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By Capt. L. Chollet, of the S.T.Ae.

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## BALLOON FABRICS MADE OF GOLDBEATER'S SKINS.\*

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### Historical Sketch of Balloon Fabrics.

Balloons utilize the lifting force of some gas lighter than air. This gas is contained in a bag or envelope which must be strong enough to withstand the stresses to which it is subjected, as light as possible and as gas-tight as possible, in order to minimize gas leakage and loss of lifting force from the admission of air.

Of these three qualities, gas-tightness is the most essential characteristic of balloon fabrics. It is true, moreover, that this property can be attained to a greater or less degree, according to the object in view. A mediocre degree of tightness answers for free balloons, since they remain inflated for only a few hours at a time. Captive balloons, which need to remain inflated for several months, must be made of very tight fabric. Lastly, it is important to obtain the most perfect tightness possible for airships, which must remain inflated for many months and for which the least diminution of the lifting force affects the carrying capacity.

The Montgolfier brothers employed, for a gas heavier than air, the air itself heated. Even with a very porous fabric, the diminution of the lighting force due to the lack of tightness was very small in comparison with that due to cooling. Their balloons were made of cotton cloth, lined with strong paper. The

\* From "L'Aéronautique," August, 1922, pp. 258-262.

envelope of one of them was made of two thicknesses of cloth, between which there were three thicknesses of ruffled paper.'

The physician Charles, and the Robert brothers, who employed hydrogen, adopted silk cloth coated with caoutchouc.

In September, 1783, several months after the experiment of the Montgolfier brothers at Annonay, (June 5, 1783), and several days after that of Charles and the Robert brothers at Paris, (August 27, 1783), Baron Beaumanoir sent up an 18-inch hydrogen balloon of goldbeater's skin. This experiment brought into fashion balloons of goldbeater's skin, which were sent up in large numbers by Parisians.

The Aero-Montgolfière, with which Pilâtre de Rosier killed himself, June 15, 1885, was made of Taffeta impregnated with linseed oil, dried with litharge and covered with goldbeater's skins, glued on with a strong glue mixed with honey and linseed oil.

The balloons, constructed toward the end of the 18th century, were made of cotton or silk cloth, covered with paper or with oil varnish, gum arabic or caoutchouc.

The captive balloons of the First Republic were made of silk covered with a varnish prepared by Conté. The tightness was remarkable, since, according to the statements of historians at the time, the balloon companies were able to remain away from the hydrogen generator for several weeks, without the balloon losing any considerable fraction of its lifting force. Conté's formula was lost and never found.

During the greater part of the past century, the history of

perostation is that of the free balloon and the tightness obtained by varnishing cotton or silk fabric was quite satisfactory. Since, on the other hand, most of the airship projects were never begun to be put into execution, there was not much progress made in the tightness of balloon fabrics. Mention should be made, however, of the attempt of Marey Monge to make a copper balloon, though it did not ascend, owing to the failure of the hydrogen before the inflation was completed.

When, several years after the war of 1870-1871, Col. Charles Renard undertook the necessary experiments for determining the best materials for captive war balloons, the tightness of the fabrics was one of the problems to which he gave special attention. Many varnishes were tried, but all attempts to reconstitute the famous varnish of Conte were in vain. Col. Renard prepared a varnish, which was called Chalais varnish and which gave very satisfactory results for free and captive balloons. Unfortunately, the manipulation of varnished balloons is very difficult and the fabric deteriorates with time.

It was not until the beginning of the present century that endeavors to improve military balloons and construct airships led to the discovery of balloon fabrics much tighter than varnished fabrics. Caoutchouc was employed to make a gas-tight skin. The rubberized fabric consists of one, two or three thicknesses of cotton or silk cloth and from one to four layers of caoutchouc.

In France, where nonrigid airships alone found favor until

within a few years, rubberized fabrics furnished an excellent solution of the tightness problem, alike for airships, captive balloons and free balloons, and but few attempts have been made to substitute for caoutchouc any other substance more impermeable to gas.

In Germany, on the contrary, where, from the beginning, efforts have been directed to rigid airships, the problem of balloon fabrics does not present itself in the same manner. A weaker fabric could be used, since the gas was distributed in a certain number of gas bags or ballonets, protected by an outside envelope. On account of the considerable weight of the hull, it was necessary, however, to attain the maximum degree of tightness and lightness. It was in Germany that rubberized fabrics were first made, but experiments were very soon directed toward the employment of goldbeater's skin.

In England, the use of goldbeater's skin for balloons was quite common before the war. Captive military balloons and the airship "Nulli Secundus" were made entirely of goldbeater's skin without the addition of any fabric.

When, at the beginning of 1917, the construction of rigid airships was contemplated in France, the question of employing goldbeater's skin for making ballonets arose. It was only at the beginning of 1920, however, in the presence of the results obtained by the English and after receiving many reports on what had been accomplished in Germany during the war, that a thorough and methodical study of the use of goldbeater's skin was undertaken by the S.T.Ae. (Technical Section of Aeronautics).

