CONSTRUCTION TECHNIQUES IN STEEL FISHING VESSELS

What is being done to integrate new items of equipment with modern methods? I will try to cover some of the developments that have been and are taking place, in two shipyards that I have been associated with over the last decade.

The engineering, planning and building of steel ships, including fishing vessels, has recently reached a fairly high state of development in modern shipyards. The reduced subsidy and resulting reduction in the placing of orders has delayed the chance to see just how effective these new developments will be, but without doubt, economic improvements have been made.

Fig. 1 shows the flow pattern through a shipyard 10 years ago. Plates were stored vertically, requiring several men, plus a crane, plus a truck to both unload on arrival and reload later for distribution to the pickling bath. Here the acid bath removed the millscale and then the plates required a thorough washing, drying and painting before passing on to the plate shop.

If over 5/16" thick, the plate edges were bevelled, often by hand chipper, before being butt welded from one side and then turned over to make the back-runs. Sufficient plates were joined to cover the panel or bulkhead outline.

Meanwhile, the Mould Loft would prepare full scale wooden templates from faired up lines, laid out full size on the mould loft floor. The men here worked with backs bent low over the floor, perched on small stools running on castors. Hardly a position to produce for 8 hours a day!

When the templates met the plates, markers transferred to template outline, frame spacing and bracket details to the plates. The latter were then cut by hand torch, and the frames welded in place.

Plates requiring special work or forming would be taken by truck to the breaker or plate rolls in another area of the shop.

Frames and beams would be shaped to templates in the angle shop and in almost all cases, the furnace was necessary.

Panel sizes were limited by cranes and transportation capacity, with 25 tons being our maximum and that time.

Small erection blocks were positioned on the building berth and the framing and shell plating often added piece by piece. (see Photo #1).

Double bottoms, stern frame and bow assemblies were the first parts to be affected by the gradual changeover to shop-fabricated blocks but transportable weight and yard layout were very limiting.

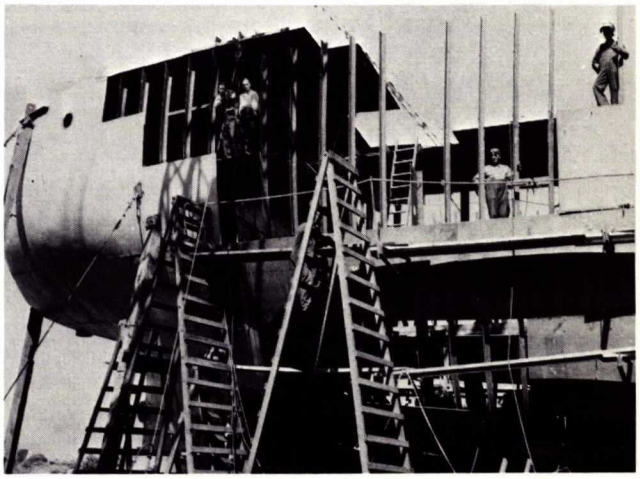


Photo No. 1

How has this changed now? Fig. 2 shows the flow pattern for a modern shipyard.

Plates are now stored horizontally in an area between two parallel crane tracks.

Plate handling is now highly mechanised, an overhead crane with magnetic hoist now being able to cover the entire storage area for fast unloading from trucks and rail cars.

For production, plates and shapes are selected from the pre-marked piles and placed by the crane on to a roller conveyor. They then pass automatically through a "plate preparation booth" that sandblasts, primes and dries both sides of each plate without turning it. The plates are then remarked and fed by conveyors to a position under one of the overhead magnetic lift cranes that feed all the working areas of the plate shop.

In general, plates are passed either to the "parallel gas-cutters" where they are trimmed for width and bevelled for welding, or to the profile cutting machine.

This latter "invention" warrants more explanation. Basically, this machine has a centre body, containing, besides the controls and electronics, a transparent drum on which a 1/10 scale template drawing is placed. The projected cutting lines from this drawing are traced by a photoelectric cell that follows either the line edge or its centreline, depending on the method chosen.

From the centre console project two scanning arms that can each cover plate widths of up to 12′. These arms carry the cutting torches. As the drum rotates, the centre console complete with operator and scanning arms, moves back and forth to cover plate lengths of up to 80′. Any plate requiring more than a small amount of curved or intricate cutting, will be passed to this machine – and that means about 55 per cent of all plates for a small trawler.

An important additional feature is the machine's ability to "pop-mark" the plates where frames, girders and longitudinals will be located and welded at the next stage.

The required drawings for this machine are prepared in a new "mould-loft" where ideal working conditions encourage high productivity. Their chalk lines, battens and wood have given way to drawing pens, splines and mylar-base film.

Plate outlines can now be nested (interlocked); with brackets filling every available corner so resulting in the minimum of scrap.

Plate thicknesses and over-all sizes have been standardized as an obvious aid to the system and the magnetic hoists allow the plates to be lifted without distortion – an important aspect with automatic machinery.

The new mould loft also proudly operates a "shell development jig" that enables twisted shell plates to be developed on 1/10 scale, in a fraction of the time previously taken. A system of adjustable pointers allows a mock up to be made of almost any part of the hull form and a special paper is used to pick up the developed outlines and frame locations for a shell plate.

Returning to the plate shop, the cut plates are conveyed to the press, punch or rolls as necessary and finally to the sub-assembly area where they are joined and the frames added.

All through this operation, the plates have remained horizontal and to avoid turning, new techniques have been developed to produce perfect butt welds of plates from one side only. Very heavy thicknesses still require the back run(s) but the limit is going up and up and even today, very few, if any, plates for a trawler would require turning over. Plate edges no longer require bevelling if under 9/16″.

Shapes up to 15″ deep are now formed cold, so for trawlers and similar sized vessels, the frames are right at hand, for immediate panel assembly.

As these panels are completed, they are carried by fork-lift truck to a buffer storage area that guarantees the erection shop, material to work with.

Erection is now carried out completely under cover. Units are built-up from the pre-fabricated panels and with powerful overhead cranes having the capacity to lift and turn the units, all major welding is made "down hand". (See Photo #2).

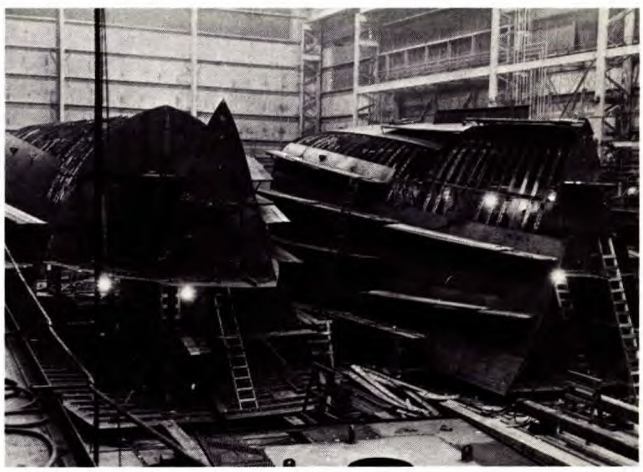


Photo No. 2

If space in the large erection ship is required for other contracts, the completed units are slid outside. (See Photos #3 & #4).

When the machinery is in place, the units are brought together and butt welded, a local cover being arranged in winter time to maintain good welding conditions.

With only the masts, rigging and some outfit equipment to be added before the final painting, the "steel construction" part is complete. (See Photo #5).

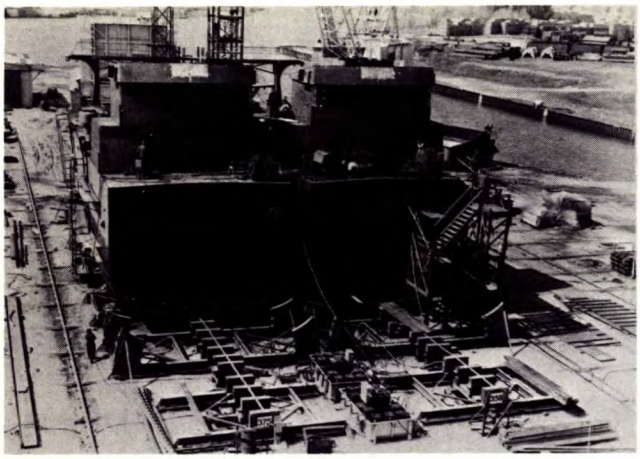


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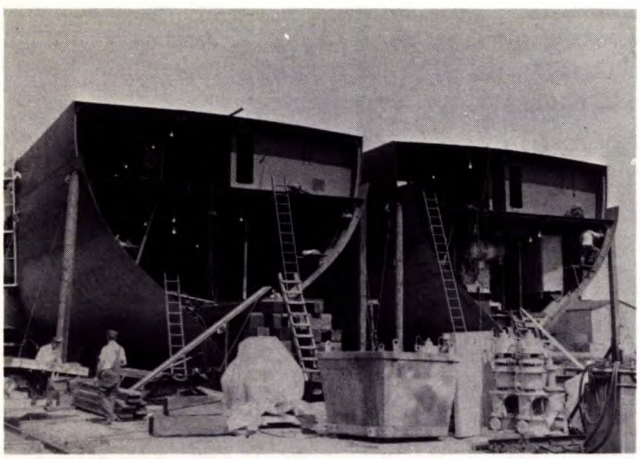


Photo No. 4

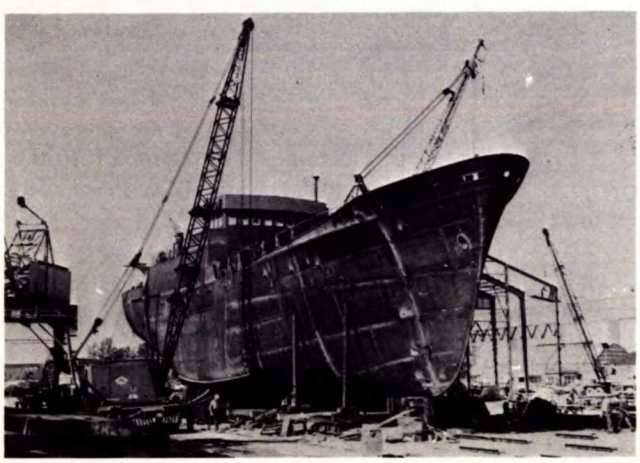


Photo No. 5

Occasionally, sufficient time is available between contracts for the vessel to be completely erected in the shop, (See Photos #6 & #7) where services for all trades are readily at hand, and it is possible that future expansion will allow this to occur more frequently with a resulting increase in productivity.



Photo No. 6

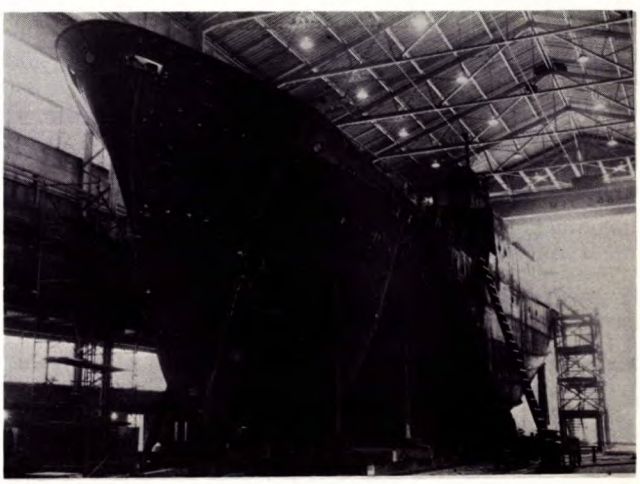


Photo No. 7

Let us now look at the smaller vessel – up to 100′ – and the methods adopted by a smaller yard to achieve results comparable with that outlined in the previous pages.

Photo #8 shows a 78′ side trawler being erected on a base, consisting of 3 girders pre-formed to the vessel's sheer line.

The bulkheads and web frames were set-up about 4′ apart and the longitudinal framing set into the slots pre-cut.

The shell was then placed over the frames and welded from the inside.

As this vessel was to be the prototype of about 15 similar vessels, the construction of the base girders was well justified.

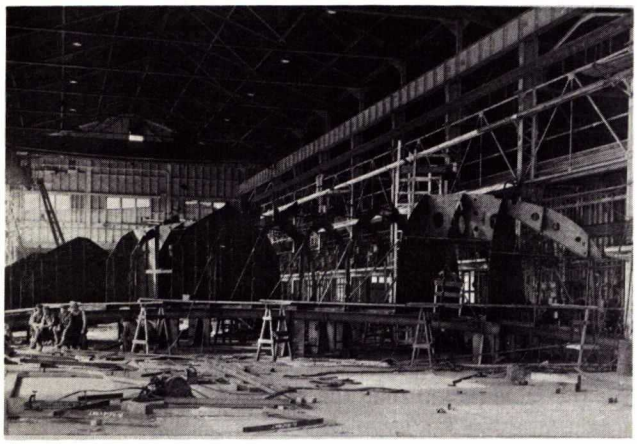


Photo No. 8

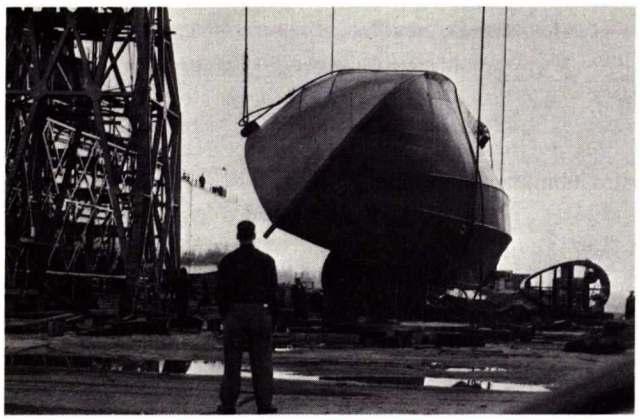


Photo No. 9

This prototype was turned for completion by lifting it bodily, an impractical method in the average small yard with limited crane capacity. (See Photo #9).

To solve this problem and virtually eliminate all overhead welding, a rotating jig was devised that houses the 3 base girders and so allows the same basic assembly method to be used. (See Photo #10).

This jig consists of 4 rings, each turning on 4 rubber covered rollers, each with a load capacity of 40,000 lbs. (Fig. 3).

In practice, the vessel is turned approximately 3 times during the construction and this is easily accomplished with light cranes and wire rope. The rings incorporate steel keel blocks with a rail on each side. (See Photo #11).

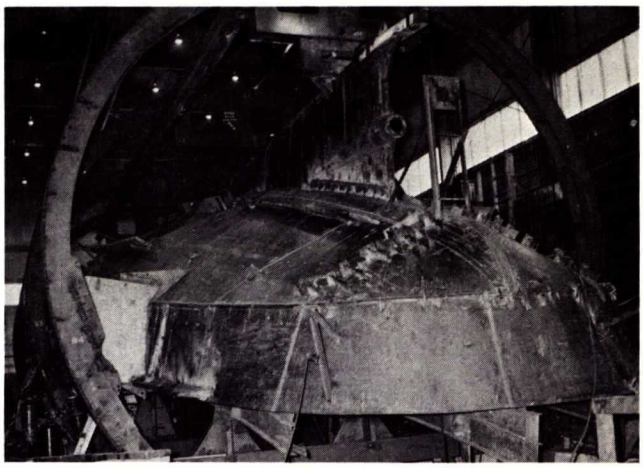


Photo No. 10

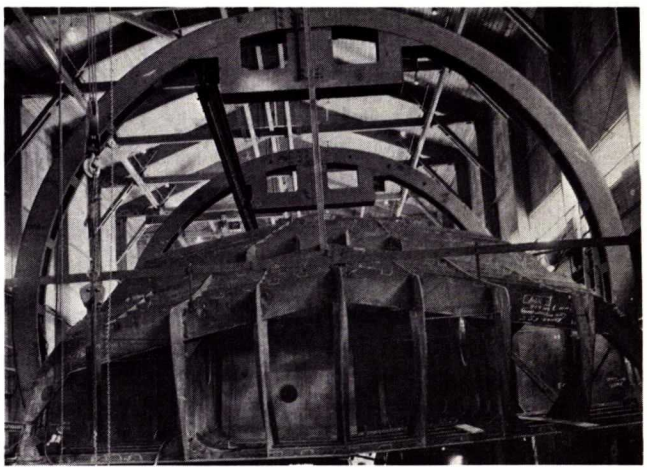


Photo No. 11

When a hull is complete, it is jacked up and 2 special rail carriages are placed under the keel. It is then a simple job to haul the vessel out from inside the rings, onto the main slipway, which has rails of the same dimensions, height and spacing.

Although developed for longitudinal framing, this jig has since been used to construct a transversely framed vessel, using pre-fabricated deck and shell panels. (See Photo #12).

The success of these rings was such that the main yard resorted to them for the construction of a prototype

hydrofoil hull, that demanded the highest standard of workmanship. (See Photos #13 & #14).

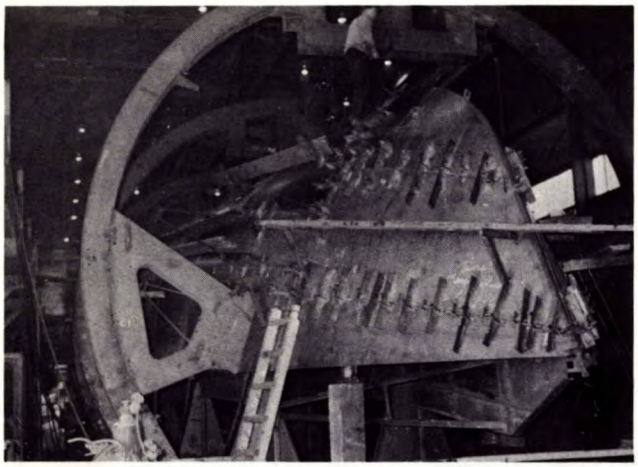


Photo No. 12

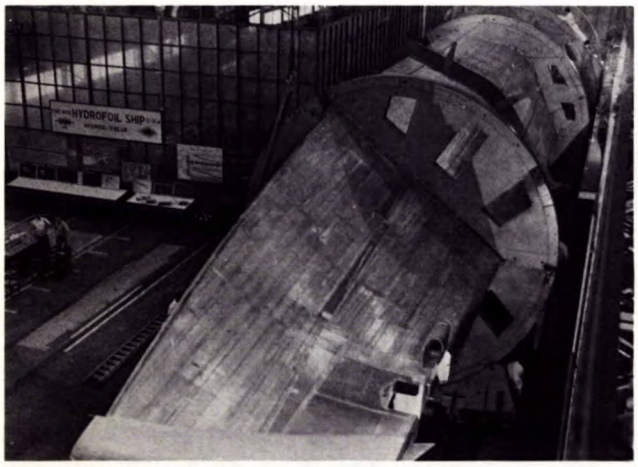
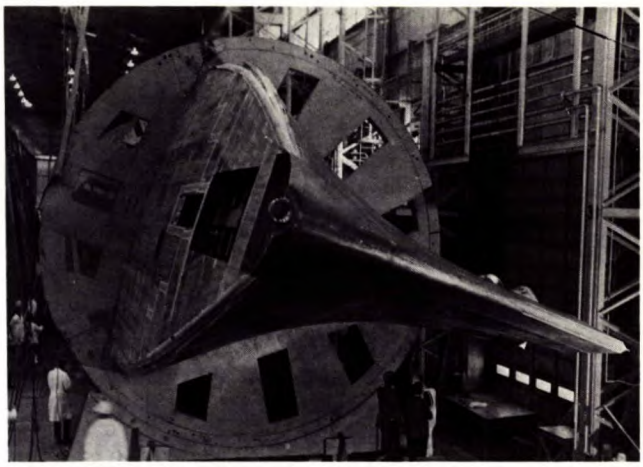


Photo No. 13

In the introduction to this paper, I mentioned two items that require special consideration, if construction in steel is to stay competitive:–

a) Keeping methods up to date and production costs down.
b) Do something to effectively reduce corrosion and associated maintenance.

The first item has been briefly covered in this paper and the second is outside its scope. However, when considering and perhaps comparing a steel vessel with one of other materials, some mention to this maintenance problem must be made.



Basically, it is a question of simple economics for the owner. Are his maintenance costs due to corrosion higher over the same period than the cost of a superior coating or protection system? Tanker owners are finding that they are and so are specifying special epoxy coatings with costly surface preparation and application care.

Trawler owners should be encouraged to work with the shipyards to make a thorough study to see how their particular situation stacks up.

But are really satisfactory coatings available? The top paint manufacturers claim they have some highly effective coatings – if the owners are prepared to pay the price – up to $30.00 a gallon! Complete zinc spraying would be one alternative to study – as would the possible use of a corrosion resisting steel such as Corten.

Without regular maintenance – such as hosing down with fresh water, paint retouching and regular greasing of moving parts – the average trawler requires sandblasting and repainting every 12 months, and this applies to any enclosed fish handling space, as well as to the exterior.

Thick epoxy base coatings (now available for deck coverings) – applied by special gun, brush or by trowel to clean, dry and grease-free surfaces – could well provide a solution for protection of the fish handling area.

Stainless steel can now be welded to mild steel, for pivots and shafts that would otherwise last only months.

Good coating materials exist and more are constantly appearing, but the shipyards must keep informed of their possibilities.

With facts from the owners on their particular maintenance costs, a balanced decision could be reached that, I am sure, would show gains to the operators and make for better looking vessels.

CONCLUSION

Steel fishing vessels have been with us for a long time now, for several very sound reasons:–

1) They are tough and strong and even when poorly maintained, still have a good service life. Not many other materials can withstand an axe, when chipping ice clear at 20°F.

2) Shipbuilding steel has a reliable, repeatable quality that is expensive and difficult to equal in most other materials. Unnecessary overweight is therefore not required to compensate for possible unknown flaws.

3) Industry is now well developed and geared, to work and handle this material, efficiently and economically.

4) The strength/weight/cost ratio of steel is superior to all materials except wood – and the latter is becoming harder and harder to obtain. See table:–

Material	Design Yield	Lbs Cu. Ft	Strength Weight	Approx. ¢/Lb.	Strength/Wt ¢/Lb.
Rolled Mild Steel	35,000	490	71	8	7.9
High Strength Stl					
Corten A 242	50,000	490	102	12	8.5
CHT 100 A 514	85,000	490	173	17	10.2
Plywood BC Fir	7,000	45	155	25	6.2
Mahogany				45	3.5
Hardwood	6,000	45	133	14	9.5
Fiberglass R.P.	17,000	98	173	50	3.5
Ferro-Cement	3,000	150	20	4	5.0
Alum. 54S-H31 A	31,000	173	179	50	3.5

It is granted that the above figures may vary somewhat and that they do not show the complete story, but they do give some indication of why wood and steel have served us so well.

5) Shipyards equipped to build in steel can easily diversify into other steel consuming industries, to cover the inevitable slumps that shipbuilding has and will occasionally suffer.

6) Steel is readily available and is easily repairable, even in fairly remote areas.

A FINAL NOTE

Material alone is not by any means the complete picture. A successful shipyard must have the technical knowledge and experience to assist the customer in finalizing on size, power, layout and equipment that will give the owner the highest return for his dollar expenditure.

This build-up of knowledge and experience takes years of specializing in methods, materials and fishing practice at sea, in order to learn best how to listen to and how to advise the owner fishermen, whose traditional vessels and methods have been their livelihood for so many years.

No longer can shipyards wait to be told what they are to build. They now have a responsibility to the owner to advise him of what gains he may expect with certain new items of equipment or a revised fishing gear layout.

The final choice is still the owner's, but the shipyards must "ferret" out the new methods and ideas that are springing up world wide and use their experience to advise their customers on beneficial changes.

Shipyards must spend time on research and development and so produce trawlers that are more efficient in use and yet built more efficiently and so less costly.

Those firms who do not have the resources, experience or foresight will fall by the wayside, as other industries have shown.

