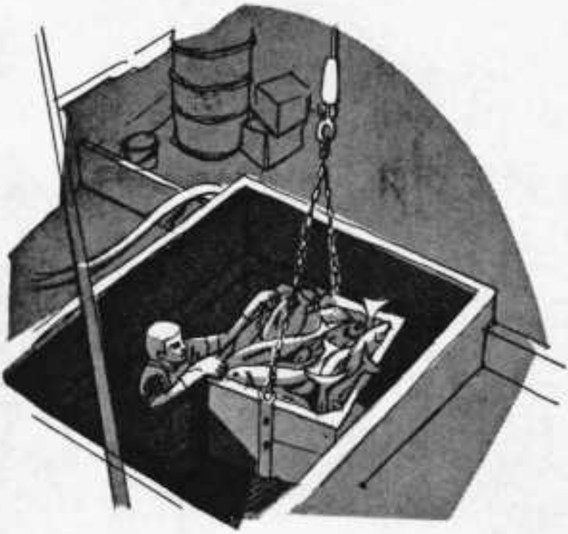
/ 2/1/0/7/

Plastics as a Fish-Hold Lining Material



Circular of Information 631
November 1971
Agricultural Experiment Station
Oregon State University, Corvallis

CONTENTS

This publication is supported in part by the National Oceanic and Atmospheric Administration (maintained by the U. S. Department of Commerce) Institutional Sea Grant #2-35187.

This information is published by Oregon State University as part of the National Science Foundation Sea Grant program.

Plastics as a Fish-Hold Lining Material

Burton W. Adams and R. Barry Fisher*

SUMMARY

This publication describes the suitability of certain plastics for lining the fish-stowage compartments or pens in fishing vessels. These plastics are more suitable than stainless steel, mild steel plate with protective coatings, or aluminum. The selected plastics must be durable to resist the marine environment, of relatively low installation and maintenance costs, and must be easy to install and maintain.

ABS (acrylonitrile–butadiene–styrene), Acrylic-PVC (polyvinyl-chloride), PE (polyethylene), PVC (polyvinyl-chloride), and Epoxy were judged to have acceptable properties. A selection of epoxy or acrylic-PVC would provide the best installation at the highest cost for plastic materials. A PVC installation should cost the least.

INTRODUCTION

An inspection and sanitation bill for the fishing industry is currently before the U.S. Congress. Among other provisions, this bill mentions inspection of fishing vessel holds and pens for cleanliness and minimal acceptable sanitation standards. In all probability the government will not specify surface materials to be used in fish holds and pens, but will specify low bacteria counts and elimination of fungi.

Increasing public awareness of sanitary measures and the desire for improved product quality in the fishing industry dictates a need for examining low-cost and effective methods of protecting seafood products from contamination aboard the vessel.

Most fishing vessel holds are sheathed with wood, and the pen bulkheads and pen boards are also of wood. Fish holds are currently either painted or possibly treated with other preparations. These surfaces are rough, water absorbent, and the covering materi-

* Research Assistant in Civil Engineering and Associate Professor of Fisheries, Oregon State University, respectively.

als are difficult to maintain at a high standard of cleanliness, e.g., removing slime or decaying biological material. It almost certainly will be economically unfeasible, if not impossible, to maintain these surfaces in a manner that will meet minimum standards of a new inspection and sanitation bill.

The fish hold and pens should be lined with inexpensive, durable materials that can be easily installed by fishermen with a minimum of special tools and labor. Further, these sheathing materials must allow easy cleaning and maintenance by the fishermen.

This publication evaluates certain plastics that will provide acceptable fish-hold sheathing materials. These plastics should result in lower material cost and less labor than installations using stainless steel, protective-coated mild steels, or aluminum.

Therefore, suitable fish-hold lining materials must provide a number of desirable properties.

