be supplied continuously by the dirigible scouts. Station balloons are raised and fire-control functions performed. With capital ships aircraft should be used for reconnaissance and fire-control; with destroyers, submarines, and auxiliaries, for piloting. If victorious, aircraft should be used to locate the enemy vessels and assist in running down all that seek to escape. If defeated, aircraft are invaluable in assembling the scattered forces and aiding them to escape.

Coastwise Operations. Aircraft of the coast patrol are expected to give timely warning of the approach of hostile forces, to conduct offensive operations against all invaders, and to provide thorough aerial service to the military and naval forces. The exterior elements should consist of dirigibles; the secondary line of seaplanes, and these supplemented by station balloons and airplanes over the shore. This scheme should provide an aircraft screen along the maritime frontier for offensive and defensive action.

Blockades. Aircraft, chiefly seaplanes, should form the *close-in* or primary elements of a blockade. Station balloons on blockading vessels and dirigible scouts should be used in the secondary line. The functions of naval aircraft when operating against seacoast fortifications will be regulated by the nature of the operations and by the activities of the coast defense air service. Aircraft will be useful in detecting offensive operations, especially destroyer and submarine attacks. Bombing raids and torpedo-plane attacks should be countered by combat aircraft and anti-aircraft artillery.

Anti-submarine Operations. Aircraft are useful in the search for submarines, and are valuable weapons for use against the *undersea boat.* It is well established that objects which lie deep in the water are plainly visible from overhead, while lost to view at or near the surface. In fact, from a moderate altitude, the submerged submarine appears to the air scout to be on the surface. Dirigibles are better submarine spotters than airplanes or seaplanes, on account of the more favorable low speed, and because of the more effective types of radio apparatus carried on airships. The air scout *spots* the submarine, calls the nearest surface patrol boat, and guides it to the locality. If the submarine rises, the patrol boats attack by gunfire; if the diver remains submerged and comes to rest, a mine may be lowered against it.

MILITARY AVIATION

CHAPTER 6

ANTI-AIRCRAFT DEFENSES

The advent of aerial navies into warfare has had the effect of destroying the insulation of inland points against attack, other than by field forces. Under the existing methods of making war, when aircraft attack peaceful cities and fortresses alike, it is evident that a comprehensive scheme of anti-aircraft fortifications and defenses must be evolved to provide security. Great difficulty has been experienced, however, in stopping aircraft from moving at pleasure through the air, crossing the most formidable tactical barriers, practically with impunity. The erection of anti-aircraft defenses, involving anti-aircraft artillery in fortifications or fixed batteries and in mobile units; combat station planes; searchlight, detector, outpost and interior stations, possibly aerial mine fields, should not be neglected at important military sites or cities, liable to such form of attack.

A proper anti-aircraft defense should comprise the above named elements; all the ground units linked together by wire and radio communications.

The air defense of a position or city should be under the control of an *air defense commander,* who should direct the operations through his subordinate commanders.

Anti-Aircraft Armament

Anti-aircraft guns are divided into two classes:

(a) High power guns on fixed mounts.

(b) Light guns on movable mounts.

High Power Guns on Fixed Mounts. These are generally used for the defense of important positions exposed to aircraft attack. Fire-control, searchlight and other stations, magazines and other equipment of a permanent nature should be installed. Except for special types of anti-aircraft guns designed for use against super-planes and dirigibles, the heavy fixed models are sufficiently portable to permit of their being moved and mounted in a comparatively short time. The emplacement consists of a simple gun block of concrete. Anti-aircraft armament may, therefore, as a rule, be treated as movable units.

Light Guns on Movable Mounts. This class of armament is used with mobile forces or in mobile detachments, for defense against hostile aircraft, and designed to be moved from place to place as required. These guns are light rapid-fire pieces (perhaps

1, 1½ or 2 pdr. guns) having high mobility, in order to reach aircraft engaged on short tactical flights or brief visitations. This type should be mounted on specially designed motor trucks. More time is available for firing on airplanes and dirigibles engaged upon strategic reconnaissance, bombardment raids, patrol or combat duty, or fire-control flights. Some of these craft, particularly the bombardment and fire-control planes and dirigibles are slower and offer more favorable targets. For all these reasons a heavier type of mobile gun may be used, say a 6 pdr. Fire-control is more deliberate and accurate. Whereas the lighter gun is assigned generally to brigade and divisions in the field, the 6 pdr. should be allotted to army corps and general headquarters for distribution to meet the requirements. In permanent fortifications or in air defense units for the protection of important positions, all types should be provided as needed. Explosive and special incendiary, combination time and percussion shells should be used.

Fire-Control. The best results are obtained by the use of *sheaf fire* from a group of three or four guns, arranged in the angles of a triangle or square, the sides of which are about 200 feet long. An observer takes post at the center of the group from which position he directs the firing operations. All the guns of a *sheaf* are fired with the same azimuth, if that method is used, or aimed with the same firing data. Pieces are generally fired in *salvos.* A bracket is obtained from which corrections can be made. The emplacement mount and carriage should be such as to provide ease and rapidity of action and control. An automatic sight should be used. Fire-control data should be obtained and *set* by means of self-contained instruments. Base lines involving primary and secondary observing stations are not suitable. Complications should be avoided. Every effort should be made to produce simplified and direct methods.

Fire Action. The trajectories of anti-aircraft guns become so unsteady at high altitudes, owing to loss of velocity, that a hit is more a matter of chance than of accuracy of fire. Small errors at the gun are greatly magnified at the *maximum ordinate* of the trajectory.

The chief problems confronting the anti-aircraft gunner are given below.

Lack of approximate rigidity of the trajectory when firing at angles exceeding 15°. (Aircraft targets are to be found at angles up to 90°.) "The shape of any trajectory depends on the time of flight and the direction of the force of gravity with reference to the line of sight."

