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COMPARISON OF HYPALON® AND URETHANE COATED FABRICS FOR USE IN RIGID INFLATABLE BOATS

by

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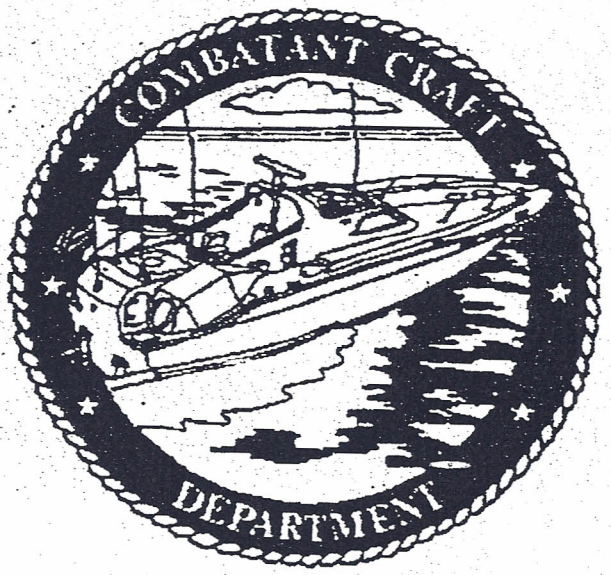

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CDNSWC TM-20-93-78 Comparison of Hypalon® and Urethane Coated Fabrics for Use in Rigid Inflatable Boats

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ABSTRACT

Since its introduction into the fleet, the Rigid Inflatable Boat (RIB) has become a widely used small boat within the U.S. Navy. Past designs have incorporated an inflatable tube constructed of Hypalon® coated nylon fabric. In the U.S., polyurethane is becoming the industry standard coating for inflatable fabric applications. Urethane coated fabrics have several attributes (stronger bonds, cleaner production and weight savings) that make them an attractive replacement. This report discusses the applicability of urethane coatings for use as a replacement for Hypalon® coatings in construction of the inflatable tube on the RIB.

ADMINISTRATIVE INFORMATION

The Carderock Division of NAVSURFWARCEN Det Norfolk, Combatant Craft Department has issued this report in response to SEATASK #30093120 issued by Naval Sea Systems Command PMS 325A31 (formerly PMS 3001).

INTRODUCTION

Navy RIBs are boats which combine a rigid fiberglass hull and an inflatable tube. Hypalon® was the most widely used fabric for inflatable applications at the time the 24'(7m) RIB was developed and is used for its tube material. With recent improvements in manufacturing technology, urethane coated fabrics have gained popularity. For various reasons which will be discussed in this report, urethane coated fabric tubes were adopted for the 10m NSW RIB which is presently under construction.

Construction and repair techniques, characteristics and reported experiences with both fabric types are examined and compared in this report in order to evaluate urethane coated fabrics as a replacement for Hypalon® coated fabrics in tube construction for U.S. Navy RIB's.

DISCUSSION

CONSTRUCTION

An understanding of the construction processes used with Hypalon® and urethane coated fabrics is necessary to evaluate the impact of changing materials for RIB tubes. The differences in the two processes affect facilities and skills required as well as production costs. The construction processes for Hypalon® and urethane coated fabrics are presented below.

Hypalon®

The construction of the 24'(7m) RIB tube from Hypalon® coated fabric requires solvent laden adhesives to achieve bond seams. These solvents are potential health hazards and there use is therefore highly regulated by the Occupational Safety and Health Administration (OSHA). The adhesive specified for the 24'(7m) RIB, BOSTIK 2405, is the most widely used adhesive for bonding Hypalon® coated fabrics. BOSTIK 2405 is a difficult adhesive to use and has not always been readily available. Although it has excellent performance characteristics, its short shelf life and application procedures complicate the production process. Due to packaging problems, American users have recently had difficulty obtaining the adhesive from the British manufacturer.

Bostik 2405 adhesive has a nine month shelf life from the date of manufacture and must be stored between 40° and 77° F. The pot life for the mixed uncured adhesive is six to eight hours in a closed container and even shorter in open containers due to solvent evaporation. In addition, pot life decreases with the age of the adhesive. These factors detract from the usefulness of the adhesive both in production and for repairs.

