APPENDIX E

## MANUFACTURE OF THE GAS BAGS OF R.101

This document was written by the Works' fabric manager and resident chemist, J. W. Ward Dyer. He prepared it, in November 1930, for the Simon Inquiry. At the Works, Dyer created and maintained the airship's cloth cover and the gas bags. In this document he detailed the creation of a gas bag from 50,000 oxen entrails. Dyer's training as a chemist shines through as he discusses the solutions, varnishes and glues applied to the skins. He became fascinated by airship fabrics while studying at the University of London. His MS thesis, there, in 1920, was on "The chemical and mechanical changes accompanying the decay of certain types of non-rigid airship fabric, together with considerations on some aspects of the weathering and protection of fabrics." He continued this line of research at the Works, where he tirelessly searched for the perfect airship fabrics. For example, to find the right cloth for R.101's cover he once shone a mercury vapor lamp on a piece of cotton for a week until it turned biscuit yellow and "showed a complete loss of strength."

This document focuses on the preparation of the animal entrails to create a gas bag. Dyer calls them "skins," but the gas bags were constructed from oxen cecum—the intraperitoneal pouch at the beginning of the large intestine. Although today we would use a synthetic material, none were acceptable at the time. No plastic or rubber had the three qualities of cecum that were ideal for a gas bag: the cecum was thin, and so lightweight, it was flexible, and nearly impermeable to hydrogen. In the first half of this

document Dyer describes the production of a gas bag from arrival of the animal entrails packed in salt to the assembly of the processed entrails into a gas bag with a volume of 250,000 to 500,000 cubic feet. One marvels at how he ever arrived at the precise steps—soaking in glycerin, the exact temperature of the gluing room, the humidity of the assembly shop, and the fine sandpaper used to abrade the edges before final assembly. In the second half of the document he describes the types of cotton appropriate for gas bag construction, the composition of the glues used, how the strength of the seams was tested, how to repair a gas bag in situ, and the time to deflate a gas bag with a volume of 500,000 cubic feet.

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MR. JOSEPH WILLIAM WARD DYER, MSc (Lond.) AIC, Fabric Manager and Chemist, Royal Airship Works, Cardington, will say:

The gasbags are made of a cotton fabric lined with goldbeater skin, these two components of the bag being united by a special form of glue. The separate processes in making the gasbags are as follow:

- Scraping the skins.
- Laying the skins.
- Gluing the sheet of skin to the cotton fabric.
- Cutting the complete skin and fabric sheet to its correct shape.
- Joining these sheets together to form the bag, and after various fittings such as filling and emptying valve sleeves and handling patches have been attached finally varnishing the material on both faces. Those operations are described in detail below.

**Scraping the skins**

The skins are taken from the salt in which they are packed and washed in warm water, scraped free from excessive fat and other foreign matter, again

washed and soaked overnight in a 5 percent solution of glycerin in water.

**Laying the skins**

The next process is to assemble the individual skins so as to form a large sheet of skin ready for gluing. Such a sheet will form a large component of the finished part, for example, the whole end of a small bag, one-half or one-third of the end of a large bag or a quarter or one-fifth of the body of a bag. This will be readily understood by a reference to the model. The skin sheet at this stage is made rather larger than and roughly the same shape as the component part of the bag which it is intended to cut from it when the fabric has been glued to it. The assembly of the skins into this sheet is carried out by laying them one at a time in a wet condition with the margins of adjacent skins overlapping about half an inch on a smoothly stretched canvas cloth which rests on a board to give it firm support, so that the skins laid on it can be firmly pressed down and smoothed out. The board slopes away from the worker at an angle of about 50° and below the board in front, the canvas on which the skins are to be laid is wound on a roller. The canvas continues upwards away from the worker and on to a second roller at the back of the bench. It will be clear that the board, the canvas and the rollers must be slightly wider than the width of skin sheet it is desired to make. As the work progresses, the canvas is wound from the front roller to the back roller bringing fresh stretches of it over the working board in turn to be covered with the overlapping skins in the way referred to. Beyond the upper edge of the sloping board, the cloth carrying its assemblage of skins on the way to the second roller at the back of the bench passes over supporting slats of wood. It is thus well ventilated: the skin sheet therefore, dries and is readily peeled from the canvas before the latter is rolled on to the second roller. The canvas is thus merely a background on which the skin sheet is assembled and the sheet as it leaves this stage is merely a sheet of skin with no fabric attached to it. It may be termed two-ply skin sheet, for on the working board referred to each width of canvas as it comes up from the roller is covered with a double layer of the wet overlapping skins. From the glycerin water in which the skins have been worked, the dry skin sheet retains a little glycerin. This slightly increases its flexibility as glycerin is hygroscopic and goldbeater skins are rendered flexible by the presence of moisture. Small holes in the goldbeater skins as received or made in the act of scraping them are of quite common occurrence. These are patched with small cuttings of wet skins in the act of laying the skins on the board. It should he stated that no

adhesive of any kind is used to make the individual skins unite into the large sheet.

