

COMBINED SECOND AND THIRD QUARTERLY REPORT

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MANUFACTURING METHODS AND TECHNOLOGY PROJECT TO ESTABLISH PRODUCTION TECHNIQUES TO MANUFACTURE RIGID ARMOR FOR RADAR ANTENNA HARDENING

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1 SEPTEMBER 1977 TO 28 FEBRUARY 1978

TECHNICAL SUPPORT DIRECTORATE
UNITED STATES ARMY ELECTRONICS
RESEARCH AND DEVELOPMENT COMMAND
FORT MONMOUTH, NEW JERSEY

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ABSTRACT

A basic step involved in the preparation of the polypropylene film prior to its lamination into a ballistic panel involves the orienting or stretching of the film. Processing problems have been encountered by the vendor selected for this task.

Using processing steps that vary from those used successfully in previous development work, the vendor has not as yet produced satisfactory oriented film and his ability to process film that will meet specification requirements is in doubt.

As an immediate solution to this problem, AMMRC is planning to supply sufficient material for the engineering and confirmatory sample panel fabrication phase. Alternate possible sources for the balance of the oriented film required for the program are noted in this report.

Subscale process development work has been initiated and some of the molding characteristics and problems have been identified.

Major tooling for the program has been received, inspected, and functionally checked.

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1.0 PURPOSE

The purpose of this program is to establish production techniques and production capabilities for the manufacture of armor panels. The armor panels are intended for use with flat radar antenna to provide protection from munitions fragments.

The armor panels will be flat molded sheets of various sizes and edge finishes. The sheets will be molded from cross-plyed assemblies of unidirectionally oriented, blown film made from a dielectric grade polypropylene. A protective over lay will be molded into the panel surfaces and camouflage will be incorporated in or onto a portion of the panels.

The program is divided into four tasks as described below:

Step 1 Engineering Samples

Two sets of two each panels will be produced in order to demonstrate the ballistic capabilities of the selected materials and processes.

Step 2 Confirmatory Samples

Ten sets of two each panels of various sizes, thicknesses, and camouflaging methods will be produced in order to demonstrate the total capabilities of the panels in regards to environmental stability, electronic transmission, and ballistic characteristics. In addition, camouflaging techniques and panel trim and edge fusing will be demonstrated.

Step 3 Pilot Run

Thirty-two sets of two each panels will be produced in order to demonstrate the capacity of each production step and verify the capability of the line to fabricate at an acceptable rate.

Step 4 Production Capability Demonstration

An in-plant demonstration will be held in order to show the production capabilities of the pilot production line to invited representatives of industry and government.

The first quarterly report described in detail the program objectives, tasks, and schedule.

2.0 INTRODUCTION

The following is a combined report for two quarterly periods covering the time period between September 1, 1977 through February 28, 1978.

Activity in this period was limited because Swedlow was unable to obtain satisfactory orienter film.

The film orientation supply problem, preliminary subscale panel processing summary, as well as tool tryout results are covered in this report.

3.0 ORIENTED FILM

One of the basic processing steps involved in the preparation of the molded ballistic panels is the film orientation. This step involves an oven draw or stretch of the film to a ratio of at least 12 to 1. During this orienting process the strength of the film increases in the stretch direction and decreases in the transverse direction.

The high draw ratio requires precise process controls to prevent excessive splitting, fibrillation, and wrinkling.

Problems encountered in this area are discussed below.

3.1 Orientation Problem

After an extensive search, Swedlow has not been able to locate a film orienting vendor capable of or willing to attempt the high draw orientation of the film other than E-B Industries of Simsbury, Conn.

E-B Industries Film Fiber Division has, to date, made three attempts to orient film to the specification 12 to 1 draw requirements. To date, the highest draw achieved using full width film has been 10.3 to 1. This oriented film and other films produced with lesser draw ratios were fibrillated or split to a degree that precludes their fabrication into electrically satisfactory panels.

3.2 Processing Step Variations

E-B Industries' equipment and procedures are set up to produce tape and woven cordage at a high production rate. Their equipment is set up in-line starting with a slot die extruder.

Several of the processing steps are different from those used in previous successful film orientation lines by Phillips Chemical and that being presently used by AMMRC, Watertown, Mass.