Changes in the air density, as the altitude increases, affect the ballistics of anti-aircraft artillery erratically, and cause wide variation in the rate of burning of time fuses. Drift of the projectile, due to the rifling of the bore, increases with the angle of sight and then decreases until it disappears in vertical fire, introducing further complication. Time fuses are unsatisfactory owing to the nature of the fire. Percussion fuses do not always function in passing through the frail materials of the aircraft target. The appearance of *bursts* is such that *overs* and *shorts* are easily confounded. Percussion fused shots that do not find the target, fail to explode, give no firing data, and are a menace to those on the earth near the point of impact, generally falling on friendly territory. Observation of fire or targets at heights is very difficult. The aerial target moves at high speed and this, combined with the rapid change in the trajectory curves, leads to complications. In gunnery, deflection is not as difficult an adjustment as range, but with aircraft targets moving at high rates of speed and at comparatively short ranges, deflection changes are very considerable.

"In investigating the various factors it is seen that for exact gunnery, large corrections must be applied varying with the altitude, direction, and rate of travel of the vessel."

With great complications injected into the problem of aerial gunnery and with insufficient time available for computations, nothing short of simple and direct methods can be of use. High muzzle velocity is mandatory to produce steadiness of trajectory and in reducing the time of flight.

The following features are essential in anti-aircraft gun design:

Anti-aircraft Ordnance. Long range, high muzzle velocity, rapid rate of fire, self-contained, automatic sights and scales, graduated in altitudes, with drift, and deflection scales, all designed for firing at angles of sight between 45° and 75°. The projectiles should be fitted with combination percussion-time fuses, and effective tracers. Projectiles to produce smoke of different colors are used to give reference points for fire adjustment. Anti-aircraft guns should be specially designed. Field guns are not satisfactory.

Location of Guns. Permanently installed anti-aircraft guns should be located in positions affording all possible concealment from air scouts. Mobile guns should not be deliberately exposed. Gun flashes are prominently seen from the air. This does not apply as strictly to the fire of anti-aircraft guns which are difficult to detect. This is due to the small flame and smoke emitted from these guns generally of very small caliber, and to the fact that the gun is pointed skywards, reducing the length of the flame as viewed from above. Care should be exercised to avoid exposing anti-aircraft guns to the fire directed at other targets. Groups of the types in use are mutually supporting when separated by a distance of about 1,000 yards. Limitations are imposed upon the uses of anti-aircraft defenses. Range-finding is very inaccurate. The plane may appear practically to stand still, while moving at a high rate of speed. The small size of the target, its ability to maneuver in the three planes of direction, and the high speed are all factors that reduce accuracy of fire. Results indicate that firing at ranges above 10,000 feet altitude is practically a waste of ammunition. Firing overhead usually results in more damage to friendly forces than to the enemy aircraft. Larger calibers may remedy many of the defects of the present used light armament, but each increase of caliber increases the cost and difficulty of transportation for mobile purposes, reduces rate of fire, and offers other points for consideration.

Anti-aircraft Gunfire. Rifle and machine gun bullets carry effectively to about 6,000 feet and reach a maximum range at about 7,500 feet. Bullets cause little damage either to gas bags or planes, unless a tank or radiator is pierced, the crew of aircraft struck, or a vital wire or brace severed. Incendiary bullets (washed with certain chemicals) are used with deadly effect against gas bags. Expanding bullets should prove very effective, but these are prohibited by the laws governing civilized warfare. The one-pounder projectile carries considerably higher than the bullet, but reaches its limit of steadiness and effectiveness at 10,000 to 11,000 feet. It appears that aircraft are entirely safe from rifle and machine gun fire above 7,500 feet. Above 9,000 the fire of anti-aircraft artillery becomes rapidly uncertain, and a vital hit is a matter of chance. Shrapnel hits, like bullets, must strike a vital spot to be effective. Explosive shell produce better results. The detonation does not have to be in contact with the aircraft to destroy it. If close enough, the racking effect of the explosion may be sufficient to crush the wing of an airplane or burst the envelope of a gas bag, or in the case of the airplane, throw some delicate adjustment out of order, which is generally as good as a hit.

Regardless of the degree of success experienced with anti-aircraft artillery, it must be used freely and persistently for the moral value even if the material results achieved are slight. Fire interferes with the airman's work, driving him to higher levels, at which his work is less accurate if not valueless.

ANTI-AIRCRAFT DEFENSE STATIONS

Projects for anti-aircraft defense should contemplate the use of fixed guns for primary duties, supplemented by the action of mobile batteries and equipment. Sheafs of four guns each should be located upon favorably high and commanding points from which fire can be delivered in all overhead directions. Groups of four sheafs should be so disposed that they are *mutually supporting* (separated by about 1,000 yards). The interior defense line, consisting of groups and sheafs of anti-aircraft artillery, should be located on the perimeter of a boundary encircling the defense area at an average distance of five or six miles from the center of the position protected. Additional lines of batteries should be erected outside this line according to the required strength of the defenses. Strong groups should be placed on the exterior lines as the first duty of the defenses is to prevent the invaders from reaching their objective. Shelling aircraft within the limits of a city will undoubtedly cause more damage and casualties among the inhabitants than among the personnel of invading aircraft.

Detector Stations. These should be placed at the outposts. Listening towers equipped with microphone instruments, electrical sound-wave amplifiers, observation telescopes, and every other facility for detecting the approach of aircraft by sound or appearance, should be provided. Sites free from fog and areas free from noises should be used. These stations should be in wire communication with other elements of the defense system. Radio should be installed for communication with aircraft engaged in pursuit of invaders.