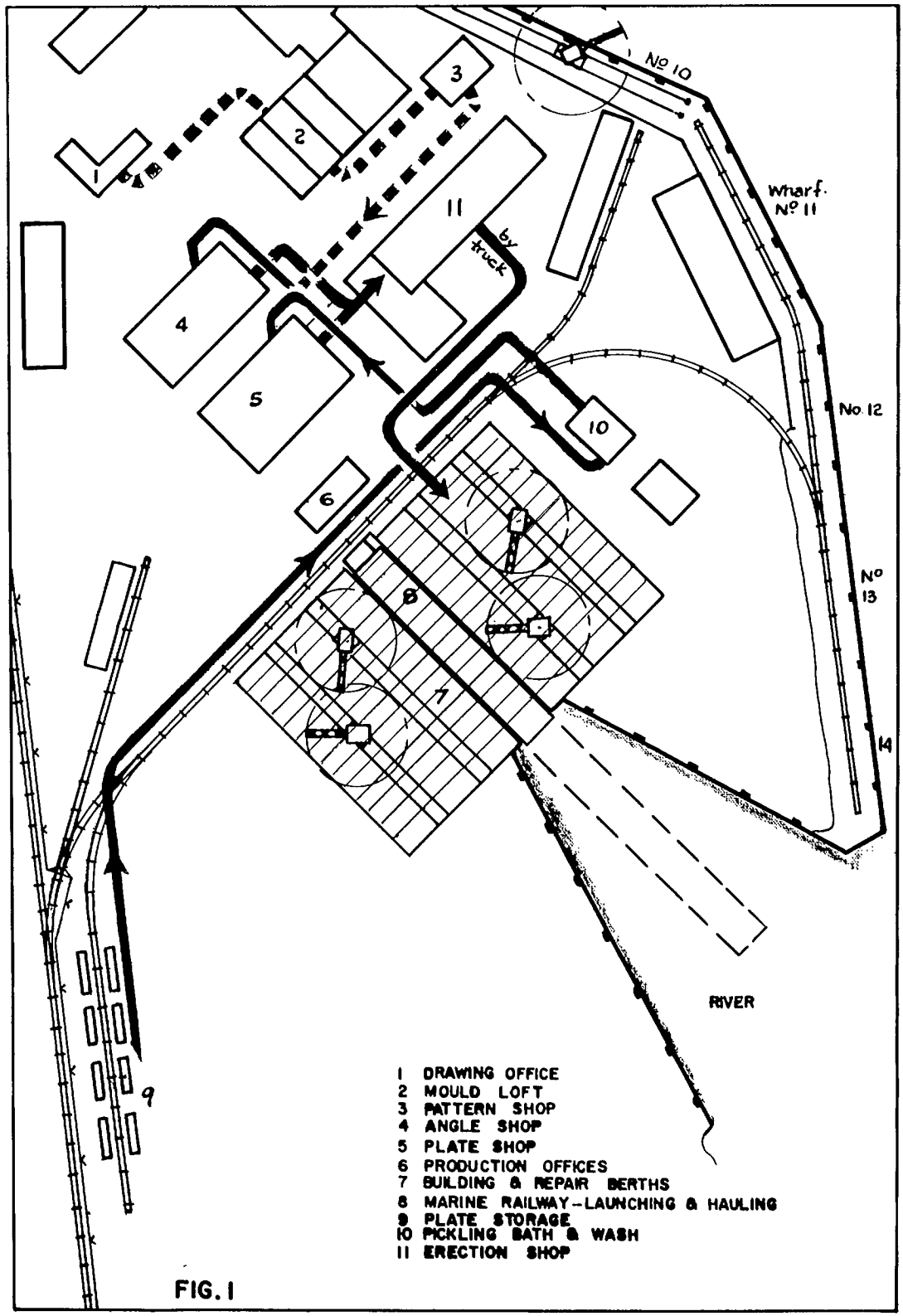

No 10
Wharf. No 11
No 12
No 13
14
by truck
RIVER
1 DRAWING OFFICE
2 MOULD LOFT
3 PATTERN SHOP
4 ANGLE SHOP
5 PLATE SHOP
6 PRODUCTION OFFICES
7 BUILDING & REPAIR BERTHS
8 MARINE RAILWAY—LAUNCHING & HAULING
9 PLATE STORAGE
10 PICKLING BATH & WASH
11 ERECTION SHOP

FIG. 1

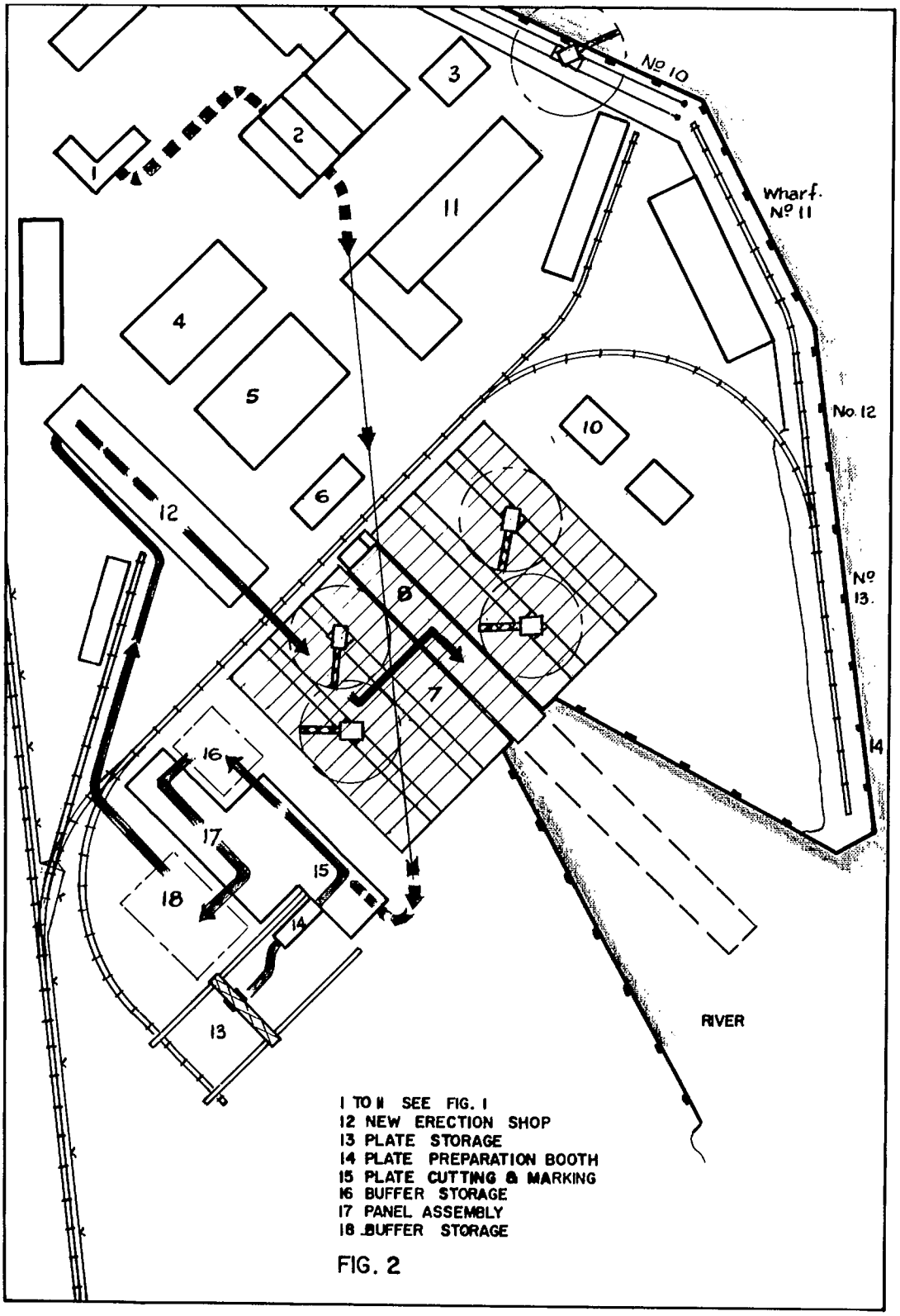
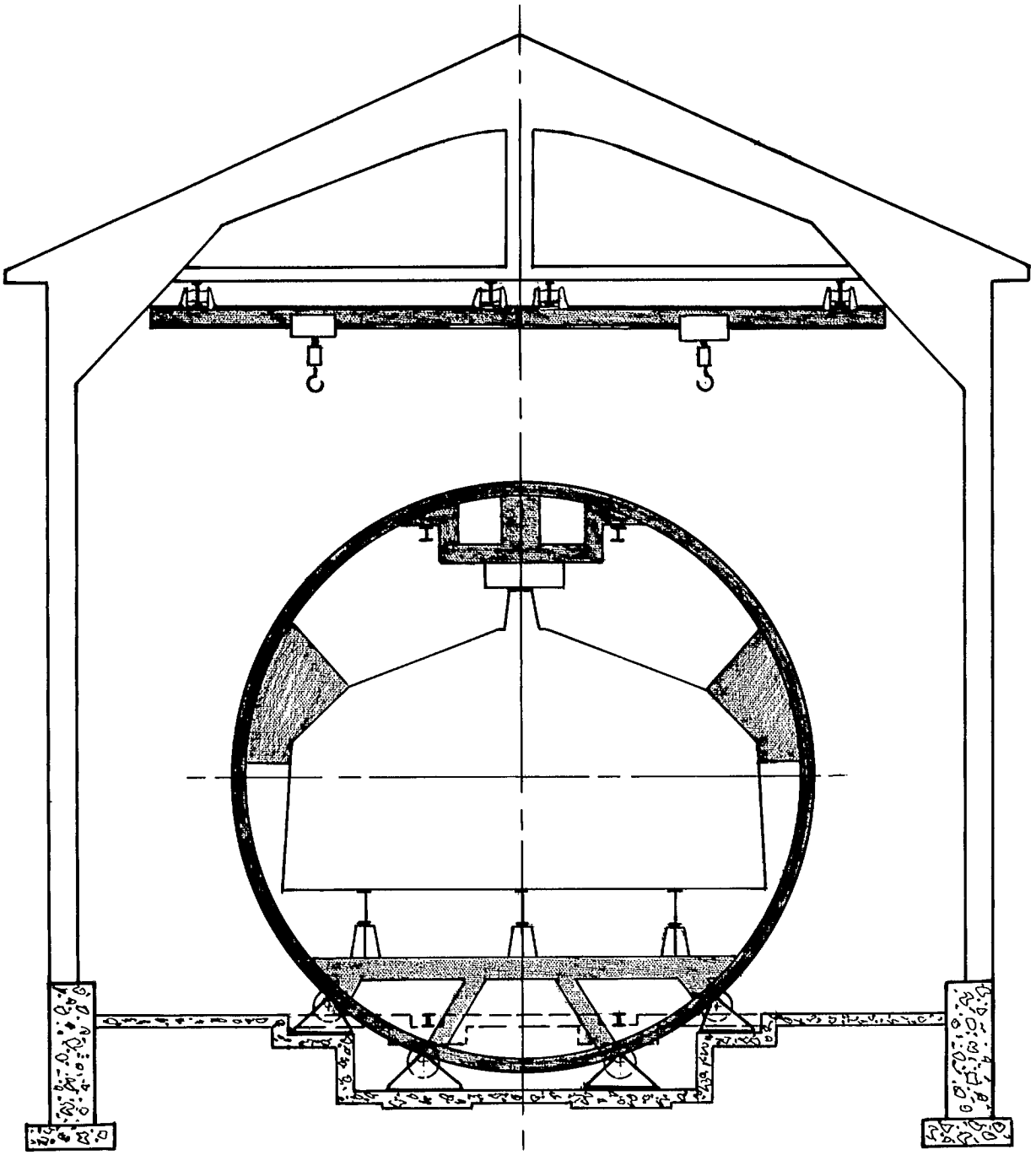

No 10
Wharf
No 11
No. 12
No
13.
14
RIVER
1 TO 11 SEE FIG. 1
12 NEW ERECTION SHOP
13 PLATE STORAGE
14 PLATE PREPARATION BOOTH
15 PLATE CUTTING & MARKING
16 BUFFER STORAGE
17 PANEL ASSEMBLY
18 BUFFER STORAGE

FIG. 2



ARRGT OF ROTATING JIG

FIG. 3

Construction Techniques for Wooden Fishing Vessels



Mr. Potter

by

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In 1954 he joined Dwight S. Simpson and Associates. This Company has now been succeeded by Mr. Potter's own company of Potter and M'Arthur, Inc.,

Mr. Potter is a member of the Society of Naval Architects and Marine Engineers and has participated in I.M.C.O. and F.A.O. fishing vessel design meetings.

ABSTRACT

This paper is divided into three main sections: a review of standards for wooden construction of fishing vessels and their origins, as presented by Lloyds, Bureau Veritas, Det norske Veritas, American Bureau of Shipping, FAO 1955 (Dwight Simpson), FAO 1955 (H. C. Hanson), and Robert A. Smith, 1946; the influence of available material under the headings "Variation from Standardized Scantlings", "Selection for Equal Durability" and "Effects of Preservatives", and construction techniques, including general, sawn frame, bent frame, composite, and strip plank. The conclusion is that development in the construction of wooden fishing vessels will continue, sparked by the ingenuity of builders and the technological advances of materials and fishing practices.

1. REVIEW OF STANDARDS FOR WOODEN CONSTRUCTION OF FISHING VESSELS

There are many formalized standards and scantling tables for wooden construction of vessels, most of them developed by underwriters. In the course of time some of these rules have acquired official status and govern the construction of vessels. Among these are:

Lloyds Register of Shipping	Rules for Wood and Composite Ships
White Fish Authority	Standard Specifications for the Construction of Scottish Wooden Fishing Vessels
Bureau Veritas	Rules and Regulations for the Construction and Classification of Wooden Fishing Vessels
American Bureau of Shipping	Rules for Building and Classing Wood Vessels
Det norske Veritas	Rules for Building and Classification of Wooden Vessels

The Whitefish Authority and the Bureau Veritas rules mentioned above are specifically for fishing vessels. Two papers on fishing vessel construction were presented at a meeting in 1959 sponsored by FAO, printed in "Fishing Boats of the World, Vol. II."

A Suggested Standard for Wooden Trawler Construction by Dwight S. Simpson.

This was amended slightly in a paper by Potter, FAO meeting in 1965, printed in "Fishing Boats of the World, Vol. III."

Scantling Tables, Steel and Wood Fishing Vessels, by H. C. Hanson.

Another useful reference is a paper on "Scantlings for Small Wooden Vessels" by Robert A. Smith.

All these sources give useful tables of sizes of construction members and fastenings and suggestions for construction of various types.

It is interesting to compare standards of various countries and regions. Some rules show the carry-over of old practices such as the extensive use of natural-crook knees and forged ironwork, and some of these same rules include recent practice, such as sections on glued laminated parts. Some, such as the American Bureau of Shipping rules, are unchanged since 1921 and deal mostly with large vessels of softwood construction and must be used with discretion in construction of fishing vessels.

Rules of this sort are helpful to everyone in the business of building wooden fishing vessels, but the truth is they are based on the practice and experience of master builders whose understanding and skill have produced well built and enduring vessels. In this paper I do not propose to re-write any of the material in the listed references or others of the kind, but to mention some practices which have been found useful in the various types of construction. Where these seem obvious to those experienced in the trade, I hope they will forgive such inclusions for the sake of those not so experienced. Where there are better ways than I know I hope others will come forward and share their knowledge.

The first need in building a good wooden fishing vessel is to understand the service required of her and how to build her to meet this need. A longliner does not have the heavy loads to bear that a dragger does. A scalloper has heavy dragging loads and must be built and heavily sheathed to take the pounding of heavy rakes. A seiner will be loaded until the decks are awash, a lobster dragger will expect to fill the hold with seawater and the scalloper will steam around with some ice and a small weight of shucked scallops in the hold and a deck piled high with shell.

The best way to get a durably built wooden fishing vessel is to find a builder of integrity and experience who knows how to select pieces of wood that will last in the places they are fitted, and who will arrange the construction to prevent rot.

2. INFLUENCE OF AVAILABLE MATERIAL

Wooden vessel scantling tables are based on certain species of woods and qualities affecting strength and durability. There is usually a table of increased sizes of members where species of less strength are used. In practice, sometimes it is impractical to use any of the listed species and local species are used. Another important variable is cost. The ideal material or grade may be too expensive to be justified.

The subject of wood species and qualities for various parts of a vessel is being covered by others at this conference, and some of the references listed also give recommendations.

It is not logical to use different species or grades which vary widely in expected life in service. One should try to match the construction of the legendary One-Hoss Shay, which lasted through a long and useful life, each part exactly matching the others in durability. Thus it would be short-sighted to use monel fastenings in a soft-wood vessel which may last only 10 years, or to install black steel tanks of a thickness unlikely to last at least 20 years. To rip out leaky tanks and install new ones is a major job.

There is a variation from the idea expressed above – today we do not have unlimited supplies of high quality timber, and it is common to treat some parts of the wooden construction with copper napthenate or other preservatives to prolong their life. Pressure treatment is no doubt the right method but impractical in shipbuilding except for elaborate construction unsuited to fishing vessels, at least in our economy. The usual practice is to brush on the preservative and even then the result is only approximate, as it is unreasonable to expect that each newly bored hole or final cut for fitting will be faithfully coated with the preservative.

3. CONSTRUCTION TECHNIQUES

a. General

Every piece on boatbuilding emphasizes the importance of lofting, so I should not fail to put it in somewhere. In

bent-frame construction all the parts tend to fit together somehow and a rough-and-ready job can do without much layout work if the builder is experienced. A sawn-frame vessel really costs less to build if the lay-down is careful and reasonably complete. One very successful builder asks for offsets on every third frame and uses one template for three frames, which requires a little dubbing to fair in.

Most of the construction techniques in use today are the same or variations of those in use for centuries. Some of these have been forgotten at times, and I mention a few which may be useful reminders.

Setting up a wooden vessel is the reverse of setting up a steel vessel in one respect. The wooden vessel has many members bent upward at the ends which constantly try to straighten out and cause the vessel to hog. The steel vessel will sag due to welding shrinkage. To offset the hogging tendency, the keel should be laid with a spring or sag in the middle, 1 1/2 to 2 inches per 100 feet of length.

Scarph joints generally are made with their length six times the thickness of the piece. A plain scarph is often used in pieces which are fitted in groups, such as the multi-member clamp and shelf or a bilge stringer with five or six members. Where these members are bent it is best to use a flat scarph–that is, the tapered parts are bent in the same way as the rest of the piece. A hooked scarph is better for end loading but harder to fit. A perfectly good substitute is to fit a flat scarph with a key set diagonal to the cut scarph and with a slight taper to the key. If the scarph nibs are cut with a slight open bevel and the scarph length is a little long, the bolting and then driving of the tapered key will lock the scarph tightly.

Bolting up of the keel and keelson assembly for a sawn frame vessel can be simplified by judicious choice and sequence of bolting. With a two-part keel with worm shoe, the following is recommended. Assemble keel on the flat along the ways, through bolted and rabetted. Spike on worm shoe and turn assembly upright and brace on keel blocks. Erect frames across the keel, drifting to keel. Install keelson and drift through frames and into keel within 2 inches of worm shoe.

Layout and equipment of the shop must be suited to the size and type of vessel to be built and to the construction. Too big an investment in the shop burdens the cost of overhead and conversely, too little or inadequate tooling will be expensive in manhours and very likely reduce the quality of the job. A man of many years' experience watched a new yard being started in opposition to his own. He was not worried about the competition, as he remarked it took about three operators to go broke building up a yard before it could be run profitably.

Layout of a good shop is an exacting affair and I would not presume to propose any specifics. Obviously if you are building a 40-footer, all the wooden parts are easy to lift and place and you only need a shearleg or other means to set the tanks or engine. If building a heavy-framed vessel of 100 feet or more the lifting and setting equipment must be strong and provide mechanical handling in most parts of the shop. If assembling such a vessel under cover there must be a travelling crane over the building ways adequate to handle an assembled frame, a timber for the keel, sternpost, etc., and the tanks, and possibly the engine. If building outside, a truck crane would do the same job. A steam box with boiler will be in a fixed position and must be in a good location relative to the building berth or bending slab, whichever is being used.

Shop tools for the 40-footer or similar boat might be on movable bases to relocate as needed. On larger jobs they will be fixed and must be in proper relation to the raw materials and construction site. A small bandsaw and circular saw will be very handy if brought aboard the vessel during the fitting of joinery and for such jobs as chocking around tanks, etc.

Power hand tools have really come into their own in recent times. A small light chain saw can be used to fit the butts of frame buttocks or cut the butt ends of planking. A power hand planer can fit scarph joints, dub frames, plane mountings for winches and engines, etc. Electric drills are old stuff, but large heavy boring jobs may be better done with a slow-turning air drill. Skilsaws and bayonet saws make easy work out of what was laborious.

A shop must have a few basic tools of standard type, sized to the job-tilting handsaw, planer, circular saw, jointer, bar and C-clamps, planking clamps, jacks, chain falls, etc.

In present day fishing vessels of all sizes there is a lot of steel used. This includes steel deckhouses, hatch covers, sheathing on hull and decks, a lot of fittings such as steel

spars, gallows frames, exhaust pipes, tanks, etc. The modern builder must have means to do this work, at least in part, and uses cutting torches and electric and gas welders as a common thing. Fortunately these are portable and are moved around as needed.

Fastenings are a big subject and can't be covered in a brief way, but a few notes may be in order. Generally speaking, a slightly undersize hole must be bored for every fastening and this requires a source for slight variations in drill sizes. Exposed ends of fastenings usually are bunged but occasionally are puttied. One function of fastenings is to resist the tendency of members to slide lengthwise, which puts a side load on the fastening. In softwood planking fastenings are frequently serrated nails of quite strong material such as bronze or monel which are ideal except for two things. They are too slender for much side loading, and, in case of repair, they can't be removed. Wood screws are better.

In recent years, the usual fastenings for heavy wood construction have been a combination of through-bolts and drift bolts of galvanized steel. In spite of early fears, these have proved very durable. Some builders will head over keel bolts and similar fastenings over clench rings. The rings should be wrought iron (not malleable) and should be a little oversize, otherwise they tend to split. It should be remembered that a yellow metal fastening develops verdigris and tends to slip in the wood, which is all right for a wood screw, serrated nail or rivet but not suitable for a drift or common nail.

As is commonly known, fresh water must be kept from working into the upper parts of a vessel to help prevent rot. The ends of the vessel seem to be most affected, but anywhere that rain or melted snow and ice can penetrate is looking for trouble. Pining in around bulwark stanchions is the common seal for a vulnerable spot and here is one place to use copper napthenate. Soak the wedges through and through. The vertical grain pine makes a fine wick to invite the water in. Often the bulwark stanchions are independent of the framing and are fitted between frames. They are easier to replace than the frame heads. Some advocate a sort of drip or wick arrangement to feed copper napthenate (formerly kerosene) into the heart of timbers such as the stem.

b. Sawn Frame

The main point to remark on here is the problem of high propulsive power in today's fishing vessels, and how to build the stern strongly enough to deal with it. Our practice is to use a stern post in one piece from keel to deck, locked in at both ends, and about three times the shaft diameter in cross section in way of the shaft. It is locked to the deadwoods forward of it and to the horn timber aft of it by two timbers called "feathers" which notch into the sides of the stern post. The shaft log, in two pieces split along the center of the shaft horizontally is fitted with splines and through bolted. The bored hole for the shaft through the shaft log and stern post should be lined with lead expanded in place. Where the stern post tenons into the keel side plates of heavy steel are fitted, let into the wood, extending fore and aft along the keel and with an arm extending up the sides of the stern post. Heavy bolting is angled through all members. The end result is to make a structure strong enough to accommodate a 1000 HP installation in a 105-foot vessel. Then the problem is to get a decent flow of water around this heavy stern post into the propeller and quite a few vessels have vibration trouble because of turbulence in the flow of water in this area. First, the bolting must be kept near the centerline at the aft end, or there is no solution. Then the flange of the stern bearing must be rather diamond shaped, and then, lastly, the builder must be persuaded to fair off as much as possible, instead of settling for a 3/4 inch radius on the corners.

On these heavier vessels we use heavy floors fitted to the bosom of the frames in way of the main engine, and fit steel engine bearers on a heavy base plate bolted to the floors. This minimizes the chance for misalignment due to come and go with the timber.

A general remark on the heavier vessels applies really to all: a really excellent construction job would reduce the scantlings towards the ends and this would be easier to fit, even though it requires some planning and extra trimming. Sawn frames taper in molding from keel to deck and since the molding at deck stays constant the shorter frames near the ends average lighter than in the middle of the vessel. In the same way, it is not logical to carry the midship cross-sectioned area of bilge stringers, clamps and shelves right into the ends. Where a bilge stringer consists of five members or so, taper one off at each end at the 1/4 length and another between there and the extreme end, or some such sequence.

Deck beams should be reduced in molded depth toward their ends, to about 60% of the depth at centerline. By making this reduced depth constant along the sides of

the vessel and holding to the selected camber, the depth of the beams along the centerline will be reduced toward the ends of the vessel and incidentally make the tops of the shelving more nearly level.

Bulwark stanchions in the ends of the vessel frequently have a sharp bend at the deck. Here is one place for a natural crook instead of a weak short grain piece.

c. Bent Frame

The available material for bent frames has a strong influence on the job. Ideally, in this part of the world, true white oak – Quercus Alba – is best. Stock should be cut from young trees, just as needed. Dry stock tends to be brittle.