Proper surface preparation of the tube is essential for adequate bonding when using BOSTIK 2405. Before applying the adhesive the fabric surface must be cleaned, abraded, and cleaned again to remove any particles created during the abrasion process. An even coat of an adhesive and a curing agent mixture is applied to both prepared mating surfaces of the coated

fabric. For maximum adhesion, two thin coats are preferable, with the first coat requiring 20 to 30 minutes to dry before applying the final coat, which dries to the proper state for bonding in five to fifteen minutes. Some cure time prior to bonding is required to allow the adhesive to become tacky in order to minimize slippage during fabrication. The surfaces are joined by hand, taking care not to trap any air, and using as much pressure as possible. The adhesive requires seven days to fully cure and develop design strength, but develops a workable bond in 48 hours. During the curing process, water or water vapor can reduce its bonding strength. Therefore, special precautions are required to ensure that the adhesive, curing agent, and mixed uncured adhesive are not contaminated. The need for strict conformance to all manufacturer's instructions and the adhesive's extreme sensitivity to temperature, humidity and shelf life make it costly and difficult to use.

BOSTIK 2405, and Hypalon® adhesives in general, form a seam consisting of a material surface which is bonded to an adhesive which is in turn bonded to a second material surface. The adhesive portion of this bond will easily degrade if solvent is applied even after curing. A common fabrication technique is to apply adhesive to all parts and allow it to dry. Prior to assembly the adhesive is reactivated using a Tolulene solvent. This method is unsatisfactory when using BOSTIK 2405 because solvent may become trapped in the bond. If this occurs, BOSTIK 2405 will plasticize at higher temperatures and can cause the seam to creep and/or fail. In addition, if solvent is used to clean off excess adhesive at seam edges it may migrate into the seam. This can cause failure when the joint is exposed to higher temperatures such as may be experienced when the tube is in direct sunlight on a hot day.

Urethane

A heat weld bonding process is used in the construction of urethane coated fabric inflatable tubes. Material surfaces which are to be joined are fed into an electronically controlled welding machine. Heat and pressure are applied to fuse the two fabric coatings into one continuous

material. The heat weld bonded material may be used as soon as it has cooled to handling temperatures. This welding process requires expensive machinery but yields a very strong and reliable joint. Heat weld machines are largely automatic and require little manpower. In addition, the simplicity of the weld process requires less skill to produce reliable joints. Utilization of this process also allows for the removal of hazardous solvents from production areas. These factors result in increased production speed and reduced manufacturing expenses.

In areas where the seam is not accessible for heat weld bonding, an adhesive is often used. About 10% of the seams on a urethane inflatable tube are bonded using a urethane based adhesive. These types of adhesives react chemically to fuse the two surfaces into one structure. Before applying the appropriate adhesive, surfaces must be free of oil, dirt, and dust. An even coating of adhesive is applied to both clean surfaces. The adhesive is then allowed to dry until it is tacky at which time the surfaces are joined with firm pressure. No clamping is required to hold the materials together during this process.

Comparison

The elimination of solvents from the fabrication process of urethane coated fabrics avoids health and environmental concerns with the adhesives used for Hypalon® coated fabrics. Additionally, since there is no excess adhesive when heat weld bonding urethane coated fabrics, no cleanup is required around the seams.

Cooley, Inc. quotes the cost of a nominal 32 oz/yd^2 urethane coated fabric as $28 per linear yard while a 40 oz/yd^2 fabric costs $37 per linear yard. The price of a 30 oz/yd^2 Hypalon® coated fabric from Reeve's Brothers, Inc. is approximately $29. Price quotes are as of November 1993 for a 60 inch wide fabric. The minimum order required is 500 linear yard for the urethane and 600 linear yard for the Hypalon® with a 6-8 week delivery. Production costs for a complete inflatable tube could not be determined, however, cost comparisons among other inflatable items

manufactured using both processes are available. The Naval Air Development Center (NADC) has had experience with inflatable life preservers fabricated from urethane coated fabric. NADC currently can obtain urethane coated fabric life preservers for $90 per jacket while comparable neoprene coated nylon life preservers cost $130 per jacket. This is noteworthy because it suggests that a reduction in costs of the final product can be achieved. Cooley claims a 25% cost reduction since switching from solvent bonded Hypalon® coated fabrics to heat weld bonded urethane coated fabrics.