**Gluing**

The gluing is done in a special shop in which the temperature is maintained at a minimum of about 68° to 70° Fahrenheit. This is necessary to ensure that the glue remains in the proper condition, that is fluid and workable, in the operation of gluing the cotton fabric to the skin. The skin sheet is held by clamps along one edge of a table a little more than a meter wide whose length is slightly greater than the width of the sheet. It is then slightly moistened with water and gently pulled towards the other edge of the table to eliminate most of the wrinkles and is then clamped along that edge too. At this stage each width of skin sheet is inspected for holes which may have escaped patching in the previous operation. To this width of prepared and now repaired skin sheet, the appropriate cotton fabric about one meter wide is glued. The gluing operation may be carried cut in either of two ways and both ways were used in the gasbags of R.101. The first method is called gluing through the cotton and the second gluing on the skin. The first method was used in all bags except the bag NO. 8.A. made for the new bay of the ship. In the first method, the length of cotton is laid on the skin sheet and the glue is applied to the upper face of the cotton and rubbed in by hand and squeegee. In the second method, the glue is applied direct to the skin surface and the cotton fabric previously rolled on a roller is rolled on to the glued surface and as in the former method well pressed down with the hand and squeegee. There is no difference in the quality of the product by either method, but the second one is slightly more rapid. It must be understood that the skin sheet to which the fabric is being glued in this way is the continuous piece made on the skin laying bench and that as it passes over the gluing tables for the attachment width by width of the cotton fabric, each width of the latter is overlapped about an inch on the margin of the preceding panel. This overlapping joint we speak of as a "panel seam." In all the bags except NO. 8.A. these panel seams were covered with a tape of thin cotton fabric and about 1¼″ wide. This taping was omitted in the panel seams of all parts of bag NO. 8.A. This matter is further discussed in connection with the strength of the fabric and of the seams in the fabric in a subsequent paragraph. It will be appreciated that the discontinuous sheet of skin has now been covered with these continuous but overlapping panels of cotton fabric. The glue is of special quality, and in addition to the prime quality

of good adhesive power, flexibility is essential. The basis is a high grade hide glue. With appropriate adjustments of the proportion of glue base to water, many high quality glues would be admissible in this work. We have, however, used one throughout, namely Messrs. Cannon's I.L. propeller glue. A typical formula for the glue is the following:

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|---|---|---|
| Water | … | About 200 gms. |
| Glue | … | 18 gms. |
| Creosote | … | 0.8 gms. |
| Glycerine | … | 16.5 gms. |
| Turkey Red Oil | (75% grade) | 10.0 gms. |

The formula is referred to as typical and not as *the* formula, because the proportion of water is varied to produce the desired working viscosity which varies a little from one purchase of glue to another. The creosote is present as a preservative and to prevent, or at any rate to retard, the growth of molds. The glycerine is by its hygroscopic nature, to render the glue flexible and the turkey red oil indirectly promotes the same end. For Bag NO. 8.A. a different formula was used, in that the turkey red oil was omitted, for it had been discovered that the purpose served by the presence of the oil was rather better served if instead of putting it into the glue, the appropriate amount was introduced into the cotton fabric itself before the gluing. The applied glue was rendered to a large extent waterproof by subsequent application of a weak solution of formaldehyde. This is in the form of a 1 percent aqueous solution was applied by brush to the cotton face of each panel immediately after the gluing operation and while the glue was yet soft. In the gluing shop parlance, this operation is always referred to as "fixing."

**Marking and cutting**

The material from the gluing shop is laid out on the assembly shop floor where the appropriate form and dimensions are marked on it from drawings. Two further operations are done at this stage. One is the attachment of the various fittings, that is, sleeves, handling patches, etc. Another is that a careful inspection is made of the skin surface for any defects and these are remedied.