Specifically, E-B Industries uses a slot die extruder instead of a blown film extruder, a circulating air oven instead of a radiant heat oven, and does not employ an annealing roll at the film take-up station.

A comparison of the two processes is schematically shown in Figures 1 and 2.

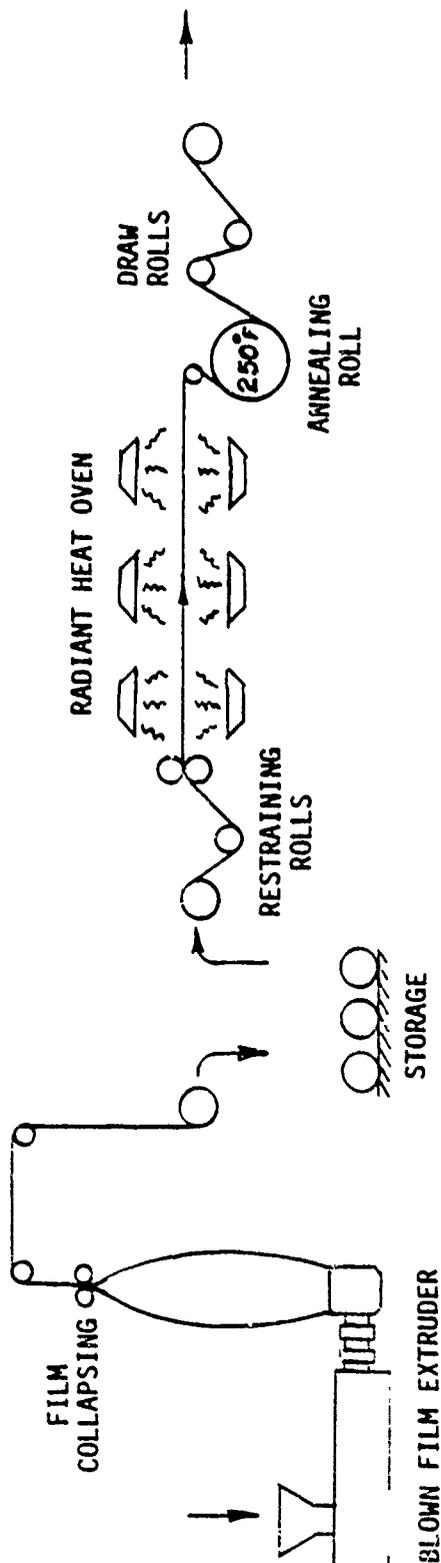


FIGURE 1. FLOW SHEET PHILLIPS/AMMRC FILM ORIENTING PROCESS

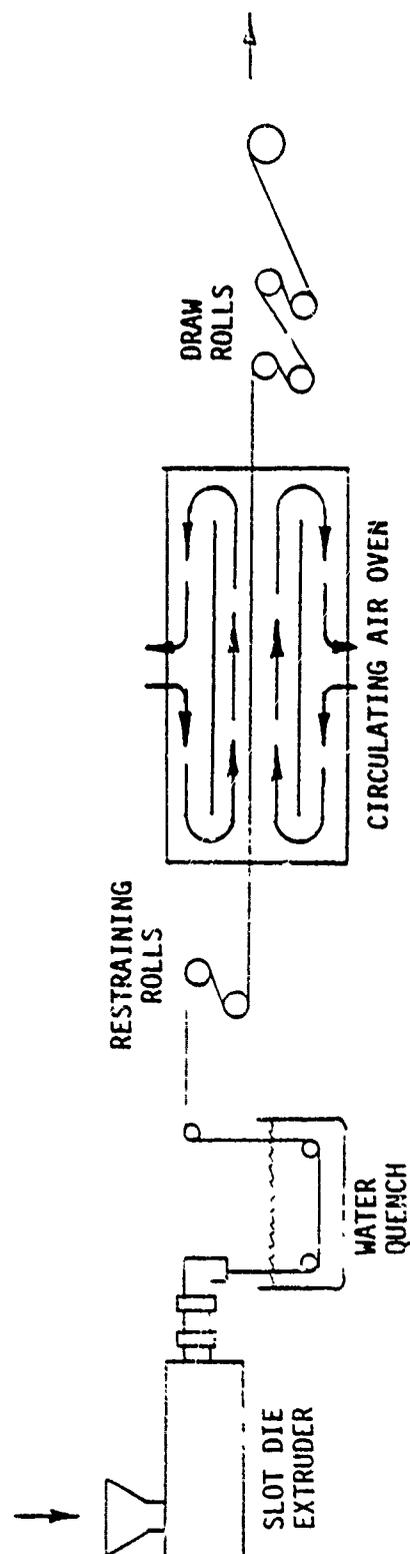


FIGURE 2. FLOW SHEET E-B INDUSTRIES FILM ORIENTING PROCESS

Specific processing differences between the two systems are summarized below:

