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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 safety of at least six is maintained throughout the design. Fabric for small ships such as have been built to date weighs from 14 to 16 oz. per square yard. Experiments have been made constructing fabric of silk lined with gold-beater’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 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 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

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(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 com-
partments by a collapsible fabric diaphragm.
Their purpose is to maintain a constant pres-
sure 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 dan-
gerous 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 pres-
sure does not become either too high or too low.
A pressure that is too high may burst the en-
velope 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 balloonets. Two balloonets 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 deter-
mine 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 differ-
ent from former designs it may be possible to de-
terminate the sizes and location of the controlling
surfaces from information gained from the ear-
lier 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 lo-
cating 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 the 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 ship 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-At-
lantic flyer, the R-34, and become still more in-
significant when compared 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 navi-
gation of the air it will be necessary for her to
adopt a constructive policy soon or be almost
hopelessly outclassed by the other nations.