**Varnishing**

This having been done, the sheet is then varnished to within about a 6-inch border all round with the appropriate varnish on each face. On the skin face,

the varnish is a highly [sic] quality proprietary oil varnish. Many will do almost equally well; we have used Messrs. Naylor's extra flexible varnish. On the cotton face the same varnish with the addition of some beeswax and aluminum powder and an appropriate amount of diluents is used. This outer varnish is applied slightly warm. The object of both varnishes is, of course, to increase the waterproofness of the fabric.

**Main assembly**

The term "main assembly" is used to indicate the joining of the bay by means of the circumferential seams. Reference to the model will show that there are other main seams. All these main seams are of precisely the same construction. Those other than the circumferential ones are usually joined before the varnishing is done. The structure of a main assembly seam can be seen from the drawing and from the sample exhibited. The operations are as follows:

The skin surface which is to enter the overlap is gently abraded with very fine sandpaper. The cotton face which is to enter the overlap is slightly wetted with warm water. Warm seaming glue is then brushed on one face and some of the fixing solution referred to in the section on gluing is applied to the other face. The two faces are then applied and the join well pressed down. This overlap join is then covered as shown in the drawing and the sample with a taping of plain fabric cut on the bias and stuck down with some of the same seaming glue, the fixing solution being afterwards brushed on the outside the whole well pressed down and any excess of glue at the margins cleaned up with a hot damp swab. When thin joint has set, the whole piece is reversed so that the skin face becomes uppermost and the skin surface for a short distance on each side of the edge of the overlap is gently abraded. A narrow bias cut tape is stuck over this edge and over this again a double layer of wet skin, so as to render the skin lining continuous over the main seams. The seam and the marginal 6″ or so previously left unvarnished is now varnished within and without as previously explained for the main area of the fabric. The formula of the seaming glue is given below:

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|---|---|
| Water | 3,600 gms. |
| Glue | 1,000 gms. |
| Creosote | 45 gms. |
| Glycerine | 200 gms. |
| Turkey Red Oil | 1,350 gms. |

It is rather more concentrated than the panel glue and has a little less glycerine. The atmosphere in the Assembly Shop is maintained at a fairly high relative humidity about 70 to 80 percent usually, whenever the fabric has to be moved and pulled about very much. This is in order to maintain the flexibility of the fabric and enable it to withstand without damage to skins the unavoidable vigorous handling required in moving the parts and in packing the bag. It is no part of this report to deal with inspection, but it is merely mentioned here that at all stages, the materials and workmanship are under the scrutiny of the Works Inspectors and these in turn under the Inspectors of the AID. For this reason, it is not as a rule necessary to carry out a minute inspection of a completed bag, but all completed bags are inspected before packing.

**Main materials**

*Cotton Fabric* Three kinds have been used in these gasbags:

- Bags NOS. 3 to 12 inclusive
- Bag NO. 2 except a portion of the F.E.
- Bag NO. 13 Parts of forward end and forward tapers and part of body
- Bag NO. 14 Forward and after tapers

were made from "D" quality cotton to Specification D.T.D.94. It has a breaking load of about 35 lbs an inch.

- Bags NOS. 1 and 15 and is wholly
- Bags NOS. 2, 13 and 14 in the parts not made of "D" as stated above

were made from a lighter cotton known as "D.X" for which a provisional specification issued for that contract only was used, which is as follows:

Weight 50 gms. per sq. meter
Threads per inch 118, 3 in warp and weft
Strength 500 kgs per meter (mean)
450 kgs per meter (minimum)

Bag NO. 8.A. was made from a new and improved type of fabric known at present as "G" fabric, for which a provisional specification as follows is in use:

*Weight* Not more than 57 gms. per square meter (uncoiled)
*Weight* Not more than 64 gms. per square meter with oil
*Threads per inch* 135 in warp and weft
*Strength* 30 lbs per inch in warp and weft
*Extension* 8–12 percent in warp and weft

It will be seen that these fabrics differ in strength and that the weaker fabric has been used for the smaller bags, while the medium fabric (the "G") was used for a very large bag. There is no reason based on the loads which come on the gasbag fabric in use, for choosing a stronger fabric for the larger bags, but in manufacture and in handling, because they are heavier they may get more vigorous treatment and strength in a gasbag fabric is required more in this connection than to meet the stresses which legitimately come on it in use. These are very small indeed. It is no part of gasbag manufacture but rather of design to deal with this quantitatively, but the statement may be made here and no doubt can be confirmed from Design Memoranda that the maximum loads on the fabric in use do not exceed 1 lb. per inch run. It will be seen from the specification given above and allowing nothing for the increased strength given by the skin that there was a very ample margin.