REPAIRABILITY

Hypalon®

Damage to inflatable tubes includes punctures, tears, cuts or abrasions and may be repaired with Bostik 2405 adhesive. The damaged area is repaired by applying a Hypalon® coated fabric patch to the tube using the same procedure utilized in construction of the tube. Seven days are required to allow the adhesive to fully cure, however, a workable bond results in 1-2 days. If a large area is affected, the damaged area can be disassembled using heat and solvents to soften the adhesive and the fabric can then be replaced. If done carefully, bonded seams can be taken apart without damaging the coated fabric.

Urethane

The damaged area of a urethane coated fabric tube can be repaired using either an adhesive or a weld gun. Urethane based adhesives form a union of the two materials resulting in a uniform seam or joint. For this reason the seams on a urethane coated fabric tube can not be disassembled, therefore for large repairs the damaged fabric is cut out and replaced with an overlapping patch. The nature of urethane based adhesives allows usable bonds to be produced in 5 hours with a full cure in 24 hours.

The weld gun is a hand-held device that can be used to create heat weld bond seams. It requires an external power source but would allow immediate repairs to be accomplished onboard ship or at a maintenance facility.

Comparison

As previously stated, the nature of the urethane based adhesives allows repairs to be completed more quickly than repairs made with Hypalon® adhesives. The currently specified Hypalon® adhesive, BOSTIK 2405, has a one week full cure time whereas a urethane adhesive fully cures in one day. A workable bond requires only five hours for urethane adhesives versus two days for BOSTIK 2405.

Another important aspect is the nine-month shelf life of the BOSTIK adhesive. The shelf life of the adhesive may be reduced when obtained from its British manufacturer due to the fact that the adhesive has to be imported. In such a situation there may be only a few months of usable life remaining for the adhesive. Typical urethane adhesives have a shelf life of at least 12 months. In addition, several domestic manufacturers produce urethane adhesives. On the basis of stocking alone, urethane adhesives are more desirable.

CHARACTERISTICS

Hypalon®

When Hypalon® coatings are used for inflatable applications the inner surface of the fabrics are typically coated with neoprene to improve air retention capability.

Resistance to flammability and ultraviolet radiation can be provided through additives. The additives are added to the coating before it is applied to the fabric during manufacture of the coated fabric. However, pigments reduce the strength characteristics of Hypalon® coated fabrics.

Currently Reeve's Brothers Inc. is the only domestic manufacturer of the Hypalon® coated

fabric specified in the 24'(7m) RIB specifications. Use of foreign sources for coated fabrics in Navy contracts is prohibited by law.

Urethane

Heavier urethane coated fabrics, in the 30 - 40 oz/yd² range, have 65% of the coating on the outer surface and 35% of coating on the inner surface. This extra external coating increases the abrasion resistance of urethane coated fabrics.

As with Hypalon® coatings, pigments can be added to make urethane coatings both ultraviolet and flame resistent. Reports that urethane coated fabrics have poor ultraviolet resistance stem from the fact that lightweight urethane coated fabric is often used for survival equipment. These designs utilizing thinner materials are for a single use and do not require stringent ultraviolet resistance. After one use these types of items are discarded. In addition they have no requirements to be stored in direct sunlight so ultraviolet resistance is not a key design requirement.

Comparison

Table 1 presents comparisons of typical strength characteristics for a 40 oz/yd² Hypalon® coated fabric, 40 oz/yd² urethane coated fabric and a 32 oz/yd² urethane coated fabric. A 40 oz/yd² Hypalon® coated fabric is the material specified for the 24'(7m) RIB and a 32 oz/yd² urethane coated fabric is specified for the 10m NSW RIB. Both materials presented exceed the strength specifications for the 24'(7m) RIB and for the more stringent 10m NSW RIB specifications. The data shows that the 40 oz/yd² urethane coated fabric is considerably stronger than the 40 oz/yd² Hypalon® coated fabric. The lower weight (32 oz/yd²) urethane coated fabric also exceeds the strength and abrasion resistance of the heavier Hypalon® coated material. This indicates that the use of a comparable urethane coated fabric could result in substantial weight savings.