1. They must resist the corrosive effects of sea water, concentrated brine solutions, and strong detergents.
2. Low water absorption is necessary.
3. Low initial installation costs and maintenance costs are mandatory.
4. The lining materials must possess a high degree of resistance to biological and fungi attacks and/or a buildup of biological and fungi organisms.
5. The material must be tough and possess flexing capability to match vessel hull "working" at sea under low temperatures.
6. High impact resistance under conditions of low temperature is necessary.
7. The lining materials must have a high degree of resistance to abrasion caused by repeated scrubbings of the hold and abrasive impact of ice.
8. The materials must be easy to install and repair with a minimum of special tools.
9. Several types of plastics are susceptible to serious damage by ultraviolet radiation from direct sunlight. Therefore the selected plastic must be relatively resistant to sunlight.
10. The lining materials must be easily cleaned by a variety of strong cleaning agents, including live steam.

MATERIAL CONSIDERATIONS AND LIMITATIONS FOR LINING FISH HOLDS AND PENS

Fish holds and pens are exposed to a variety of environmental variables, such as near-freezing sea water temperatures as low as 28° F, and colder if refrigeration is used. The lining materials in the fish hold may be subjected to high temperatures if steam cleaning is utilized. The lining materials must be resistant to strong alkalies and detergents, since it is expected that they will be used for cleaning. Low cost is required not only of the basic lining material, but the costs of installation and repair must also be low. This means that the fishermen must be able to install the material themselves without the need of expensive special equipment and special training.

MATERIAL SELECTION

The cost and relative merits of stainless steel, aluminum, and mild steel with a protective coating are contrasted to the cost of plastics.

Stainless steel. The principal reason for rejecting stainless steel as a hold lining material is cost. A representative stainless steel, type 304, costs about 55 cents per pound (in 1969) or 15 cents per cubic inch. This means that a stainless steel sheet, 1/32-inch thick, would cost about 70 cents per square foot. Some types of stainless steel have good physical properties as a lining material for fish holds, but some will pit rapidly in slow-moving sea water. Fabrication is slow and expensive. If stainless steel sheets are tacked in place, bacterial deposits in and around seams would present continual sanitation problems. If the seams are welded, the stainless steel is susceptible to rapid corrosion in weld areas because it cannot be annealed in the boat. It should be pointed out that welding in the hold presents a serious fire danger (particularly true on a vessel with foam insulation).

Aluminum. Selected aluminum alloys can be used successfully in the marine environment, provided proper precautions are taken. Alloys of the 5000 and 6000 series are normally good performers in sea water. However, cautions must be observed in using aluminum in sea water. All aluminum alloys exhibit such active potentials in seawater that dissimilar-metal corrosion can cause severe problems. Aluminum must not be used around copper (a common material in refrigeration) as copper-corrosion products will be deposited on the surface of the aluminum causing rapid corrosion of the aluminum.

Aluminum is also relatively expensive. For example, aluminum alloy 5086 in a 1/8-inch thickness (1 3/4 pounds per square foot) would cost $1.07 per square foot. Aluminum alloy 6061 would cost about $0.98 per square foot. Approximately 17,500 pounds of 1/8-inch-thick aluminum would be required for lining 10,000 square feet of hold space. Finally, aluminum sheathing would be subject to the same seam-joining problems encountered with steel: seepage and buildup of bacteria for tacked sheets and susceptibility to corrosion if welded.

Mild steel w/coating. The price of mild steel in 1969 was about 12 cents per pound. One-eighth-inch-thick plate would cost about 60 cents per square foot, plus the cost of a protective coating. In addition to the expense of lining a fish hold with coated mild steel, the same problems of fabrication are present as with stainless steel. The added weight of the steel plate must be considered; a steel lining could weigh up to seven times that of a plastic lining.

Plastic. The cost of a 1/16-inch-thick plastic sheet should range from 10-50 cents per square foot. Table 1 lists cost comparisons between the four groups of materials. The various thicknesses of materials listed are felt to be the most suitable for fish-hold installation.

Table 1. Cost comparisons between four groups of materials

Material	Thickness In.	Cost per square ft.
Stainless steel	1/32	$0.70
Mild steel w/c	1/8	0.80-1.00
Aluminum	1/16	0.60-0.65
Plastics	1/16	0.10-0.50

Plastics appear to have the lowest cost potential. Table 2 contrasts the various properties of different plastics. The plastics are relatively easy to fabricate and install. Watertight seals may be made by welding permanent seals on sharp right angles or butting areas between the fish pens and bulkheads.

