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REINFORCED PLASTIC SONAR DOME MATERIAL INVESTIGATION. VOLUME I.--ETC(U)
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REINFORCED PLASTIC SONAR DOME MATERIAL INVESTIGATION

VOLUME I
PANEL CONSTRUCTION

LEVEL II

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Molders & Fabricators of Reinforced Plastics

LUNN LAMINATES INC.

WYANDANCH • LONG ISLAND • NEW YORK 11798

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CONTRACT N00140-66-C-0573 for
United States Navy Underwater Sound Laboratory
New London, Connecticut

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REINFORCED PLASTIC SONAR DOME MATERIAL INVESTIGATION

VOLUME I

PANEL CONSTRUCTION

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(11) 1968

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Lunn Laminates, Inc.
Straight Path
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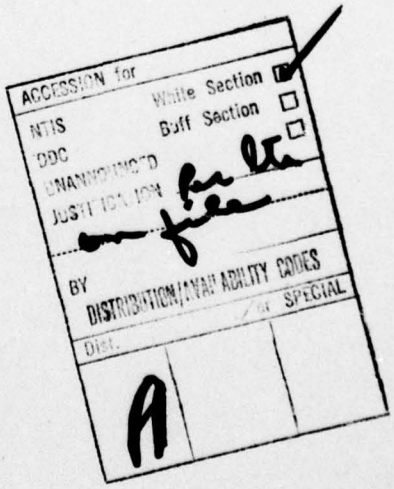
AB

This report is submitted to inform the United States Navy Underwater Sound Laboratory of the results obtained from the Reinforced Plastic Sonar Dome Material Investigation.

This investigation was performed by Lunn Laminates, Inc. under Contract Number N00140-66-C-0573.

It comprises four volumes as noted in the Table of Volume Content.



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INTRODUCTION

The purpose of this study was to develop reinforced plastic (RP) laminates for sonar domes that would be superior to those that have been or are being produced for vessels of the United States Navy. It was conducted in two phases.

PHASE I

The first phase of the work conducted by Lunn Laminates, Incorporated, consisted of developing different constructions of laminates which included the following:

Varying the matrix materials (epoxy and polyester resins, urethane and polysulfide rubbers),

Varying the percentages of rigid and flexible resins used, and

Employing cloth reinforcements constructed of materials using nylon, polypropylene, glass, Fortisan and Dynel.

Sixty-four 12" x 12" x 1/8" panels were constructed and subjected to damping and physical property measurements. With this data as a guide, twenty-three constructions were chosen for further examination. Measurements were made of their acoustic damping and mechanical properties on panels that were 30" x 30" x 1/2", or 1-1/2" thick.

Data on the PHASE I panels, and the reasons for the selections of the PHASE II panels, based on transmission loss and flow-induced noise calculations on typical AN/SQS-23 and AN/SQS-26 surface ship sonar domes, are contained in United States Navy Underwater Sound Laboratory Confidential Technical Memorandum No. 2133-010-68, "Fiberglass Reinforced Plastic Laminates for Sonar Domes" of 10 January 1968.

PHASE II

This report is on the second phase of the work by Lunn Laminates, Incorporated. It concerns the eleven reinforced plastic laminates that the United States Navy Underwater Sound Laboratory selected for further study as a result of the PHASE I effort.

Six of these laminates were constructed in panels that were 6' x 6' x 3/4" and 1-1/2" thick, and five, which were not adequately explored in PHASE I, were 36" x 36" x 3/4" and 1-1/2" thick. Acoustic, damping and mechanical properties of these laminates are given in this report.

MATERIALS AND PRODUCTION OF PANEL #308-M

MATERIALS

Reinforcement:	Turner Halsey S-1313 Polypropylene.
Resin:	90% Allied rigid PE-941 and 10% Allied flexible PE-9600 Polyester resin.
Catalyst:	0.5% Methyl Ethyl Ketone Peroxide.
Promoter:	0.2% Cobalt Napthenate.