On the 24'(7m) RIB, Willard Marine Inc. has reported a final assembled tube weight of 272 lbs. Assuming that:

- Hypalon® adhesive weight is 8% of total tube weight
- the weight of the urethane adhesive used would equal one-tenth the weight of Hypalon® adhesive used because of the predominance of heat weld bonds
- urethane coated fabric is 25% lighter than the Hypalon® coated fabric specified on the 24'(7m) RIB

An equivalent tube weighing 190 pounds could be manufactured from urethane coated fabric, resulting in a weight saving of 82 lbs. In addition, this lower weight would be accompanied by an *increase* in strength.

Cooley Inc. performed flammability tests on urethane and found a burn rate of 1" per minute in accordance with Flammability of Automotive Interior Materials - Horizontal Test Method - SAE J369a.

When issues such as flammability and ultraviolet resistance are considered, problems arise due to the fact that most manufacturers do not test their coatings or fabrics to stringent specifications. Both urethane and Hypalon® coatings are known to burn in their natural state and eventually ultraviolet radiation will have detrimental effects on both types of coated fabrics. Obtaining data for resistance to flammability or ultraviolet radiation is difficult because these tests are not standardized and are not usually performed. As previously mentioned, additives can reduce these detrimental effects at the expense of strength, but acceptable levels must first be defined.

There were no flammability specifications for the Hypalon® coated fabric used on the 24'(7m) RIB. Therefore, no direct comparison can be made to possible urethane coated substitutions. However, no basis has been found to reject urethane coated fabrics with regards to flammability or ultraviolet resistance. Future specifications should address the subjects of flammability. Characteristics of interest are ignition and burn rate.

Expected tube life is a critical factor in setting forth performance specifications concerning the level of ultraviolet protection required. The British Royal Navy considers the life of a tube to be eight years but in actuality they are experiencing an average of five years per tube, or approximately three tube assemblies over a fifteen year boat lifetime. To our knowledge no data has been collected on the tube life expectancy on U.S. Navy RIB's used as ship's boats.

TABLE 1. Strength comparison of Hypalon® and urethane coated fabrics

	Cooley Inc. L4084UPW Urethane	Reeve's Brothers, Inc. Hypalon	Cooley Inc. L3384UPW Urethane
Weight(oz/yd²)	40.0 ± 2	41.0 ± 3	32.0 ± 1
Tensile Strength (lbs/in)	Warp = 820 Fill = 635	Warp = 600 Fill = 550	Warp = 883 Fill = 787
Tearing Strength (lbs)	Warp = 84 Fill = 92	Warp = 80 Fill = 80	Warp = 67 Fill = 78
Puncture Resistance (lbs)	285	225	145
Coating Adhesion (lbs/in)	39	16	43
Abrasion Resistance	Test Not Yet Available	Pass @ 4500 cycles	Pass @ 5000 cycles
Commercial Cost	$37.00/lin. yd.	$29.00/lin.yd	$28.00/lin.yd

1. Both fabrics manufactured by Cooley Inc.: Tensile strength in accordance with FED STD 191-5102. Coating Adhesion in accordance with FED STD 191-5970. Tear Strength in accordance with FED STD 191-5134.1. Material coated 65% on exposed surface and 35% inside surface for improved abrasion resistance on outer surface.

2. Reeves Brothers balanced coated fabric (equal weights of Hypalon® on the exterior surface and neoprene on the interior surface. Tensile strength in accordance with ASTM D 751-73, section 13. Coating Adhesion in accordance with ASTM D 751-73 section 40.1.2. Tear Strength in accordance with ASTM D 751-73, section 29. Abrasion in accordance with ASTM D 3389-75. Puncture in accordance with Mil-T-6396, section 4.6.17.

3. Cooley's L4084UPW is a relatively new production fabric. Cooley has yet to fully test the fabric. Cooley expects to exceed the strength of the L3384UPW with further testing. This is likely to occur since the strength of any coated fabric is based on the substrate or base cloth used with the coating addition only slightly increasing strength. Cooley's 33 and 40 oz/yd² fabrics have the same base cloth with more coating being applied to the heavier fabric. This results in the 33 and 40 oz/yd² materials having somewhat equivalent strengths.