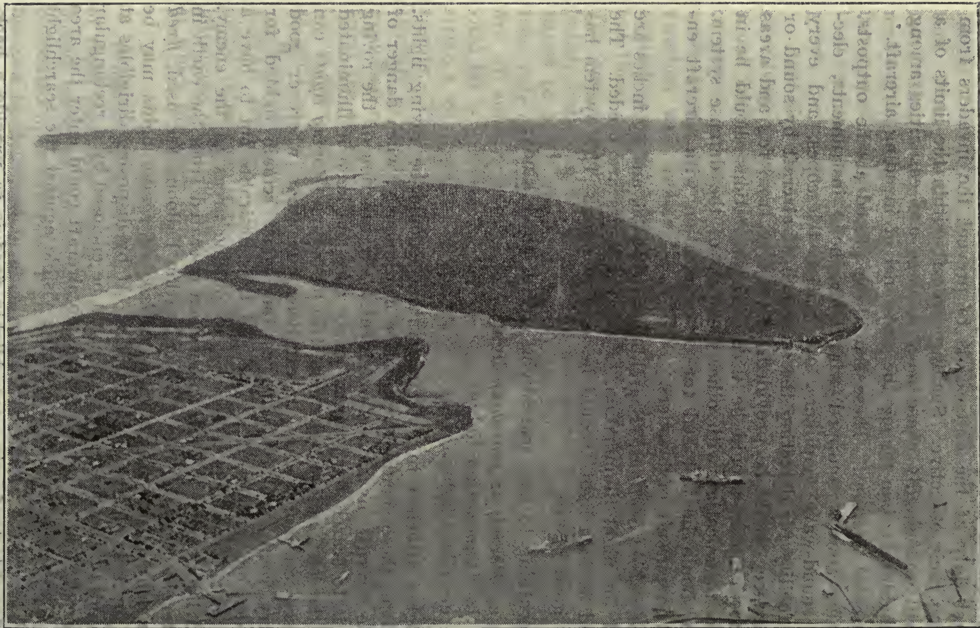
Searchlight Stations. Searchlights of 24, 36, and 60 inches are useful for night illumination. Powerful lights are needed. The 24 and 36 inch lights should be used in pairs. This system has given good results.

According to use, searchlights are of three kinds:

a. *Roving* or *searching* lights.
b. *Illuminating* lights.
c. *Fixed* lights.

Lights attached to detector stations should be roving lights. At night, these should be *in action* continuously, when danger of hostile aircraft invasion is imminent. The function of the roving light is to search for targets, locate one, and keep it illuminated until the *illuminating* light gets it in his beam. *Roving lights* can be used on motor cars to excellent advantage wherever good country roads are available, as they must remain lighted for considerable periods at a time and it is desirable not to have a fixed position which will serve to outline areas to the enemy. Fixed lights possess little value when operated from the earth in counter aircraft schemes. When station balloons are used, *fixed* lights may possess some value. *Fixed* or *roving* lights may be used on dirigibles at high altitudes. If by disposing dirigibles at the angles of a square, an area could be enclosed by a rectangular outline of light, it is obvious that no aircraft could enter the area at a lower level without becoming visible against the searchlight beam and so suffering exposure.

The object of using searchlights *fixed* is to provide a background against which the target is silhouetted. All classes of lights should be provided with the outposts. No hostile aircraft should be permitted to pass this line unrevealed. Illuminating



This city by the open sea invites attack if unfortified, and undefended against air raids lights should be assigned to each *sheaf* of three or four anti-aircraft guns; perhaps a battery of at least two lights to each battery of counter aircraft guns.

Upon notification of the approach of hostile aircraft, all lights should be put into action. Illuminating lights should be kept occulted, until ordered to cover the target. *Illuminating lights* remain "in action" only while the hostile aircraft is under the fire of the battery to which attached. The light or lights for a given battery should be located at a distance of about a half mile from the position, to avoid interference with the gunners.

Outposts should consist of detector and searchlight stations, anti-aircraft gun batteries, and aircraft stations. Station balloons, employed as observation towers at heights of a few hundred feet should prove useful. These craft should be equipped with all necessary instruments for detecting the approach of hostile craft. Specially designed lighter-than-air craft (employed captive) may be armed with machine guns and rapid fire rifles for use against low altitude invaders that seek safety from anti-aircraft artillery.

Aircraft. The types of aircraft used for defense against aircraft raids will ordinarily consist of cruiser and pursuit airplanes. Dirigibles should be used for night patrol duty, especially for use against other dirigibles. These should avoid combat with invading airplanes, withdrawing as airplanes rise to the attack from below, and thereafter performing reconnaissance and information duties. All aircraft should be armed for counter aircraft operations. Cruiser planes and dirigibles should be armed with rapid-fire rifles and machine guns, and carry bombs. Pursuit planes should be equipped both with machine guns and bombs. All should carry fire-ball and incendiary bombs, fire-rocket guns, and incendiary bullets for use against dirigibles.

The types of aircraft selected to drive off the invaders should depend upon the type of adversary as well as upon other considerations. The most important step is to get the defending planes into the air in the shortest space of time and to guide them to contact with the hostile forces. To secure speedy contact, a series of aircraft stations around the city or position are to be preferred to a single or central station. Where a number of stations are distributed throughout the defense area, planes are sent out with less confusion and interference, with a minimum of lost time, and may reach their objective in a shorter space of time. Moreover, distributed aircraft stations enable the commander to *dispose* his aircraft forces, directing an attack on the invaders' rear, flank, or from above; in other words, to make the most favorable tactical dispositions, even to the point of surrounding the quarry, when he enters the area. In this sense, *searching* lights may be used in such numbers on the outer defense line as to provide practically a fixed wall of light. Hostile aircraft could not cross such a line undetected, and once within the enclosed area, it is conceivable that proper aircraft forces could effectually surround them.

Radio equipped aircraft are necessary to proper coöperation with observation stations on the ground. In the absence of radio, a positive system of signalling should be adopted. Light signals should be arranged showing the sector or section over which hostile aircraft are discovered. Messages at night may be efficiently transmitted by searchlight signals, employing telegraphic or wigwag codes.

Aerial mine fields may be used, employing a vast number of small captive balloons, each carrying a charge of high explosive and incendiary material designed to intercept aircraft at night. Electrical connections to the earth should be made to safeguard against explosions in case a balloon should break away from its moorings and come to earth.

General. The anti-aircraft defenses should be divided into convenient sectors or districts, each commanded by an officer subordinate to the commander of the defenses. All stations in a sector or district should be under the control of its commander.

Great care should be exercised by all ground forces before opening fire on aircraft to ascertain their nationality.

The action of troops, other than the anti-aircraft forces, in attacking hostile planes should not be employed, except in cases of emergency or in the absence of proper anti-aircraft artillery. Usually the fire of troops is difficult to control, the effect small if any, and the dangers great of causing destruction to friendly forces. The vulnerable target offered by aircraft is perhaps less than 25 square feet and this target at ordinary flying heights offers a very unfavorable objective. At heights below 4,000 feet, rifle fire may be of some value against aircraft. Opposed to aircraft operating at altitudes up to 500 feet, rifle and machine gun fire constitute the only defense at present.