Canadian Rock Elm is highly regarded for bending stock but my limited experience with this material is that the grain is very uneven and does not bend smoothly.

Brown ash will do for a lightly framed boat but tends to rot.

Hackmatack (Larch) is often used for lobster boats and small boats such as peapods. Knees cut from the joint of trunk and main root are the traditional ship knees and are very durable. They make excellent stem knees in smaller vessels. The main fault with the use of hackmatack for bent frames is that very often the frame is made too small in cross-section for the job it is to do, and tends to crack where weakened by fastenings.

Up to about a 60 foot boat the frames can be bent in place inside the ribbands. A frame molded over about 1 1/2 inches should be strapped during the bending to keep it from splintering, and with restraint on the ends to keep compression on the wood rather than tension to the point of failure. Compression failure is common on a quick bend with a frame over 3 inches in molding.

A frame molded over about 2 1/2 inches, especially if subjected to quick bends, will be better bent on a slab or floor, allowed to set, and then molded or beveled and fitted cold. The frame should be overbent and allowed to straighten a little in the final fitting.

Frames are easier to bend if sided a little more than the molded dimension, although they are not as stiff as a square section frame for the same weight of frame. Two thicknesses can be used, one inside the other, provided they are through-fastened. Splitting a heavy frame with a thin saw cut in an area of extreme bend is commonly done but sometimes leads to weakness if done at the heel of the frame where it is bolted to a floor member. The square section frame gives more flexibility as it can be turned to bend with the flat of the grain.

Some boats are built with heavy floors bolted to the keel and the frames set in with no connection to the floors, depending on the strength of the planking to carry the load. A better job is to fit and bolt the floors to the frames.

Plank fastenings are not as simple in a bent frame boat as for a sawn frame job. The frame is too light to receive heavy driven fastenings, and because it is relatively slender it tends to split if many fastenings are driven in line with the grain. Bronze wood screws are best, galvanized screws OK if the threads are not clogged with zinc, and serrated nails of bronze or monel OK if used with planking of dense material. Galvanized boat nails, clenched, are good but require a two-man team.

The bottom structure on many bent frame boats must be stiffened with stringers and girders, especially in boats of flat form aft and with considerable installed power.

d. Composite

In this day and age it might be thought out of place to include a discussion of composite construction. At one time vessels were built with steel framing and deck structure and bulkheads and stringers and the rest of wood. There is no thought to promote this here, but to show that there is a place for a combination of wood and steel in fishing vessel construction.

Mention has already been made of steel engine foundations and steel deckhouses and steel sheathing, all of which are accepted as good practice. In recent times the upsurge of seining in the Canadian Maritimes has brought some problems to the builders of vessels for this service. These vessels carry tremendous loads and usually have the propulsion engine forward, with the propeller shafting extending about 2/3 the length of the boat. This combination of loads and shafting can lead to structural problems and one progressive Canadian builder described to me a heavy steel keelson structure which he has built in on vessels of this type. This could take the form of a box in cross-section, with the two vertical sides flanged

and bolted to the wood sister keelsons and the top fitted with W.T. removable plates in way of the shaft bearings. Such a box is a practical way to run piping, steering leads, etc.

Another requirement of modern fishing vessels is for a ramp stern which is better made of steel than wood. We have experience with this type of structure and it works out very well. The whole ramp, fairing to the hull, bulwark, etc., is made up of steel weldment and bolted to the wooden hull.

e. Strip Planking

This is an approach to laminated, glued construction which I believe is being treated by others, but may be worth a word or two here.

In some services and in smaller sizes this method of planking may be useful. It has one serious drawback, and that is the difficulty of repair. The usual method is to mill the strips of planking material with a hollow and crown on matching edges. Width of strips is governed by the amount of shape in the hull, as no barreling of the planking is done. Fastenings are edge nails and toenails to frames, so no fastenings show on the surface which saves bunging, etc. Glue is applied to all faying surfaces and the dried glue on the outside of the hull must be machine-sanded off.

This type of planking is fine for a fill-in construction job such as many fishermen undertake. The stock is light and requires few tools. Quality of the planking stock can be too poor to use for regular planking, as the strips are scarph-joined at their ends and so any defects can be cut out. On some models the forms can be set up upside down, ribbanded and framed over the ribbands and strip-planked over the frames. Alternatively, the strip-plank is done over the molds and the frames bent in afterwards.

4. CONCLUSION

There is an endless variety of construction practices in the construction of wooden fishing vessels. The development will continue, sparked by the ingenuity of builders and the technological advances of materials and fishing practices. It is a tribute to the versatility of wood and the skill of today's builders that excellent, durable fishing vessels of wood construction are being built today and competing successfully on an economic basis with every material that has been used for the purpose.

Construction Techniques and Glues Used in Laminated Timbers in Fishing Vessels



Mr. Felszegi

by

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Mr. Felszegi graduated from Mount Allison University in 1957 with a Bachelor of Science Degree and Engineering Certificate, and continued at the University of New Brunswick until 1959, when he received his degree in Civil Engineering. After graduation he worked on various hydroelectric and townsite projects across Canada. In 1961 he joined T.P.L. Industries Ltd. (formerly Laminated Structures) and after four months in Montreal was transferred to Jos. A. Likely, Limited, in Saint John, N.B.

Since 1961 he has designed or has influenced the design and construction of many laminated timber structures throughout New Brunswick, Prince Edward Island and Nova Scotia.

Some of the first uses of laminated timber in the Maritimes originated through his efforts, namely, the new laminated Main Mast for the Schooner "Bluenose II"; dragger keels, stems and stern posts for wooden dragger construction, and creosoted long span glued laminated bridges for timber logging access roads.

He is an active member in both the Association of Professional Engineers of New Brunswick and the Engineering Institute of Canada. He is also a member of the Village of Fairvale Community Planning Commission.

ABSTRACT

Glued Laminated timber emerged from World War II as a product of a new and growing industry. New waterproof adhesives developed during the war provided the necessary material required to economically laminate timber for marine use.

However, laminating timber for any end use whether it be for building construction or fishing vessel construction requires the ultimate in equipment materials, technical personnel and quality control.

When properly manufactured under specific guidelines (toward end use), it is a sophisticated product capable of providing durable components for any structural system. This paper attempts to briefly illustrate some of the techniques, factors and conditions that must be controlled to effectively produce laminated timber for fishing vessel construction.

Some factors are; species of wood, moisture content, surfacing, glues, glue application, pressure clamping and curing.

It is possible to reduce the number of bolted or fastened connections by at least 50% and reduce the number of components to nearly one third when laminated timber is used for the stem, stern post and keel assembly.

Possibly this could be a good source of economy if there is close collaboration between the naval architect, the ship builder and established laminators.

INTRODUCTION

The use of laminated timber for marine applications is not new. The U. S. Navy pioneered the use of laminated timber in the construction of minesweepers and other smaller vessels to meet the wartime needs.

Advances made in the development of improved waterproof adhesives during World War II have given us the opportunity to carry on the established traditions. Rugged R.C.M.P. boats plying the waters of the Maritimes and the B.C. Coast have keel and hull structures of glued laminated timber.

Early waterproof adhesives required curing at temperatures of 300° F or higher but newer types such as the resorcinol or the melamine type make it possible to cure at temperatures of 70° to 140° F depending upon the species of wood.

The method of design for ship construction is basically the same as for ordinary structural work except that tests and experience have led to the frequent use of higher allowable working stresses than are justified by theory alone.

Laminating for vessel construction is a specialized technical operation requiring a precise series of tolerances. All steps in the laminating procedure from surfacing to glue spreading to curing require more rigid control than those for average structural use.

Generally, any species of timber can be glued laminated providing all the conditions of proper moisture content, surfacing, glues, glue spreading, clamping pressure, jig time, curing time and temperatures are met.

Canadian Standards have outlined all the requirements that must be met in the following specifications:

CSA 0122 – 1959 Specification for Glued-Laminated Softwood Structural Timber

CSA 0177 – 1965 Qualification Code for Certifying Laminating plants and equipment

CSA 0112 – 1959 Specification for Adhesives.

Hardwood species have a CSA standard for laminating but it is my understanding that it has not yet been published. Basically it is the same as the softwood specification except for open assembly times, clamping pressures and temperatures (generally higher than for softwoods).

TIMBER SPECIES USED

In Canada, Douglas Fir has proven to be the most economical species to laminate on the basis of strength, stiffness and workability derived per dollar cost. For instance, a Douglas Fir structural laminated beam is 25% cheaper than an Eastern Spruce laminated beam of equivalent structural capacity.

In fishing vessel construction we find that hardwood is most often used for stems and stern posts. This works in well with the laminating process in that hardwoods can be bent to smaller minimum radii than Douglas Fir or other softwood species.

Lamination Thickness	Species		
	Douglas Fir		White Oak
	Tangent Ends	Constant Curvature	
1/4"	2'7"	2'7"	1'6"
3/8"	4'0"	4'7"	2'6"
1/2"	6'0"	7'2"	3'7"
5/8"	7'8"	9'10"	4'10"
3/4"	9'4"	12'6"	6'1"
1-5/8"	32'0"	40'0"	16'0"

It should be illustrated at this stage that the standard lamination thicknesses used are 3/4" and 1-5/8" net. Any deviation from these laminations incurs extra costs and

waste of material. However, it is sometimes necessary to reduce lamination thicknesses to achieve minimum bending radii.

If we require a minimum radius of 2'6" in a White Oak section, a 3/8" lamination would be required. This means 2" stock (net 1-5/8") would have to be resawn to obtain 3 pieces of 3/8" stock. In addition to labour incurred there would be a net loss of 1/2 inch of good lumber. To summarize, all straight laminating work uses a net laminating thickness of 1-5/8". This standard lam can be bent to a minimum radius of between 40'0" and 16'0" depending upon condition and species. The net 3/4" lamination thickness is used to a minimum radius of 6'1" to 12'6". The restructive conditions shown in the table apply for other radii.

It should be noted that no steaming of laminations is permitted. All material is kiln dried and must not be less than 7 or more than 16% moisture content at time of gluing.

Surfacing tolerances or the variation in thickness between points in the length or width of a piece of laminating lumber or between pieces of laminating lumber to be used in the same lamination shall not exceed plus or minus 1/128 inch (.0078").

Mating surfaces of scarf joints held together under light pressure without glue should not permit the insertion of a .005" thick feeler gauge at any point in the joint.

GLUES USED FOR LAMINATING

Generally glues for structural and marine applications may be classified as natural or synthetic resin adhesives.

I. Natural Adhesives –

- A. Protein Adhesives: 1. Animal
  2. Blood Albumin
  3. Casein
  4. Soya Bean
- B. Starch Adhesives: 1. Corn
  2. Tapioca

II. Synthetic Resin Adhesives – A. Thermosetting
B. Thermoplastic

Casein glues are used for structural components where service conditions will not raise the moisture content of the timber above 16%. Obviously this type of glue is not desirable for marine use.

Our interest lies in the use of Thermosetting adhesives which gives a rigid bond rather than the Thermoplastic which gives a flexible bond.

The Resorcinol formaldehyde resin adhesives have characteristics similar to those of Phenol-formaldehyde resins but have an advantage in that assembly and curing operations may be performed at room temperature although hot pressing and curing at moderately high temperatures give improved strength and durability. Ideal temperature ranges are minimum 70° to 180° dependant upon species of laminating stock.

With the application of heat, it is necessary to raise the relative humidity to insure that adequate moisture is present thereby maintaining the equilibrium moisture content and eliminating checking of lumber while curing.

PROPERTY OR CHARACTERISTIC	CASEIN GLUE (Water resistant)	RESORCINOL-WATERPROOF
Strength (Dry)[1]	Very high to high	Very high to high
Strength (Wet)[2] After soaking 48 hrs.	25-50% of dry strength	Very high nearly 100% of dry strength
Durability (Prolonged Soaking)	Deteriorates rapidly	Very high if Resin is unadulterated
Rate of Setting	Rapid	Very fast with heat
Working life	Few hours to a day	Few to several hours
Temperature Requirements	Unimportant	Minimum 70°-140°
Application	By hand or rollers	Rubber covered rollers
Drilling effect on tools	Moderate to pronounced	Moderate
Spreading Capacity[3]	Ave. 40-60	Ave. 35-50

NOTES: 1. Based chiefly on joint strength tests.
2. Based on Plywood strength tests.
3. Based on reports from various manufacturers, (expressed in sq.ft. of single glue line per pound of dry glue for veneer work.)

Once the lumber is surfaced and scarfed (if necessary) a dry layup is generally performed for straight components or a full size pattern is made to establish jig layout if the component is curved.

Surfaces of individual laminations are coated with glue and the assembly is placed in the jigs and clamped. Steam and heat are usually applied for the curing process.

Clamping pressure is in the order of 100 to 150 p.s.i. on the glue lines and usually is maintained for 12 to 15 hours.

It must be stressed at this point that the open assembly time, working temperatures, clamping pressure, curing time and temperature are all critical factors in producing a strong laminated timber structural component.

CONCLUSION

Again it must be emphasized that laminating of timber in any quantity or quality must be executed with the ultimate of equipment and quality control.

This fact cannot be overstressed. At present it must be accomplished with expensive machinery and equipment housed in a quality controlled environment.

On this basis the laminating industry has much to offer to the construction of wooden fishing vessels.

Recent experience on the supply of laminated stems, stern posts and keels has indicated that the laminated timber costs have been slightly more expensive than with the use of solid native timbers (if they had been readily available). It is the opinion of the writer that more economy can be derived by closer collaboration between the naval architect, engineer, shipbuilder and laminator. Hopefully, the end result would be; slight modification of sections to meet supply standards; change of sections by reference to stress analysis and modifications thereof by the experience of persons involved; and finally long range planning by the companies to establish quantity requirements. If a manufacturer has to laminate a section he applies certain basic costs such as full scale pattern, minimum quantity purchasing of laminating stock, etc. If he knew that two more sections would be required within a few months, he could save the pattern and order sufficient lumber to complete the requirement for future work or he could laminate all the material at one time and hold it on consignment. These are a few of the factors that influence the cost of manufacturing laminated timbers.

This paper has been prepared with three basic components in mind; the stem, keel and stern post. Laminated timber can be supplied to fulfill almost any other function in a vessel. The economics, however, would have to be analysed—probably when the Naval Architect, Shipbuilder and Laminator meet to exchange views.

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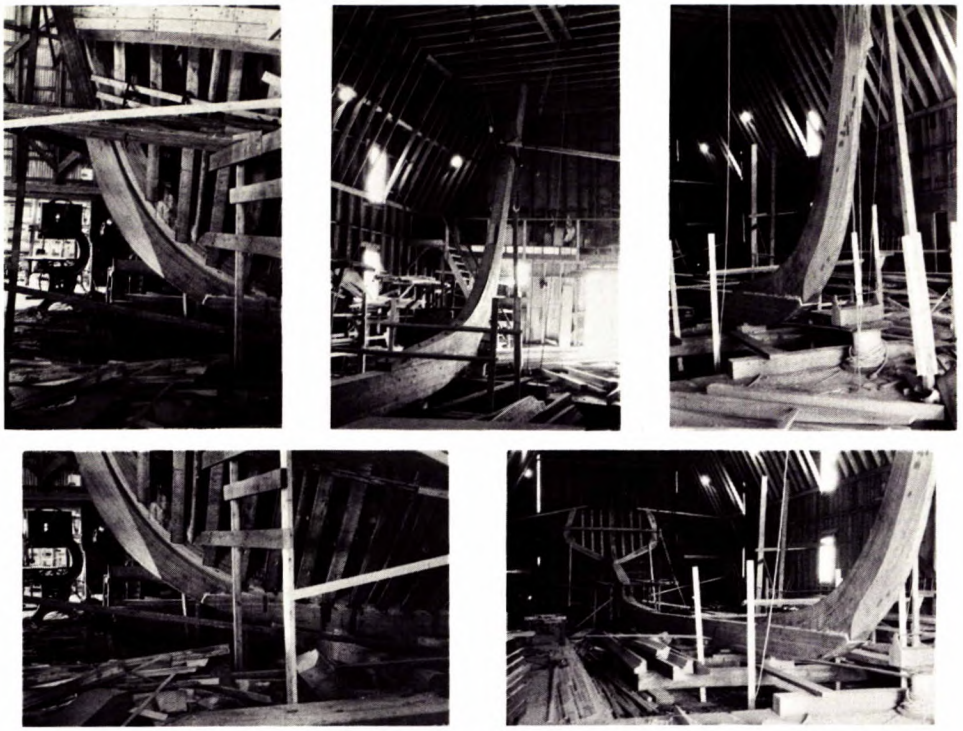
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Various views of layup of laminated keel, stem and stern post for 56-foot fishing dragger.



Douglas fir laminated arches – section across knee approximately 6′4″. Span out to out 82′0″.

Construction Techniques in Aluminum Fishing Vessels



Mr. Matsumoto

by

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Mr. Matsumoto was born in Japan in 1918 and went with his mother to Prince Rupert, Canada, when he was six years old. From his father, he learned how to use tools at an early age, with the result that he designed and constructed a 14 ft. clinker-built rowboat at the age of 13.

By working in his father's boat yard he became familiar with every phase in the construction of wooden and steel boats, and was able to design and build numerous fishing vessels before he was 21.

The boat building business was stopped by the Second World War, but immediately after, Mr. Matsumoto and his father re-entered the business in Nelson, B.C.; it was later moved to Vancouver where it has been in operation for the past 18 years.

Mr. Matsumoto has been in the boat building industry now for 35 years, during which time the shipyard has constructed over 500 boats between 25 and 94 feet in length. Since 1960, no fewer than 225 of these vessels have been built of aluminum.

ABSTRACT

The purpose of the paper is to summarize the main techniques in engineering and fabricating aluminum fishing vessels. Because a complete description cannot be presented, only those aspects of construction which are unique to aluminum vessels or which are of special importance in application to aluminum vessels are given, with hopes that they sufficiently cover this subject.

The three main topics are the structural engineering aspects, the fabrication techniques, and the methods in dealing with corrosion. Because these features dealing with the construction of aluminum vessels are based on the properties of the marine aluminum alloys, it is of importance that these properties be understood. Also, different marine alloys produced by the aluminum companies differ in their properties, therefore careful selection is required in applying the suitable types to their respective purposes.

The welding techniques have made the greatest improvements of all the processes concerned in aluminum vessel construction. The new methods have put the aluminum vessel on a par with vessels of any other material in the views of economy, seaworthiness, and fishing capabilities. It is mainly due to the advancements in welding techniques that aluminum fishing vessels are appearing in increasing numbers on the present commercial fishing scene, where ten years ago, there were very few or none.

INTRODUCTION

The use of aluminum in the construction of boats and ships is not unique, in fact it goes back as far as the 1890's. Most of the aluminum vessels in the past were of riveted construction and therefore did not succeed in commercial use because of the high cost of the material and production labour, and furthermore because of the problem of corrosion. During the 1930's the marine-type aluminum alloy

was developed. This advancement in metallurgy, together with the advancements in welding processes made possible the application of aluminum alloy to fishing vessel construction.

Aluminum alloys are very light and have a high strength per weight ratio–169 pounds per cubic foot. The marine aluminum alloys are extremely durable because they resist corrosion on both fresh and salt water, and will not rot, rust, warp, or absorb moisture. Used in the construction of fishing vessels, the marine-type aluminum alloy gives the vessel a light weight with high strength per weight, low centre of gravity for stability, greater speed per horsepower, and a minimum cost of maintenance.

STRUCTURAL ENGINEERING AND FABRICATION TECHNIQUES

The most important aspects of construction of aluminum alloy vessels are the structural engineering and fabrication techniques.

The ship's structure requires adequate strengthening to overcome stress and vibration fatigues. If the structural strengthening is inadequate, "vibration" or "brittle fatigue" fractures may result in the areas where exterior and interior motions transmit vibrations; this problem may occur especially around the propulsion source. The main preventive measures against occurrence of such vibration fractures are the web frames with longitudinal construction and proper frame spacings, which provide the required strengthening.

Forming and fabricating aluminum is done with the same equipment as is used for other metals or wood, with slight modifications. For example, shearing, nibbling, and blanking are the same methods used in steel construction, while cutting with saws is the same as for wood except knife blades and saws require proper setting and teeth with gullets to clear the chip dust. These methods, together with the new and improved techniques in welding, have made possible the production of the present aluminum alloy fishing vessels.

Two welding processes which have been developed and which are applied mainly to aluminum are the M.I.G. (Metal Inert Gas) process and the T.I.G. (Tungsten Inert Gas) process. These inert gas, shielded-arc processes are used exclusively for non-ferrous metal fabrications. The M.I.G. process is suitable for all position welding, and the T.I.G. process is used for butt welding of pipe and for welding complex shapes where fast change of position is required.

Correct welding procedures and techniques in dealing with aluminum are of such importance that competent welders are required to overcome the problems of lack of fusion, the locally stressed areas, oxide inclusions or porosity, crater cracks and stress weld cracks. The welding engineering can surmount the problems of stress and brittle failures.

CORROSION

Electrolysis, well known as galvanic corrosion is the main factor of deterioration of any metal used in the construction of fishing vessels. For example, rust occurs in unprotected steel and the steel can be completely oxidized; on the wooden vessels where all types of metals are used a galvanic or electrolytic reaction occurs and therefore an anode is necessary to protect the metals applied. Electrolytic reactions can be avoided by eliminating direct contacts with noble metals or by use of dissimilar metals.

"Pitting" or "frosting" are terms used to describe the oxidation of bauxite occurring on the surface of both the protected and unprotected marine aluminum alloy. It has been found that about 50% of the oxidation or weathering takes place within the first six months of the boat's use and completes itself within the following two years. After two and one half or three years of boat use the oxidation disappears and the pitting becomes negligible.

Fishing vessels can be painted or remain unpainted on the exterior and the interior surfaces, but it is essential that these surfaces be brushed and cleaned with detergents because the uncleaned material creates a poultice corrosion, especially in the bilges of the fish-hold. If painting is required the aluminum alloy surfaces are etch primed and painted with zinc chromate as a base coat. The finishing coat of paint is then applied, provided it contains no lead, copper, or mercury. An underwater antifouling paint of tributal tin oxide is then painted over the zinc chromate base paint. If the underwater is unpainted sea growth such as mussel and grass will adhere on the bare aluminum alloy surfaces, therefore they must be washed down about twice a year, when seeding begins.

"Crevice corrosion" occurs in joints on riveted construction between two aluminum surfaces and between aluminum and other materials such as wood or rubber, therefore bitumastic, neoprene composition or zinc chromate paint is applied.

"Deposition attack" is the result of a chemical reaction between copper and aluminum which takes place when copper pipes and tubing are used if the copper is left unprotected.

Ferro-Cement Boat Construction



Mr. Samson

by

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Mr. Samson was born on the Canadian prairies in 1937 and joined the Royal Canadian Navy when he was 17. He later spent six years overseas working in various boatyards around the Pacific. He started his own boatyard in Richmond, British Columbia, in 1966. Mr. Samson has made several trans-Pacific crossings in sail boats and power boats. Much of his boat yard work has been on the building, repair and maintenance of fishing boats.

ABSTRACT

In this paper Mr. Samson, a pioneer of ferro-cement boat construction, discusses in detail the construction of a ferro-cement hull through from lofting to completion of plastering. He does not touch on the merits or disadvantages of this relatively new medium, but rather confines himself to construction techniques.

He takes as an example the construction of a 44-foot salmon troller designed in the S.M.D.E. office specifically for ferro-cement.

Mr. Samson covers the recently developed building technique which involves web frame construction, and this is probably the technique which will be used in the construction of fishing vessels up to the 100-foot mark.

The paper contains the latest information on building materials and mixtures, etc.

OUTLINE OF METHOD

Any description of ferro-cement boat construction could run into lengthy chapters but the following is a concise outline of the method which will most probably be adopted in the building of a fishing vessel.

We will refer to this method as the web framework technique – a method which should be found to be most suitable for medium to large size fishing vessels. Other techniques now being widely used in the industry are the pipe framework and cedar mold methods. Many improvements in ferro-cement building technique lie ahead and this web framework method serves as an example of this. The many refinements it presents would not have been possible without the earlier efforts.

At the outset it must be made clear that the web framework technique is for one-off construction. It was evolved to bring about improvements in structural construction techniques, and not to illustrate production methods. And, while it does streamline construction, the end product is the same, the building materials are the same. The basics of wire mesh, reinforcing bar and mortar have not been cast aside.

A 44-foot West Coast troller, recently designed by Samson Marine Design Enterprises in Vancouver, will serve as the demonstration vehicle in this discussion. Construction of this vessel is taken through from the very first stages.

The first consideration is the structure which will support the hull throughout construction – and this can

also serve as the structure which will shelter the hull. Too much emphasis cannot be placed on this structure and Illustration No. 111 details a suitable type of building in which lofting can be carried out under good conditions.