The plastic materials listed in Table 2 are available for installation in the form of resins or sheets. Composite plastics were not considered because of

Table 2. Important Material Properties Summary*

Material	Resistant to strong alkalies**	Tough at 10° F.	Resists biological growth	% Water absorption in 24 hours	Easy fabrication	Possible candidate (why not)
ABS High impact	E	Yes	Yes	0.3	Yes	Yes
Acrylics	F	No	Yes	0.2	Yes	Brittle, too rigid
Acrylic-PVC	E	Yes	Yes	0.06	Yes	Yes
Cellulosics	P	Yes	No	5.0	Yes	Can support biological growth
Chlorinated polyether	E	Yes	Yes	Nil	No	Expensive
Epoxys	E	Yes	Yes	0.09	Yes	Yes
Fluorocarbons	Inert	Yes	Yes	0.01	No	Expensive
Nylons	E	Yes	Yes	0.04	No	Expensive
Phenolics	F	No	Yes	1.2	No	Brittle
Polycarbonates	E	Yes	Yes	0.15	Yes	Expensive
Polyesters	F	Yes	Yes	2.0	Yes	Weak alkalie resistance
Polyethylenes	E	Yes	Yes	0.1	Yes	Yes
Polypropylenes	E	Yes	Yes	0.01	Yes	Yes
Polystyrenes	E	Yes	Yes	0.2	Yes	Yes
Vinyls	E	Yes	Yes	0.04	Yes	Yes

* Information presented in this table was developed from several sources listed in the bibliography. The primary sources were *Modern Plastics Encyclopedia* and "Plastics," *Machine Design*, references 5 and 9, respectively, in the bibliography.

** Rating Key: E = Excellent; F = Fair; P = Poor.

their relatively high cost. Several plastics in Table 2 have been eliminated as possible candidates for lining material because of one or more undesirable properties.

Fluorocarbons, nylons, and chlorinated polyethers were eliminated because of high cost. Polycarbonate sheet would be a good material choice as it has desirable physical properties, particularly high impact strength at low temperature, but the cost is prohibitive. Acrylics and phenolics were eliminated because of their high cost and poor flexing properties. Phenolics also exhibit poor resistance to strong alkalies. Cellulosics (such as cellulose acetate) were eliminated because they are susceptible to serious fungus and biological attack. Polyesters as resins to be used with sheets of fiberglass cloth or chopped fiberglass were eliminated because of their poor resistance to strong alkalies in spite of the economical possibility of rapid installation by spraying. (It should be noted that "fiberglass" is usually glass fibers in a polyester resin.) By contrast, epoxys as resins for use with glass fibers were not eliminated due to their comparatively high cost because their physical properties appear excellent for a fish pen lining material.

The following plastics were acceptable in all categories listed in Table 2.

A detailed examination of such factors as comparative cost, ease of application, suitability in relation to the fish-hold environment, etc., must be made to make a decision between the plastics listed as acceptable in Table 3.

Table 3. Potential Acceptable Plastics

Type of plastic
1. ABS
2. Acrylic-PVC
3. Polyethylene (PE)
4. Polypropylene (PP)
5. Polystyrene (PS)
6. Vinyl (PVC)
7. Epoxy

ABS is a medium-cost plastic which has desirable material properties for lining fish compartments: excellent abrasion resistance; high-gloss surface; nontoxic, odorless, and resistant to oils except vegetable types. ABS requires black pigmentation incorporated during manufacture, such as carbon black, to provide protection from ultraviolet (UV) radiation from the sun.

Acrylic-PVC is relatively expensive. It is available in standard sheets four by eight feet. Sheets 13 feet in length are available on special order at a surcharge of 2 percent. It is tough, flexible, and exhibits excellent chemical resistance. As it is a new product (developed during the past three years) there is no data on long-term resistance to weathering. Short-term tests (two years) indicate some loss of impact resistance.