PRODUCTION OF PANEL

Panel was fabricated in two stages, each with 22 plies of reinforcement. Each ply had its warp direction rotated 45° from the preceding ply. Since Turner Halsey does not manufacture S-1313 in widths larger than 60", many plies were constructed of more than one piece of reinforcement. When a ply of reinforcement contained more than one single piece of reinforcement, butt joints were used and staggered throughout the panel.

Wrinkles formed in the panel from the exotherm caused by polymerization of the resin. When subjected to 200°F for 40 hours, panel warped. Because the panel warped during post curing, a second panel was made and allowed to cure at room temperature for 30 days.

MATERIALS AND PRODUCTION OF PANEL #408-M

MATERIALS

Reinforcement:	Turner Halsey S-1313 Polypropylene.
Resin:	90% Allied rigid PE-941 and 10% Allied flexible PE-9600 Polyester resin.
Catalyst:	0.6% Methyl Ethyl Ketone Peroxide.
Promoter:	0.2% Cobalt Napthenate.

PRODUCTION OF PANEL

Panel was fabricated in four stages, each containing 44 plies of reinforcement. Each ply had its warp direction rotated 45° from the preceding ply. Since Turner Halsey does not manufacture S-1313 in widths larger than 60", many plies were constructed of more than one single piece of reinforcement. When a ply of reinforcement contained more than one single piece of reinforcement, butt joints were used and staggered throughout the panel.

Wrinkles formed in the panel from the exotherm caused by polymerization of the resin. When subjected to 200°F for 40 hours, the panel warped. Because the panel warped during post curing, a second panel was made and allowed to cure at room temperature for 30 days.

MATERIALS AND PRODUCTION OF PANEL #322

MATERIALS

Reinforcement: 181 Fabric.

Resin: 50% Ciba rigid 509 and 50% Ciba flexible 508 Epoxy resin.

Hardener: 24% Ciba DP-138.

PRODUCTION OF PANEL

Panel was fabricated in two stages, each with 39 plies of reinforcement.

The viscosity of the resin hindered removal of air from the panel. When fabrication of panel #422 began, the number of plies of reinforcement was decreased per stage to overcome this difficulty. From the results of Panel #422 fabrication, this panel should be made in at least three stages to obtain a void-free panel.

The gel time schedule for the epoxy mixture used is approximately 25 to 35 hours at 72°F.

From experience in fabrication of vacuum molded panels with this epoxy, if such a gel schedule is used, the panel should be left under vacuum for an additional 24 hours after gel. As an alternative procedure, which was used for this panel, subjecting the panel to a temperature of 100°F for 24 hours is sufficient to gel the panel and allow removal from vacuum.

After fabrication was completed the panel was post cured for 24 hours at 225°F.

MATERIALS AND PRODUCTION OF PANEL #422

MATERIALS

Reinforcement: 181 Fabric.

Resin: 50% Ciba rigid 509 and 50% Ciba flexible 508 Epoxy resin.

Hardener: 24% Ciba DP-138.

PRODUCTION OF PANEL

The viscosity of the epoxy mix was slightly higher than the polyesters used and therefore increased the difficulty of removing excess resin and air from the panel. Because of the anticipated difficulty in removing the air, the first stage contains only 10 plies of 181 fabric. No difficulty was encountered in removing air from the first stage so the amount of fabric was increased to 15 plies in the second stage. Again no difficulty in removing air was encountered. The third and fourth stages contain 20 plies each and the difficulty in removing the air began to increase. The fifth and last stage contains 30 plies and a great amount of time and energy was needed to remove the air.

The gel time for the epoxy mixture used is approximately 25 to 35 hours at 72°F. From experience in fabrication of vacuum molded panels with this epoxy, if such a gel schedule is used, the panel should be left under vacuum for an additional 24 hours after gel. As an alternative procedure, which was used for this panel, subjecting the panel to a temperature of 100°F for 24 hours is sufficient to gel the panel and allow removal from vacuum.