The need of powerful air defenses to guard important cities and vital military objectives is indisputable.

Bathed by the waves of an aerial ocean that may serve to bring hostile as well as friendly fleets to our doors, the whole surface of the earth is an open shore, every city an air port, every field a dock. Every air lane that leads to important objectives is, therefore, a ship channel, which should be defended by anti-aircraft fortifications.

APPENDICES

A—Glossary of Aero Technics.

B—Codes.

C—Junior Military Aviator Tests.

D—Equipment Airplane Tool Chest.

APPENDIX A

GLOSSARY OF AERO TECHNICS

(The definitions marked *, are taken from Aeronautic Nomenclature—National Advisory Committee for Aeronautics.)

Aero: Pertaining to the air.

*Aerofoil: A thin wing-like structure, flat or curved, designed to obtain reaction upon its surfaces from the air through which it moves.

Aerodrome: Popular name given to a flying field (correctly means flying machine).

Aerodynamics: Science of "air in motion" and resultant effects.

Aeronaut: Pilot of a lighter-than-air craft.

Aeronautics: Science of aerial navigation.

Aeronef: Any heavier-than-air craft.

Aeroplane: See airplane.

Aerostat: Any balloon.

Aerostatics: Science of effects produced by air at rest.

Aileron: Balancing plane or flap, placed at the lateral extremities of the planes, which can be actuated from control levers or other device in the pilot's control to maintain lateral stability, i. e., balance of the machine from side to side.

*Aircraft: Any form of craft designed for the navigation of the air—airplanes, balloons, dirigibles, helicopters, kites, kite balloons, ornithopters, gliders, etc.

*Airplane: A form of aircraft heavier than air which has wing surfaces for sustentation, with stabilizing surfaces, rudders for steering, and power plant for propulsion through the air. This term is commonly used in a more restricted sense to refer to airplanes fitted with landing gear suited to operation from the land. If the landing gear is suited to operation from the water the term "Seaplane" is used. (See definition.)

Pusher: A type of airplane with the propeller or propellers in rear of wings.

Tractor: A type of airplane with the propeller or propellers in front of wings.

Air Pocket: A local condition of the air, up-trend, down-trend, aerial fountain or cataract, wind-layer, or gust of unusual violence which causes the machine to fall for some distance producing the effect of entering a vacuum. A hole in the air, or vacuum, at altitudes navigable by man in the present day vehicles of flight, is impossible. The term and principle are erroneous.

Airship or Aeronat: A dirigible balloon.

*Air-speed Meter: An instrument designed to measure the velocity of an aircraft with reference to the air through which it is moving.

ALTITUDE: Height or elevation, measured by an aneroid barometer or barograph.

*ANEMOMETER: An instrument for measuring the velocity of the wind or air currents with reference to the earth or some fixed body.

ANGLE-DIHEDRAL: The angle between two planes. It is measured from a prolongation of either plane to the other plane of the combination.

ANGLE OF INCIDENCE: Angle between the chord and the horizontal, i. e., the angle at which the wing is tilted. (See chord.)

*ANGLE:

Of Attack: The angle between the direction of the relative wind and the chord of an aerofoil, or the fore and aft axis of a body.

Critical: The angle of attack at which the lift is a maximum.

Gliding: The angle the flight path makes with the horizontal when flying in still air under the influence of gravity alone.

*ASPECT RATIO: The ratio of spread to chord of an aerofoil.

AVIATOR: Pilon or steersman of an airplane, or other heavier-than-air craft.

AVIPLANE: Machine that flies by flapping of wings, like a bird; also called an ornithopter.

*AXES OF AN AIRCRAFT: Three fixed lines of reference; usually centroidal and mutually rectangular.

The principal longitudinal axis in the plane of symmetry, usually parallel to the axis of the propeller, is called the fore-and-aft axis (or longitudinal axis); the axis perpendicular to this in the plane of symmetry is called the vertical axis; and the third axis, perpendicular to the other two, is called the athwartship axis (or transverse or lateral axis). In mathematical discussions the first of these axes is called the X axis, the second the Z axis, and the third the Y axis.

BALLONET: Bag of air, placed within a gas bag for the purpose of exerting outward pressure and acting upon the gas to maintain the shape of the envelope.

*BALLOON: A form of aircraft comprising a gas bag and a car, whose sustentation depends on the buoyancy of the contained gas, which is lighter than air.

Captive: A balloon restrained from free flight by means of a cable attaching it to the earth.

Kite: An elongated form of captive balloon, fitted with tail appendages to keep it headed into the wind, and deriving increased life due to its axis being inclined to the wind.

*BANK: To incline an airplane laterally, i. e., to rotate it about the fore-and-aft axis. Right bank is to incline the airplane with the right wing down.

*BANKING RUDDER: See Aileron.

*BAROGRAPH: An instrument used to record variations in barometric pressure. In aeronautics the charts on which the records are made are prepared to indicate altitudes directly instead of barometric pressure.

*BIPLANE: A form of airplane in which the main supporting surface is divided into two parts, one above the other.

*BODY OF AN AIRPLANE: A structure, usually inclosed, which contains in a streamline housing the power plant, fuel, passengers, etc.

*CABRE: A flying attitude in which the angle of attack is greater than normal; tail down; down by the stern—tail low.

*CAMBER: The convexity of rise of a curve of an aerofoil from its chord, usually expressed as the ratio of the maximum departure of the curve from the chord as a fraction thereof. "Top Camber" refers to the top surface of an aerofoil, and "Bottom Camber" to the bottom surface; "Mean Camber" is the mean of these two.

*CAPACITY:

Lifting: The maximum flying load of an aircraft.

Carrying: Excess of the lifting capacity over the dead load of an aircraft, which latter includes structure, power plant, and essential accessories.

*CARRYING CAPACITY: See Capacity.

*CENTER: The point in which a set of effects is assumed to be accumulated producing the same effect as if all were concentrated at this point.

Of buoyancy: The center of gravity of the fluid displaced by the floating body.