<u>Step</u>	<u>E-B Industries</u>	<u>Phillips/AMMRC</u>
Film Fabrication	Slot die extruded and water -quenched	Ring die extruded, blown, air-cooled, and collapsed
Film Heat-up	Circulating air oven	Radiant heat oven
Film Annealing	Not employed to date (could be added to line)	250°F anneal at the draw roll

Characteristics that are probably limiting E-B Industries' results are less thickness uniformity and more die lip mark-off of the slot die film as compared with the blown film, film crystallinity differences resulting from the water quench, loss of the advantages of drawing an essentially two-ply film that results from collapsing a blown film, and much increased oven turbulence.

As indicated in Figure 2, the oven hot air flow enters at the front end of the oven making this the hottest area. The film necks or stretches at this location. This subjects the stretched film to air turbulence for almost the full length of the oven.

In the radiant oven process, oven sections are controlled so that stretching occurs near the end of the oven.

The latter problem, oven turbulence, coupled with a rapid processing rate that is needed to accommodate the minimum slot die extruder output causes considerable film agitation and presents the most probable degradation cause.

The above noted differences in the processing steps may present insurmountable processing problems that will prevent E-B Industries from matching the results previously achieved and established as specification objectives.

3.3 Proposed Solutions

In order to provide material to initiate the resumption of the manufacturing program, AMMRC will process and provide Swedlow sufficient material for development and fabrication of sample panels for both the engineering and the confirmatory samples.

The balance of the oriented film needed in order to complete the pilot run panels and other program requirements would be supplied through

one of the following options.

- 1) E-B Industries to supply the balance of the required oriented film material after successfully resolving processing problems.
- 2) Swedlow to setup an in-house film orienting line to produce the required additional material.
- 3) AMMRC to supply additional material for the balance of the program.

The first option is, of course, dependent on E-B Industries' successful development of their film orientation procedures. The second option requires evaluation from a cost and schedule standpoint.

The third option is the only sure, timely source of oriented film. However, if material is obtained from AMMRC, one of the program objectives - the development of a commercial film orientation source - will not be achieved.

4.0 SUBSCALE SPECIMEN FABRICATION

4.1 General

Subscale specimen fabrication was started during this period both for the purpose of fabricating electronic specimens and for the development of molding parameters.

Specimens fabricated to date have not been of sufficient quality for dielectric and loss-factor testing.

4.2 Specimen Molding Description

Specimen laminates were made with 2000-2200 psi pressure maintained throughout the molding cycle. A vacuum debulking at 25 inch Hg was used prior to molding and a 28-29 inch Hg vacuum was maintained during the molding cycle.

The materials molded were hand cross-plyed from sample rolls submitted by E-B Industries and a sample roll supplied by AMMRC.

The molded specimen preparation steps are listed below and the molding assembly is shown diagrammatically in Figure 3.

- 1) The film material was hand cross plyed into an over size stack.
- 2) The cross-plyed film stack was cut to net molding size using a power paper shear.
- 3) Plies were stripped from the trimmed stack to achieve the desired stack weight.
- 4) The stack was placed between two 1/8 inch aluminum caul plates. (Best specimen edge conditions were achieved when the stack was trimmed at least 1/4 inch undersize to the caul plates).
- 5) A .003 inch diameter iron/constantan thermocouple was located at mid-panel to monitor molding temperature.
- 6) The film stack and caul plates were enveloped with two plies of 15 oz. glass fabric bleeder.
- 7) The assembly was vacuum bagged with a nylon film using a chromate sealing material and a gland type vacuum fitting.
- 8) The bagged assemblies were held at least 15 hours at a moderate vacuum (25 inches Hg).
- 9) Prior to molding, the assembly was evacuated to a gauge reading of 28-29 inches Hg. This vacuum was maintained through the molding cycle.