4. Prices as of November 1993

INDUSTRY OPINION

Over twenty industrial contacts (see Appendix A) were consulted for information on their experience with Hypalon® and urethane coated fabrics. The contacts included tube manufacturers, boatbuilders, repair facilities and boat users. In the past five years, industry has seen a slow movement towards the use of urethane coated fabrics. Most urethane coated fabric supplier's and inflatable boat and tube manufacturers had previously used Hypalon® coated fabrics. The whitewater rafting industry still uses Hypalon® coated fabrics due to the 15 year track record of Hypalon® coated fabric tubes. The hesitancy of these whitewater raft manufacturers to switch is partly due to the high initial costs required to switch from Hypalon® to urethane coated fabric production. Also, urethane coated fabrics are stiffer. This makes them more difficult to roll up and store, and the fabrics do not perform as well under frequent inflation and deflation of the tubes. Despite these problems, many companies have switched to urethane coated fabrics and no industrial source reported disappointment with the results of the urethane coated fabric inflatables.

Industrial claims concerning urethane coated fabrics and their use on inflatable boats are striking. Maravia Corporation, an inflatable raft manufacturer, claims the switch to urethane coated fabrics in 1988 has cut the number of boats returned for maintenance by 70%.

Currently only a few manufacturers produce 30 - 40 oz/yd^2 urethane coated fabrics. Manufacturers for non-marine applications only produce up to 20 oz/yd^2 urethane coated fabrics, but all said they could incorporate a heavier material in production quantities.

GOVERNMENT EXPERIENCE

Two government agencies are working with urethane coated fabric inflatable boats. The United States Army has incorporated urethane coated fabric in their three, seven and fifteen-man assault rafts. The Army switched after observing urethane coated fabric rafts in the whitewater industry for over four years. Over 3500 urethane coated fabric rafts have been delivered to the

Army by California Inflatables, Inc. and they have experienced no problems with their rafts specifically related to the urethane coated fabrics.

Within the past two years, the United States Coast Guard has approved urethane coated fabrics as an acceptable substitute for neoprene coated nylons used on Coast Guard inflatable boats after initial fears concerning hydrolysis. Hydrolysis is an adverse effect of a combination of heat and water which causes the coating to blister and delaminate from the fabric. Failures of this type were generally quick to occur and very spectacular. This problem has been resolved to the satisfaction of the Coast Guard by the incorporation of polyether based polyurethane as opposed to polyester based polyurethanes. The Coast Guard specification is equivalent to the heated immersion test required on the 10m NSW RIB. Since the resolution of the hydrolysis issue, the Coast Guard has experienced no adverse problems related to the material.

CONCLUSION

Urethane coated fabrics have many properties which make them desirable substitutes for Hypalon® coated fabrics. Urethane coated fabric tubes can save weight while increasing strength, simplify supply problems concerning repair adhesives, allow quicker repairs and reduce potential health issues during manufacture. The industrial move to urethane coated fabrics and the cleaner production process are additional benefits. Based on similar material costs between the two fabrics and NADC's experience with life jackets, any differences in final tube (production) prices should be minimal. The U.S. Army and Coast Guard have already accepted urethane coated fabrics for inflatable applications. No special requirements are needed to obtain a urethane coated fabric tube as proven on the 10m NSW RIB currently being constructed with a urethane coated fabric tube.

Concerns over adverse environmental effects on the coated fabric can be addressed with the addition of pigments to increase the resistance to the specific problem. Flammability and ultraviolet resistance can be added to the coatings as desired, however, these additives do have detrimental effects on strength characteristics.

RECOMMENDATION

Urethane coated fabrics should be adopted as a replacement for Hypalon® coated fabrics in tube construction on U.S. Navy RIB's. Lighter fabrics such as the 32 oz fabric used on the 10m NSW RIB are recommended. However, if service experience dictates, heavier fabrics can be substituted for longer tube life.

Appropriate specification requirements for flame retardancy and ultraviolet light resistance should be developed. This is needed whether continuing with Hypalon® coated fabrics or switching to urethane coatings.

It would be beneficial to work with manufacturers in order to better understand the composition of additives used that add ultraviolet resistance, flame retardancy or any other characteristics of interest to urethane coated fabrics. The effects these additives have on physical strength characteristics should be examined so that an acceptable balance can be reached. A good material performance specification could be developed in cooperation with manufacturers that would address concerns such as flammability and ultraviolet resistance. This approach would ensure the eventual specification is feasible and allows competition. In the interest of fairness, more than one manufacturer should be involved to make sure that no proprietary processes or additives are invoked in the specification to be developed.