It should also be pointed out at this stage that in this 44-foot troller design the fish pens and bulkheads have all been designed on stations for ease of construction (see Illustration No. 1104).

After the lofting is complete 1/4-inch plywood patterns are cut for the webs and bulkheads and on these are carefully marked the waterlines, diagonals and buttocks. This will aid in setting up the hull.

Two layers of 1/2-inch 22 gauge chicken wire are now lightly stapled to one face of the plywood patterns. The inside edges are neatly trimmed off with shears while the outside edge is allowed to run wild for 6 inches. This overlap will later join into the hull and to achieve this on the curved areas darts must be cut at 6-inch intervals on the overlap.

While the patterns are still lying on the workshop floor one-inch by one-eighth-inch strap iron should be attached to the neatly trimmed inside edges and to any edges which will not later mate with mortar. These strap edges will give a neat finish and can be attached in position with nails.

The strap edges are applied where bulwark stanchions, access cut-outs and fish pens occur together with all areas of framing which are not joined with the hull. These form screeds which give the plasterer a landing for his trowel.

A length of 1/4-inch cold-rolled reinforcing bar is now spot welded into the corner formed by the strap edge and the mesh-covered plywood pattern. A second length of 1/4-inch reinforcing bar is now stapled to the outside edge of the mesh-covered pattern, giving a true outline of the mold. Continuous lengths of re-bar are then filled in on the pattern on approximately 2-inch centres with shorts welded into areas which form the keel, bulwark braces and engine bed braces.

Short lengths of the 1/4-inch reinforcing bar are cut in readiness for positioning across these continuous lengths of rod. They are welded in place on 6-inch centres and odd ones should be attached at 45-deg. angles for bracing. These shorts are allowed to protrude for about one foot beyond the outside edge (see Drawing No. 106).

Two more layers of the 1/2-inch 22 gauge chicken wire are now stapled on top of this re-bar framework with the inside edge again trimmed off neatly with the shears. And again, darts must be cut into the outside edge at 6-inch centres, the outside again being allowed to overlap for 6 inches.

In the medium-sized fishing vessel, these now preformed webs would not be plastered at this stage. In the larger vessel, however, it might be considered advisable to plaster at this point and provide stiffening for the vessel during the remainder of the construction. In this case, the strap iron screeds would be replaced by three-quarter-inch by one-inch wooden screeds or whatever thickness of bulkhead is designed into the vessel. These web patterns would then be plastered right on the workshop floor.

Returning now, however, to our 44-foot troller we are ready to commence the setting-up of the vessel. Using waterline "A" as our guide, lengths of 2 x 12" lumber are attached to the frame patterns, and these are hung in position as shown in Illustration No. 111.

The next step is to shore-up a length of channel iron which will run along the straight length of the keel. This serves a number of purposes and provides an ideal grounding shoe. Sharp corners of mortar are inclined to chip and the channel iron eliminates this danger. The bottom of the keel has also proven a difficult area in which to achieve perfect penetration. The channel iron helps provide the finish and is further a good stiff member to assist in the set-up and reduce movement throughout construction. When shored-up in place this channel iron is welded to the web frames to ensure against shifting during construction (Diagram No. 108).

The channel iron is used along the straight length of the keel and where the sweep of the bow commences a length of one-inch cold rolled steel rod is substituted. This is allowed to run wild beyond the sheer line and can be secured overhead for further stiffening.

The shaft log is now set-up as shown in Illustration No. 110 and when this is complete the stern assembly can be set up.

After ensuring the hull is fair the task of welding in place the longitudinal lengths of 1/4-inch reinforcing rod

can begin. It will be found simplest to spot weld the longitudinals first along the water lines and then fill in with lengths on 2-inch centres. Quarter-inch re-bar ribs can now be spot-welded into place vertically on 6-inch centres. Extra rods should be placed in the stem area, parallel to the stem and about one-inch apart for re-inforcement.

Short rods are bent around the inside of the stem and welded in place as shown in Illustration No. 111.

The wire mesh which was left protruding from the web frames will now of course have been bent over to allow placement of the longitudinals, two layers in each direction and the short rods protruding from these frames can also now be bent at right angles and welded into place. These should all be bent longitudinally, fore and aft alternately.

It should perhaps also be pointed out at this stage that as the deck is constructed in the same manner as the hull the vertical rods forming ribs in the hull should be lapped in and welded to rods running athwartships on the deck. The re-bar on the deck should follow the contour on two-inch centres. All beds and joints should have a minimum of a five-inch radius.

Hatch coamings, etc. should also be finished off at this stage and edged with one-inch strap iron screeds.

While the over-all thickness of the hull and deck will ideally vary little over three-quarters of an inch, the one-inch screed is used to ensure that all stray ends of mesh can be well buried in the mortar.

The engine beds are next framed up before the 2 x 12 lumber braces are removed. These lumber braces are removed one at a time and transferred to an overhead position, see Illustration No. 111. The hull is then braced to these lengths of lumber by lengths of re-bar attached to the deck.

The hull is now ready to receive the wire mesh – eight layers of the 1/2-inch 22 gauge chicken wire. Four layers are attached to each side of the rods. Mesh obtained in lengths 3′ x 150′ will be found the easiest to work with. Desired lengths can be doubled and suspended from the sheer, ensuring that the joints are lapped. On the inside, the wire mesh must lap over the mesh on the web frame.

The mesh must be laced as tightly as possible, using tie wires or hog ring fasteners.

When the mesh is tightly laced, the 1/4-inch wooden plywood patterns can be freed from the staples and the mesh secured on the webs. And, when the wire mesh is tightly laced all over, 3/4-inch plywood wooden blanks can be positioned for any through-hull fittings, deck fittings, limber holes etc.

Now is the time to put braces under the bilges to eliminate any danger of distortion when the wet mortar is applied. The hull framework can now be well hosed to oxydize the mill-scale off the reinforcing bars.

Scaffolding must now be rigged in preparation for the plastering.

The mix to be used on this hull is as follows:

200 lbs. sand — All sand must pass a No. 8 sieve with 10 per cent passing a No. 100 sieve. There must be an even grading curve of the inbetween sizes, see Illustration No. 451. The sand should be sharp and ingenious in origin..

87 1/2 lbs. Type 5 Portland Cement. Sulphate resistant.

15 lbs. Pozzolan or fly ash.

4 1/2 imperial gallons of water or sufficient to allow penetration.

The first part of the hull to be plastered is the keel, using a vibrator to ensure penetration. This is followed by the underside of the decks and the webs.

The mortar is then applied to the inside of the hull and is squeezed through as thoroughly as possible, with the finish applied from the outside.

The top of the deck should be plastered one week later using a latex bonding agent. The coat applied to the underside will provide the necessary form for this.

It can normally be expected that a hull of this size will take 14-18 hours to plaster with an eight to ten man crew. Two shifts would be advisable.

The outside of the hull should be given a trowel finish. The temperature for the plastering work should be between 50-80 degrees and the wetting down process should begin after 24 hours. This will be carried out continuously for three weeks.

After this curing period, the outside of the hull should be etched with muriatic acid and well rinsed. Two coats of a tar based epoxy are then troweled on to protect any stray ends of wire mesh which may be protruding. The hull can then of course be painted to suit, again using an epoxy paint on the topsides and vinyl anti-fouling.

The wooden cabin is to be through-bolted into position and all deck-fittings will be bolted into place using hardwood backing blocks.

The fish hold will be insulated with sheet styrofoam glued onto the inside of the hull. One layer of wire mesh can be applied over this and plastered, allowing the inside of the hold to be easily cleaned.

The fuel tanks and water tanks will be constructed from mild steel.

The forepeak of the vessel can also be lined with the styrofoam covered with a white vinyl. Spruce sparring can be placed over this to provide a warm, clean foc'sle.

In summary, the fishing boat hulls already in service appear to withstand impact reasonably well. While damage has been encountered it has been quickly and inexpensively repaired. The damaged areas have been pounded out using a dolly on the inside and a pin mall outside. After pulverizing the area the rod and mesh is straightened and new plaster applied.

The hulls in service have to date reported no damage through electrolysis. Corrosion is minimal providing the hull exterior is well sealed and maintenance is low.

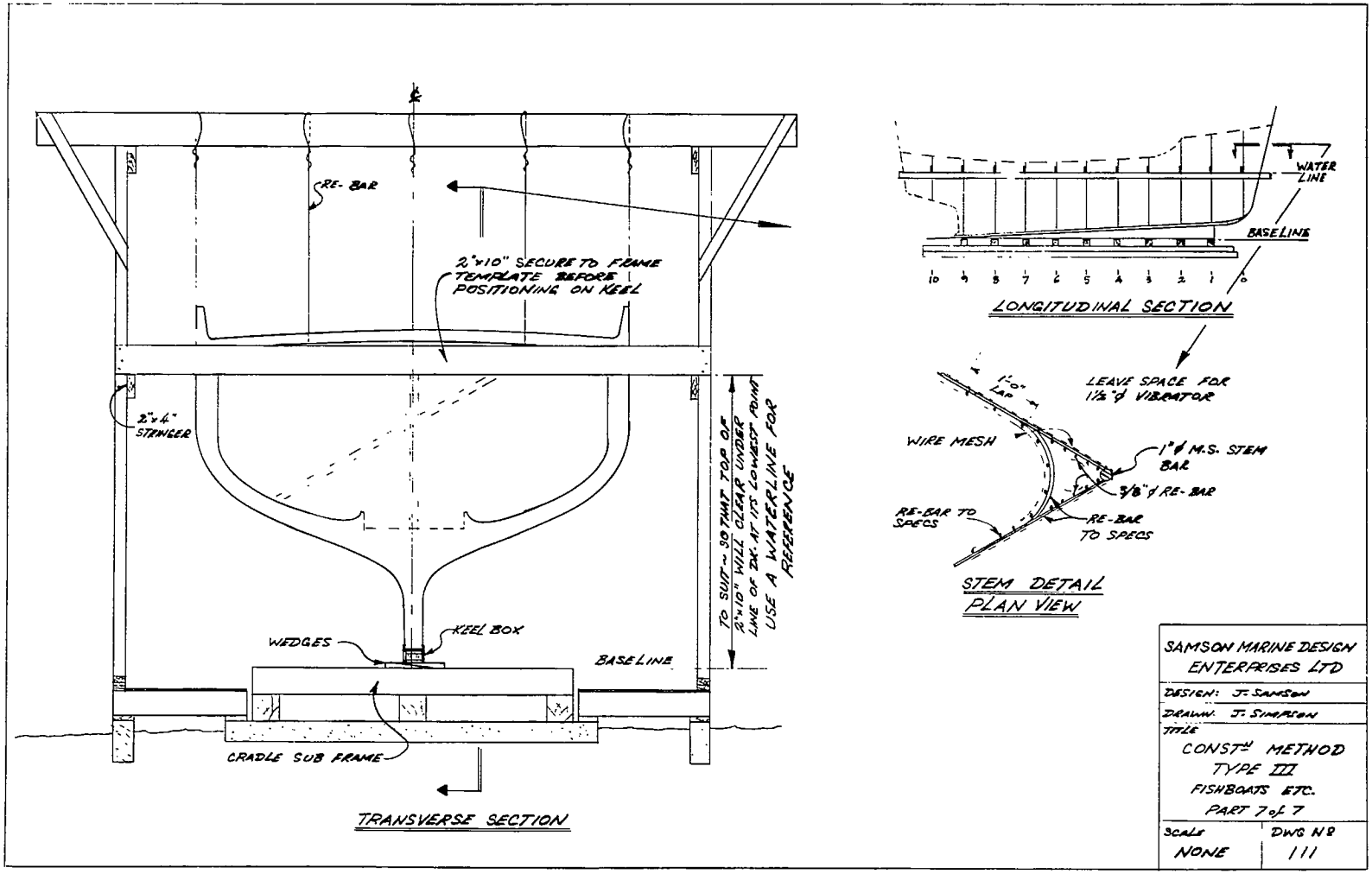
Seepage is nil and cement has proved a good material for absorbing engine vibration. Steel and cement have very compatible expansion co-efficients.

While all these factors point to the practicability of ferro-cement construction it should be pointed out that light high speed planing hulls are not suitable to the medium. However, large hulls are only limited in size by relation to the thickness of reinforcing through which the mortar can be successfully forced.

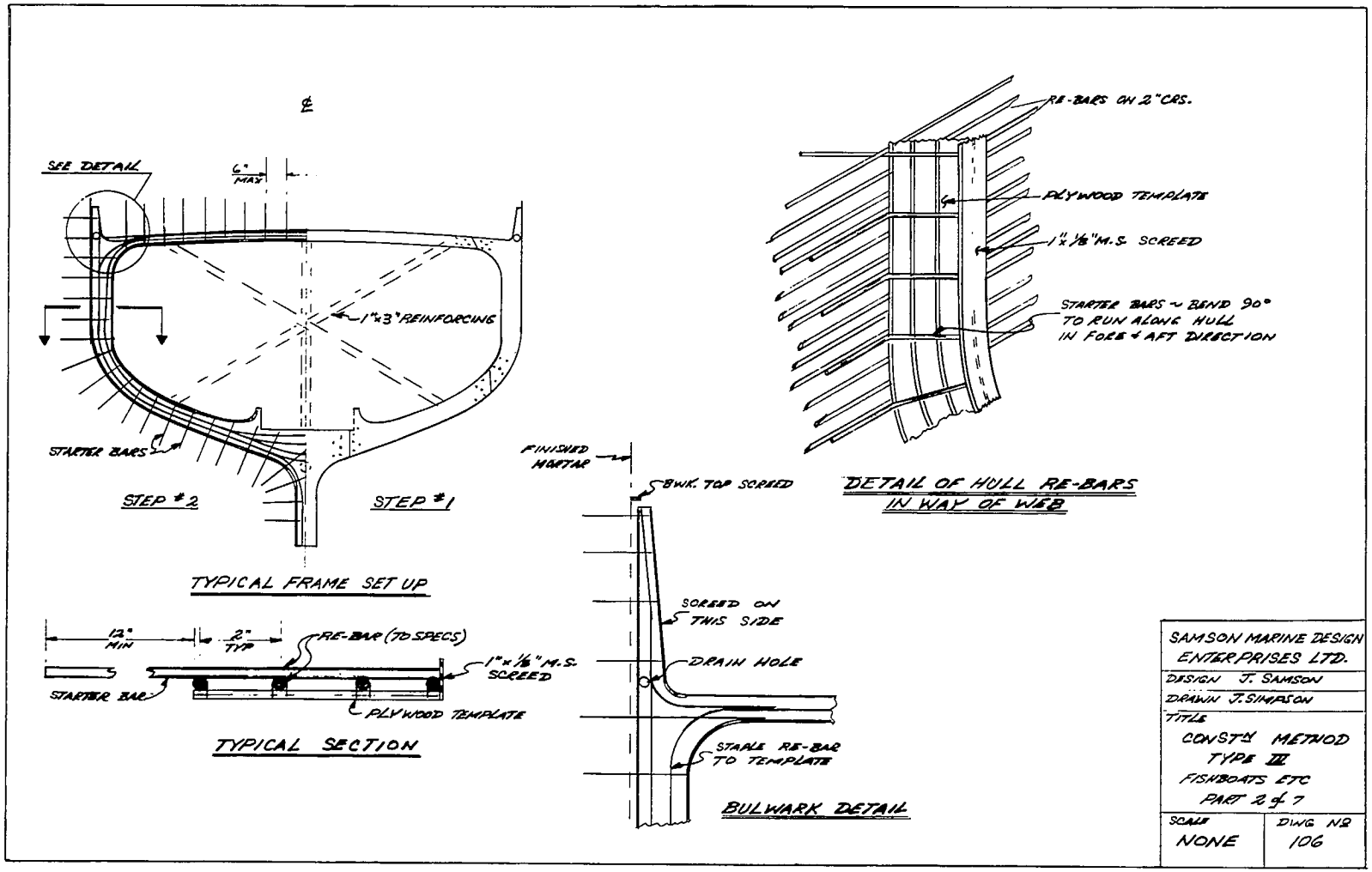
Another factor weighing in favor of ferro-cement is its ductability which is lower than steel, aluminum or fibre-glass. And of course, ferro-cement appears to improve with age. It should also be pointed out that the medium achieves its waterproofing properties from the high percentage of fines present in the mixture and not from additives.

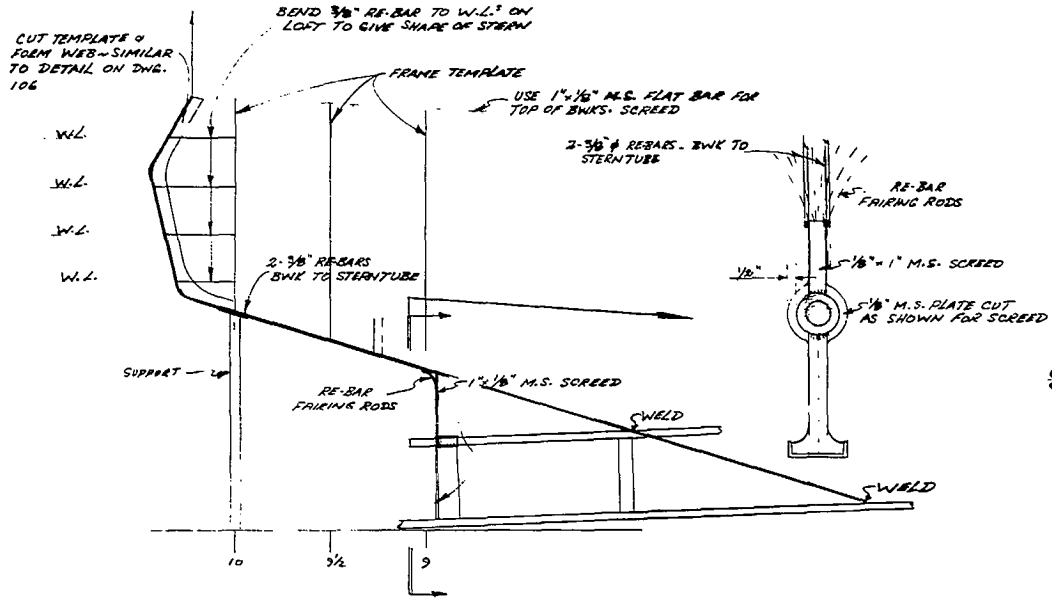
As we said at the outset, this has been little more than a very brief outline of one construction method which can be used with the ferro-cement medium. There are other methods and other techniques which can be successfully applied in fishing boat construction. Now that more attention is being paid to the ferro-cement medium it is almost a certainty that even more improvements will be made—probably quite rapidly.

Perhaps it is well to remember the words of one leading ship builder who said: "It is a matter of economics. When initial construction and maintenance become too expensive, new materials will be found to take their place".

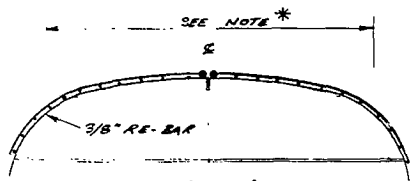


SAMSON MARINE DESIGN ENTERPRISES LTD	
DESIGN: J. SAMSON	
DRAWN: J. SIMPSON	
TITLE: CONST^{N} METHOD TYPE III FISHBOATS ETC. PART 7 of 7	
SCALE: NONE	DWG NO: 111

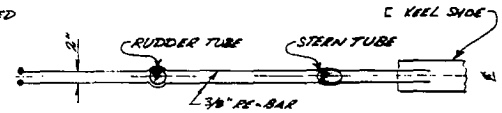

℄
SEE DETAIL
6" MAX
1"x3" REINFORCING
STARTER BARS
STEP #2
STEP #1
TYPICAL FRAME SET UP
12" MIN
2" TYP
RE-BAR (TO SPECS)
1"x⅛" M.S. SCREED
STARTER BAR
PLYWOOD TEMPLATE
TYPICAL SECTION
RE-BARS ON 2" CRS.
PLYWOOD TEMPLATE
1"x⅛" M.S. SCREED
STARTER BARS ~ BEND 90° TO RUN ALONG HULL IN FORE & AFT DIRECTION
DETAIL OF HULL RE-BARS IN WAY OF WEB
FINISHED MORTAR
BWK. TOP SCREED
SCREED ON THIS SIDE
DRAIN HOLE
STAPLE RE-BAR TO TEMPLATE
BULWARK DETAIL
SAMSON MARINE DESIGN ENTERPRISES LTD.
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DRAWN J. SIMPSON
TITLE
CONSTN METHOD
TYPE III
FISHBOATS ETC
PART 2 of 7
SCALE
NONE
DWG NO
106