Of pressure of an aerofoil: The point on the chord of an element of an aerofoil, prolonged if necessary, through which at any instant the line of action of the resultant air force passes.

Of pressure of a body: The point on the axis of a body, prolonged if necessary, through which at any instant the line of action of the resultant air force passes."

CHASSIS: Erroneously used for "running-gear" or "running-carriage." The running gear or carriage carries the airplane and enables it to run along the ground. It comprises wheels, shock-absorbers, skids, struts, spreaders, axles, and wires.

CHORD: Of an aerofoil section. A right line tangent to the under curve of the aerofoil section at the front and rear.

Length. The length of the chord is the length of the aerofoil section projected on the chord, extended if necessary.

CLIMBING: Term used to denote rate of ascent of an airplane.

*CONTROLS: A general term applying to the means provided for operating the devices used to control speed, direction of flight, and attitude of an aircraft.

CONTROL-POST: Wheel-post lever, or levers, or other device, by means of which the pilot operates the air controls of a flying machine.

DECK: The surfaced plane of a flying machine. May be either single or double surfaced.

DIHEDRAL: (See Angle-dihedral).

*DIRIGIBLE: A form of balloon, the outer envelope of which is of elongated form, provided with a propelling system, car, rudders, and stabilizing surfaces.

Non-rigid. A dirigible whose form is maintained by the pressure of the contained gas assisted by the car-suspension system.

Rigid. A dirigible whose form is maintained by a rigid structure contained within the envelope.

Semi-rigid. A dirigible whose form is maintained by means of its attachment to an exterior girder construction containing the car.

*DISK AREA OF A PROPELLER: The total area of the disk swept by the propeller tips.

DIVE: To descend at an abnormally steep angle.

DIVE, HEAD OR NOSE: To nose over into a vertical drop.

DOPE: Solutions applied to fabric of airplane surfaces to make them strong, firm, air-tight, and waterproof.

*DRAG: The total resistance to motion through the air of an aircraft, i. e., the sum total of the drift and head resistance.

*DRIFT: The component of the resultant wind pressure on an aerofoil or wing surface parallel to the air stream attacking the surface.

ELEVATOR: A surface attached to the rear-most extremity of the tail of an airplane, in the horizontal plane, and hinged on a line to the main planes. The use of elevator is for steering and balancing the machine in the vertical plane.

EMPENNAGE: A non-lifting tail.

*ENGINE, RIGHT OF LEFT HAND: The distinction between a right-hand and a left-hand engine depends on the rotation of the output shaft, whether this shaft rotates in the same direction as the crank or not. A right-hand engine is one in which, when viewed from the output shaft, looking toward the output end, the shaft is seen to rotate clockwise.

ENTERING EDGE: The leading or front edge of a deck or plane.

ENVELOPE: The gas container of a lighter-than-air craft.

EQUILIBRIUM: State of rest of a body. Stability is the measure of the work that must be done to overturn such a body.

FAIRING: Any attachment placed on an airplane to round off the projections to a streamline form, reducing drag or resistance. This expedient is commonly practiced and is of the greatest importance, since for every 10 pounds of head resistance or drag eliminated, nearly 100 pounds more of weight can be carried in the machine with the same power. Streamlining is the most direct way of increasing the efficiency of an airplane.

FIN: A vertical plane surface, either flat or having convex cambered surfaces, arranged vertically as a rule and always parallel to the line of flight. A KEEL is a vertical fin placed beneath the planes of an airplane. A PANEL is a vertical fin set between the upper and lower planes of a biplane, or between any two or all three of the decks of a triplane. The object of fins is to produce stability.

*FLIGHT PATH: The path of the center of gravity of an aircraft with reference to the air.

*FLOAT: That portion of the land gear of an aircraft which provides buoyancy when it is resting on the surface of the water.

FUSIFORM: Streamline form.

FUSELAGE: The main central body of an airplane, usually carrying power plant, cockpit for occupants, tail, and tail-controls. (The wings are attached on either side of the fuselage, normally, and the chassis is fitted under it.)

GAP: The vertical distance between the surfaces of a biplane or multiplane. (This distance should never be less than the chord of the plane.)

*GLIDE: To fly without power.

*GLIDER: A form of aircraft similar to an airplane, but without any power plant. When utilized in variable winds, it makes use of the soaring principles of flight and is sometimes called a soaring machine.

*GUY: A rope, chain, wire, or rod attached to an object to guide or steady it, such as guys to wing, tail, or land gear.

GYRO PLANE OR HELICOPTER: A heavier-than-air craft deriving flotation from revolving planes.

HANGAR: Building or tent that houses aircraft.

*HEAD RESISTANCE. The total resistance to motion through the air of all parts of an aircraft not a part of the main lifting surface. Sometimes termed parasite resistance.

HELICOPTER: A heavier-than-air craft deriving flotation from horizontal propellers.

*INCLINOMETER: An instrument for measuring the angle made by any axis of an aircraft with the horizontal.

KEEL: (See Fin).

*KEEL PLANE AREA: The total effective area of an aircraft which acts to prevent skidding or side-slipping.

KING-POST: A vertical strut, supported by two tie wires or cables, commonly used to strengthen wing spars at weak points, as when the upper plane of a wing overlaps the lower at the wing tips.

*KITES: A form of aircraft without other propelling means than the towline pull, whose support is derived from the force of the wind moving past its surface.

KITE BALLOON: See Balloon, kite.

*LANDING GEAR: The under structure of an aircraft designed to carry the load when resting on, or running on, the surface of the land or water.

*LEEWAY: The angular deviation from a course over the earth, due to cross currents of wind.

*LIFT: The component of the force due to the air pressure of an aerofoil, resolved perpendicular to the flight path in a vertical plane.

*LONGITUDINAL: A fore-and-aft member of the framing of an airplane body, or of the floats, usually continuous across a number of points of support.

MONOPLANE: A single deck airplane.

MOTOR: See Engine.

MULTIPLANE: A heavier-than-air craft having more parallel, super-posed planes than a triplane.

NACELLE: The car or gondola of a dirigible or the enclosed shelter for the occupants of a biplane or multiplane.

