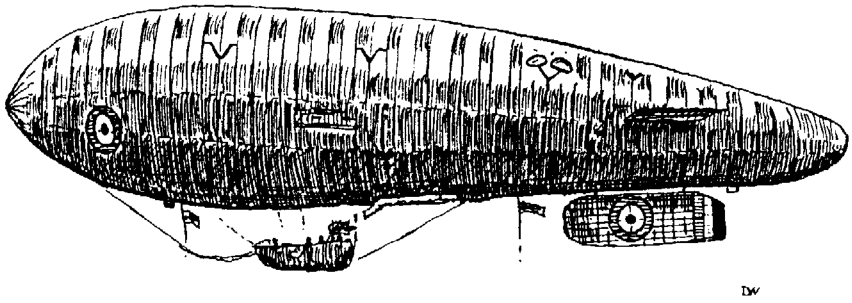
What Constitutes a Gas Bag ?



by John Davis

The short answer to the question might well be ‘the author of any overlong and boring Journal article'. Nevertheless, at the risk of being called one myself, I submit the following description of materials and testing methods used in the manufacture of gas envelopes for British WW1 airships, such as the Submarine Scout, Coastal and North Sea types. This offering is intended for true lighter-than-air enthusiasts, so I will forgive any readers who choose to move on to other, less specialised articles.

Although the lifting properties of both hydrogen and helium were well known prior to 1914, only hydrogen was put to any practical wartime use. It is, of course, the lightest gas known and can be manufactured quite cheaply, using a variety of methods. Its one great disadvantage is however, its high flammability and explosive properties when contaminated with even small amounts of air. Helium, on the other hand, is non-flammable but lacks the lifting power of hydrogen. At that time it was also extremely expensive to manufacture and was produced only in the United States, where an embargo had been placed on its exportation.

Both hydrogen and helium have the ability to easily escape through any of the basic flexible materials then available for use as airship fabrics. Prior to the war most fabrics used for this purpose consisted of strong cotton or linen material with an outer weather-resistant coating and an inner gas seal made from goldbeaters' skins. This method had been developed in continental Europe some time before the turn of the century but was unknown in England until the arrival there of an Alsatian named Weinling, who passed on the details to the War Office. The British government kept the information secret for some time before making it generally available to industry.

Goldbeaters' skins were the inner linings of the intestines of oxen, cut up into rectangles measuring approximately 8½" x 11" (2l5mm x 280mm). These were dried before being glued onto a backing of fine Egyptian cotton or linen. While in storage they were kept supple with a thin coating of glycerine. Early experience gained by the army Kite Balloon Section showed that the skins tended to crack after a time due to the combined effects of heat, light and moisture. The useful life expectancy of an airship envelope was only about three years.

Even before the war, goldbeaters' skins were difficult to obtain; most of the available supply had been taken up by the various German airship companies. A considerable amount of effort was, therefore, put into finding a suitable substitute.

Silk, Ramie and Zeppelin fabric were all tested and subsequently rejected, for the following reasons:

SILK: Light and strong, but found to lose considerable strength when rubber-coated.

RAMIE: A Malayan nettle fibre-based fabric. Very strong, but also heavy and expensive.

ZEPPELIN FABRIC: Found to absorb water easily. Supply had been difficult before the war and was not expected to improve.

The material finally chosen was cotton, which was manufactured in the following grades:

GRADE	WEIGHT (gms/sq mtr)	STRENGTH (kg/mtr)
A	130	1300
B	105	1100
C	80	800
D	65	650

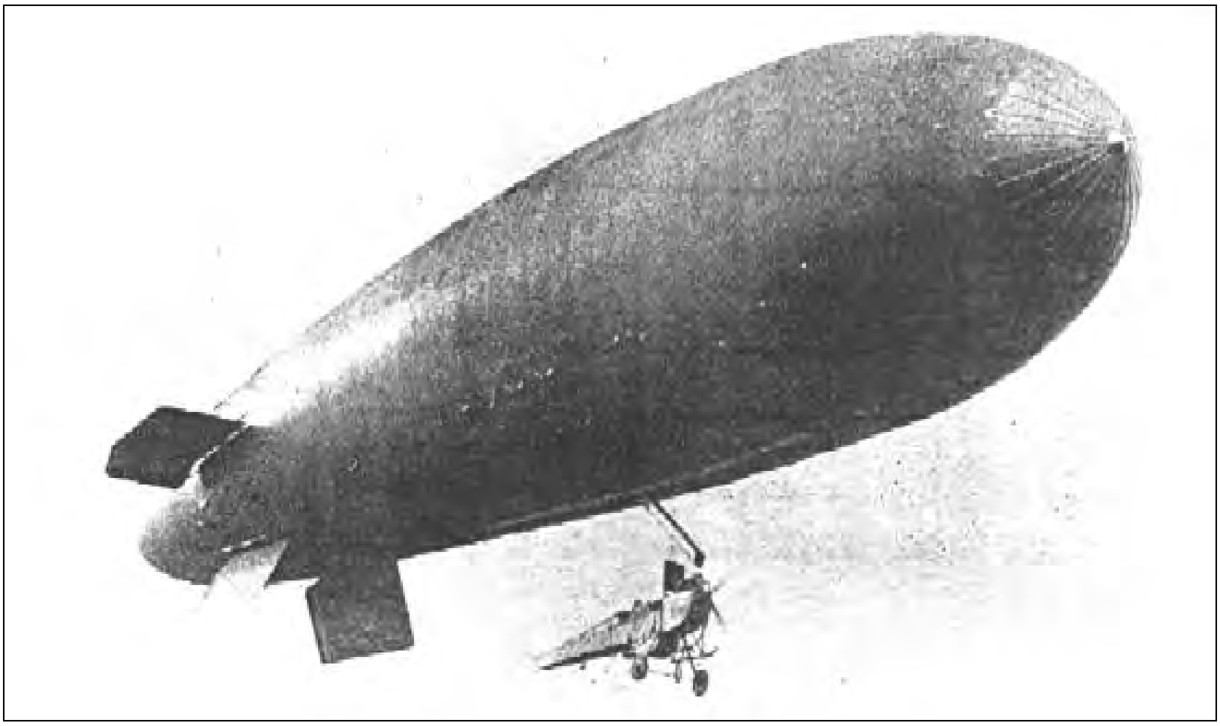
After a few trials, all envelopes were made from two thicknesses of 'C' Grade cotton, with the layers biased; although some early envelopes were made with parallel warp and weft in both layers. The other grades were used to reinforce those areas of the envelope thought to be most highly stressed, such as the rigging attachment points, and weaker areas like the ripping panels (fitted to the top of the envelope to allow the rapid release of gas in an emergency).