ELEVATION OF STERN SET-UP



PLAN VIEW
TYPICAL DETAIL AT STERN.
IN WAY OF W.L. TEMPLATE



PLAN VIEW OF 3/8" RE-BAR
KEEL TO BWK

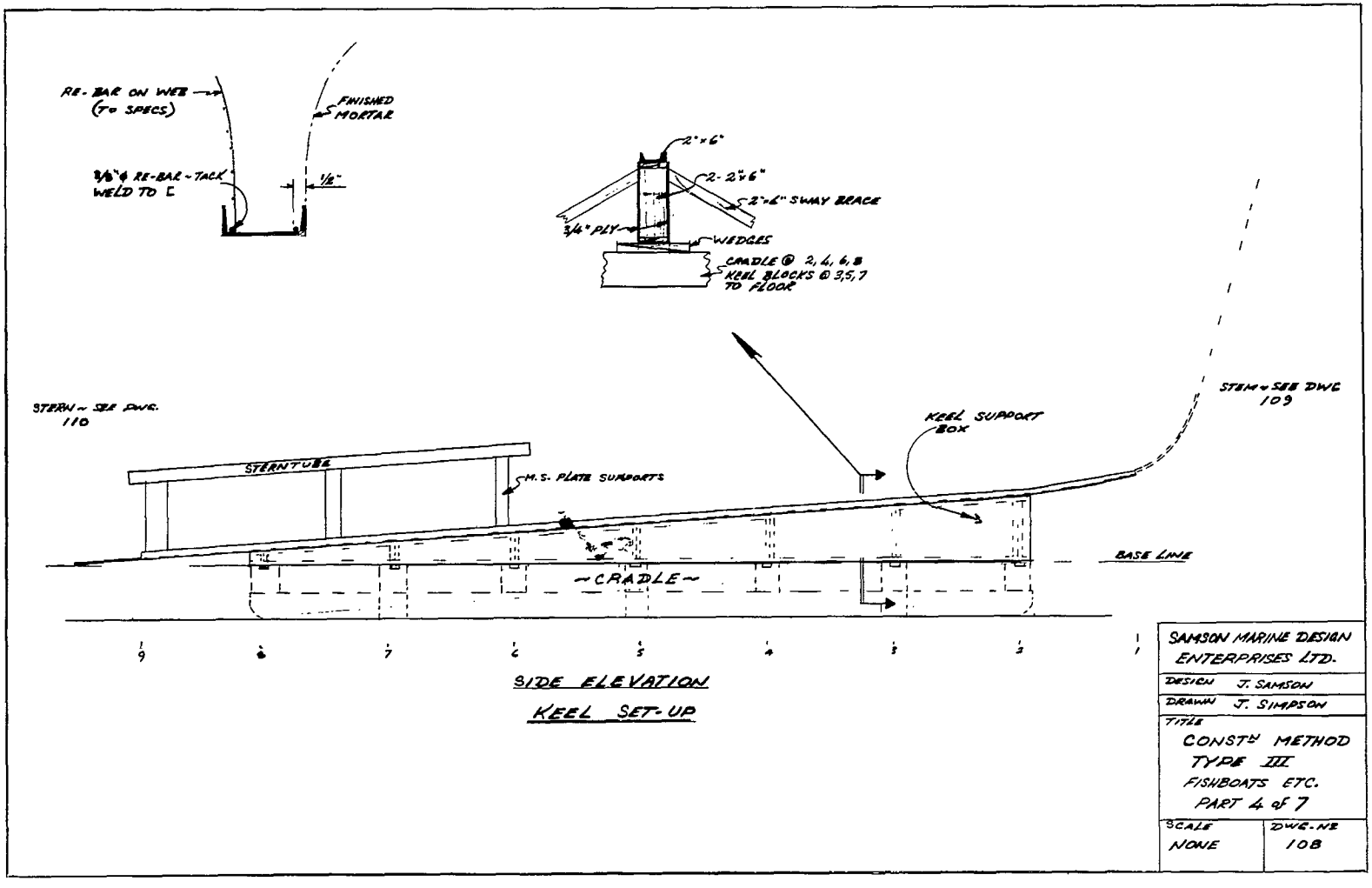
* NOTE

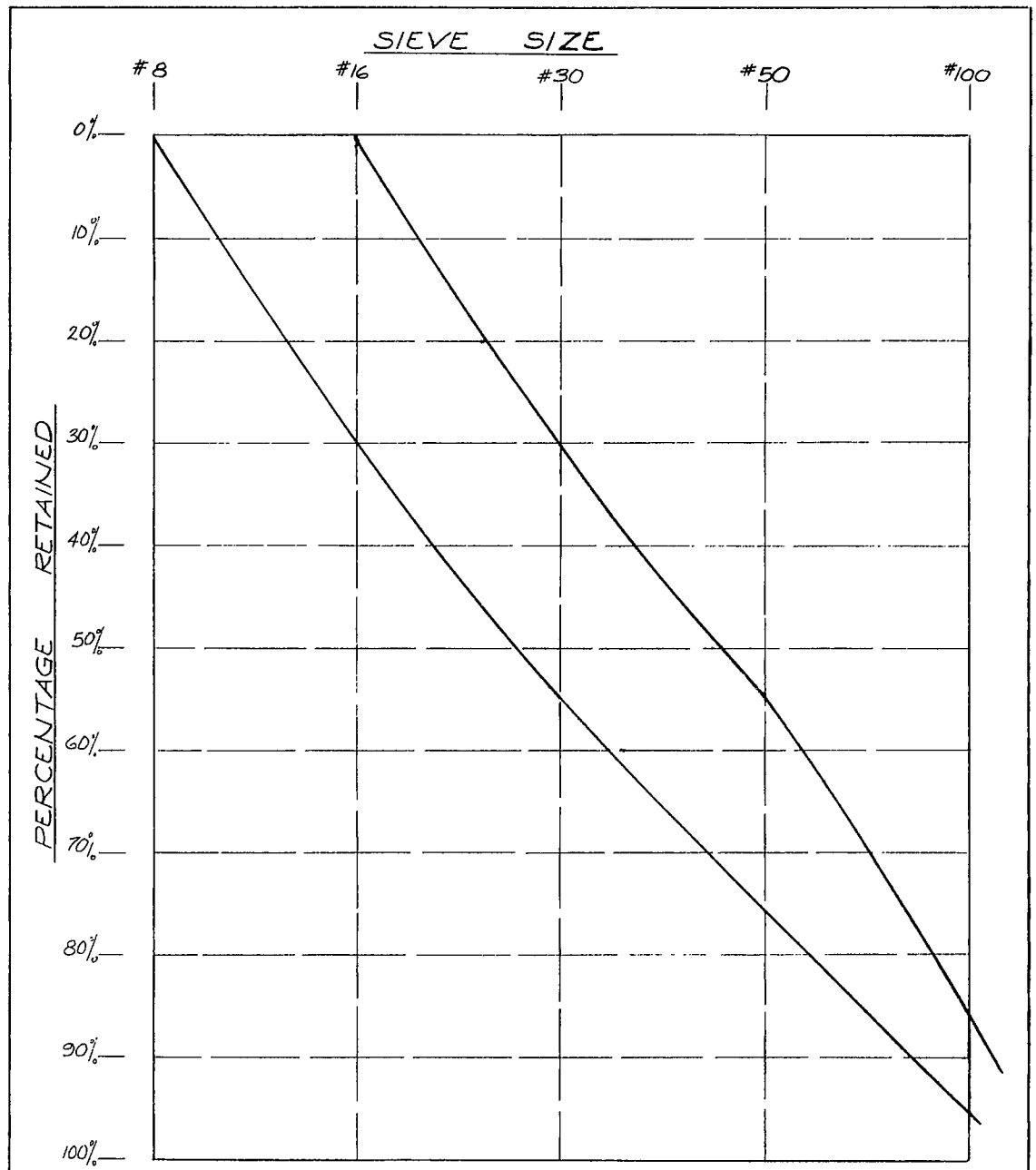
LOWE'L RODS ON THE BOTTOM OF THE VESSEL ARE ON 2" CRS. & ARE TURNED UP & FANNED OUT SO THEY FORM VERTICAL RODS ON 6" CRS. AT THE BULWARK.

SAMSON MARINE DESIGN ENTERPRISES LTD.

DESIGN J. SAMSON
DRAWN J. SIMPSON
TITLE
CONST^N METHOD
TYPE III
FISHBOATS ETC
PART 6 of 7

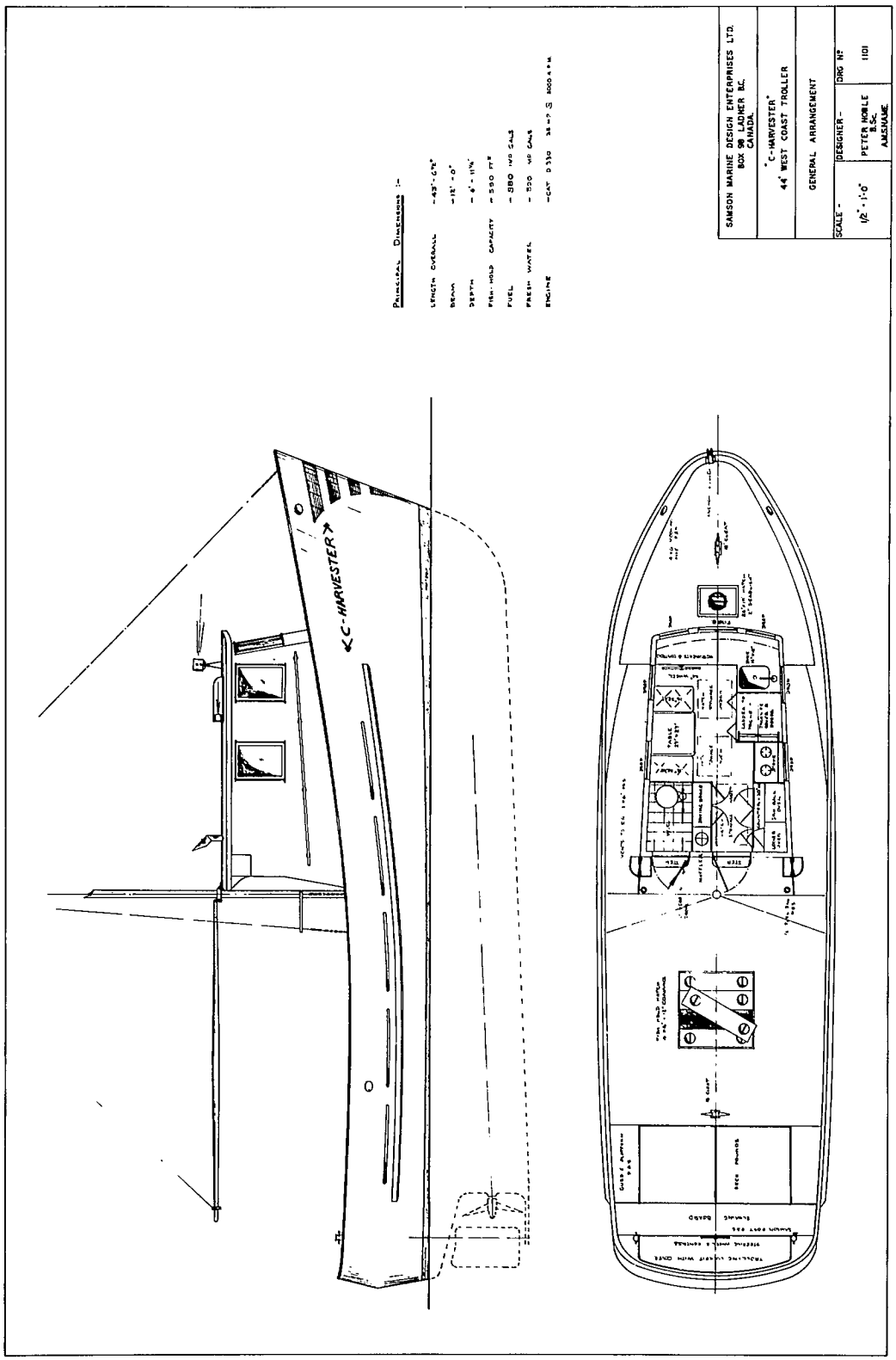
SCALE NONE
DWG. Nº 110

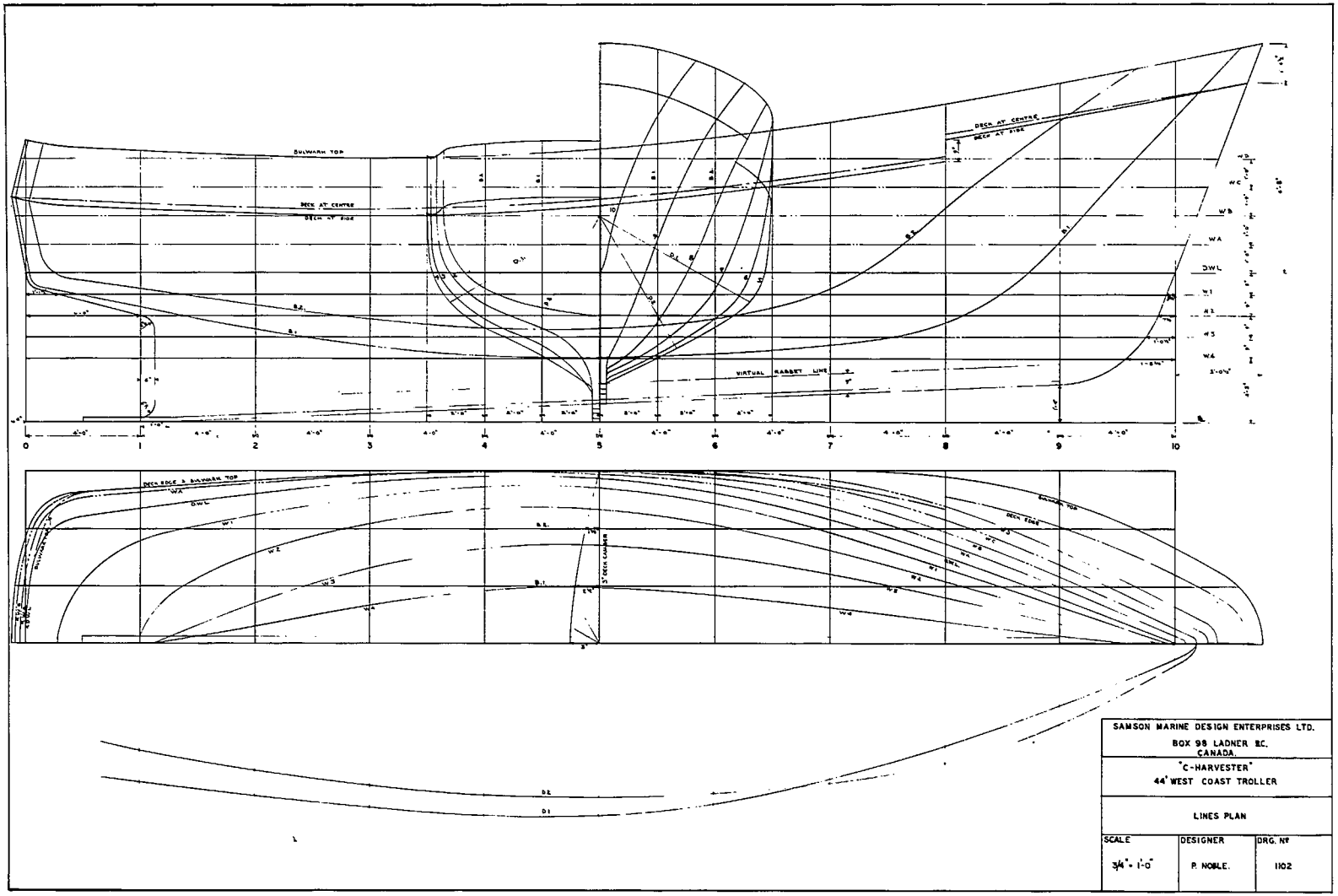

RE-BAR ON WEB (To SPECS)
FINISHED MORTAR
3/8"ϕ RE-BAR - TACK WELD TO C
1/2"
2"x6"
2-2"x6"
2"x6" SWAY BRACE
3/4" PLY
WEDGES
CRADLE @ 2, 4, 6, 8
KEEL BLOCKS @ 3,5,7 TO FLOOR
STERN - SEE DWG. 110
STEM - SEE DWG 109
KEEL SUPPORT BOX
STERNTUBE
M.S. PLATE SUPPORTS
BASE LINE
- CRADLE -
9
8
7
6
5
4
3
2
1
SIDE ELEVATION
KEEL SET-UP
SAMSON MARINE DESIGN ENTERPRISES LTD.
DESIGN J. SAMSON
DRAWN J. SIMPSON
TITLE
CONSTN METHOD
TYPE III
FISHBOATS ETC.
PART 4 of 7
SCALE NONE
DWG-NO 108



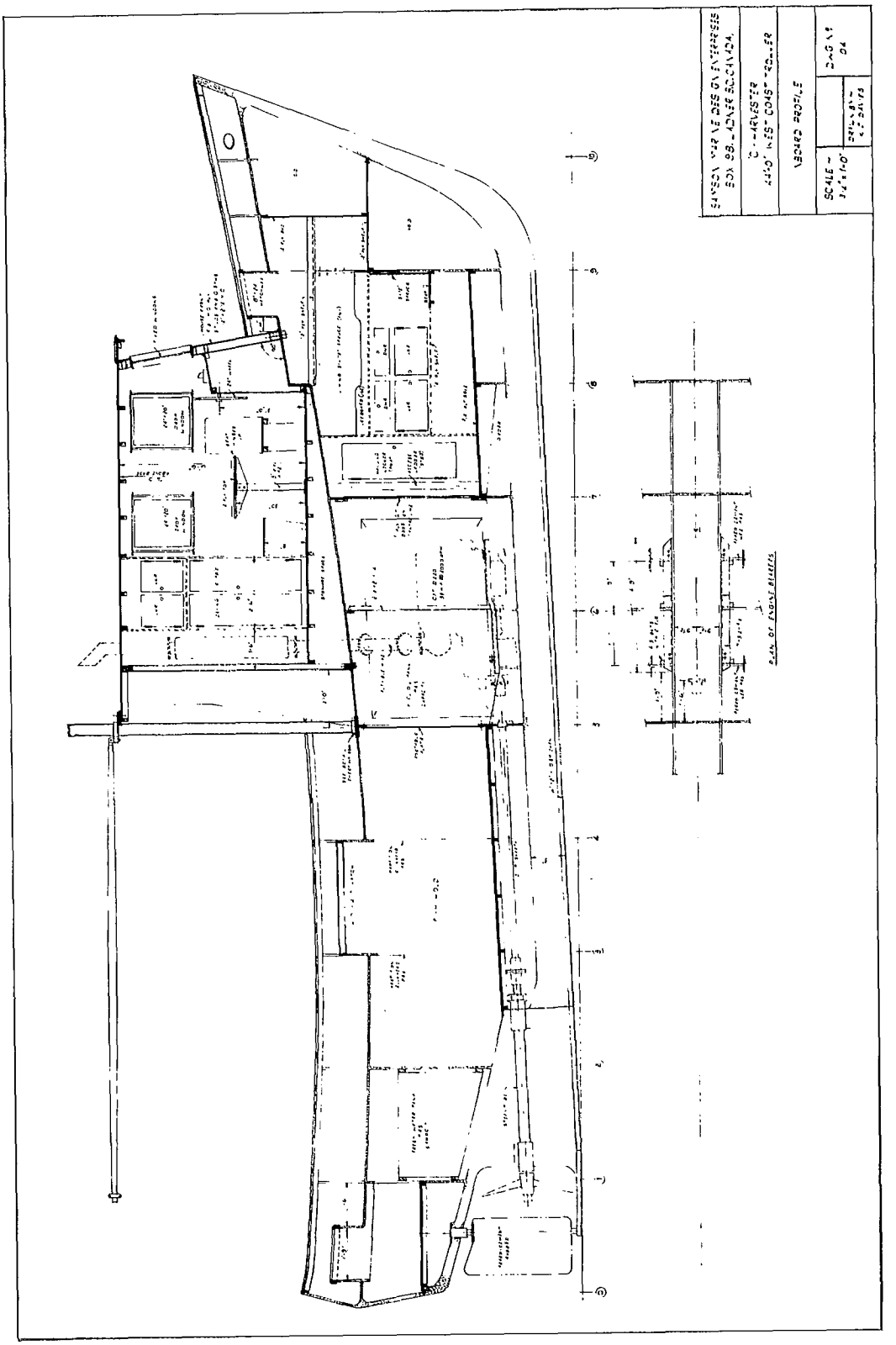
SIEVE ANALYSIS GRAPH

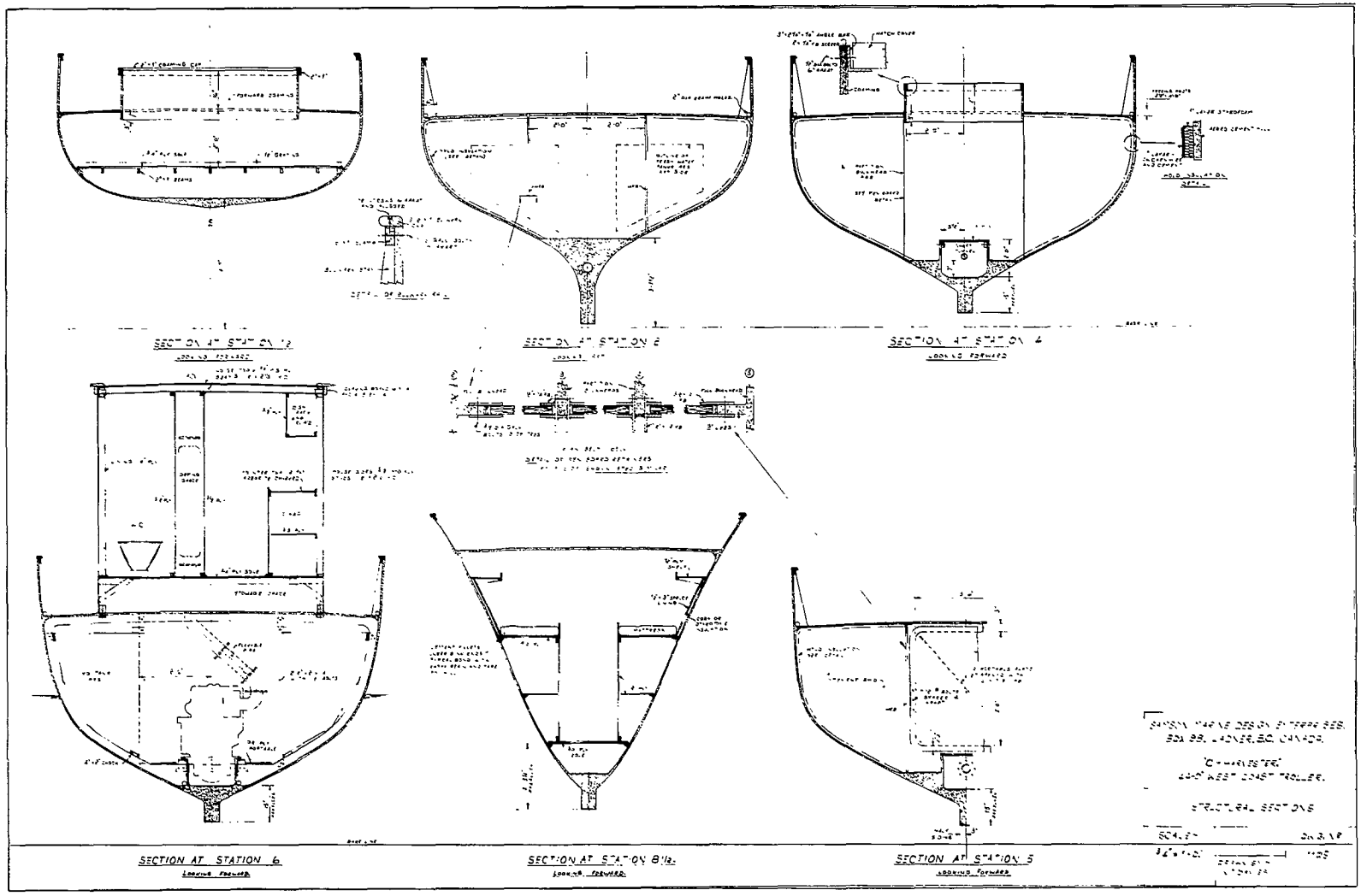
- 100 % TO PASS THE #8 SIEVE.
- 10 - 15 % TO PASS THE #100 SIEVE.
- EVEN GRADING CURVE ON IN-BETWEEN SIZES.
- SHARP SAND FROM IGNIOUS ROCK.


SAMSON MARINE DESIGN ENTERPRISES LTD.
BOX 98 LADNER B.C.
CANADA.
"C-HARVESTER"
44' WEST COAST TROLLER
GENERAL ARRANGEMENT
SCALE -
1/2" - 1'-0"
DESIGNER -
PETER MOLLE
B.Sc.
DRG Nº
1101
PRINCIPAL DIMENSIONS :-
LENGTH OVERALL - 43'-0"
BEAM - 12'-0"
DEPTH - 6'-11"
FISH HOLD CAPACITY - 550 ft³
FUEL - 380 IMP GALS
FRESH WATER - 200 IMP GALS
ENGINE - CAT D330 3406 @ 2000 r.p.m.
"C-HARVESTER"

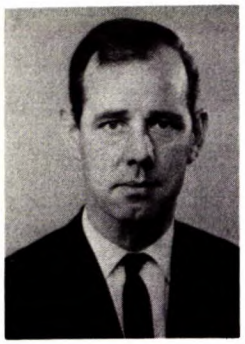


SAMSON MARINE DESIGN ENTERPRISES LTD. BOX 98 LADNER BC. CANADA.		
"C-HARVESTER" 44' WEST COAST TROLLER		
LINES PLAN		
SCALE 3/4" = 1'-0"	DESIGNER P. NOBLE.	DRG. Nº 1102




SECTION AT STATION 2
SECTION AT STATION 4
SECTION AT STATION 6
SECTION AT STATION 8½
SECTION AT STATION 5
"CHARLESTER"
STRUCTURAL SECTIONS

Commercial Fishing Vessels in Glass Fibre Reinforced Plastics (Construction Techniques and Future Trends)



Mr. Pike

by

D. S. Pike
Goldharbour (Pty.) Ltd.
Cape Town, S.A.

and
Martin Yeatman
Yeatman, Endal & Co.
Halifax, N.S.



Mr. Yeatman

Mr. Pike completed an apprenticeship at a Brithish south coast shipyard with technical studies at Southhampton University and subsequently at the Birmingham College of Advanced Technology. He joined Lloyds Register of Shipping in 1953, becoming a Senior Surveyor, principally engaged in Glass Reinforced Plastic Ship construction. He is at present a Director of Goldharbour (Pty.) Ltd. Cape Town, South Africa, Industrial Plastic and Marine consultants.

Mr. Pike wrote the first part of the paper. Part Two was written by Mr. Yeatman, who started his career with Vickers Armstrong, Ltd., in Newcastle-upon-Tyne, where he served a five-year apprenticeship. He studied naval architecture at King's College, Durham University, and was awarded his B.Sc. degree in 1954. He worked for three years with the company after completing his apprenticeship, and for the last year and a half was Assembly Shop Manager.

His recent experience with other companies includes the following: Saint John Dry Dock and Shipbuilding Company, Ltd. – one year as assistant to the general manager, with various technical and administrative duties; Nylands Verksted, Norway – one and one-half years as head of Planning Section, New Vessels (tankers, naval vessels, industrial fabrication); Bathurst Marine Ltd., Georgetown, P.E.I. – started as Production Manager in Bathurst, N.B., and was later moved to Prince Edward Island to take charge of building the new shipyard in Georgetown. The shipyard has designed a number of stern trawlers.

Mr. Yeatman started his own business in June 1965 as a consulting naval architect and marine engineer, with the object of offering his services mainly to the fishing industry. In May 1966, he brought Mr. Anders Endal into partnership, and formed the firm of Yeatman, Endal and Company. Mr. Endal had been chief designer at the Georgetown Shipyard, and contributed an extensive experience of fishing vessel design to the partnership.

ABSTRACT

In Part I, Mr. Pike briefly describes the basic principles of G.R.P. materials and production, and goes on to discuss in some detail design and production problems, and techniques of production and quality control, in the light of his experience, particularly with the 74-ft. and 83-ft. fishing boat classes with which he was associated in South Africa, which are the largest G.R.P. commercial fishing vessels in service to date. In Part II, Mr. Yeatman explains the main implications for fishing boat designers of the use of G.R.P. Brief reference is made to lessons derived from a comprehensive design study and cost analysis which the authors recently carried out for the Industrial Development Service of the Department of Fisheries of Canada on a 97 ft. G.R.P. fishing vessel.