*NOSE DIVE: A dangerously steep descent, head-on.

ORNITHOPTER: A flying machine designed to fly by flapping wings, like a bird; also called an aviplane.

PANEL: (See Fin).

PANEL WING: An independent, detachable section of a wing, between two struts. Some wings are solid, i. e., one piece from fuselage to wing tip. Other wings are composed of two or more sections.

PITCH: The distance at right angles to the blade, that a propeller would travel if it were moving through a substance in which there could be no slip.

PITCH, TO: To plunge in the fore-and-aft direction.

Roll, To: To rotate around the fuselage as an axis.

Yaw, To: To plunge toward the left and right of the true direction, due to gusts or lack of rudder control.

*PITOT TUBE: A tube with an end open square to the fluid stream, used as a detector of an impact pressure. More usually associated with a concentric tube surrounding it, having perforations normal to the axis for indicating static pressure. The velocity of the fluid can be determined from the difference between the impact pressure and the static pressure. This instrument is often used to determine the velocity of an aircraft through the air.

PLANE: The supporting surface of a heavier-than-air craft; also called the deck or surface. The customary designation, plane, is not as correct as the term deck.

PROPELLER OR SCREW: A wooden blade used as a propeller for "pushing" or as a screw for "pulling" aircraft.

Disk area of. See Disk Area of a Propeller.

**Right-hand.* One in which the helix is right handed.

PUSHER: See Airplane.

PYLON: (a) Main, central supporting mast or post of a monoplane, used to stay the wings.

(b) Signal towers, marking a flying course.

(c) A derrick to launch airplanes not provided with running gear. (Obsolete.)

(d) Greek word for "post."

*RACE OF A PROPELLER: The air stream delivered by the propeller.

REMOU: Local disturbance of the atmosphere.

RIBS: Main and fore-and-aft members of a wing section or deck.

RIGHTING TIPS: (See Ailerons.)

RIGID DIRIGIBLE: (See Dirigible, rigid.)

ROLL, TO: (See under Pitch.)

RUDDER: Vertical plane used to steer a flying machine to the right or left.

SCARFING: Process of repairing wooden members by splinting on new sections.

*SEAPLANE: A particular form of airplane in which the landing gear is suited to operation from the water.

SIDE-SLIP: Term applied to a partial or complete slip of an airplane, sideways, involving more or less complete loss of control. (Generally implies slip towards inside of circle on a turn.)

SKIDS: Horizontal wooden members of the chassis or running gear.

SKID, TO: Term applied to a slip or slide towards outside of circle on a turn.

*SLIP: This term applies to propeller action and is the difference between the actual velocity of advance of an aircraft and the speed calculated from the known pitch of the propeller and its number of revolutions.

SOARING: Gliding or coasting in a current of air, which is rising more rapidly than the gliding apparatus descends. This requires no internal power. The force of gravity supplies the force maintaining the required speed.

SOARING MACHINE: (See Glider).

SPAN: The distance from wing tip to wing tip, sometimes called the spread.

SPAR: Main members of the framework of an airplane wing, deck, or plane, running in a transverse direction across the line of flight, i. e., from wing tip to wing tip.

STABILITY, STATIC: The tendency to return to normal attitude (with respect to the relative wind) when forced from the normal by some outside influence.

DYNAMIC: Stability that is obtained by disposition of surfaces to produce "damping moments" tending to return the machine to normal when acted upon by forces that cause it to yaw (or swerve), roll, or pitch.

NOTE: Stability is obtained by use and disposition of secondary or auxiliary planes, or by arrangement of the main planes. Stability costs efficiency, and should therefore be reduced to the minimum required for the purpose.

STABILIZER: Fins designed and placed for a particular type of machine, to counteract any tendencies to yaw or pitch or roll.

*STAGGER: The amount of advance of the entering edge of the upper wing of a biplane over that of the lower; it is considered positive when the upper surface is forward.

*STALLING: A term describing the condition of an airplane which from any cause has lost the relative speed necessary for steerageway and control.

*STATOSCOPE: An instrument to detect the existence of a small rate of ascent or descent, principally used in ballooning.

*STAY: A wire, rope, or the like, used as a tie piece to hold parts together, or to contribute stiffness; for example, the stays of the wing and body trussing.

STEADINESS: Somewhat related to dynamic stability, is the tendency to "describe uniform paths in space," opposing rolling or pitching.

*STEP: A break in the form of the bottom of a float.

STEER: To guide by means of controls.

STEPPED: Where two or more super-posed planes are laced in tiers, like a flight of stairs; also called STAGGERED.

*STREAMLINE FLOW: A term in hydromechanics to describe the condition of continuous flow of a fluid, as distinguished from eddying flow where discontinuity takes place.

*STREAMLINE SHAPE: A shape intended to avoid eddying or discontinuity and to preserve streamline flow, thus keeping resistance to progress at a minimum.

STRUT: Upright spreader between the main planes or decks of super-posed planes. Vertical members of the chassis (running gear). Any member placed to withstand compression.

SWEEP: When an aerofoil passes through, or is passed around by, a mass of fluid, the vertical distance downwards through which the disturbed air acts is called the sweep. It is assumed to approximate the dimension of the chord. This vertical effect, acting upon the plane above it, is sometimes called "interference."

*SWEEP BACK: The horizontal angle between the lateral (athwartship) axis of an airplane and the entering edge of the main planes.

TAIL: The extension of the main body (or bodies) or outriggers from the main planes, carrying control surfaces, usually the elevators, stabilizer, and the rudder.

TAIL, LIFTING: In which a horizontal, fixed tail-plane is provided to carry a part of the weight of the machine.

TAIL, NON-LIFTING: In which the tail is not designed to carry any weight.

TANDEM AIRPLANE: A type of airplane in which one or more main planes are placed in rear of a similar main structure.

TERMINAL: The loop made in a wire or cable, with the other devices used to give it a permanent fastening to a fitting. All tie wires in airplanes are so fitted.

*THRUST DEDUCTION: Due to the influence of the propellers, there is a reduction of pressure under the stern of the vessel which appreciably reduces the total propulsive effect of the propeller. This reduction is termed "thrust deduction."