### GOLDBEATER'S SKIN.

This is the current term for the prepared outside membrane of the large intestine of the ox, used for separating the leaves of metal in goldbeating.

Immediately after slaughter, the body of the animal is cut open and the bowels removed. The membrane is separated from the intestine by hand and laid aside. It has the form of a cylindrical bag of 0.5 to 1 meter long and about 0.1 meter in diameter, split along a generatrix to within a few centimeters of the end.

In the large slaughter houses of North and South America and Australia, the separation is done with much care, so as to avoid tears. The membranes (or "skins") are then sent to the section which prepares them. They are thoroughly cleansed, assorted and separated, according to size, into two classes; then spread out and covered on each side with a thin layer of very fine salt. They are then put 25 in a pack, all the same side up, rolled up, tied and placed in casks containing 3000 - 3500 skins of the first class or 4500 - 5000 of the second class. Skins thus prepared can be kept a long time without deterioration.

The European slaughter houses are too small to have a separate section for treating the membranes. Generally the gut workers themselves attend to collecting the skins and either treat them immediately or prepare them to send to specialists. In the latter case, the skins are cleansed, salted and tied up in bundles of 25 or 50.

There are very few specialists in this work in France and most of their raw material comes from America and Australia, the balance from local dealers and slaughter houses. The skins, after drying, are passed through baths of potash or soda, oxygenated water and sulphurous acid for removing grease and color. They are then stretched singly on boards and dried. They are then ready for use. Each skin forms a sheet 0.6 to 1 meter long by 0.15 to 0.20 meters wide, similar to a sheet of tissue paper. Goldbeater's skin, thus prepared, is used principally by goldbeaters, and by perfumers for covering stoppers of bottles.

#### Employment of Goldbeater's Skin in Germany.

Experiments on the employment of goldbeater's skin in preparing balloon fabrics were probably undertaken in Germany from the beginning of their researches in connection with airships. It seems, however, that at the time of the declaration of war, the period of these experiments had not been terminated and that the question of materials for the ballonets of rigid airships had not been definitely settled. The Zeppelin which landed at Luneville in 1913 had, in fact, some ballonets of varnished fabric, some of rubberized fabric and others of goldbeater's skin. In this domain, as in many others, the war brought about considerable progress and, in 1918, there were being made in Germany, many thousands square meters per day of goldbeater's skin fabric, the tightness of which was practically perfect.

Goldbeater's skin from oxen and cows did not enter alone

into the composition of the fabrics made by the Germans during the war. One animal furnishes only one such skin and 15 of them were required to prepare one square meter of the fabric. Twenty-four Zeppelins, each with a ballonnet surface of 20,000 to 30,000 sq.m., were put into service during 1917. It follows, therefore, that the Germans, reduced by the blockade to their own resources and to those of their allies, were obliged to resort to substitutes possessing nearly the same qualities as goldbeater's skin.

Skin G was the regular goldbeater's skin.

Skin P was the corresponding preparation from the intestines of hogs, in fragments about 0.95 meters long. It could be taken from neither too young nor too old hogs.

Skin L, in lengths of 1.1 - 1.3 meters, was the inside membrane of the portion of the intestine of an ox or cow known as the "crown intestine."

The manufacture of goldbeater's skin fabrics is based on the following property. If two skins are superposed after the treatment and allowed to dry, they adhere perfectly. If therefore, a certain number of skins are juxtaposed with an overlap of a few millimeters, there is obtained, after drying, a single leaf possessing the same qualities as the component skins. If, before drying, a second layer of skins is placed on the first layer, under the same conditions, there is obtained, after drying, a very homogeneous double skin, the tightness of which is

practically perfect, since the single skin is already very tight by itself.

Goldbeater's skin fabrics were used during the war almost exclusively in making the ballonets of rigid airships. It was only near the end of the war that the Germans placed in service a few captive balloons made of such fabrics. For airships, the first layer was always composed of skin G, the second being either skin G, P, or L. For captive balloons, skin P was used, either double or in combination with skin L. For the remainder of this article, we will consider only the manufacture of airship ballonets.

The ballonets of rigid airships are cylinders or frustrums of cones with flat ends. They are made in a certain number of sections of as large dimensions as can be conveniently worked, which are then varnished and glued together.

The collection of the goldbeater's skins was very systematic in Germany during the war. Each butcher was required to deliver the ones from the animals he killed. Agents exercised strict control in Austria, Poland and Northern France, where it was forbidden to make sausages. The skins were cleaned and salted on the spot and then sent to the factory where the fabrics were made.

On arrival at the factory, the skins were separated into three classes: G, P, and L. After the defective skins were discarded, the rest were scrubbed and washed in cold water and then in warm water at 35 and 45°C, so as to remove all salt, foreign substances, mucous and grease. Silver nitrate tests showed

whether the cleansing was complete. The skins were next left over night in a tank of clear water and then 24 hours in water containing 5% of glycerine. They were then drained and sent in pails to the gluing room.

In this room, the sheets of double skins were made, on which the fabric was ultimately glued. The equipment of this room comprised:

The gluing table, steeply inclined, which had (beginning at the bottom) a plain part 1.5 meters high, a latticed part 2 meters high and a roller.