After fabrication was completed the panel was post cured for 48 hours at 220°F.

MATERIALS AND PRODUCTION OF PANEL #311-M

MATERIALS

Reinforcement: Wellington Sears SN-308 Nylon.

Resin: 90% Allied rigid PE-941 and 10% Allied flexible PE-9600 Polyester resins.

Catalyst: 0.6% Methl Ethyl Ketone Peroxide.

Promoter: 0.2% Cobalt Napthenate.

PRODUCTION OF PANEL

The warp direction of the reinforcement in this panel has been rotated 45° from the warp direction of the preceding ply. Due to warpage when post cured at 225°F for 24 hours, the first panel was discarded and a second one fabricated. The second panel was fabricated in one stage and contains 30 plies.

After room temperature gel, the panel was allowed to cure at room temperature for 30 days.

MATERIALS AND PRODUCTION OF PANEL #411-M

MATERIALS

Reinforcement:	Wellington Sears SN-308 Nylon.
Resin:	90% Allied rigid PE-941 and 10% Allied flexible PE-9600 Polyester resins.
Catalyst:	0.6% Methyl Ethyl Ketone Peroxide.
Promoter:	0.2% Cobalt Napthenate.

PRODUCTION OF PANEL

The warp direction of the reinforcement in this panel was rotated 45°from the warp direction of the preceding ply. Due to warpage when post cured at 200°F for 48 hours, the first panel was discarded and a second one fabricated.

The second panel was fabricated in one stage and contains 60 plies. After room temperature gel, the panel was allowed to cure at room temperature for 30 days.

MATERIALS AND PRODUCTION OF PANEL #349-M

MATERIALS

Reinforcement: Owens-Corning OCF-ECF 12% elastomer coated glass and 181 fabric.

Resin: 90% Allied rigid PE-941 and 10% Allied flexible PE-9600 Polyester resins.

Catalyst: 0.6% Methyl Ethyl Ketone Peroxide.

Promoter: 0.1% Cobalt Napthenate.

PRODUCTION OF PANEL

Panel was fabricated in two stages, each containing 36 plies of reinforcement. The reinforcements in the panel were alternated from ply to ply with both surfaces of the finished panel containing the 181 reinforcement. Besides alternating the reinforcements, the warp direction of every group of two plies (each group contains one ply 181 and one ply Owens-Corning OCF-ECF with parallel warp directions) of fabric has been rotated 45° from the preceding group's warp direction.

Owens-Corning OCF-ECF reinforcement presents a handling problem because of the unidirectional weave and loose binder of the material. Once cut to desired pattern dimensions, the fabric unravels and loses its integrity. When attempting to remove excess resin and air from the panel, the plies of OCF-ECF shift and move from pre-arranged positions resulting in a different warp direction than desired. If the fabric is held in position by tape, the warp direction still shifts because there is no binder to hold each individual strand into position. Due to the distance between strands, approximately 1/16", air is trapped in these voids and cannot be easily removed.

After room temperature gel, panel was allowed to cure at room temperature for 30 days. Panel was not post cured at elevated temperatures because of the elastomer on the Owens-Corning fabric.

MATERIALS AND PRODUCTION OF PANEL #449-M

MATERIALS

Reinforcement: Owens-Corning OCF-ECF 12% elastomer coated glass and 181 fabric.

Resin: 90% Allied rigid PE-941 and 10% Allied flexible PE-9600 Polyester resin.

Catalyst: 0.6% Methyl Ethyl Ketone Peroxide.

Promoter: 0.1% Cobalt Napthenate.

PRODUCTION OF PANEL

Panel was fabricated in three stages. The first and second stages contain 36 plies each and the third contains 32 plies of reinforcement. The reinforcements in the panel were alternated from ply to ply with both surfaces of the finished panel containing the 181 reinforcement. Besides alternating the reinforcements, the warp direction of every group of two plies (each group contains one ply 181 and one ply of Owens-Corning OCF-ECF with parallel warp directions) of fabric has been rotated 45^{0} from the preceding group's warp direction.