- 10) The specimens were laminated in a 50 ton hydraulic press and molded using the temperature, pressure and time cycle shown in Table I.

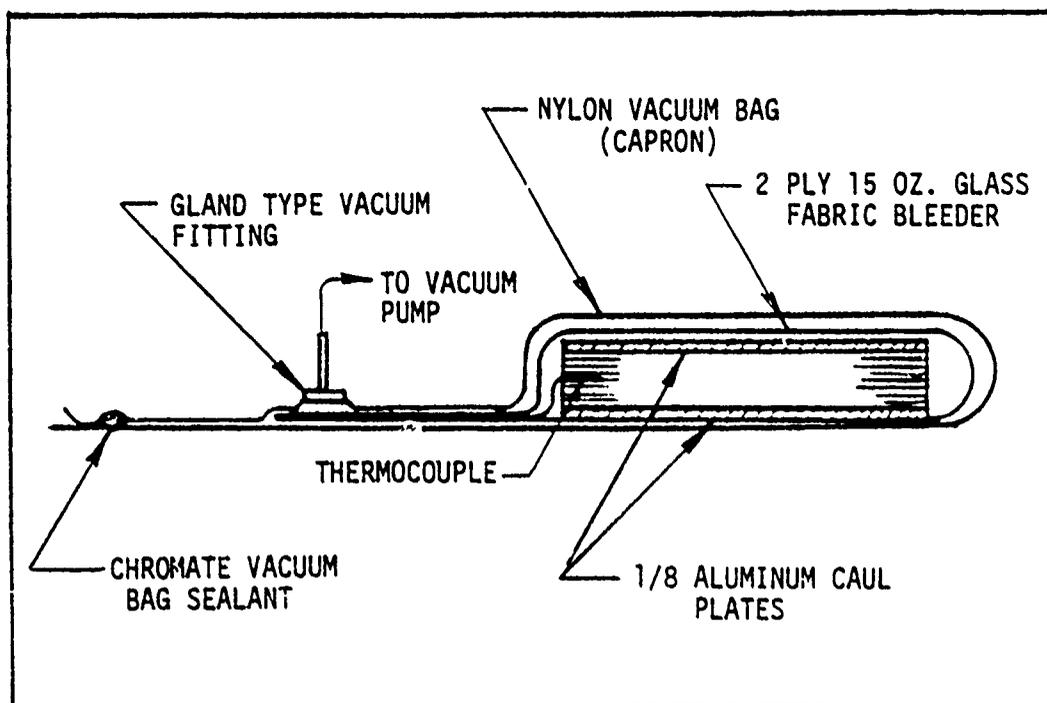


FIGURE 3. DIAGRAM VACUUM BAGGED ASSEMBLY

4.3 Specimen Molding Summary

Initial specimen molding work shows that end item defects are the result of film, tooling, and processing variables.

Some of these effects that have been identified in this initial work are discussed below.

Nonlamination

Nonlaminated areas noted in the test specimens resulted from lack of effective pressure locally. The oriented film rolls had consistent

thickness variations from edge to center or edge to edge across the film. If samples were cross-plyed in such a way that thickness extremes stacked in the same area, these areas were subject to different effective pressures and the low pressure areas showed nonlamination.

Careful ply rotation that prevents thick/thin area stack up or increased lamination temperature and time (increased film flow) minimized this problem.

These problems associated with variations in film thickness apply to the hand lay up samples. It is expected that mandrel cross-plyed film will randomly distribute the thickness variations and eliminate the thickness stack up problems.

Delaminations

Edge - Edge delamination occurred wherever there was a discontinuity of the molding surface.

In the case of subscale specimen molding, delaminations occurred when the panel growth extended over the caul plates. These local delaminations appear to be caused by thermal contraction differential strains and/or peel caused by caul plate removal.

Surface - Small local surface delaminations occurred on the faces of several of the panels. The cause of these delaminations is not readily apparent. (Note that none of the panels included protective surface plies of biaxially oriented film).

Subsurface - Subsurface delamination appears to be associated with contamination introduced at some point in the process.

Trapped Air - Trapped air occurred in the specimens molded from the film samples supplied by E-B Industries. This material was fibrillated or split to the extent that it was difficult to hand layup a uniform film stack.