*Skins* These were bought under the inspection of the AID, visual and hand tests for cleanliness, size and strength being the criteria.

*Glue* Every batch received from Messrs. Cannon was tested and moreover batches of the composite glue used in the Gluing Shop were periodically tested in two ways. First, for viscosity; second, sample panel seams were frequently made and tested for breaking strength, and in addition panel seams out from the actual work were also tested. Full records of these tests exist in their original form. Such tests were a part of routine inspection.

**The strength of the joints or seams**

As stated above very frequent tests were made as a part of the inspection of work in progress. These constitute a test of the strength of the bag for if the seam holds, the strength of the finished fabric is realized and if not, then the strength of the weaker part, that is the seam, is measured. The tests on seams were carried out on pieces 3 inches wide and about 8 inches effective length. These were always cut from unvarnished material. Two sets of three, four or five such pieces were prepared for each test and before the test one set was

conditioned for not less than seventy-two hours in an atmosphere of 65 percent relative humidity (these constituting the normal or dry test) and the other set was conditioned for not less than seventy-two hours at 95 percent relative humidity (this constituting the wet test). The specification for these tests stated that the piece must not break nor the seam part under a load of less than 20 lbs per inch. This specification was applied throughout, whichever of the three cottons referred to above had been used as the basic fabric of the bag. A special note may be added with regard to the panel joints in Bag NO. 8.A. where the "G" fabric was used. As stated earlier, those panel joints were untaped (the main seams in this bag as in all others were taped with a wide taping). The taping adds nothing to the strength of a join and in an unsewn joint is there merely to prevent the edge lifting. As we had abundant proof that the edges of seams made by us did not lift and as we had observed that other experienced makers of gasbags of this type, that is the Germans, used no tape on such joints, it was omitted, saving a little weight and a manufacturing operation without any decrease in the quality of the product.

**Pair of gas bags**

Copies of the workshop reports made at the time of reconditioning all the bags during December 1929–March 1930, and of the further reconditioning of Bag 9 only in July–August 1930, are appended.

The defects found in bags after service are:

1. Small holes through fabric and skin.
2. Cracked skins.
3. Skins separated one from another.
4. Both layers of skin lifted from the cotton.
5. Lifting tapes or seam edges.
6. Mold.
7. Fittings, such as sleeves etc. becoming loosened from their attachment to the fabric of the bag.
8. Large rents as distinct from holes referred to in (1). Sometimes there are clean cuts made deliberately during deflation.

**Method of repair**

1. Clean off outer varnish, apply patch of cotton on the outside with glue. Re-skin the inside and re-varnish the repair region.
2. Re-skin with new wet skins. Varnish over when skins are dry.
3. As (2) unless very trifling. Minute separation of skin from skin is found

in the best newly made fabric and it is left untouched.

4. Remove the separated skins, re-skin over a layer of glue. Varnish when dry.
5. Clear away varnish. Glue edges down. Re-varnish.
6. Action depends on judgment as to how serious it is. If it is bad cut it out and repair by insertion of a new piece of the composite fabric. The method of inserting this is to all intents and purposes similar to the making of a main seam. Several slightly moldy places—R.101's bags were, after consideration and consultation left as they were and specially marked that information as to tendency of mold to spread might be acquired from subsequent inspection of the bags. Mold has to be guarded against in this type of gas bag, but R.101's were scarcely at all affected and tests show that mold that looks rather bad has caused little or no deterioration.
7. Glue then down again or replace them and the fabric around them according to the circumstances.
8. Cut out the fabric about the rent or cut and replace with new fabric as in (6).

In the above work ordinary seaming glue is used for the insertion of new pieces and for re-gluing parts where it would have been used originally. For re-skinning a glue modified by the addition of a little acetic acid is used. The function of the acetic acid is to keep the glue, though nearly cold on the fabric lying on the floor, fluid for long enough for the re-skinning to be carried out. If the glue set too quickly poor adhesion would be the result.

**Note on approximate rate of deflation of a gas bag**

Each of the large bags of R.101 had four empty necks (or deflation sleeves) about 18″ diameter. When such necks are open there are four clear vents totaling about seven square feet. The time taken for about 70 percent of the gas to escape from a large bag through these openings (for handling purposes the rate of discharge is usually reduced considerably when about 70 percent has been allowed to escape) is or the order of twenty to twenty-five minutes, the top outer covers being turned back for this operation. Some 500,000 cubic feet of gas thus escapes, in the time stated, through seven square feet of opening and under a mean pressure or about 1″ of water.

RAW [Royal Airship Works]

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