Polyethylene is low cost and available in three types: low, medium, and high density. High-density PE properties are superior to the medium- and low-density forms; better resistance to stress cracking, better abrasion resistance, and superior impact resistance. The susceptibility of PE to stress cracking should not pose a problem as stress in the material will be low in this type of installation. Carbon black must be added to protect the PE against UV radiation. A PE installation appears to have the best possibility for the lowest total cost.

Polypropylene. General-purpose PP exhibits poor low-temperature performance. High-impact PP has better low-temperature performance, but its cost is more than high-density PE. PP cannot be adequately protected against UV radiation with a UV absorber alone; an anti-oxidant is also necessary, again increasing cost. Therefore, PP is not recommended.

Polystyrene in an unmodified condition tends to be brittle at low temperature compared to the other plastics in Table 3. PS deteriorates on prolonged exposure to ultraviolet radiation from sunlight and generally exhibits poor outdoor weatherability. Hence, polystyrene is not recommended.

PVC. There are two types of *polyvinyl chloride* that have acceptable properties for lining fish pens: high-impact type II PVC and plasticized PVC (low plasticizer content).

High-impact type II is more rigid than plasticized PVC. Its chemical and abrasion resistance are better; however, it costs about 50 percent more than plasticized PVC. Some difficulty may be experienced in procuring these particular PVCs.

Epoxys as resins to be used with glass fibers appear to have the best material properties of all the plastics for lining the fish pens except cost, which is high. It is expected the initial higher cost will be more than offset by its excellent properties and anticipated longer life. The acceptable plastics and their approximate costs are listed in Table 4.

Table 4. Approximate Cost of Acceptable Plastic

Plastic	Approximate cost (1/16" X 1 sq. ft.)
ABS high impact	$0.20*
Acrylic-PVC	0.37**
Epoxy (room temperature cure)	0.30**
Epoxy (fast curing at 40° F)	0.50**
Polyethylene (high density)	0.10*
PVC (high-impact type II)	0.18*
PVC (plasticized)	0.12*

* Dec. 1968 ** April 1970

Material cost is not the whole cost. The methods and tools required for fabrication and installation of the plastics greatly affect the total cost. Table 5 summarizes the preferred methods of joining the various plastics in a fish hold.

Table 5. Recommended methods of welding thermoplastics

Plastic	Hot gas welding	Heated tool welding[1]	Solvent welding[2]
ABS	B*	B	A
Acrylic PVC	A	A	A
Polyethylene High density	B	A**	No solvent
PVC			
High impact	A	A	A
Plasticized	A	B	A

* A = recommended, B = second choice
** Small sections

[1] A heated tool utilizing a Nichrome steel blade, equipped with a thermocouple and temperature indicator, is recommended.

[2] Solvent welding usually results in weaker joints than the heated-tool or hot-gas method.

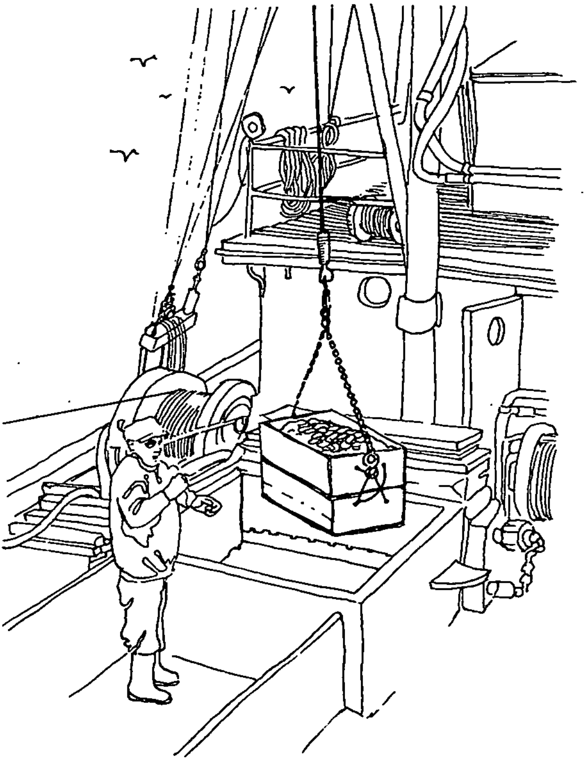
ABS is best welded with a solvent. The best solvent will be recommended by the plastic supplier. Solvent welding requires no additional expense for fabrication tools, only the cost of the solvent which is usually applied with a brush.