The non-uniformity of the layup rather than the splits were probably the cause of the entrapment problem. It is expected that some film splitting will not preclude the making of laminates without air entrapment.

Table I summarizes the molding sizes, procedures, and results.

TABLE I. SUMMARY OF SPECIMEN HOLDING

SPECIMEN NO.	MATERIAL SUPPLIER DRAW-RATIO	NOMINAL SIZE	PRECONDITION VACUUM	HOLDING VACUUM **	HOLDING PRESSURE*	HOLDING CYCLE	RESULTS AND APPEARANCE
1212-1	Marlex 9317 Phillips 12:1	1/2 x 3 1/2 x 3 1/2	72 Hrs. at 25 inches Hg	28-29 inches Hg	2000 PSI	84-348°F 57 minutes	Translucent, surface and subsurface delaminations
1217-1	Marlex 9317 Phillips 12:1	1/4 x 3 1/2 x 3 1/2	20 Hrs. at 25 inches Hg	28-29 inches Hg	2040 PSI	72-342°F 88 minutes	Translucent, minor edge delaminations
1220-1	AMOCO 10-5014 E-B Inc. 9:1	1/4 x 6 x 6	23 Hrs. at 25 inches Hg	28-29 inches Hg	2000 PSI	121-338°F 88 minutes	Transparent, large edge delaminations. Considerable trapped air and edge flow.
1221-2	Marlex 9317 Phillips 12:1	5/16 x 3 1/2 x 3 1/2	24 Hrs. at 25 inches Hg	28-29 inches Hg	2040 PSI	110-348°F 83 minutes	Translucent, large delamination of single ply at mid-specimen
1229-1	AMOCO 10-5014 E-B Inc. 9:1	5/16 x 3 1/2 x 3 1/2	25 Hrs. at 25 inches Hg	28-29 inches Hg	2200 PSI	106-350°F 52 minutes	Transparent, small areas of surface delamination, considerable trapped air throughout
1230-1	MGZ-030-02 E-B Inc. 10.3:1	5/16 x 3 1/2 x 3 1/2	24 Hrs. at 25 inches Hg	28-29 inches Hg	2000 PSI	72° to ? 108 minutes (lost thermo couple)	Transparent, surface delamination, trapped air

* Full positive pressure throughout heatup and cool down

** Vacuum pressure maintained throughout molding cycle

5.0 TOOL FABRICATION AND TRY OUT

All major tools and special equipment were received during this report period. These tools were setup for tool try out and subscale panel fabrication.

Tool try out results and problems are discussed below.

5.1 Power Paper Shear

The 42" Dexter power paper shear was received in October. Initial try out and film cutting for process development sample fabrication indicated that all required film stack shearing can be accomplished without equipment modification.

Cuts made by the shear are clean and without edge fusion.

5.2 Mold Die and Mold Support

The mold die and mold support were received in the second month of this report period. (Design drawings of these two items were included in the first quarterly report).

These two tools, which work in conjunction with each other, were setup in a high tonnage hydraulic press and functionally checked.

Some rework was required to correct guide pin problems and steam chamber leakage problems. This rework was accomplished in December.

6.0 PROGRAM FOR NEXT 3-MONTH PERIOD

6.1 Receiving and Inspection of Cross-Plied Pads

Receipt and inspection of ninety (90) cross-plied film pads is scheduled for the beginning of the next period.

These film pads made up from film oriented by Phillips Petroleum Corporation and mandrel cross-plied by Engineering Technology, Salt Lake City, will supply sufficient material to support the program through the fabrication of confirmatory samples.

Pad size will be 38" x 50" with a nominal areal density of 1.25 pounds per square foot.

6.2 Determination of the Source of Oriented Film for the Balance of the Program

An investigation of the film orientation options presented in Section 3.3 and a decision on the source for the balance of the oriented film material needed for the program is scheduled for next period.

6.3 Process Development - Subscale

Subscale panel fabrication will be continued in order to develop further processing background.

6.4 Oriented Film Handling and Cutting Procedures

Cutting, stacking, weighing and handling procedures required for processing full-scale panels will be developed during the next quarter.

6.5 Process Development - Full Scale

Full-size panel molding (32" x 42") will be undertaken next period in order to evaluate scale-up problems and to develop processing procedures to be used on engineering sample panel fabrication.