Non-rigid Airships

By F. D. Swan, M. E. '20

All the airships built in America up to the present time have been of the non-rigid type. In this type of ships there are no structural members in the envelope or bag to maintain its shape but is dependent entirely upon the pressure of the gas in the envelope, the shape of the patterns by which the fabric is cut and the distribution of the loads for its symmetry and strength. The most important builders of airships in this country are the United States Rubber Co., the B. F. Goodrich Rubber Co. and the Goodyear Tire and Rubber Co. of which the latter named has been the most successful as well as the largest producer.

Among the problems of the designer of this type of ship are fabric, reduction in weight of parts consistent with strength, proper distribution of loads to produce equilibrium, ballonets, control and power plant. The fabric problem is very important both from the standpoint of cost and weight. Fabric as usually constructed consists of two and sometimes three layers of cotton cloth between layers of compounds of rubber. The layer of rubber which is exposed to the weather is composed of a compound which resists the action of rain,, snow, wind and sun, and is primarily for the purpose of weather proofing and is not necessarily of a nature to resist the diffusion of hydrogen. Between the two layers of cotton cloth is a layer of rubber the chief duty of which is to make the fabric gas-tight. An inside proofing is some times, though not always, added to aid in preventing diffusion. The rubber is spread on the cotton cloth by machines called spreaders which roll the rubber compounds into the meshes of the cloth. In the case of two ply fabric one ply is made straight while the other ply after being spread is cut on an angle of 45 degrees into pieces of the proper size and turned through this angle when the two plies are rolled together. In the finished fabric then the warp of the two plies is at an angle of 45 degrees which makes a strong fabric capable of resisting the tendency of the envelope to twist. The question of how much gas-tight film to put between the two plies of cloth is largely a question of cost as to whether it is cheaper to increase the gas-film, increasing the fabric weight and thereby reducing the useful load or carrying capacity for a given volume, or to save the added weight of extra gas-film and allow a certain diffusion of hydrogen to take place and to replenish the ship with fresh gas at intervals. A compromise is usually affected allowing a diffusion of from 15 to 20 liters of hydrogen per square meter per 24 hours. Considering the large surface of the envelope the cost of hydrogen to replenish this diffusion is an item of some importance.

Since the weight of the fabric of the envelope is about one third of the total weight of the ship it must be made as light as possible and yet maintain a tensile strength of at least six times the stresses to which it is subjected. In other words a factor of afety of at least six is maintained throughout the design. Fabric for small ships such as have been built to date weighs from 14 to 16oz. per square yard. Experiments have been made constructing fabroc of silk lined with goldbeater's skin which have produced very low diffusion as well as light weight but the cost of this material is nearly prohibitive of its use in large quantities. The car, stabilizers and control surfaces, and car suspension are all built in a manner to minimize weight without sacrificing strength. Hence the very best of materials and workmanship must be employed and the inspection and testing of all work must be very rigid. The cars are built of laminated wood or veneer and covered with linen which is doped and varnished and form a light, smooth covering. Cars for several small sport type ships have been built in which the shell of the car has been made entirely of three ply veneer reinforced inside by bows of laminated wood. This gives a strong rigid structure with very light weight. The stabilizers and control surfaces are built of very light wooden trusses well braced and are covered with linen similar to airplane wings.

Probably the most important point in the design is that of equilibrium. It is desirable to have the ship in equilibrium with the nose down 2 or 3 degrees below the horizontal when the engine is not running so that when the propeller is running the moment of its thrust about the center of resistance of the ship will be sufficient to raise the nose to the horizontal position. To obtain equilibrium the ship is considered a beam having three concentrated loads acting on it. These are, the lift of the gas considered as acting upward at the center of buoyancy of the mass of gas, the weight of the envelope, control surfaces, valves and all parts above the car considered as a concentrated force acting at their center of gravity. and the weight of the car acting at its center of gravity. It is then a simple matter to take moments about a point and place the car at such a position that the clockwise moments equal the counter-clockwise moments. The center of buoyancy is found by dividing the volume of gas into a number of small sections, computing the volume of each section and multiplying it by its moment arm from any chosen point; the sum of the movements of all the sections of gas about this point divided by the total volume of gas gives the distance of the center of buoyancy from the point about which moments were taken. To determine the center of gravity of the envelope it is similarly divided into sections, the weight of the envelope fabric and attachments in each section carefully computed and moments taken about a chosen point; the sum of all the moments about the point divided by the total weight of the envelope and attachments gives