Acrylic-PVC is suitably welded by the three methods in Table 5. A heated tool is felt to be the most suitable method for fish-pen applications.

PE has no commercial solvent so must be welded by a heated tool or hot gas.

Rigid PVC is readily welded by the three methods in Table 5. *Plasticized PVC* is best welded by hot gas or solvent. Hot-gas welding equipment requires an initial outlay of about $400, therefore, solvent welding is recommended.

Epoxy requires no special welding method as it comes as a resin and a hardener which are mixed prior to hand layup of the resin. It does require a very clean surface to adhere to. Consequently, most of the fish pens would have to be lined with thin plywood sheets that have been coated with a preservative such as Cuprinal on the down side. The clean plywood would provide an excellent surface to obtain a good bond with the epoxy coating. *CAUTION:* There is a great difference between polyester resins and epoxy resins. The readily available polyester resins have inferior chemical resistance and poor low-temperature flexing properties compared to epoxy resins.



CONCLUSIONS

The choice between the plastics in Table 5 would have to be made on the basis of each particular installation. Considerations such as desired useful life, initial cost, area to be lined, existing prices, and availability of materials are involved.

It appears the two best materials for lining the fish holds are epoxy and acrylic PVC. They are similar in price, relatively expensive compared to the other plastics. The biggest difference is the method and time required for installation.

Acrylic-PVC comes in standard sheet sizes. It requires no prior surface preparation. The pieces are cut to fit, tack nailed in place, and the seams welded with a hot tool. It is expected that there will be more waste material if sheet is used instead of resin, particularly for intricately shaped holds. Waste material must be considered in the total cost. Sheets of Acrylic-PVC can be applied over foam insulation with adhesives suggested by the supplier of the plastic. The rough foam insulation in the hold should be smoothed with a power sander to reduce voids in the foam surface. This partially smoothed surface will then give an even and firm foundation and bond for the adhesive and Acrylic PVC sheets.

An epoxy installation requires substantial surface preparation. The surface must be very clean, free from all oils and grease, to obtain a good bond. The epoxy resin is mixed with a hardener (curing agent) and applied to the hold surfaces. Fiberglass cloth may be used successfully with a second or finish coat of epoxy. The curing time required is dependent upon the temperature, the type of epoxy resin, and the curing agent. Curing time can vary from a day to a week. An epoxy that cures rapidly at a relatively low temperature (40° F) may cost considerably more (Table 4).

Epoxies will bond with foam insulation, but the resultant covering will not have suitable high-impact strength because of the foundation provided by the foam. Also, an excessive amount of epoxy would be used with no guarantee of filling all the voids in the sprayed foam. A workable compromise in a foam-insulated hold would be to line the hold with 1/8″-thick plywood (downside treated with Cuprinol) and then cover the plywood with epoxy. In the case of a vessel without foam insulation in the hold, consideration should be given to the already mentioned practice of lining the hold with 1/8″-plywood and then covering the plywood with epoxy.

The cheapest acceptable installation would probably be solvent-welded plasticized PVC if it is available. Polyethelene (high density) is an inexpensive and acceptable material, but the hot-gas welding equipment recommended for bonding PE increases the cost about $400.

Epoxy is certainly the best covering for pen boards and is easily applied to new pen boards.

For lining fish holds, plastics provide better corrosion resistance than steels. They are cheaper and easier to install. There is no fire hazard during installation. Approximate cost of materials to cover a hold surface of 10,000 square feet are listed in Table 6.