TIE: A member, usually a wire or cable, placed to withstand tension. (See Guy.)

TORQUE, PROPELLER: The propeller or screw of an airplane tends to rotate it on the fore-and-aft axis in a direction opposite to the direction of rotation of the blade.

TRACTOR: (See Airplane.)

TRAILING EDGE: The rear edge of an aerofoil or deck.

*TRIPLANE: A form of airplane whose main supporting surfaces are divided into three parts, superposed.

*TRUSS: The framing by which the wing loads are transmitted to the body; comprises struts, stays, and spars.

TURNBUCKLE: The device which unites two wires, attached at the other extremities to fittings, which enables tightening the entire tie to the desired tension.

VEER: Variation in the direction of the wind.

VELOMETER: (See Air-speed Meter and Anemometer).

VOL-PIQUE: (See Nose Dive).

VOL-PLANE: Gliding descent without power.

WAKE OR WASH: Disturbed stream of air caused by the passage of an airplane.

*WAKE GAIN: Due to the influence of skin friction, eddying, etc., a vessel in moving forward produces a certain forward movement of the fluid surrounding it. The effect of this is to reduce the effective resistance of the hull, and this effect, due to the forward movement of the wake, is termed the "wake gain."

In addition to this effect the forward movement of this body of fluid reduces the actual advance of the propeller through the surrounding medium, thereby reducing the propeller horsepower.

*WARP: To change the form of the wing by twisting it, usually by changing the inclination of the rear spar relative to the front spar.

WEBS: Reinforced section of the ribs in a plane or deck. (See Ribs.)

*WING LOADING: The weight carried per unit area of supporting surface.

WINGS: Each of the planes on each side of an airplane. The biplane has an upper right wing and a lower right wing, for example. The triplane would have three right wings and three left wings, etc. The entire right (or left) plane structure is called the right (or left) wing.

WIRES, DRAG OR DRIFT: Wires that tie the wings to the body taking up the drag or head resistance. ANTI-DRIFT: Wires that oppose the drag or drift wires to keep them taut while on the ground. FLYING: Wires that take up the lift of the wing, in flight, transferring the stresses to a main central beam, or supporting structure. LANDING: Wires that carry the load of the wings while on the ground.

YAW, TO: (See under Pitch).

*YAW, ANGLE OF: The temporary angular deviation of the fore-and-aft axis from the course.

APPENDIX B

Codes

(Codes from Signal Book, United States Army, 1914)

The International Morse or General Service Code

The International Morse Code is the General Service Code for use by the Army of the United States and between the Army and the Navy of the United States. It is written as follows:

Alphabet

A	. –	N	– .
B	– . . .	O	– – –
C	– . – .	P	. – – .
D	– . .	Q	– – . –
E	.	R	. – .
F	. . – .	S	. . .
G	– – .	T	–
H	. . . .	U	. . –
I	. .	V	. . . –
J	. – – –	W	. – –
K	– . –	X	– . . –
L	. – . .	Y	– . – –
M	– –	Z	– – . .

Numerals

1	. – – – –	6	– . . . .
2	. . – – –	7	– – . . .
3	. . . – –	8	– – – . .
4	. . . . –	9	– – – – .
5	. . . . .	0	– – – – –

Punctuation

Period	. . . . . .
Comma	. – . – . –
Interrogation Point	. . – – . .
Hyphen or dash	– . . . . –

The American Morse Code

The American Morse Code is used officially by the Army for electrical signalling. It is written as follows:

A	. –	G	– – .
B	– . . .	H	. . . .
C	. . .	I	. .
D	– . .	J	– . – .
E	.	K	– . –
F	. – .	L	—

M	— —	U	. . —
N	— .	V	. . . —
O	. .	W	. — —
P	. . . . .	X	. — . .
Q	. . — .	Y	. . . .
R	. . .	Z	. . . .
S	. . .	&	. . . .
T	—		

NUMERALS

1	. — — .	6	. . . . . .
2	. . — . .	7	— — . .
3	. . . — .	8	— . . . .
4	. . . . —	9	— . . —
5	— — —	0	——

PUNCTUATION

Period	. . — — . .
Comma	. — . —
Interrogation	— . . — .
Hyphen (HX)	. . . . . — . .
Dash (DX)	— . . . . — . .

VISUAL SIGNALLING

SIGNAL BOOK, U. S.

Signalling by Flag, Torch, Hand Lantern, or Beam of Searchlight (without shutter)

GENERAL SERVICE CODE

For the flag used with the General Service Code there is one *position* and there are three *motions*. The *position* is with the flag held vertically, the signalman facing directly toward the station with which it is desired to communicate. The first *motion* (the dot) is to the right of the sender, and will embrace an arc of 90 degrees, starting with the vertical and returning to it, and will be made in a plane at right angles to the line connecting the two stations. The second motion (the dash) is a similar motion to the left of the sender. The thi d motion (front) is downward directly in front of the sender and instantly returned upward to the first position. This is used to indicate a pause or conclusion.

The beam of the searchlight, though ordinarily used with the shutter like heliograph, may be used for long-distance signalling, when no shutter is suitable or available (in a similar manner to the flag or torch), the first position being a vertical one. A movement of the beam 90 degrees to the right of the sender indicates a dot, a similar movement to the left indicates a dash; the beam is lowered vertically for front.

To use the torch or hand lantern, a footlight must be employed as a point of reference to the motion. The lantern is most conveniently swung out upward to the right of the footlight for a dot, to the left for a dash, and raised vertically for front.

To call a station make its call letter until acknowledged, at intervals giving the call or signal of the calling station. If the call letter of a station is unknown, signal A . – at intervals, followed by the call or signal of the calling station until acknowledged. In using the searchlight without shutter throw the beam in a vertical position and move it through an arc of 180 degrees in a plane at right angles to the line connecting the two stations until acknowledged; a similar procedure is employed with the torch or hand lantern. To acknowledge a call, signal MM – – – – front followed by the call letter of the acknowledging station.

If the sender discovers that he has made an error, he should make AA . – . – front, after which he begins with the word in which the error occurred.

To break or stop signals from the sending station, make with the flag or other signal apparatus the signal BK – . . . – . – front.