Owens-Corning OCF-ECF reinforcement presents a handling problem because of the unidirectional weave and loose binder of the material. Once cut to desired pattern dimensions, the fabric unravels and loses its integrity. When attempting to remove excess resin and air from the panel, the plies of OCF-ECF shift and move from pre-arranged positions, resulting in a different warp direction than desired. If the fabric is held in position by tape, the warp direction still shifts because there is no binder to hold each individual strand into position. Due to the distance between strands, approximately 1/16", air is trapped in these voids and cannot be easily removed.

After room temperature gel, panel was allowed to cure at room temperature for 30 days. Panel was not post cured at elevated temperatures because of the elastomer on the Owens-Corning fabric.

MATERIALS AND PRODUCTION OF PANEL #360

MATERIALS

Reinforcement: Owens-Corning S-901/81 S-Glass.

Resin: 20% Allied rigid PE-941 and 80% Allied flexible PE-9600 Polyester resin.

Catalyst: 0.5% Methyl Ethyl Ketone Peroxide.

Promoter: 0.15% Cobalt Napthenate.

PRODUCTION OF PANEL

Panel was fabricated in two stages. First stage contains 38 plies and the second stage contains 28 plies.

Because of the special finish on the glass, removal of excess resin and air was difficult.

After room temperature gel, panel was post cured at 200°F for 44 hours.

MATERIALS AND PRODUCTION OF PANEL #460

MATERIALS

Reinforcement: Owens-Corning S-901/81 S-Glass.

Resin: 20% Allied rigid PE-941 and 80% Allied flexible PE-9600 Polyester resin.

Catalyst: Resin was catalized with 0.5% Methyl Ethyl Ketone Peroxide.

Promoter: 0.1% Cobalt Napthenate.

PRODUCTION OF PANEL

Panel was fabricated in four stages. Each stage contains 38 plies of reinforcement.

Because of the special finish on the glass, removal of excess resin and air was difficult.

After room temperature gel, panel was post cured at 200°F for 72 hours.

MATERIALS AND PRODUCTION OF PANEL #503

MATERIALS

Reinforcement: 181 Fabric.

Resin: 90% Allied rigid PE-941 and 10% Allied flexible PE-9600 Polyester resins.

Catalyst: 0.5% Methyl Ethyl Ketone Peroxide.

Promoter: 0.15% Cobalt Napthenate.

PRODUCTION OF PANEL

Panel was fabricated in two stages, each containing 39 plies of reinforcement. No special production requirements or caution was needed during fabrication.

Panel gelled at room temperature and was post cured at 200°F for 72 hours.

MATERIALS AND PRODUCTION OF PANEL #603

MATERIALS

Reinforcement: 181 Fabric.

Resins: 90% Allied rigid PE-941 and 10% Allied flexible PE-9600 Polyester resins.

Catalyst: 0.5% Methyl Ethyl Ketone Peroxide.

Promoter: 0.15% Cobalt Napthenate.

PRODUCTION OF PANEL

Panel was fabricated in four stages. First stage contains 32 plies of reinforcement, the second and third stages contain 36 plies each and the fourth stage contains 25 plies of reinforcement. No special production requirements or caution was needed during fabrication.

Panel gelled at room temperature and was post cured at 200°F for 72 hours.

MATERIALS AND PRODUCTION OF PANEL #526

MATERIALS

Reinforcement: 181 Fabric.

Resin: Ciba 6005 Epoxy Resin.

Hardener: 8% Ciba 951.

PRODUCTION OF PANEL

Panel was fabricated in three stages, each containing 24 plies of reinforcement.

The viscosity of Ciba 6005 epoxy is 7,000 to 10,000 cps at 25°C and because of this high viscosity, removal of excess resin and air is difficult. To ease removal of air and excess resin each stage was reduced to 24 plies instead of the normal 32 - 36 plies.