The "doublier" made of very strong, closely-woven cotton cloth. The seams had to be very carefully made, so as to avoid folds. The "doubliers" were either 11 x 42 meters or 23.5 x 38 meters, the gluing tables being a little wider than the "doubliers."

The "doublier" passed over wooden cylinders placed end to end in a trough under the table. It was mounted on the plain part and stretched on the edges by means of strips and clamps. The workmen were stationed at intervals of 1.5 meters and the skins were brought to them by twenties in enameled iron pans. The skins were lifted by the long side with all the fingers of the hand and laid on the "doublier" with their longest dimension upward and the wrinkled side down. They were then spread out and smoothed carefully by hand, so as to remove air bubbles. The edges were lifted with a special knife. The skins overlapped one another about one centimeter. Thus there was made a layer about one meter

high, ending about 5 cm from the lower edge of the table. The second layer was begun at about 10 cm from the bottom, with the longest dimension of the skins at right angles to that of the skins in the first layer and with the wrinkled side up. After this first section was finished, defects (scratches, thick edges, fat, etc.) were sought out and remedied. The "doublier" was then moved up one meter and the second section was made, care being taken to match each layer to the corresponding layer of the first section, and so on. The drying was done by means of fans blowing on the latticed portion. The "doublier" passed over the top roller and descended behind the table. There the sheet of double skins was carefully removed and placed in a trough.

The sheets were then sent to the assembling room, along with the fabric for joining them. There they underwent two examinations: the first, by transparency, for discovering defects (scratches, holes, absence of one layer, etc.), which were marked with red or blue pencil; the second, on a polished table covered with waxed canvas, for discovering by touch any grains of sand, which were marked. They then went to the gluing room, where there were special tables 35 to 40 meters long and about 1.5 meters wide. The sheet was placed in one of the troughs of the gluing table. The first strip of about 1.5 meters was placed on the table and held loosely with pincers. It was moistened by hand with 5% glycerine water and stretched. The defects were then repaired by means of pieces cut out of a double sheet of skin and glued with a glue more concentrated than ordinary glue. As soon

as all the defects were repaired, the gluing proper was begun. The gluing gang consisted of one forewoman and eight to ten workwomen stationed on both sides of the table. The first two women spread, over an area 1 x 1.3 meters, about 250 cc of glue at about 40°C. The next two women unrolled the fabric and held it up. The next women stretched it and applied it with brushes. These operations had to be performed very rapidly, for the glue hardened on cooling. The gluing was thus continued by lengths of 1.3 meters. When the first one-meter strip was finished, it was dried by means of fans and then slid over the edge of the table, thus there was brought on to the table a second one-meter strip, which underwent the same operations. The glue contained 10 kg of gelatine, 8 kg of glycerine, 10 kg of sulphoricinate of soda and small quantities of creosote and caustic soda for each 100 kg of water. The varnishing and assembling of the various sections of the ballonets took place in the assembling room.

The Zeppelin Company had made, before the war, arrangements for the construction of its ballonets at Tempelhof, a suburb of Berlin. The factory was not completed, however, until after the armistice. During the war, the skins and fabrics were assembled at Britz. The ballonets of the Schütte-Lanz Company were made in the Riedinger shops at Augsburg.

The German goldbeater's skin fabrics had, for a weight of 130 to 150 g per sq.m, a tightness permitting the loss of only a few liters of hydrogen per sq.m in 24 hours, under a pressure of 30 mm of water.

Goldbeater's Skin Fabrics in England.

During the war, the English used only rubberized fabrics, both for their small, nonrigid airships and captive balloons. The use of goldbeater's skin was first considered, when they undertook the construction of large airships. At that time, the process employed by the Germans was known, at least in a general way. Nevertheless, probably to avoid the necessity of so large an outfit, the English balloon makers adopted a mixed fabric, composed essentially of a cotton fabric, a layer of caoutchouc and a layer of goldbeater's skin.

The raw materials, employed in making ballonets for English airships, are: a very lightly rubberized fabric composed of a 90-gram cotton fabric covered with a caoutchouc film weighing about 10 g per sq.m; goldbeater's skin, freed from salt, washed and glycerinated, by a process similar to that employed by the Germans, and then dried.

In making a ballonet, the ends and cylindrical or conical parts are assembled without seam by simply gluing with the caoutchouc solution. On each of these sections there are glued goldbeater's skins by means of a very clear solution of caoutchouc (3.5 kg of para rubber for 180 liters of naptha). Two coats of this glue are applied and allowed to dry and then a third coat is applied. The goldbeater's skins are then put on, with an overlap of a few millimeters.

After applying the goldbeater's skins, the ballonet sections are coated with copal varnish on the goldbeater's skin side only

and then assembled by simply gluing, without making a seam. Care is taken to unglue slightly the goldbeater's skins on the edge of one of the sections, so that the glue will hold the fabric together. Then the skins are flattened down and reglued to the skins of the other section. The tightness and weight of this fabric compare favorably with those of the German goldbeater's skin fabrics.

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