To start the sending station, signal CC front A front, – . – . – . – . front . – front, followed by the last word correctly received. The sender will then resume his message, beginning with the word indicated by the receiver.

Each word, abbreviation, or conventional signal is followed by front.

CONVENTIONAL VISUAL SIGNALS

The following conventional signals will be used with the flag, or torch, hand lantern, or beam of searchlight (without shutter):

End of a word	front
End of a sentence	front front
End of a message....................	front front front
Signature follows	sig front
Error	AA front
Acknowledgment (or) I understand..	MM front
Cease signalling	MMM front
Repeat after (word)	CC front A front (word)
Repeat last word	CC front front
Repeat last message	CCC front front front
Move a little to the right	RR front
Move a little to the left	LL front
Move a little downhill	DD front
Signal faster	FF front
Wait a monent	. – . . front
To break, or stop sending	BK front

PROPOSED CODE FOR CONTROL OF ARTILLERY FIRE FROM AN AIRPLANE

Letter of Alphabet	*If Signalled from Battery to Airplane.* (By canvas strips)	*If Signalled from Airplane to Battery* (By "Very" lights)
1 X	Commence observing for "range."	Range correct.
2 ...... E	Commence observing for "line."	Line correct.
3 V	Go out (straight away from battery).	Must go out for better observation.
4 I	Come in (straight toward battery).	Must come in for better observation.
5 ...... N	Cannot comply with last signal (trouble).	Cannot comply with last signal (distress).
6 .... Δ	Stand by for next signal.	Have completed last signal.
7 ...... T	Turn (ignore last signal) or (last observation completed).	Must turn for better observation.
8 ...... H	Incline to the right.	Must incline to the right for better observation.
9 L	Incline to the left.	Must incline to the left for better observation.
10 II	Close flight (flight complete) or (descend).	Must descend.
11 III	Observe for "burst."	"Burst" (or fuse) correct.
12 IV	Sun obscures your signals.	Your signals are not clear.

The battery normally employs strips of white canvas to make the signals. It will be noted that any of the above letters can be made with three strips of canvas.

The observer of the airplane signals by the use of any one of the schemes provided for him. The usual practice is by Very Lights.

Canvas strips 15′ x 3′ are visible from an altitude of 9,000 feet.

APPENDIX C

JUNIOR MILITARY AVIATOR TESTS

(a) Five figures-8 around pylons keeping all parts of the machine inside of circle whose radius is 300 feet.

(b) Climb out of a field 1,200 x 900 feet and attain 500 feet altitude, keeping all parts of machine inside of field during climb.

(c) Climb 3,000 feet, kill motor, spiral down changing direction of spiral, that is from left to right, and land within 150 feet of previously designated mark.

(d) Land with dead motor in a field 800 x 100 feet, assuming said field to be surrounded by a 10 foot obstacle.

(e) From 500 feet altitude, land within 100 feet of previously designated point, with a dead motor.

(f) Cross country triangular flight, without landing of approximately 60 miles.

(g) Straightaway cross country flight without landing, of about 90 miles.

EXTRACT COPY OF SECTION 13 OF ARMY REORGANIZATION BILL

Provided further, That when it shall be impracticable to obtain from the Army officers suitable for the aviation section of the signal corps in the number allowed by law the difference between that number and the number of suitable officers actually available for duty in said section may be made up by appointments in the grade of aviator, signal corps, and that grade is hereby created. The personnel for said grade shall be obtained from especially qualified civilians who shall be appointed and commissioned in said grade; Provided further, That whenever any aviator shall have become unsatisfactory he shall be discharged from the Army as such aviator. The base pay of an aviator, signal corps, shall be $150 per month and he shall have the allowances of a master signal electrician and the same percentage in pay for length of service as is allowed to the master signal electrician.

APPENDIX D

STANDARD EQUIPMENT

AIRPLANE TOOL CHEST

(Cover)

1 Saw, hand, 26″.
1 Hammer, riveting, 8 oz.
1 Combination square, bevel and level, 12″.
1 Rule, folding.
1 Hacksaw frame.
1 Dividers, pair 6″.

(Top of Chest)

1 Wrench, Stillson, 14″.
1 Screwdriver, 7″.
1 Screwdriver, 5″.
1 Nail-puller.
1 Knife, draw 8″.
1 Hammer, tinsmith's, 1 pound.
1 Hammer, claw.
1 Tape, steel, 100 feet.
1 Brace, 10″.
1 Iron, soldering, 1½ lbs., 1 iron, soldering, jeweler's.
2 Center punches.
24 Blades, Hacksaw, coarse, 12 blades, Hacksaw, fine, 1 chisel, cold, ¼″, 1 chisel, cold, ½″.
saw, fine, 1 chisel, cold, ¼″, 1 chisel, cold, ½″.
1 Screwdriver, 8″.
1 Calipers, 6″.
1 Wrench, monkey, 6″.

(Upper Drawer)

1 Bit, expansive, ⅞ to 3″.
1 Pliers, round nose, 6″.
1 Pliers, snipe nose, 4″.
1 Pliers, adjustable, 8″.
1 Pliers, side-cutting, 8″.
1 Pliers, adjustable, 6″.
2 Pliers, auto, combination, cutting 6 and 8″.
1 Nipper-cut, 7″.
2 Pliers, diagonal, 6″.
1 Pliers, compound, side-cutting, 8″.
1 File holder.
1 Pliers, adjustable, 8″.
1 Spoke shave, 3″.
1 File cleaner.
10 Files, assorted, with canvas roll.

1 Screwdriver, 4″.
2 Wrenches, bicycle, 5″.
1 Palm, sewing; 8 needles, assorted; 1 ball flax and 1 ball wa

(Lower Drawer)

1 Stone, carborundum, 5″.
1 Torch, gasoline, flat.
1 Set thin open end wrenches with canvas roll.
1 Set drills, Morse, straight shank, with canvas roll.
1 Plane, block, 1⅝″.
1 Drill, hand.
1 Wrench, 7″.
3 Reamers, taper, bit stock, 1¼, 1-5/16, and 1⅜″.
1 Hatchet, half (small).
1 Snips, tinner's.