The two fabric layers were glued together with a type of vulcanized rubber (about 30 gms/sq mtr) sandwiched between them. An additional heavy coating (about 70 gms/sq mtr) was applied to the inner surface to prevent gas loss. The finished material was subjected to a simple testing procedure, which involved cutting a cross-shaped test piece, with arms wide enough to produce a square section at its centre. This was suspended by clamps fitted to the end of each arm and a weight was hung from the centre of the square section. It was soon realised, however, that this was not a very accurate method because of uneven stress distribution and the localised high stress areas at the junctions of the arms.

In operational use, it was found that fabric failures sometimes occurred in quite unexpected places. Further tests were carried out on the fabric after a more detailed assessment of the loading pattern had been undertaken. The forces acting upon the envelope resulted from a variety of load factors, such as internal gas pressure, the attachment points of suspension cables for the fuselage and external fuel tanks, sheave blocks for guiding cables to flight controls, and gas and air valves.

During the next four years, the following became the standard testing procedure:

(A) Test pieces of 2-ply fabric were made into 5" (125mm) diameter cylinders, 30" (760mm) long, with metal end closures. These were inflated, to set up both circumferential and longitudinal tensions.



The first Sea Scout airship.

(B) The above test was repeated, with the cylinder ends gripped in an Avery testing machine, which further increased the tensile stress.

(C) Other cylinders, measuring up to 3.4 metres in diameter, were manufactured and tested to destruction, using air-pressure.

(D) A model of the entire envelope, 20 feet (6 metres) long was made, using 3-ply fabric, into which a complete 2-ply gore was fitted, with all normal attachment fittings added, to scale. This was inflated and various model loads attached; the times taken to burst or distort the envelope being carefully noted.

(E) The above tests were repeated at various times, using samples of single and double-ply fabrics that had been pre-aged, in order to determine the effect of service damage and life expectancy.

In service both the cotton and rubber were found to decay as a result of the action of light, heat and tension; light having the most detrimental effect. A report, published in THE JOURNAL OF THE SOCIETY OF DYERS AND COLOURISTS, dated January 1917 and referred to the War Office for study, showed that ultra-violet light, in the presence of oxygen, caused a rapid deterioration in the strength of linen fabric fibres. It was, of course, impractical to protect the material from oxygen, but possible to provide some protection from the UV light. Various forms of dyes, dopes and paints were tried before it was finally decided to cover the upper half of the envelopes with a rubber-based coating, applied at 50 gms/sq mtr.

With all that rubber protecting the fabric is was thought that most of the problems had been solved. However, during further tests the material continued to show signs of failure - albeit after longer periods of time.

More investigations revealed that the rubber, being of the vulcanizing type, contained up to 5% free sulphur. This oxidised quite rapidly and in a moist atmosphere produced a weak (sulphuric) acid that attacked the cotton fabric fibres. Heat generated within the envelope during warm weather also caused an increase in the rate at which the rubber oxidised.

Adding dyes to the rubber solution helped to protect the rubber itself, but yet again, this tended to cause damage to the cotton. The most commonly used outer finish seems to have contained 20% Litharge, with a final covering of aluminium to help reflect excess heat.

Samples of the finished fabric were subjected to tension tests for prolonged periods. It was found that some outer protective coatings tended to roughen under prolonged tension. This allowed the aluminium to rub off more easily, causing a speed-up in the oxidisation of the rubber in localised areas. his, in turn, led to premature failure of the underlying cotton fabric.

The early (pre-1914) history of lighter-than-air flight is a litany of similar problems experienced by all airship designers and builders. These invariably caused frustrating delays and the postponement of flight trials. Some gas bags or envelopes were quite incapable of becoming airborne until they had almost reached the end of their useful lives. In fact, had the adverse effects of fabric ageing been even vaguely understood at that time, it is highly probable that many of them would never have flown at all!