PART I

by

D.S. Pike

1.0 INTRODUCTION

The principles of reinforced plastics are well known and is not intended to comment in detail upon the fundamentals of the process, its chemistry or mechanics, but for those not completely familiar with the material, it may be of assistance if the salient features are briefly outlined.

Basically, the operation involves the use of a thermosetting resin which for ship construction purposes is usually of the polyester series. As the name thermosetting implies, the chemical reaction required to cause setting is produced by the application or generation of heat and the heat or exotherm is generated by the addition of other components reacting with the resin to form a carefully balanced and controlled chemical system.

Resin will remain in a fluid or plastic state for considerable periods and the introduction of another component, a catalyst, is required before the thermosetting reaction can be commenced. The catalyst is usually an organic peroxide. Among the most widely used are cyclohexanone peroxide and the methyl ethyl ketone peroxides in paste and liquid forms respectively.

The third essential in the resin system is the accelerator, and may be either amine or cobalt soap based. Its function is to increase the speed of the chemical reaction of resin and catalyst, thus boosting the exotherm generated and so reducing gelling and hardening times to meet production level requirements. It is important to remember that this reaction, once commenced, cannot be halted and is irreversible. Unlike thermoplastic resins which can be re-moulded within limits by the application of low temperature heat, thermo-setting resins remain as cast, and although physical properties commence to diminish at moderate temperature levels, plastic flow does not usually take place until immediately before combustion occurs.

Polyesters, whilst exhibiting good compressive strength properties, have low rigidity, tensile and impact strength, so that before use can be made of this material for structural purposes, the introduction of a reinforcing component is necessary.

The reinforcing material must have low weight-high strength characteristics, be chemically compatible with its encapsulating medium, be corrosion resistant and remain stable under changes of temperature. Further desirable features are thermal coefficients of expansion, approximating those of resin, and low water absorption rates.

The material developed for this purpose and at present most widely used, is glass fibre in a variety of bound and woven forms which, in addition to fulfilling the foregoing requirements in part at least, also offers an acceptable interfacial bond between resin and reinforcement, has good handling characteristics – all at relatively low cost.

Reinforced plastics offer a construction medium which can, within reason, be moulded to any required shape or form. Having first constructed the mould, curvilinear or irregular sections may be formed and reproduced without the need for costly and complicated pressing equipment required for other materials.

Moulding of hulls is at present carried out by the "contact" or "hand lay-up" method and the laminates are produced in moulds of the form and shape required, by laying plies of glass reinforcement impregnated by resin and consolidating before application of the succeeding layers of reinforcement.

To conclude this introductory section, it may be of interest to re-iterate the advantages of reinforced plastics applied to ship building:

(a) A light weight and high strength material;

(b) A material completely impervious to marine corrosion;

(c) Much reduced hull maintenance costs;

(d) Increased pay load capacity over ships of any other material.

In addition to the foregoing, there are a number of benefits associated with reduced heat leakage and skin friction losses, together with other advantages.

2.0 DESIGN CONCEPT

When the first attempts of ship construction in G.R.P. were made by the author's company some five or six years ago, no previous experience was available on which to base design criteria or formulate basic parameters, but it was at this stage that a most important decision was taken, to proceed only with the design and development of single skin laminates for ships and to exclude sandwich or core type lamination when considering even moderately stressed structures.

This decision was arrived at as a result of a series of tests which clearly indicated serious loss of strength and disintegration of core type laminates when failure of interfacial bond occurred, a phenomenon which could be induced by relatively low levels of applied shear stress. In addition this laminate type exhibited a low resistance to impact, also certain construction difficulties which together, in our view, far outweighed the advantages of section rigidity, weight and cost reductions.

Available details at that time included indicated tensile strengths of resin of about 7000 lbs/sq. inch and 14000 lbs/sq. inch with reinforcement. In the first instance only chopped strand mat was utilized. The overall strength and characteristics of the composite material were analysed and it was considered prudent to limit the maximum design stress to 2000 lbs/sq. inch, which it was thought would provide adequate compensation for such variables as ship service conditions and laminate quality consistency in addition to the effects of fatigue and solar radiation; factors about which little was known at that time.

In the absence of other data, the design proceeded along orthodox lines, using a transverse framing system incorporating four side keelsons and two or more deck girders. Further longitudinal strengthening was provided by having a box keel and side stringers in areas subjected to maximum stresses, in particular throughout the fish hold and engine room spaces.

The early shell frames and keelsons were strip laminates whilst bulkhead stiffeners were of angle section. These forms of secondary structure, whilst proving effective in service, also resulted in heavy mat-in connections which increased the labour and material content by some 50%. Matting-in is the method of connecting together two laminates which have been previously moulded separately.

Attention was then turned to other stiffener configurations, emphasis being placed upon maximum section modulus per unit area, ease of construction and assembly with the minimum mat-in. Of the stiffener forms evaluated, the hat box section gave the best all-round results, although in practice exhibited a number of disadvantages which will be referred to later.

Initially, the ships were of composite type, comprising a G.R.P. hull and superstructure and timber deck incorporating wooden deck girders. Whilst this deck system proved satisfactory from the aspects of watertightness and strength, problems were encountered with the deck to hull and bulkhead connections.

It was not long before the second generation design was evolved. This series of ships were the first all G.R.P. design and utilised a longitudinally framed system for both hull and deck with primary and secondary members of hat box section. Substantial bulkheads and deep floors provided the transverse strength and anti-racking resistance required, whilst the hull to deck connection consisted of an inward turning flange to which was attached the integrally moulded deck and bulwark by a bolting system sealed internally by a number of chopped strand mats.

Superstructures and deckhouses were similarly connect- but difficulties arose with the attachment of bulkheads and beam knees as a result of the in-turning flange and other problems associated with the fitting of rubbing bands and underdeck structure.

The first series of 74′ ships were built around this basic design and have proved very satisfactory in service, al-

though in some cases when deeply loaded in a heavy seaway, resulting in high torsion stresses about the deck flanges, some problems of water seepage were experienced initially. This tendency was subsequently eliminated by fitting transverse deck beams and substantial beam knee brackets.

Twelve ships of this type were built with the following dimensions:

Length O.A.	74′0″
Beam	21′6″
Moulded Depth	10′6″
Fish Hold Capacity	140 tons

These vessels were equipped with a comprehensive system of fish finding and handling gear and a 335 B.H.P. engine gave a service speed of about 10 knots.

About this time, detailed design work was commenced on ships of 83′ O.A. and, as a result of experience gained in the earlier vessels, a number of improvements were made. The longitudinal framing of hat box section was retained for the hull, augmented by four substantial fish hold divisions and five bulkheads.

The hull to deck connection featured an outward turning flange as an integral part of the hull moulding to which the flat plate deck, complete with two girders and transverse beams, was bolted. The edges of the hull flange and deck plate were deep veed and filled by continuous rovings. The joint was completed by several internal reinforcing and sealing mats before the beams and upper longitudinal bracketed connection was made.

Another feature of this design was the introduction of double bottom tanks which comprised a laminated plate tank top and inboard side fitted over and bolted to the floor which terminated each side of the box keel. All boundaries were then fully sealed using chopped strand mats and the centre sections of floors fitted and matted in.

These ships, of which seven were built, with a 25′ beam and moulded depth of 13′6″ provided a fish hold capacity of 185 tons. Powered by a 465 B.H.P. engine they attained a service speed of about 10.5 knots and have proved very successful under most arduous conditions.

Among more recent innovations, has been the introduction of hull corrugations and consequent partial or complete elimination of internal longitudinal framing. The corrugations have the form of open type hat box sections and are moulded integrally with the hull, thus forming the shell and principal longitudinal strength members in a single homogenous mass, in addition to considerable weight reduction of matting in connections.

A further advantage is the damping effect on the hull natural rolling motion with no measurable effect on propulsion resistance.

Returning to the factors influencing choice of strengthening member, unquestionably the hat box section fulfills many of the requirements, good modulus characteristics, the tendency, due to its form, to reduce the effective span between stiffeners and readily moulded shape, but there are two disadvantages associated with this section.

When used as a tank crown member, it is essential that the hat box section is open to tank pressure or deflection of the sides will occur resulting in reduced modulus. It is therefore essential to interrupt girders of this section at tank bulkheads, which then raises the problem of strength continuity and indicates the second disadvantage, that of bracket connections from hat box sections to other components.

By careful design, however, these difficulties are usually avoided, but when this is not possible, girder end sections can be arranged to give the shear area required.

Perhaps the most significant advance in design concept, however, has been the progressive increase in permissible design stresses in reinforced plastics. At the present time ample safety factors can be maintained using design stresses of 7000 lbs/sq. inch and we are confident that, considering materials currently available as a criteria, further increases in acceptable stress levels may be expected as more experience is obtained.

The methods of laminate strength evaluation, selection of materials, primary and secondary members and general design approach are now firmly established and can be fully substantiated by the experience provided by the fleet of over 50 vessels now in service.

The overall result of these developments is the production of a hull of great strength and rigidity with a weight advantage over a steel vessel of comparable dimensions of the order of 60% and consequent reduced displacement or increased payload capacity.

3.0 CONSTRUCTION FACILITIES

3.1 *Workshop*

Many present workshops producing large G.R.P. mouldings are buildings converted from other uses and are giving good service, but obviously the custom built shipyard is to be preferred from all aspects and it is proposed to deal here with such buildings only.

The concept of a G.R.P. shipyard is necessarily a function of many variables, geographical position, climate, proximity to raw material suppliers, size, type and number of ships to be built, in addition to many other influencing factors. In general, the basic requirements are concerned with a generous space allowance, a dry, draught and damp-proof construction including insulation where heating or air conditioning requirements so warrant, together with environmental control plant, cranage facilities and good natural and artificial lighting.

Facilities and services specific to a particular plant must depend entirely upon production engineering methods adopted, flow pattern, output level and to what degree, if any, mechanization is to be employed immediately or at some future date.

Within the workshop area and sited to provide a smooth and rapid flow to the moulding areas, are the raw material processing and storage sections. These services should be arranged to provide sufficient bulk storage capacity and usually require some mechanical handling assistance.

The reinforcement and resin are passed from storage to the processing station where the glass mats are cut to predetermined shape and length and the resin catalysed and pigmented when required. The two components then converge on a central dispensing point before issue to the works.

Since the ratio of resin to reinforcement is of vital importance, strict control of raw material quantities is essential. There are several methods of achieving this; the most widely used are the batch principle, where an operation is contracted to a number of stages and the requisite quantities of glass and resin are prepared, weighed and arranged to arrive at the dispensing point simultaneously. Alternatively, processing may be on a continuous basis where the demand information is fed to the reinforcement tailoring shop and on the arrival of material at the dispensing station, the resin requirement is obtained from the resin mixing bay.

Both methods have advantages and disadvantages but in both cases, careful programming is required to ensure arrival of materials at the moulding site in the quantities required, the correct sequence and properly prepared. Delays at this stage can affect not merely production levels but also product quality, and the time spent on devising a simple, but effective moulding program, incorporating operation phasing and materials process planning, is amply rewarded by mouldings of consistently high standards and increased productivity.

The final operation before commencing moulding is the addition of the accelerator to the resin system. This is carried out in batches and occurs only immediately before the resin is used. Full control of gelling time by modifying the quantity of accelerator added to compensate for any changes in humidity or ambient temperature is thus obtained. The latter technique should not be required, however, in a workshop with a reasonably effective environmental control system.

During moulding, the release of styrene monomer fumes occurs, which can make working conditions difficult when laminating large sections and in confined spaces. Mechanical ventilation is therefore essential in the interests of laminators and laminate quality, but care should be taken to provide air refreshing only and to avoid the use of high velocity fans which can only cause turbulence, make conditions immeasurably worse and result in styrene vapour migration with a subsequent adverse effect on laminate cure.

Absolute cleanliness in the moulding area is of paramount importance if laminate contamination is to be avoided. This is not difficult provided a little care is exercised and an organised program of floor cleaning and tool maintenance is adopted.

Facilities and services ancilliary to the moulding processes are those associated with moulding trimming, assembly and fitting. Compressed air tools are widely used and an adequate supply of air at convenient tapping points is required.

It is desirable to completely segregate the mouldings and finishing operations, so that full shipwrighting and engineering services are necessary within the shipyard complex and incorporating a slipway.

3.2 *Climatic Control*

Of primary importance in any plastics operation is the control of workshop temperature and relative humidity. Fairly rigid temperature limits of 55° to 70° are imposed since variations in excess of these values have a marked effect on gelling and curing times. The permissible moisture content of the air is more flexible and the acceptable range varies between 40% and 65% relative humidity.

Most areas throughout the world require climatic control in the form of heating and de-humidifying plant and in some cases a degree of temperature reduction is necessary to stabilize and maintain environmental conditions, within the prescribed limits. Widely fluctuating climatic changes will result in constant adjustment of the resin – catalyst – accelerator system and can only unnecessarily complicate the laminating process.

For optimum results, therefore, both in respect of laminate quality and productivity, closely regulated workshop conditions are essential. There are no particular problems involved and the warm air system widely in use in Canada is extremely effective. A well insulated building with draught excluding arrangements fitted at access openings should present no greater problems of control than those experienced in any heated building.

3.3 *Quality Control*

Services under this heading comprise two distinct but complementary fields.

1. Supervisory duties, visual inspection and tests.
2. Laboratory control of materials, physical testing of specimen laminates and evaluation of test results.

It is sometimes forgotten that in addition to the end product a material is being formed; a material which must exhibit certain predetermined mechanical characteristics consistently throughout the entire laminate, and although numerous test pieces are "laid-up" with the object of obtaining samples which are truly representative of the principal laminates, they are indicative only and in no way relieve supervisory or inspection staff of the responsibility of ensuring that the material is correctly applied.

It must also be remembered that whilst pleasure craft constructed in G.R.P. have given outstanding service since their inception some ten years ago, it is only during the past few years that full use has been made of this material's immense potential as a strength member. In consequence, the practices and techniques previously adopted with their associated acceptance standards are no longer valid and the importance of strict quality control cannot be overemphasized.

Clearly defined inspection procedures should be established and it is the duty of inspection personnel to ensure that a consistently high standard of workmanship is achieved and maintained. The most effective method of attaining these standards is by adequate supervision during the laminating process.

Laboratory technicians also provide a vital link in the chain, since in addition to processing the test samples through the various applied tests, it is also their function to effect check tests on all batches of materials supplied, before works acceptance. Frequent checks in respect of catalyst and accelerator content of resin systems issued to production, should be made throughout the day so that gelation and hardening times may be confirmed.

They will also be responsible for recording ambient conditions in the workshop at the required intervals and ensuring that the resin system is compensated when necessary.

The physical tests carried out in the laboratory will include straight tensile tests, bend, flexural and impact. In addition, burn-off checks to verify resin to glass ratio and water absorption tests should also be carried out and recorded.

Each ship on completion should be provided with or covered by a comprehensive test report, including details of all results and positively identifying materials used by their group or batch numbers.

At first sight, the whole concept of glass reinforced plastics for ship construction may appear complicated and involved, but this is not the case. There are, as in any process involving the formation of basic materials and their application, certain fundamental rules to observe and the end product is directly related to careful adherence to these basic principles.

3.4 *Personnel*

It is proposed to comment only on staff connected with the plastics section of the shipyard and, executive personnel apart, the staff requirement consists of supervisory and inspection grades and the labour force.

Great care should be exercised when selecting staff intended for overseeing duties since as previously stated, the quality of the finished laminate is much dependent upon their care and diligence, in ensuring that the correct procedures are carried out.

The training of this personnel therefore is of considerable importance. In the first instance they should be instructed in all phases of practical moulding, resin mixing, types and uses of all materials, until fully competent to undertake any of the operations involved. Their interest should be stimulated by a short course relating to the basic chemistry of plastics so that a more complete appreciation of the process may be obtained.

Ideally, and circumstances permitting, this nucleus of fully trained, although relatively inexperienced staff should then be responsible for the instruction of laminators, selecting the most promising for the positions of leading or charge hands. It is our experience that preliminary training of laminators will take several weeks and a further two months will elapse as the operator progresses through the stages of simple mouldings to the more complicated laminates.

Contrary to some opinions, laminating is not an unskilled process, but neither does it require lengthy periods of apprenticeship or training and although initially at least the labour fall-out may be higher than in other industries, the wastage costs are not excessive.

4.0 CONSTRUCTION METHODS

The "Contact" or "Hand Lay-Up" method is used exclusively in ship construction and is the simplest form of reinforced plastic moulding, requiring the minimum of equipment and capital expenditure.

In general the building of ships in G.R.P. may be broken down into three phases:

1. Construction of moulds
2. Moulding principal components and assembly
3. Fitting out and completion

4.1 *Moulds*

Mould construction in all hand lay-up processes is of fundamental importance not merely because the laminate will faithfully reproduce the mould form, including its imperfections, but must also be easily assembled and dismantled, be extremely robust and rigid, in addition to having a moulding production capability sufficient to fully amortise the entire mould costs over the requisite number of vessels, as determined by the operation economics.

Among other factors influencing the design and choice of materials are those concerning the available local skills in male plug manufacture, if a conventional G.R.P. mould is used. It is also desirable to have interchangeability of mould sections so that limited variations of hull dimensions, if not hull form, may be achieved.

At the present time there is a preponderance of G.R.P. moulds in use and which, if carefully handled, should permit the construction of 30 to 40 mouldings, but it is clear that as vessel sizes increase, the advantages of steel moulds become much more apparent, in particular where series production on a large scale is planned.

4.2 *Moulding*

There are probably no aspects of reinforced plastics more widely discussed at the present time than the methods of applying the reinforcement in association with the resin.

Since the greatest proportion of vessels currently built in plastics are small craft in the range of 10 to 35 feet, where operating conditions are not severe and design stresses conservative, the technique of spraying a mixture of chopped strand reinforcement and resin has considerable support. The early difficulties of controlling accurately the resin to glass ratio have been largely overcome but many manufacturers of mouldings remain unconvinced that complete mixing of the convergent twin sprays of catalysed and accelerated resin is obtained. Other difficulties are associated with thickness variation, loss of styrene and absorption of oxygen and moisture during the process in association with modified strength characteristics of sprayed reinforcement.

The inherent strength of chopped strand mat is derived from the multi-directional lay of random fibres with the further advantages that stress resistance is similarly disposed in all directions. Any appreciable deviation from this

formation, and such is the case with sprayed reinforcement, results in an irregular stress pattern when loaded and invariably in reduced strength.

Our development is based on the use of chopped strand fibre in mat form and woven glass filament rovings from which it is possible to reliably predict the tensile and flexural strengths obtained in practice.

In general our approach to principal hull laminates involves a composite section incorporating woven rovings over a core of chopped strand mats with further mats of this type outside the rovings, thus making the most advantageous use of the high strength rovings and providing good impact resistance.

In all laminates involving more than one layer of reinforcement, the adhesion of the succeeding layer to that preceding it is of vital importance and unquestionably the most satisfactory results are achieved by purely chemical or primary bonds. To obtain this, it is necessary to apply the succeeding layer during the period of commencement to completion of gelation and since, for economic reasons, this period rarely exceeds 30 minutes, the moulding of heavy section laminates of large area is of necessity an operation requiring careful planning and timing.

For optimum results in reinforced plastics, large complex mouldings such as a ship should be one homogenous mass, consisting of successive primary bonds with no delays in the moulding process to interrupt this pattern. Since, however, this is not yet possible for a variety of practical and economic reasons, use is made of mechanical or secondary connections which have proved very satisfactory.

Construction methods in respect of the ships built to date have varied considerably and no doubt will so continue, but the general pattern and sequence of operations have remained unchanged. Production may be carried out using a circular or line flow pattern dependent on facilities and requirements. Commencing at the hull moulding stage, the shell laminate is "laid-up" including longitudinal framing and is followed by fitting and matting in floors, shell frames or their formers, bulkheads and any tanks moulded integrally with the hull.

Concurrent with this operation, the main deck and bulwarks are moulded complete with their various strengthening members. It is important that these two primary structures be built simultaneously, since both components will have reached the same cure level when joined in a later operation and will therefore be less prone to differential shrinkage as complete cure is attained.

At this stage, it is probable that two weeks have elapsed since commencement of hull moulding and whilst still in a "green" or semi-cured state, the hull moulding may, if treated with care, be safely removed from the mould and placed in specially constructed cradles which support the hull along the full length of the keel.

Large items of equipment such as main machinery, shafting and separate tanks are then installed and the preformed deck and bulwark moulding placed in position. Dependent upon the type of connection, the laminated and bolted attachments are made, as required. Superstructure units are installed fully outfitted with furnishings and all equipment and, on completion of all plastics work, the vessel is moved to the outfitting and finishing area.

4.3 *Outfitting*

There is no clear cut division between the last operation and this. Obviously they tend to overlap and there is no reason why they should not proceed independently provided a careful check is kept on environmental contamination and dust extraction equipment available when a machine tool is in use.

Where integrally moulded water or fuel tanks are fitted, tank testing can be a source of difficulty. Initially, fuel and water tanks were tested hydraulically, primarily because it was thought a more severe test and secondly, in the event of a structural failure, was likely to prove less destructive than testing by air.

In the event, however, water testing proved to be a laborious and not always conclusive method of testing since, having first located a leak in a tank boundary connection, it was necessary to empty and thoroughly dry the tank interior. This involved installing portable heaters to remove surface moisture and finally carefully washing the defective area with methanol alcohol before repairs could be effected.

Much of this preparation work is avoided when using air as a test medium and a simple test rig provides adequate over-pressure protection. An ultrasonic leak detection device can be of great assistance when tank testing.

The remainder of the outfitting operation is completed as for ships in conventional materials with the exception that use cannot be made of welding for the attachment of pipes and fittings. Pipes and cable runs are carefully planned during the early design stages of the vessel and it is known with certainty exactly where and how a pipe or fitting is to be installed. Arrangements are then made to incorporate metal or wood inserts in specific parts of the laminate which are drilled and tapped and so permit a standard set screw or wood screw type attachment.

Reinforced plastics will readily machine and no difficulties have been experienced when boring the stern frame and rudder stock boss. Heavy sections can also be tapped with safety, providing fairly coarse threads such as Whitworth are used. Alternatively, metal inserts or patent locking devices may be used.

The main engine is secured in the hull by either a G.R.P. or all-metal bedplate. These bedplates are simply matted in to the hull if of G.R.P., but if constructed of steel the transverse floor members are trimmed to the hull bottom profile and matted-in on both sides of each floor and intercoastal.

Since there is little or no adhesion between steel and polyesters the built-up angles and steel bedplate members are through bolted.

In general, where main engine inertia forces are high, in particular with engines in the medium speed range, we have preferred to fit steel bedplates, since the engine inertia is more readily absorbed, resulting in less vibration.

Deck machinery may be fitted in a variety of ways, bolted direct to metal inserts or mounted to separate bedplates, which in turn are secured to the deck laminate. Hatch coaming closing devices, air and sounding pipes, etc. are dealt with in a similar manner as for steel or wood ships.

Single steel plate or composite G.R.P. and steel rudders have been used and both have given good service. In the case of the composite unit, a steel spider comprising a peripheral frame and intermediate members is constructed and welded to the rudder stock, Poluyrethane slab is laid between the rudder arms, the laminate laid over the unit and built up to section using a method of interlocking the successive laminates and steel work in order to ensure complete attachment.

5.0 97′ COMBINED TRAWLER-SEINER DESIGN STUDY

The design study for this vessel is based upon certain parameters provided by the Department of Fisheries and including principal dimensions, fish hold capacity, range and speed data together with general operating requirements.

The design objectives were a lightweight high strength hull with good handling and sea keeping characteristics, incorporating a fish room volume of about 9000 cu. ft. and loaded speed of 10 knots. In addition, great importance was attached to a smooth, well rounded superstructure and avoidance of impedimenta likely to assist ice growth concentrations.

Ship design proceeded along the accepted paths of lines and general arrangement plans, hydrostatic data, etc., and comprehensive stress analyses. From these details the required section moduli were calculated and the final configuration of hull stiffening and section computed.

The hull is longitudinally framed by a system of 4 bottom and 3 side shell frames, moulded integrally with the hull in the form of corrugations which result in a maximum depth of unsupported panel between longitudinals of eight inches.

At the round of bilge, additional shell plate support is provided by fitting internal stringers to maintain the standard panel depth. These additions were not considered necessary from aspects of longitudinal strength or panel support in view of the curvilinear section of the hull at this point, but in consideration of increased impact resistance, in particular when in ice, it was decided to include these members.