Table 6. Material cost for 10,000 square feet

Material	Thickness	Cost* (materials only)
	Inch	
Stainless steel	1/32	$7,000
Mild steel w/coating	1/8	8,000-10,000
Aluminum (AL 6061 & AL 5086)	1/8	9,800-10.700[1]
Aluminum (AL 6061 & AL 5086)	1/16	6,000-6,500
Epoxy (fast cured at 40° F)	1/16	5,000 (plus cost of plywood)
Epoxy (slow cured at 68° F)	1/16	3,000 (plus cost of plywood)
Acrylic PVC	1/16	3,700
Polyethylene	1/16	1,000 (+ $400 for tools)
PVC-high impact Type II	1/16	1,800
PVC-plasticized	1/16	1,200

* Does not include cost of labor

[1] Apparent price discrepancies are based upon the price breaks for aluminum sheets.

The various plastics listed are commercially available and can be readily installed with appropriate engineering guidance which reliable distributors or manufacturers can furnish.

Specific questions to ask of manufacturers representatives would include the following:

1. What are the total costs for sheathing a given hold?
2. What, if any, surface preparations must be made?

3. What are the exact instructions for installation?
4. Will the company furnish the services of a sales engineer for technical guidance?
5. What expectations are reasonable for the life of the lining material in a fishing vessel hold?
6. How is the material best cleaned and maintained?
7. Are there additional instructions?
8. What sort of guarantees are there and under what conditions?
9. Will the manufacturer guarantee that his plastic material conforms to all U.S. Food and Drug Administration requirements for material contacts with unprocessed food products?

The apparent cost savings and high performance of the plastic materials would indicate that fishing boat owners should investigate the possibilities of the use of these materials as fish-hold and pen-sheathing materials.

APPENDIX

Detailed information regarding the plastics mentioned in this paper can be obtained from the following manufacturers.[1]

The plastics handled by the firms are listed after the company name and address.

Apogee Chemical Corporation
DeCarlo Avenue
Richmond, California 94804 — *Epoxy resins*

Commercial Plastics and Supply Company
630 Broadway
New York City
New York 10012 — *ABS, PE, PVC*

Franklin Fiber-Lamatex Corporation
901 E. 13th Street
Wilmington, Delaware 19899 — *ABS, PVC, PE*

General Tire and Rubber Company
Chemical and Plastics Division
1208 Englewood Avenue
Akron, Ohio 44309 — *ABS, PVC, PE*

[1] The companies listed here are not the only suppliers of these materials. They are the firms that offered product and technical advice for this study. No endorsement of firms or products named is intended, nor is criticism implied of firms or products not mentioned.

Rohm and Haas Corporation
Independence Mall, West
Philadelphia, Pennsylvania 19105 — *Acrylic PVC*

Shell Chemical Company
San Francisco, California — *Epoxy Resins*

Union Carbide
Chemicals and Plastics Division
270 Park Avenue
New York City, N. Y. 10017 — *Epoxy Resins, PVC, ABS, Acrylic-PVC*

BIBLIOGRAPHY

1. Barret, R. B. *Resistance of Plastics to Outdoor Exposures,* Dover, New Jersey: Picatinny Arsenal Technical Report 2102, February 1955.

2. *Guidelines for the Selection of Marine Materials,* New York: International Nickel Company, Inc., 1966.

3. Levy, Sidney, "Designing for Environmental Resistance," *Plastics World,* pp. 22-25, May 1962.

4. Merritt, J. H., *Refrigeration on Fishing Vessels,* London: Fishing News (Books) Ltd., 1969.

5. *Modern Plastics Encyclopedia 1969-70,* New York: McGraw-Hill, 1969.
   Myers, J. J. *et. al.* (ed.), *Handbook of Ocean and Underwater Engineering,* New York: McGraw-Hill, 1969.

6. *Natural Weather Aging Program on Plastics—3,4,5 Years Weather Aging,* U.S. Naval Applied Science Laboratory, September 1964.

7. Palin, G. R. *Plastics for Engineers,* London: Pergamon Press, 1967.

8. Sharp, H. G. *Engineering Materials,* London: Iliffe Books Ltd., 1966.

9. Stedfeld, Robert L. (ed.), "Plastics," *Machine Design,* Cleveland, Ohio: Penton Publishing Co., Vol. 40 No. 29, December 12, 1968.

10. Titus, Joan B., *Effect of Low Temperature (0 to −65° F) on the Properties of Plastics,* Dover, New Jersey: Picatinny Arsenal Plastics Report 30, July 1967.