CHAPTER III. PROCESSES OF MAKING THE PLASTIC HELMET LINER

Because of the comparative novelty of utilizing plastics for the Liner, M-1, and because there were three distinct approaches to its manufacture, with the high-pressure method finally accepted as superior, details of the processes followed by the various manufacturers are here described.

The St. Clair Low-Pressure Liner---The 1,300,000 liners contracted by the St. Clair Rubber Company were made by the so-called "dumb-bell" paneled preform, molded under a low-pressure process. In this process, which was worked out chiefly by LeGrand Daly, a plastics engineer, there were three main steps: (1) Six dumb-bell-shaped segments of resin-coated duck were laid up, one crossing the other, in pre-forming vessels, so as to fill out the complete radius of a hat-shape; in this stage they were preheated, which cemented them together slightly. (2) The preformed liner was placed in a die cavity and molded under 110 pounds of steam pressure for 10 minutes. (3) Finishing operations consisted of trimming and sealing the liner edges, spraying the hat with synthetic resin lacquer and baking it.

A sheet steel helmet, only a little smaller than the Helmet, Steel, M-1, was used for the female half or cavity of the mold; and a soft heat-resistant bag made of synthetic rubber and lignin, about one-quarter of an inch thick and one-quarter of an inch smaller than inside dimensions of the hat, was used as the male half or core. In the molding, the pre-formed helmet was placed within the steel die cavity which was supported in a steel casting of the same shape,

jacketed for steam; the rubber bag, placed inside the preformed helmet then was expanded with 110 pounds of steam pressure, so that the casting applied uniform pressure to the laminated material, this "curing" requiring 10 to 15 minute's time. Baking of the liner, following its passage through an automatic spraying machine which coated both inside and outside, required six minutes in an oven, whereupon the liner was ready to receive the suspension.

The material used in the Daly liner included standard 8 ounce duck, 42 inches wide, conditioned for proper moisture content and put through a conventional spreader which ran the fabric over dispensing rolls. The phenol-furfural resin used to impregnate the duck conserved appreciable quantities of phenol and formaldehyde, both scarce materials. Advocates for the low-pressure process maintained that the initial strength of the cloth fibers was more likely to be maintained than under the high-pressure process which would tend to distort and displace the fibers. Moreover, tooling costs for the low-pressure process were lower, and tooling took up less time. However, the curing process, which required a minimum of 10 minutes, was at least twice as long as that required in the high-pressure molding; so the production rate was necessarily slower, a decided disadvantage of the St. Clair liner when the demand for the article was immediate. A greater disadvantage of the St. Clair liner was its tendency to fragment in the ballistics test to a much greater extent than the high-pressure liners. This fault was the main reason why the Quartermaster Corps decided against procuring more than million-odd units which so handily filled the gap until high-pressure molders could get

manufacture under way.[1]

The Hood "Ball Winding" Process---The Hood Rubber Company entered the helmet liner picture as an experimenter looking toward a low-cost technique which would produce helmets as simply as possible with inexpensive equipment and make use of a minimum of steel and other critical materials. The construction arrived at, after eight months of experimental work, was a medium-pressure liner made with resin-impregnated, 4 ounce high count cotton sheeting instead of duck, which was greatly needed for other war purposes.

In the process, 40-inch cotton sheeting was impregnated with a quick-drying, heat-and-water resistant, fast-curing resin, and cut into long ribbons, some 2 inches, some 3/4 inch wide, which were wound on to spools. From the spools the ribbons were automatically wound around a heated mandrel shaped like a watermelon. Formed of two hollow metal halves, fastened together by a thin steel band in the center, the mandrels before wrapping were heated in 160°F. ovens and dusted with talcum to prevent sticking. The 2-inch ribbons were first wound around the entire "melon," followed by the narrower 3/4 inch, which were wound around horizontally to form the lower half and brim portion of the helmet. The resulting fabric melon then was cut in half, each a helmet preform. After trimming, a brim collar consisting of three die-cut strips of 1.60 enamel duck bond stapled together was clipped over the edge of the wrapped form, and a 3 1/2 inch disc cut from the impregnated sheeting was added as a crown patch. The purpose of the

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[1] "The Army Helmet Liner," Modern Plastics, XVIIII, (May, 1942), 35 ff., supplied the main facts in the description of the St. Clair process.