A system of full depth bulkheads, division bulkheads in the fish hold and deep frames in the engine room provide the anti-racking resistance and transverse strength requirement in addition to sectionalising the hull to form a module network of standard dimensions and thus providing increased and uniform rigidity throughout the hull.

The main deck comprises a single plate laminate and is strengthened by a system of composite longitudinal and transverse members.

Attachment of deck to hull in this instance incorporates a stressed bulwark principle. The bulwark is moulded integrally with and as an extension to the side shell. The deck laminate, after positioning, is connected to the hull by additional laminates which commence at the deck stringer boundary and continue up the bulwark. The deck and side shell are similarly connected under the deck and the attachment completed by through bolting these secondary connections at frequent intervals.

It was a requirement of this study that the design be approved by Lloyds Register of Shipping and Canadian Steamship Inspectorate. When submitting detailed construction plans to the former it was decided to take advantage of their computer program for determining longitudinal bending stresses, and it is interesting to relate that the estimated stresses, which were those used in calculating required section moduli, were considerably in excess of the computed values, indicating that actual safety factors are well in excess of the design estimates.

In order to obtain maximum capacity it was decided to construct fuel and water tanks of G.R.P., utilizing the shell as tank boundaries as far as possible. As previously stated, laminating in confined spaces, particularly those in tanks, presents some problems to laminators due to the concentration of styrene vapour. A further complication was the configuration of the stern which incorporates a stern ramp.

These difficulties were resolved by arranging the hull mould to include the deck in way of these tanks, so that, with the exception of the forward bulkheads, these tanks would be moulded integrally with the hull. This is achieved by hinging the deck section so that the greatest proportion of laminating can be carried out in the vertical rather than overhead position.

This arrangement necessitates a butt joint in the main deck and joint preparation is made by scarfing the butts during lay-up. After assembly the deck is built up to full section below and above deck and bolted.

The forward fuel tanks are formed by a single preformed laminate, incorporating one side and two end bulkheads which is matted in the hull. In this instance, the tank crown consists of an integrally moulded G.R.P. flange to which a steel plate is bolted. This arrangement provides easy access and improved ventilation whilst laminating tank internal connections and a suitable bedplate on which to mount auxiliary machinery.

The main engine bedplate is basically a steel structure comprising two longitudinal bearers and top plate together with a system of transverse and longitudinal diaphragm plates. The unit is matted in to the hull and the attachment so formed finally through bolted.

The forecastle deck and superstructure are designed for unit construction and will be built in a single mould complete with stiffening. The deck is provided with an outward turning flange and is bolt attached to a similar flange, moulded to the bulwarks. Complete watertightness is achieved by the external roving and internal sealing mats. A neoprene, or equivalent, rubbing band is mounted over these flanges.

In the fishroom the arrangement of division bulkheads, in addition to meeting a number of structural and statutory requirements, also, in association with a system of aluminium sections permits complete interchangeability of fish pond division plates or penboards. Insulation of hold boundaries is effected by fitting blocks of preformed low density polyurethane foam, set in resin and finally covered by three plies of chopped strand mat in situ.

A fully water-tight shaft tunnel is provided, arranged to permit access to shaft bearings for periodic examination and shaft withdrawal. Both rudder and stern tube are of steel in this instance but the latter is totally encapsulated externally in G.R.P.

To conclude this brief description, it may be of interest to note that the total plastics weight of this vessel is a little over 37 tons as compared with its steel equivalent of 110 – 120 tons.

6.0 FUTURE TRENDS

As stated earlier, the full potential of reinforced plastics has only recently become universally recognised and already within the short period of their general acceptance, plastics have made substantial inroads in spheres of construction media hitherto exclusively occupied by traditional materials and nowhere is this trend more clearly demonstrated than in the marine field.

At the present time, most development work has been centred around small craft in the range 50 to 100 ft. but

throughout the world there is considerable movement inclined towards extension into larger vessels. The most recent trends in hovercraft and aerofoil vehicles employ reinforced plastics as the basic medium and the navies of several countries are in process of building or contemplating construction of vessels in the coastal or minesweeper class.

Our development has been solely related to commercial vessels since whilst specialist craft are of great interest, it is our conviction that the greatest potential is to be realised in the work vessel field, not merely as a result of wider applications, but also because it is in this class of vessel that the repetitive techniques can be most usefully employed.

It is an established fact that reinforced plastic vessels are comparable to their steel and wood counterparts in all operational aspects and, in addition, we believe, have undisputed claim to considerable advantages. In earlier years, however, construction costs were high, but, as a result of the advances made in design and construction techniques, we now know and have proved that, on a series of six to ten ships, cost parity can be achieved.

The Design Study carried out on behalf of the Department of Fisheries of Canada has the distinction of being the largest commercial craft construction yet contemplated, although we are at present engaged on finalising the design plans for a vessel of 146′ O.A.

Preliminary arrangements and design concept in respect of a 200′ O.A. general purpose cargo vessel, are already in hand and our investigations clearly show the technical and practical feasibility of ships of these dimensions and greater.

Construction methods for vessels in this range will, certainly, require modification, but these will follow as a logical and progressive advance in technique, as ship lengths increase.

The limiting factors at present are those of resin and reinforcement strength characteristics and their individual stress transference behaviour, but already new materials are appearing. Apart from the epoxy resins which for shipbuilding are still cost prohibitive, improved polyesters are in course of introduction with permissible stress levels approaching 50% in excess of those immediately available. Reinforcements have undergone even more dramatic changes and the advent of boron and graphite filaments, together with silicone carbide and beryllium wire reinforcements offer enormous scope.

These reinforcements are still in the early stages of development, are extremely costly and in small quantity, but set the trend. Today's trends, however, frequently become realities within a very short time and all the indications point to continued improvement in materials and advancing design and construction techniques.

In conclusion, there can be little doubt that reinforced plastics in shipbuilding are not merely here to stay but will rapidly and progressively achieve a position of great importance and exert considerable influence upon new shipping concepts and ultimately, within the foreseeable future, will, it is believed, dominate certain sections of the shipbuilding industry.

Part II
THE CHALLENGE TO THE DESIGNER

by
Martin Yeatman

7. PROPERTIES OF THE MATERIAL

7.0 In this section, we will examine the implications for the designer of some of the properties of reinforced plastics which may be new and unfamiliar.

7.1 *Cost*

Already there are indications, if one is considering a work boat hull for which there is a requirement of a series of ten or more, that by 1970 there will be producers in reinforced plastics in several countries who will be able to bid in direct competition with steel boatbuilders. It is believed that this statement is valid for equivalent hulls in the size range 50 ft. to 100 ft. LOA. By equivalent hulls is meant those with equal deadweight, speed, seaworthiness and freeboard/stability characteristics. In other words, proper exploitation of the strength/weight superiority of R.P. must be taken into account. The above statement may not be valid in some countries when referring to wood rather than steel, but there also, no one can doubt which way things are going. It is not intended to go deeper into the economic aspect here, as Professor Harry Benford and others have published useful guides showing designers and operators the most meaningful and effective ways to measure and compare the economic performance of all

sorts of vessels. These tools of economic analysis are available, computers allow us to test the effect of changes in all sorts of variables quickly and conveniently and the sad thing is that owners still tend to provide designers with fairly detailed performance specifications which are developed by hunch or are simply duplications of previous ones that have proved successful (or partially so) in a given set of circumstances. The thing we wish to emphasize is that, regardless of speculation as to whether they will come to dominate in the workboat field to the extent they do now in the pleasure craft and ships' lifeboat fields, REINFORCED PLASTICS ARE HERE TO STAY, and therefore the fishing vessel designer CANNOT AFFORD TO IGNORE THEM. This is a challenge to and a demand upon designers, because they will at the same time, always have to acquire a good working knowledge and understanding of the properties of ferrous and non-ferrous metals and alloys and be able to choose the right material in a given application, and make an appropriate design.

7.2 *Strength/Weight Ratio*

Regardless of the strength criteria applied, it is evident that the biggest single challenge to the designer is that he must learn to exploit the fact that his hull is going to weigh *less than half* an equivalent wooden or steel hull. The results mentioned in Section 5.0 of this paper, for a 97 ft. LOA fishing vessel, were developed from existing experience on the 83 ft. class in South Africa and careful consultation with Lloyds Register staff on every detail. If anything, improvement in production techniques and reduction of the proportion of matting in, is quite likely to improve on the calculations when these vessels go into production. This is actually getting to the stage of being an embarrassment to the designer. There are two main implications.

(A) To load a hull of given displacement to an acceptable waterline, the possible ratio of fish and fuel to that of the bare vessel is so high that even with dense cargoes such as bulk herring, it will be *possible* for the fish hold to occupy a greater portion of the hull than ever, and this will put considerable pressure on developing more compact machinery and auxiliary spaces. The word *possible* above is italicized intentionally, since it will not always be desirable, and there are other ways of exploiting high deadweight/displacement ratio. Every case must be judged on its own merit.

(B) The difference between loaded and light (on arrival fishing grounds) drafts on a conventional hull is so great as to be inconvenient for some methods of fishing. We believe that this will initiate two parallel and partly independent developments, namely radically new approaches to the underwater hull form, and the use of sea water ballasting arrangements in smaller vessels than present normal practice. The latter development would dovetail in nicely with increasing use of R.S.W. for catch preservation, which we will come back to later.

Further improvements in strength/weight ratio will be difficult to exploit operationally in fishing vessels, but must be aimed at because of the high cost of raw materials.

7.3 *Actual Strength Properties*

Study of the Owens–Corning/Gibbs and Cox handbooks and more recently published results will help the designer appreciate the nature of the material and give him typical values of comparable strength coefficients to those normally used with metals, for a wide variety of reinforced polyester systems. The accompanying table just gives some typical figures that one might expect to meet. The important things to bear constantly in mind are as follows:–

Non-crystalline – no work hardening or other crystallographic changes to reckon with.

No yield point – while this means that a greater proportion of the ultimate strength range may be usable, greater care has to be exercized in the detail design of areas where stress concentration can occur. For example, when attaching heavily loaded fishing gear to an already stressed part such as the deck, it is considered prudent to entirely avoid imposing a local bending moment, either by use of pin-joint or ball-joint attachments, or by spreading the load over a considerable area of the deck.

Highly elastic – for an average laminate, the tensile Young's Modulus might be one-twentieth of that for mild steel, whereas the ultimate tensile stress might be as high as one-third that of the steel. This comparison becomes even more alarming if we bear in mind that a steel structure has to be stressed in relation to the material's yield-point to avoid permanent deformation. Fortunately, there is no reason why a fishing vessel should not be fairly flexible, and wooden boats certainly are, particularly in racking, so the designer need not attempt to match the rigidity of steel and

thereby sacrifice much of the weight advantage. Admittedly, big deflections are a problem for machinery alignment and attachment of various outfitting items, but proper use of self-aligning shaft bearings and careful engineering of pipe and cable runs and similar details will overcome most of the problems. Advantages of the high elasticity are high energy absorption without permanent deformation on impact, low fundamental frequencies of vibration, and self-damping properties of the structure as a whole (the "Feel" of an R.P. boat with respect to engine and propeller generated noise and vibration is more akin to wood than steel).

Abrasion resistance – Although superior to most woods, the resistance of R.P. to abrasion must be considered as poor when considering wire ropes and heavy fishing gear. This presents quite a challenge to the designer to develop a simple lay-out with as few points of wear as possible, and to anticipate rigging requirements for every conceivable need during fishing operations. Methods of attaching wear plates and rubbing strips are in their infancy, and it is to be hoped that ways of achieving the required effect during the moulding process will be developed.

	MILD STEEL	ALU-MINUM	R.P. (CSM)
Specific gravity	7.8	2.8	1.4
Tensile strength $lbs/in^2 \times 10^3$	70	65	16
Young's modulus $lbs/in^2 \times 10^6$	30	10	1.0
Specific strength $lbs/in^2 \times 10^3$	9	23	11
Cost per unit weight	1	6	5
Cost per unit volume	1	2	1
Thickness for equal tensile strength	1	1.8	2.4
Weight for equal tensile strength	1	0.66	0.51
Cost for equal tensile strength	1	2	1.2
Thickness for equal bending stiffness	1	1.5	3
Weight for equal bending stiffness	1	0.5	0.6
Cost for equal bending stiffness	1	3	3.5

N.B. The above figures are taken from Scott Bader Limited and therefore can be biased in favour of R.P. but they do show approximate orders of magnitude.
Costs are for materials only.

Orthotropic – account must be taken in the design stage of the directional variation in strength properties of woven reinforcements.

7.4 *Physical and Chemical Properties*

Corrosion – as far as can be ascertained, an R.P. fishing boat is not subject to corrosive attack of the structure *at all* under normal circumstances. This is, of course, a tremendous advantage. There may be one or two cleaning agents such as caustic soda which should not be used on board, otherwise there should be no problems.

The non-corrodible nature of the primary hull material, together with the flexural advantages of a cellular type of construction, lends itself well to considering refrigerated sea water for preservation of the catch. So far, ice continues to dominate, but we are by no means convinced that R.S.W. has been given a fair trial. Paint can be applied if desired, but is quite unnecessary, and the gel-coat surface, coloured by appropriate pigment, will retain a smart appearance for years.

Anti-fouling – At the moment anti-fouling paint is recommended, as marine growth will attach itself to the bottom, but experiments are in hand with long life toxic pigments for adding to the gel-coat.

Thermal – The coefficient of thermal expansion of a typical laminate is not too far from that of steel, which is convenient from the point of view of steel inserts. The conductivity and surface emissivity are very low, and although quantitative results from full scale trials are not known to the authors, fish holds with given insulation type and thickness and R.P. structure should lead to appreciable savings in ice consumption and for refrigerating power compared with any other material. Even without fire resistant additives, the low conductivity puts R.P. in a favourable light when considering fire hazards. Unfortunately, skin cooling cannot be so conveniently arranged as in steel boats, but suitable recesses in the mould can be designed so as to present a flush exterior, and minimize the risk of damage to a skin cooler.

Electrical–R.P. is a good electrical insulator, and it is very easy to control electrolysis. The same general precautions are taken as with wooden boats in designing the

electrical system. A separate grounding system (s) for the frames of electrical machinery and distribution panels, and a lightning conductor arrangement are recommended, although it is realized these have not always been provided. As long as booms do not get strongly magnetized, there are no problems with magnetic compasses.

8. CHALLENGES IN PRODUCTION

8.0 Challenges to the production engineer are probably even greater than those facing the designer, but we will touch upon them here, since both these gentlemen will have to co-operate closely and have a good general understanding of each other's job. Present production practices are described in Section 4, and in this Section, we will just try to stimulate thought and discussion by taking a couple of peeks into the future.

8.1 *The Mould*

In large fishing vessels or other workboats, we foresee that the plug will be eliminated, and the main hull mould fabricated from light-gauge steel, heat shrunk and appropriately stiffened. This will allow of zone heat control for accelerating or delaying cure. It is conceivable that this approach will lead to achieving primary bonds between major components which at present have to be treated as separate mouldings.

8.2 *Mechanization*

Labour-saving devices will have to be developed in the tailoring and moulding shops. There is unlimited scope for ingenuity in improving methods for handling materials and workpieces, and applying resin.

8.3 *Semi-Manufactured Materials*

As is pointed out in Section 3.3, a reinforced plastics moulding business is actually manufacturing the material as well as the end-product in its shops, but it is believed that increasing availability of semi-finished items such as "pultrusion" angles, pipe, flat and corrugated sheet, will induce designers and production engineers to use them where appropriate. Undoubtedly, other forms of reinforcement than the flat mat and woven materials will also become generally available. Chopped strand "pre-forms" for matched die moulding give a clue to some fascinating possibilities in this direction. In outfitting, there is also a considerable challenge to designer and production engineer to use materials and methods compatible with the hull material. These include plastics for all piping systems where approved, and ventilation trunking, resin chocking compounds for machinery mounting, considerable use of self-tapping screws for the attachment of minor items, and as indicated in Section 4.3, detailed planning must be adopted in order to exploit the possibility of matting in all sorts of lugs and fittings on the inside of mouldings before gelation sets in.

8.4 *The Secondary Bond*

As discussed earlier, it is desirable to eliminate secondary bonds in the main structure, but that may in itself prove difficult and expensive, and meanwhile, it is important to improve methods of achieving a secondary bond, with respect to cost, convenience, and strength. At the moment, a lot has to be learned about making major structural repairs to vessels which are too big to be put back into the manufacturer's shop.

9. NOTES ON THE 97'-0" GRP FISHING VESSEL DESIGN

9.0 *Background*

In spite of plentiful timber, and many wood boatbuilders, the Nova Scotia Department of Fisheries foresaw many years ago that it should be looking to a future when shipwrights and wooden boat builders were less plentiful and earning higher wages. They were also concerned about accident rates, fire, heavy repair bills, and sky-rocketing insurance premiums, and considered that new materials as well as better crew education and training might improve the situation. At the same time, the Atlantic Bridge Company group were getting into reinforced plastics and one of the first results was the "Cape Islander", which has been described elsewhere. After that, they believed that planning should start towards the day when they could offer larger fishing boats in reinforced plastics for the home and export markets. The province approached the federal Government, who in the form of the Industrial Development Service Branch that organized this conference, expressed willingness, indeed enthusiasm, to have a thorough design study conducted for the benefit of the entire Canadian fishing industry, so that realistic production costs could be estimated and technical problems brought to light.

Our firm was approached as to our interest in the project, and we were very enthusiastic because we felt

strongly we must learn how to handle reinforced plastic designs as well as steel and wood.

The Atlantic Bridge Company was very interested in the big export potential for shrimp boats of the 70′ Gulf of Mexico type but this type is not of any particular use in Eastern Canadian fisheries. The Nova Scotia and federal departments decided that a most likely fishery was for bulk herring, since there were signs that this fishery was going to be healthier than groundfish for a while to come. So a 270 short ton of herring capacity target was given, and the hull should be suitable for rigging as a midwater trawler, seiner, or lastly and less important, a groundfish trawler if necessary. Mr. Jack Gilbert of Boston, U.S.A., was asked to contribute to the design concept, and we produced a rough preliminary design for the department to look at, and the final design has not changed in any important respect from that departure point. The lines had to be changed a bit, and the depth modified when we realized how light the hull was going to be.

There were some other modifications which went along with the fishing requirements. These were specified by the Industrial Development Branch.

The Industrial Development Branch and ourselves agreed that we should consult someone with proven knowhow in big reinforced plastic structures. We felt that Goldharbour Pty. Ltd. had gone further than anyone else in the field of Commercial reinforced plastic vessel construction and design. The Department of Fisheries engaged them to advise them on all the RP technology and costing, with ourselves as producers of the final engineering information.

The author made a trip to Cape Town to learn as much as possible and to help Goldharbour get the preliminary scantlings and structural details out for this design, and took these back to Lloyds Register of Shipping for a preliminary review. The drawings are now complete and approved by Lloyds.

9.1 *Estimated Labour*

The estimated hull labour was 11,000 man hours. This has to be qualified carefully, because every yard has a different accounting procedure, and what is designated as hull and what as outfit differs from one to the other. The estimated reinforced plastic weight was 37 long tons; and the estimated light ship weight which includes quite a bit of ballast is 150 long tons. Outfitting labour including fabrication and fitting of masts and booms, is estimated at about 35,000 man hours.

It is believed that the series production discipline which G.R.P. will impose will actually tend to effect dramatic improvements in outfit productivity but the estimated figure accords with present Canadian East Coast yards performance on this class of vessel.

For the hull labour, we have an average of about eight pounds of R.P. laid per man hour, as against twenty quoted by Boughton Cobb. There are several reasons for this; the authors particularly wanted to be conservative and not to paint a deceivingly bright picture. Furthermore, we were designing a trawler and in the hull man hours we have taken the fabrication and fitting of side protection plates, a stern ramp which has a complete steel protection plate, the mast footings, and the winch and anchor seats. All these things had to be most carefully considered, and are probably a good deal more rugged than in the boat that Mr. Cobb was considering, and this probably accounts for a good bit of the discrepancy. Actual laminating rates might rise as high as 100 lbs/manhour on certain portions of the hull, and are not to be confused with hull department man hours per unit weight of laminate in the finished hull.

G.R.P. Material costs, including wastage allowance, but excluding mould costs, are estimated at about $39,000 Canadian.

9.2 *Stability*

The freeboard with a full load of herring and about 16 long tons of fuel, water and gear on board is 16″, and freeboard and stability characteristics conform with the recommended criteria published by I.M.C.O.

We do not know too much about the effect of freezing spray on reinforced plastic super-structures, but obviously soft mallets or something other than picks and shovels would have to be used to knock it off.

The GZ curve appended shows the stability characteristics in the worst condition which could be met, including an allowance for frozen spray in the rigging and superstructures, as laid down by the Canadian Board of Steamship Inspection. Experience with G.R.P. vessels may show that this allowance can be reduced – it certainly will not be necessary to increase it.

10. *Data*

It is scarcely necessary to quote a list of references at the end of a paper of this nature, since there are not more than a couple of dozen readily available sources of original data pertaining to reinforced plastics as applicable to fishing vessels, and they can probably all be reached within two removes from the bibliography in a book such as Scott Baders Polyester Handbook, which is regularly re-edited. This is convenient, but also an indication of the scarcity of experimental information available. In particular, measurements of stresses and deflections on an actual R.P. fishing boat need to be made. Factual allowances for improved skin friction need to be evolved. Underwriters will need to gather statistics on the frequency and cost of repairs. All these things will take time, and meantime, there is plenty of hard work and scope for the imagination.