Panel was allowed to gel at room temperature and was post cured at 200°F for 50 hours.

MATERIALS AND PRODUCTION OF PANEL #626

MATERIALS

Reinforcement: 181 Fabric.

Resin: Ciba 6005 Epoxy Resin.

Hardener: 8% Ciba 951.

PRODUCTION OF PANEL

Panel was fabricated in five stages, each containing 24 plies of reinforcement.

The viscosity of Ciba 6005 Epoxy is 7,000 to 10,000 cps at 77°F and because of this high viscosity, removal of excess resin and air is difficult. To facilitate removal of air and excess resin, each stage was reduced to 24 plies instead of the normal 32 to 36 plies.

Panel was allowed to gel at room temperature and then post cured at 200°F for 50 hours.

MATERIALS AND PRODUCTION OF PANEL #532

MATERIALS

Reinforcement: 181 fabric.

Resin: 10% Allied rigid PE-941 and 90% Allied flexible PE-9600 Polyester resin. An additional 4% Styrene Monomer was added to decrease viscosity.

Catalyst: 0.5% Methyl Ethyl Ketone Peroxide.

Promoter: 0.1% Cobalt Napthenate.

PRODUCTION OF PANEL

Panel was fabricated in two stages. First stage contains 36 plies of reinforcement and the second stage contains 34 plies. There were no special production techniques required in fabrication of this panel.

After room temperature gel, panel was post cured for 72 hours at 180°F.

MATERIALS AND PRODUCTION OF PANEL #632

MATERIALS

Reinforcement: 181 fabric.

Resin: 10% Allied rigid PE-941 and 90% Allied flexible PE-9600 Polyester resin. An additional 4% Styrene Monomer was added to decrease viscosity.

Catalyst: 0.5% Methyl Ethyl Ketone Peroxide.

Promoter: 0.1% Cobalt Napthenate.

PRODUCTION OF PANEL

Panel was fabricated in four stages. Stages one, three and four contain 36 plies of reinforcement and stage two contains 34 plies. There were no special production techniques required in fabrication of this panel.

After room temperature gel, panel was post cured at 180°F for 72 hours.

MATERIALS AND PRODUCTION OF PANEL #535

MATERIALS

Reinforcement:	181 fabric and Turner Halsey S-1313 Polypropylene fabric.
Resin:	50% Allied rigid PE-941 and 50% Allied flexible PE-9600 Polyester resins.
Catalyst:	0.6% Methyl Ethyl Ketone Peroxide.
Promoter:	0.1% Cobalt Napthenate.

PRODUCTION OF PANEL

Panel was fabricated in two stages. Both stages contain 36 plies of reinforcement with 181 fabric as the surface material of the finished panel. The two reinforcements were arranged so that three consecutive plies were 181 and the next ply was polypropylene. This arrangement was used throughout fabrication of panel.

The specific gravity of polypropylene is approximately the same as the resin and, as a result, the polypropylene "floats" in the resin and it is difficult to keep each ply's warp direction parallel to each other.

Since polypropylene is a synthetic material and has a tendency to warp when subjected to elevated temperatures, the panel was allowed to gel at room temperature and cure at the same temperature for 30 days.

MATERIALS AND PRODUCTION OF PANEL #635

MATERIALS

Reinforcement:	181 fabric and Turner Halsey S-1313 Polypropylene fabric.
Resin:	50% Allied rigid PE-941 and 50% Allied flexible PE-9600 Polyester resin.
Catalyst:	0.6% Methyl Ethyl Ketone Peroxide.
Promoter:	0.1% Cobalt Napthenate.

PRODUCTION OF PANEL

Panel was fabricated in four stages, each containing 36 plies of reinforcement. The two reinforcements used were arranged so that three consecutive plies were 181 and the next ply was polypropylene. This arrangement was used repeatedly throughout the fabrication of the panel.

The specific gravity of polypropylene is approximately the same as the resin and, as a result, the polypropylene "floats" in the resin and it is difficult to keep each ply's warp direction parallel to each other.