two latter additions was to give extra strength. Before molding, the wrapped helmet was put in a cold press for 10 seconds which smoothed down the ribbons compactly, preventing blisters in the finished job. The molding operation consisted of placing the preformed helmet over a rubber bag covering a force plug which was fastened to a movable frame raised by an air hoist to close into the female portion of the mold. To gain adequate molding pressure, water under a pressure of approximately 250 p.s.i. was guided to flow between the force plug and the rubber bag, transferring the heat. After a six-minute curing cycle, the pressure was released from the rubber bag and the platform on which it was fastened, dropped, blowing out the helmet liner. The entire molding operation could be performed in approximately seven minutes, so that one worker could manage seven presses with ease. After the molded liner was trimmed on a three-way cutter, its edges were buffed and burnished, and the helmet was ready for the punching machines which prepared it by punching six holes simultaneously to admit the various pieces of hardware for fastening headband and neckband suspensions and chin strap. Finally it was spray-painted with a dull, pebbly, non-reflective covering, and dried under infra-red lamps.[2]

The Hood Company engineers believed they had a superior helmet liner produced by a method better in several ways than the other methods in use. They estimated a 15 to 20 percent reduction in the use of materials, resin and fabric. The amount of "trim" from the helmet, for example, was 5/8 inches of material, in comparison

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[2]"Wind-up of the Helmet," Modern Plastics, XX, (April 1943), 8.

to 1 to 2 inches cut away in the high-pressure methods of molding. The molds were inexpensive, costing only $525 apiece,[3] compared with cost of $2,000-$2,500 on high-pressure molds. Another point in favor of the specially wound preform and air bag method was that the fabric was not crushed, but merely was compressed to a uniform thickness, with a more even distribution of fabric and resin. With equipment planned for women workers---the unit in production was operated by 99 percent female operators---the method was advantageous in view of the anticipated labor shortage.

Despite these numerous advantages, however, the Hood Rubber Company made only 206,000 helmet liners for the Army. One reason for the cessation of procurement was that the Hood liner, with its "thick" crown-spot of crossed strips, tended to show a crack part-way through under the ball test, and although no amount of hammering could crack it the rest of the way, the liner was not considered as satisfactorily meeting specifications; another undesirable feature was that the interior was not smooth-finished. The main reason, however, was that the Army was convinced the helmet liner made by the high-pressure process was the sturdier article, offering greater protection to the wearer; and no procurements of any but the high-pressure molded type were made after the first experience.

The High-Pressure Helmet Liner[5]---Processing of the high-pressure helmet liner, which varied with the different manufacturers,

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[3] Hood Co. to Major Pratt, Aug. 28, 1943.

[4] Interview with Major Pratt.

[5] Steps in this process are pictured in photographs comprising Appendix V.

had the common characteristics of high-pressure molding, done usually by hydraulic presses. The first step in the production process was to impregnate the duck with phenolic resin up to about 44 or 46 percent. Except for the Westinghouse Electric Company, which impregnated its own material, with resin made in the plant, the helmet liner contractors secured supplies of this material from sources other than their own factories. Next, the impregnated duck was die cut into the circular sectioned pieces and the reinforcing pieces which went to make the liner. Manufacturers varied in their approach on the cutting, though most of them in sectioning removed a small pie-shaped piece of material from each circle, so that in forming the sections into a hat there would not be too much overlap. They were free to use their own inventiveness in preparing the duck for the pre-form, the end requirement being that the method they adopted produce a desirable helmet after it was cured. Most of them, however, took three pieces of the duck, placing one inside the other so that the slits for sectioning would be covered and not result in a weak spot; and added reinforcing pieces at the crown or sometimes on the sides. As the third step in the process, the pre-formed hat was placed inside the mold and subjected to two minutes or more cure at 220°F., the mold coming down with a force of 150 tons. This step laminated the duck so thoroughly that a hard, smooth and shiny surfaced helmet shell resulted. A punch press could be utilized for removing the "flash" or excess plastic material on the hat's brim, whereupon the raw edge remaining was burnished to bring about a heat-seal. The shell itself complete, the steps remaining for completing the helmet liner involved a series of short mechanical operations as follows: (1) liner put into

a piercing press which punched the 11 holes needed to admit various rivets and the eyelet to carry the wearer's insignia; (2) riveting in, by separate machines along the line, of eyelet, the cap tack and garter stud to carry the chin strap, and other rivets fastening suspension and neck strap; (3) coating of the liner with a dull resin-textured paint by automatic paint spray machines or by hand paint spray; (4) baking of the paint coating either in infra-red ray ovens for two minutes, or in horizontal drying ovens, for 15 minutes. The chin strap usually was put on as the final operation before packing. Most of the plants utilized at least three factory inspectors along the way, the final one making inspection just previous to the coating process. Rejects at this point were laid aside or immediately salvaged for removable parts such as suspension, and neck strap, which could be used again. The defective shells then were burned, or, in some cases, utilized by the manufacturer, with certain changes, for other purposes.[6]

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[6] With permission of the CQMD, the manufacturers could alter the shape of the imperfect helmet liner, and by utilizing unacceptable parts for the suspension, etc., could dispose of this stock in the civilian market, selling the liners as children's toys or work helmets.