(Continued on page 27.)

NON-RIGID AIRSHIPS

(Continued from page 9.)

the distance of the center of gravity from the point of moments. The center of gravity of the car is usually obtained by experiment or by weighing.

Ballonets are air compartments within the envelope which are separated from the gas compartments by a collapsible fabric diaphragm. Their purpose is to maintain a constant pressure of gas under varying conditions of altitude and barometric pressure. On the ground before a flight it is necessary to have some air in the ballonets so that when an altitude is attained and the gas expands due to the lesser barometric pressure air may be expelled from the ballonets to keep the gas pressure from rising to a dangerous point. Conversely, on descending into a higher atmospheric pressure the volume of gas contracts and in order to keep the pressure up to safe flying condition air must be blown into the ballonets. Gas pressure in flying is usually about one inch of water at the bottom of the envelope and it is very essential that the pilot watch his manometer closely to see that the pressure does not become either too high or too low. A pressure that is too high may burst the envelope while one that is too low gives rise to the danger of buckling. The altitude to which a ship may rise without the loss of gas, which is costly, is determined entirely by the capacity of the ballonets. Two ballonets are usually placed in the envelope, one at the extreme nose end and the other at the tail and air is driven to them through fabric tubes on the bottom of the envelope by a blower located in the car, or by a scoop located in the air stream of the propeller. The scoop is arranged with a hinge joint so that it may be drawn up next to the envelope when not needed, in order to decrease head resistance.

The problem of control is of prime importance and in the case of new designs or shapes of the envelope, wooden models, made to scale, are given thorough tests in wind tunnels in order to determine with what ease it may be controlled and the size of the stabilizing and control surfaces. When the shape of the ship is not radically different from former designs it may be possible to determine the sizes and location of the controlling surfaces from information gained from the earlier design. Wooden models to the scale of one-fourth inch to the foot are always made in the design of a ship and are of great benefit in locating the control surfaces and their brace wire anchorages as well as the car suspension patches, maneuvering lines and morring bridles.

The car is suspended from the envelope by steel cables anchored to four-finger patches which are simply cemented to the envelope. When the work is carefully done this cemented joint is as strong as the fabric of the envelope and in breaking tests failure usually occurs in the fabric above the patch. One patch of this kind has supported 2000 lbs. for a month before failing, a test which is very much more severe than ever occurs on a ship in flight.

The power and size of the engine depend on the speed at which the s hip is to be driven and the type of engine installed. As a rule water cooled engines which are too light are to be preferred because of their greater reliability and their ability to run for longer periods of time without the necessity of overhauling.

While the ships built in this country for war purposes have compared favorably with foreign made ships as to performance and construction they have been very small, the largest having a capacity of 180,000 cu. ft. as compared with the 2,000,000 cu. ft. capacity of the British trans-Atlantic flyer, the R-34, and become still more insignificant when compred with the ships which England is now building having a gas capacity of 10,000,000 cu. ft. The R-34 proved its ability to cross the Atlantic but it is still too small to be of great commercial importance since its chief load across the ocean was its fuel which was nearly exhausted on the completion of the trip. No doubt the future will see ships of much greater capacity than those now dreamed of and if the United States is to be a leader in the navigation of the air it will be necessary for her to adopt a constructive policy soon or be almost hopelessly outclassed by the other nations.