Since polypropylene is a synthetic material and has a tendency to warp when subjected to elevated temperatures, the panel was allowed to gel at room temperature and cure at the same temperature for 30 days.

MATERIALS AND PRODUCTION OF PANEL #537-M

MATERIALS

Reinforcement:	181 Fabric.
Resin:	90% Allied rigid PE-941 and 10% Allied flexible PE-9600 Polyester resins.
Catalyst:	0.6% Methyl Ethyl Ketone Peroxide.
Promoter:	0.1% Cobalt Napthenate.

PRODUCTION OF PANEL

Panel was fabricated in two stages. First stage contains 37 plies and second stage contains 34 plies of reinforcement. The panel was constructed with the warp direction of each ply rotated 45° from the preceding ply.

During fabrication some of the plies shifted. The plies which shifted and reoriented their warp direction were those plies whose prearranged warp direction was at 45° and 135° to the panel's edge.

Panel gelled at room temperature and was post cured at 200°F for 72 hours.

MATERIALS AND PRODUCTION OF PANEL #637-M

MATERIALS

Reinforcement: 181 Fabric.

Resin: 90% Allied rigid PE-941 and 10% Allied flexible PE-9600 Polyester resins.

Catalyst: 0.65% Methyl Ethyl Ketone Peroxide.

Promoter: 0.1% Cobalt Napthenate.

PRODUCTION OF PANEL

Panel was fabricated in four stages. First stage contains 37 plies, second stage contains 34 plies and, both third and fourth stages contain 36 plies of reinforcement each. The panel was constructed with the warp direction of each ply rotated 45° from the preceding ply.

During fabrication some of the plies shifted. The plies which shifted and reoriented their warp direction were those plies whose prearranged warp direction was at 45° and 135° to the panel's edge.

Panel gelled at room temperature and was post cured at 200°F for 72 hours.

MATERIALS AND PRODUCTION OF PANEL #551

MATERIALS

Reinforcement: Wellington Sears S-81 Fortisan.

Resin: Ciba 6005 Epoxy resin with 10% Ciba reactive diluent RD-1.

Hardner: 9.5% Ciba 951.

PRODUCTION OF PANEL

The viscosity of Ciba 6005 Epoxy at 25°C is 7,000 - 10,000 cps and, because of this, 10% RD-1 diluent was added to reduce viscosity. The lower viscosity was needed because the epoxy resin does not penetrate through the Fortisan fabric readily at 10,000 cps.

To allow adequate time for penetration of the resin through the reinforcement and completion of fabrication, the size of each stage was reduced. The panel was fabricated in three stages with the first stage containing 25 plies, the second 24 plies and, the third 30 plies of reinforcement.

The panel was allowed to gel at room temperature. During the gelling stage wrinkles began to form as the polymerization exotherm increased. To reduce chances of further wrinkling or warping of the panel, the panel was cured at room temperature for 30 days.

MATERIAL AND PRODUCTION OF PANEL #651

MATERIALS

Reinforcement: Wellington Sears S-81 Fortisan.

Resin: Ciba 6005 Epoxy resin with 10% Ciba reactive diluent RD-1.

Hardner: 9.5% Ciba 951.

PRODUCTION OF PANEL

The viscosity of Ciba 6005 Epoxy at 25°C is 7,000 - 10,000 cps and, because of this, 10% RD-1 diluent was added to reduce viscosity. The lower viscosity was needed because the epoxy resin does not penetrate through the Fortisan fabric readily at 10,000 cps.

To allow adequate time for penetration of the resin through the reinforcement and completion of fabrication, the size of each stage was reduced. The panel was fabricated in five stages with 25 plies in the first stage, 24 plies in the second and, 30 plies in each of the remaining three stages.

The panel was allowed to gel at room temperature. During the gelling stage, wrinkles began to form as the polymerization exotherm increased. To reduce chances of further wrinkling or warping of the panel, the panel was cured at room temperature for 30 days.