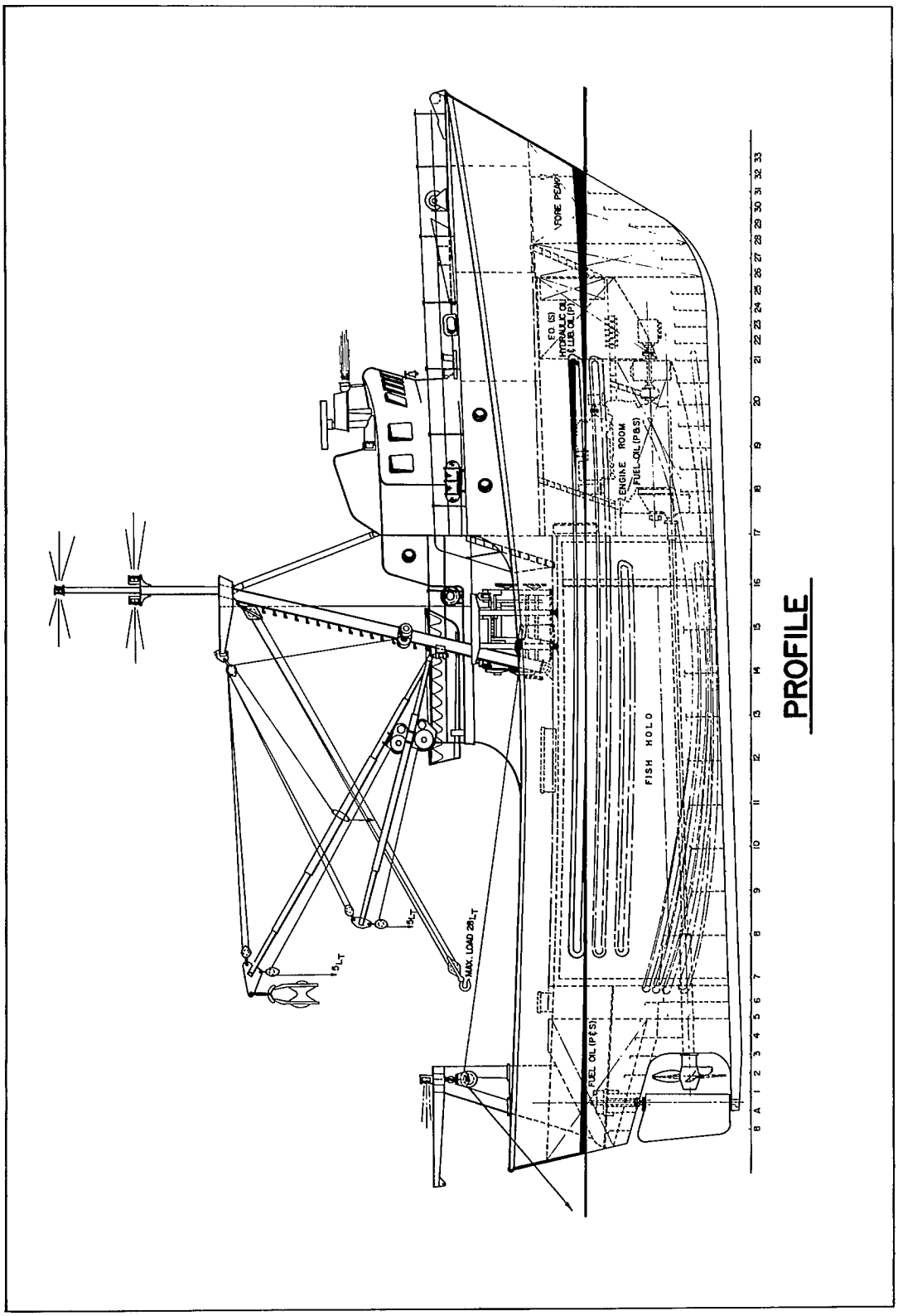
11. *Durability and Obsolescence*

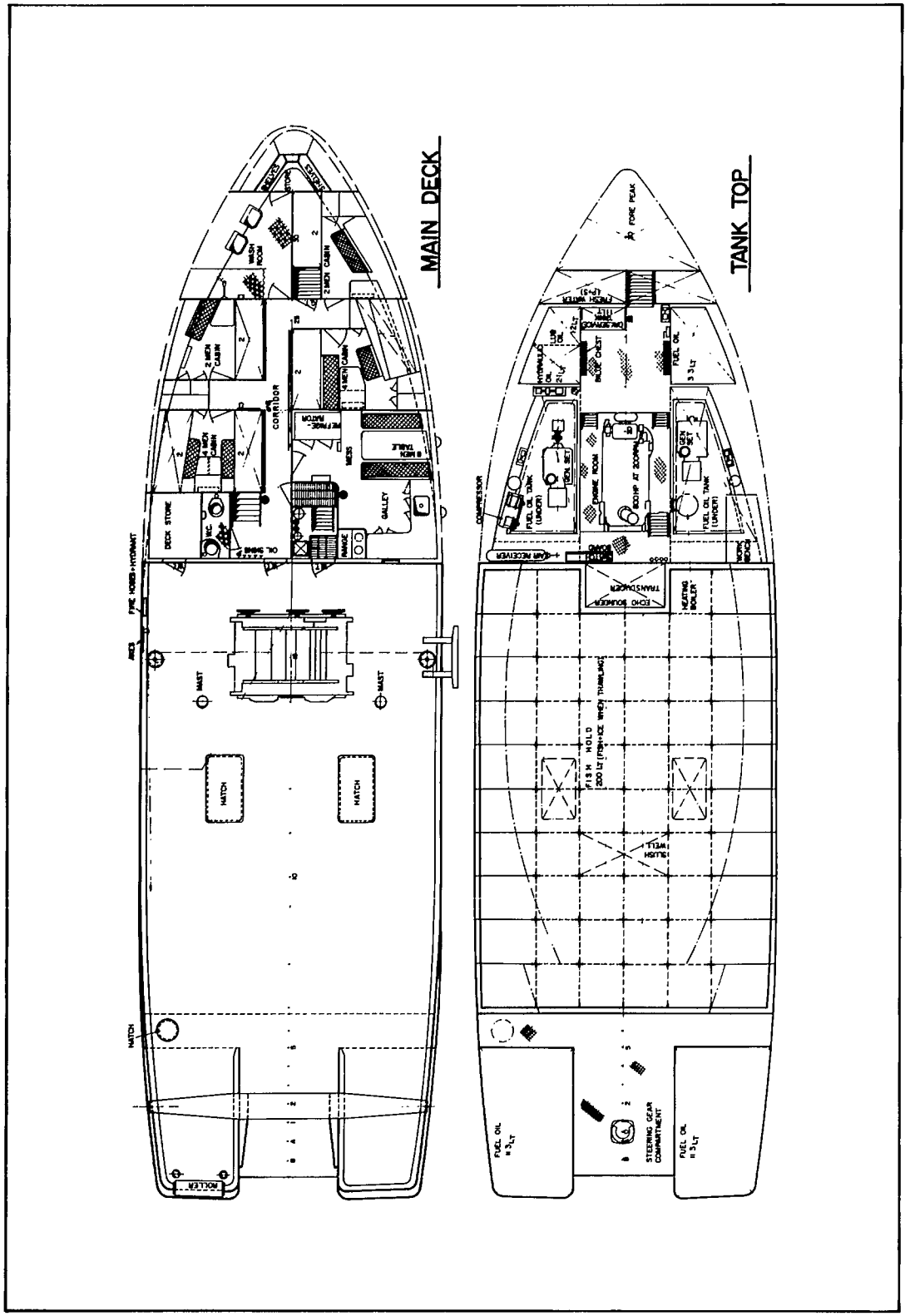
Indications are that reinforced plastic workboats will be more durable than those built of steel or wood or even aluminum, and one is tempted to ask "is this a good thing? ". Will it put a restriction on the development of new types? What do we do with obsolete R.P. boats? We cannot burn them on the fire of a winter's evening or send them back to the open hearth furnaces. Perhaps a coastline packed solid with unwanted but indestructible R.P. hulls is a realistic nightmare for future generations, but it is not considered of immediate concern. What will undoubtedly happen in 15-25 years is that a considerable international market in second-hand R.P. workboats will develop, and eventually someone will probably invent a way of ripping them up and using the product to replace something else. And with these highly speculative thoughts, we will close our paper and thank the reader for his indulgence.

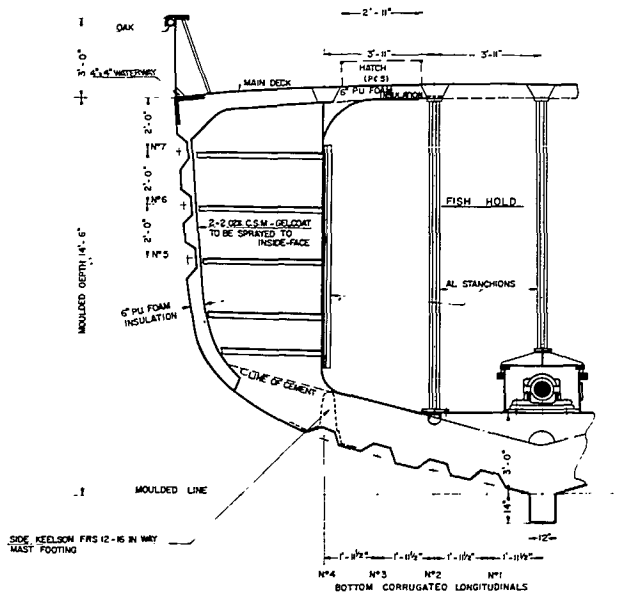
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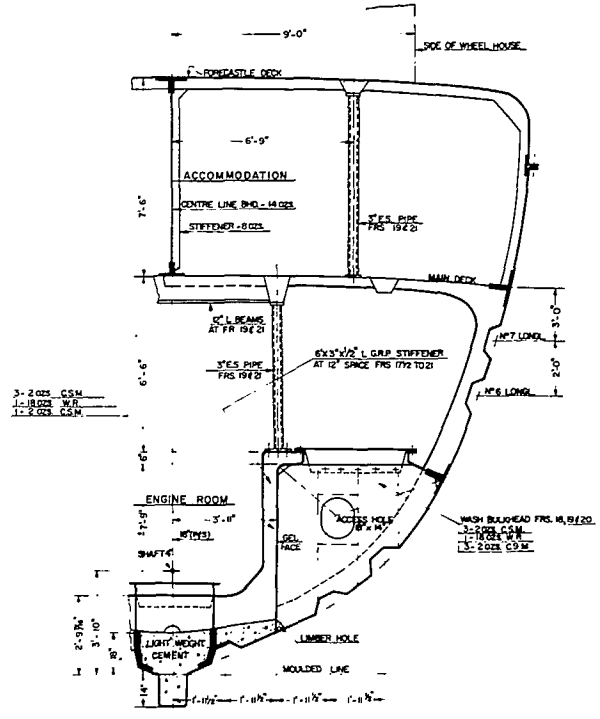
Model of 97-foot GRP fishing vessel


PROFILE
FISH HOLD
ENGINE ROOM
FUEL OIL (P&S)
MAX. LOAD 25L-T
15L-T
15L-T


MAIN DECK
TANK TOP
FORE PEAK
MESS
GALLEY
MAST
MAST
HATCH
HATCH
HATCH
FISH HOLD
STEERING GEAR COMPARTMENT
FUEL OIL
FUEL OIL
FUEL OIL TANK (UNDER)
FUEL OIL TANK (UNDER)
GEN SET
GEN SET
ECHO SOUNDER
TRANSDUCER
HEATING BOILER
WORK BENCH
DECK STORE
WASH ROOM
CORRIDOR
ANCR
FIRE HOSE + HYDRANT
COMPRESSOR



SECTION THROUGH FISH HOLD



SECTION THROUGH ENGINE ROOM

Session 4

DISCUSSION

Mr. H. E. Thompson, Hooker Chemical Company, addressed the following question to Mr. Samson: "What is the cost per board foot for ferro, and do you see any advantage in combining polyester resin mortar to gain added physical strength?"

Mr. Samson: "On the size of hull that I pointed out the material costs are about $1.00 per square foot; that's for the wire and rods, as I pointed out. I can't see that there is any point at all in putting polyester resin into the mortar mix. The cement paste itself requires the water as a kickover agent, and I feel possibly maybe a little polyester and glass in some parts, as a covering, might be an advantageous composite, but other than that I can't really see any point in putting polyester into the mortar mix."

Mr. Thompson then asked Mr. Yeatman if he saw the need for fire retardant polyesters in fishing vessels.

Mr. Yeatman: "I know the Goldharbour practice, and I think that some of the people in the United States have practised the same, and in Britain too the practice is to add antiminitroxide – don't ask me what that is, it's just a name to me – to the jell coat. It has a snuffing effect.

Professor Harry Benford, of the University of Michigan, asked Mr. Samson: "In building a large ferro-cement boat, must the application of mortar be done continuously or can you just knock off and go home at five o'clock and start again in the morning?"

Mr. Samson: "On your first boat I would say it should be done continuously, but I think Seacrete in England have developed it, and they are doing it in stages of construction depending on the type of vessel."

Mr. R. A. Harvey, Department of Fisheries of Newfoundland, asked how ferro-cement boat hulls would withstand ice conditions.

Mr. Samson: "I don't really know too well. Bob Griffiths got caught in the ice in his ferro-cement hull when he was coming through the Strait of Magellan, and he suffered a crack in the hull which was about six inches long, from grazing an ice floe, in amongst the ice, but this did not leak. Now I am not saying that if you didn't get squeezed in that you wouldn't get leaks in this because one of the weaker points of ferro-cement is impact strength, although if it is in a freezing and thawing condition where you have got a continuous expansion problem, forcing your hull in, it may react differently; I don't know."

SESSION 5, OCTOBER 3, 1968 9.00 A.M.

COMPARATIVE ASSESSMENTS AND FUTURE OUTLOOK

Moderator: Eric M. Gosse,
Deputy Minister of Fisheries,
Newfoundland



Session 5. Upper photo, left to right, W.S. Hines, J.R. Elder, D.J. Fraser, H. Benford; lower photo, left to right, K.B. Spaulding, Jr., D.A. Eisenhauer, T.M. Hagenbach, R.A. Campbell, J. Brandlmayr.

Moderator's Introduction

Mr. Gosse: *During the course of this Conference we have heard many interesting, well thought out points of view on a wide variety of subjects relating to fishing vessels. This is to be the final session and our speakers and symposium participants will be making comparative assessments of the various materials which are now available for our use.*

Estimated Hull Work and Material Content for 100 ft. Combination Fishing Vessel in Different Materials



Mr. Fraser

by

D.J. Fraser, C. Eng.,
Naval Architect,
Commercial Marine Services Limited,
Montreal

Mr. Fraser came to Canada in 1967 with the specific object of working in the gap between research and practical application. After military service he was for 13 years in the Commercial Branch of the Ship Divison, National Physical Laboratory, as an experimental officer, and undertook work on the hull form on powering of ships in general with special emphasis on fishing vessel development using statistical analysis and computer techniques to predict performances and economics.

In 1965 he was loaned to the Fishing Vessel Section of F.A.O. to join the editorial team for the Fishing Boat Conference and to work on "Fishing Boats of The World, III."

Since coming to Canada Mr. Fraser has held a position as Naval Architect with Commercial Marine Services Limited, Montreal. He is an Associate Member of the Royal Institution of Naval Architects and a Member of the Society of Naval Architects and Marine Engineers.

ABSTRACT

The construction materials considered are steel, aluminum, wood, plastic and concrete and the vessel is a 100 ft. LOA X 24 ft. breadth moulded X 13 ft. moulded depth. The general arrangement is for a typical one and half partial shelter deck combination vessel with bridge and engine room forward and fish hold aft.

Lloyd's Rules are used to derive the scantlings where applicable but the particular properties of each material are not ignored. It is considered that steel and aluminum are best suited to conic sections, whilst the other materials as used require a conventional round bilge construction. The normal methods of construction employed in Eastern Canada are followed even though more advanced techniques are now available.

Any large differences in some of the other ship constructional items caused by the variation of the basic hull material are taken into account before carrying out an analysis of the hull structural weight, material costs and man hours required for the completion of the hull in each material. These estimates are adjusted as far as possible for geographical price variations.

INTRODUCTION

The construction materials considered are steel, aluminum, wood, plastic and reinforced concrete for a 100 ft. LOA combination vessel. Lloyd's Rules are used to derive the scantlings where applicable but account is taken of the particular properties of each material. Each material is used for as much of the construction as possible even though the incorporation of another material may well have more advantages structurally and economically. The normal methods of construction employed, or easily feasible, at present in Canada are followed even though more advanced techniques are rapidly being introduced by many shipbuilders.

Differences in ship constructional items caused by the variation in the basic hull material are taken into account before estimating the hull structural weight, material costs and hours required for the completion of the basic hull. These estimates are for single geographical area so that the relative values may be compared.

THE VESSEL

After surveying existing data, the vessel's main dimensions are taken as 87′–6″ LBP; 24′–0″ Beam and 13′–0″ Depth. These dimensions concur with the trend toward deeper and beamier vessels now considered good design practice. The fish hold capacity would be of the order of 6,500 Ft.^{3} for stowage of wet fish in ice, giving a displacement of approximately 500 tons loaded departure from the grounds, and an all up equipped lightship weight in the order of 375 tons.

The engine room is forward, the fish hold aft with a shaft tunnel under to the propeller. There is a raised fo′c′s′le and a partial shelter deck on the port side. The winch would be mounted to operate athwartships and the vessel is capable of undertaking most modes of fishing with minor changes in deck gear.

MATERIALS

The hulls are considered to the same standard, that is to basic classification with no adjustments for ice reinforcement.

Steel

This vessel is constructed on the ring frame system (1) and the form is double chine, conic sectioned. The loss in hydrodynamic performance of this form is marginal and would be more than offset by permitting boat yards with limited facilities to undertake construction. The building costs for all yards would be reduced by keeping frame and plate bending to a minimum.

Aluminum

The hull form in this material is the same as for steel for the same reasons but also because great care must be exercised when attempting to bend aluminum, as cracking can easily occur and the accuracy of the overbending must be high because of the lower resilience of the alloys recommended for shipbuilding. The method of conversion of scantlings to give an adequate strength level are those recommended in (2). Each member was isolated and an attempt made to ascertain the mode of loading each structural member is required to support.

Wood

In all fairness this material is considered as though using average Canadian practice. That is, natural timbers have been used for the most part and not manufactured laminates. Much of the construction now undertaken is on a semi-professional basis with at times only semi-skilled labour. This does not imply that the vessels are poorly constructed but, due to the higher factor of safety required when using natural timber, they are heavily constructed and the techniques used are for straight forward construction. From the data contained herein the individual fisherman may be able to gauge the cost differential should he undertake some or all the construction on a semi-skilled basis.

The hull form for this and the remaining materials considered is round bilge.

Reinforced Plastic

This is single skin fibreglass reinforced construction layed up in a female mould and adheres as far as possible to the recommendations in (3). Certain alterations are incorporated over and above the proposed regulations, additional longitudinal framing in the bottom and some modification and additional material in that most awkward constructional region in this material; the point attachment of the shell, deck framing, deck and bulwarks.

Ferro-Cement

This material required quite a period of development being a comparatively recent innovation as a boat construction material for fishing vessel hulls. Entire reliance on shell strength members seemed rather unrealistic for a vessel of 100 Ft. in length when vessels presently built in this material are little more than half this length. It was considered that a shell thickness of about 1-1/4" and the addition of a reasonable number of ring frames and a substantial steel keel member is more in order. Certain amounts of pre-stressing of the reinforcement in the deck beams would also avoid excessive tensile stresses in the cement. The pre-cast ring frames when jigged up also act as supports for the reinforcing framework thus ensuring a good hull shape and a homogeneous construction.

Illustrations

Figures 1, 2, 3, 4 and 5 give details of the proposed midship sections which together with a shell expansion are the basis for the calculation of hull material content and weight. It was found easier to calculate the weights by dividing the hull into units as is shown in Table 1. This made a comparison of results easier to check and any large errors in a particular unit were evident, thus reducing the checking.

Limits

Before proceeding to the results, the limits of the investigation undertaken must be stated:

(a) Deckhouses have not been considered because of the range of material and construction methods available.

(b) The engine seats have been constructed in a material suited and compatible with the main hull structure material.

(c) Sonic insulation or translation of vibration has not been considered.

(d) The powering and hence the engine room size and equipment is considered constant.

(e) The cost of the hull construction ONLY is given and the choice of a hull material should not be decided on this criterion alone.

WEIGHT

The total weight of the hull as constructed is illustrated in Fig. 6 which shows the distribution of weight by units. The units are basically the after end, fish-hold, engine room and forward end and they are 20.7%, 33.3%, 27.0% and 19.0% of the length over all respectively. Four of the material weight curves follow a similar line but the heavy engine seats in the wooden vessel in Unit 3 are evident.

When comparing published data the fibre-glass reinforced plastic weight would seem somewhat low but most of the available data is for a hull in a more advanced constructional stage than is now envisaged.

MATERIAL COSTS

These are given in Tables 7-12. The "wastage allowance", variable with each material is an estimate of the scrap material based on Ref. 4,5 with modifications to fit good modern practice. With conic sections and a "ring frame" system of construction, the normal steel and aluminum allowance of 15% should be reduced to about 8%. The wood waste is taken as 20%. The wastage quoted by some sources for FRP construction can be as high as 20% but with a production method using such high quality and production control the factor has been taken as 10%.

The cost per unit weight of material is the current cost from the manufacturer or supplying agent in the quantity specified, without cartage and the discount obtainable on the quantity required for a single vessel production. The material cost of the FRP mould is taken as an extra material cost and is estimated from that required for a 110 ft. stern trawler (Ref. 5).

HULL TOTAL COSTS

The hull cost is given in Tables 13A-13E and an overall comparison in Table 14. Great difficulty has been met in trying to establish a reasonable work-rate; if the work rates published are used, it is difficult to see how known vessels could have been constructed for their selling prices. There is also a marked interaction between work rate, pay rate, overheads and depreciation. Published costing systems are few and are almost always estimates and not actually based on costing after the ship has been constructed.

Finally the following method is proposed: that there should be two overheads, one applicable to material costs, the other labour overhead. The material overhead is that

portion of the material cost of loft moulds, templates, drawing office work, yard management, foremen, indirect and sundry labour, tank experiments, docking, travelling, tools, power, light, ironworker's stores, gas, water, oil, coke, coal and electrical sundries that may be allotted to the hull construction. This figure for steel construction is about 5% for a material cost of $2,000,000 decreasing to about 4% for the present vessel.

The labour overhead includes the labour involved in the items composing the material overhead plus a proportion of establishment charges, holiday pay, social insurance, etc. This is about 74% for a material cost of $2,000,000 and about 95% for the vessel now being considered. A work rate of 162 man hours/ton for steel is given in Ref. 7, but with good construction procedures, a figure of 140 should be obtainable. The rate of working aluminum is difficult to assess as most yards are unfamiliar with it for large hull construction, but a total number of man hours equivalent to 90% of that for steel has been assumed. This gives a man hour/ton rate of 312.

The rate of working with wood is more obscure but for superstructures, figures of 100 man hours/ton are quoted therefore a figure of 120 is taken. The cost of direct labour for FRP construction is taken as 1/3 of the material cost which when converted is reasonably close to the 13 lbs./man hour taken on large hull construction. This would give 172 man hours/ton. For ferro-cement construction the man hours required is taken the same as for steel. When considering these work rates, it has been borne in mind that these work rates are for the hull alone and would therefore be somewhat higher than for the overall ship where other items such as piping and electrics tend to have lower work rates.

The yard overhead is varied by 10% as the overheads are dependent on the yard equipment and the preparation necessary for production.

For single hull production, the ferro-cement hull is 88% and the FRP 143% of the steel hull cost. The cost of the wooden hull is very similar to that in steel and aluminum, some 35% more expensive. For a series production of 5 and 25 hulls, the percentage decrease in cost per number of ships is taken the same for all hulls but in the FRP hull, the cost of the mould is also divided between the number of ships built. This may be a little biased in favour of the FRP hull, but series production certainly favours this mode of construction. These results are given in Table 13 and represented graphically in Fig. 7.

COMPARISON WITH PUBLISHED DATA

The comparison with published and other data is represented in Figs. 8 and 9. Both the hull weights and total costs are in reasonable agreement with those now obtained. Some of the cost data is somewhat higher being Naval and thus constructed to a higher standard than is usual in civil construction.

CONCLUSIONS

It must be remembered that the hull cost considered represents only about 35% of the total initial investment therefore the percentage cost range for total ship costs is approximately +15% to −4% of total ship cost for single hull production.

In days of rising borrowing interest rates, however, these variations are not to be ignored, steel and aluminum appear to have no further production cost reduction possibilities open to them that will not also be available to the other materials. Wood with the good use of laminates should close the gap with steel in this size of vessel.

FRP with its high quality control and production methods and at the moment at least constant raw material costs and improving techniques should be more than competitive on series production basis, but it is difficult to visualize a single production being so.

Ferro-cement, on paper looks extremely attractive price-wise, but scantlings can only be assessed. Too light or too heavy, who knows? Only by building, research and testing will its true economics be known.

Finally, the hull construction as presented is only one item in the economics of fishing vessel design. Changes in fish hold insulation and capacity are directly affected and so is the fish weight carried because of the variation in the hull weight in what is a displacement limited regime. Economics can only be generated if a fair assessment of each component part is known and that has been the object of this paper.

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ACKNOWLEDGEMENT

The author is considerably indebted to Mr. A.D. Milne for his contribution in this paper.

Table 1
Summary of Steel Weight

Item	Unit No. & Weight (Tons)				Weight Total Tons
	1	2	3	4	
Keel & stern bar	0.11	0.35	0.29	0.25	1.00
Skeg	0.80	0.42			1.22
Rudder & stern frame	2.02				2.02
Shell Plating	6.56	10.74	8.36	5.00	30.66
Floor	0.98	1.80	1.45	0.19	4.42
Shaft Tunnel Plating		1.70			1.70
Shaft Tunnel Stiffeners		0.22			0.22
Store Flats Plating	1.43			0.34	1.77
Store Flats Beams	0.11			0.06	0.17
Store Flats Girders	0.06				0.06
Main Deck Plating	2.84	4.42	3.42	1.15	11.85
Main Deck Beams	0.50	0.92	0.70	0.20	2.32
Main Deck Girders	0.20	0.58	0.47	0.10	1.35
Bottom Shell Stiffeners	0.18	0.29	0.32		0.79
Bulkheads Plating	3.85	1.58	2.60	1.40	9.43
Bulkhead Stiffeners	1.11	0.59	0.66	0.33	2.69
Main & Crant Frames	0.59	1.76	1.42	0.84	4.61
Chine & Transom Bar	0.63	0.64	0.52	0.15	1.94
Bulwark Rail	0.27	0.29	0.07		0.63
Fo'c's'le Deck Plating		0.80	2.95	1.72	5.47
Fo'c's'le Beams		0.13	0.54	0.37	1.04
Fo'c's'le Girders		0.06		0.15	0.21
Fo'c's'le Bulkheads Plt.		0.76	4.19	0.57	5.52
Fo'c's'le Stiffeners		0.07	0.61	0.09	0.77
Bkts, Breasthooks etc.	0.64	0.32	0.34	0.31	1.61
Main & Aux. Engine seats			4.81		4.81
Total Weight	22.88	28.44	33.72	13.22	98.26
8% Allowances	24.71	30.72	36.42	14.28	106.12

Table 2
Summary of Aluminum Weight

Item	Unit No. & Weight (Tons)				Weight Total Tons
	1	2	3	4	
Keel & Stem Bar	0.06	0.21	0.17	0.15	0.59
Skeg	0.38	0.20			0.58
Rudder & Stern Frame	0.99				0.99
Shell Plating	2.97	4.78	3.84	2.75	13.84
Floors	0.54	0.99	0.69	0.11	2.33
Shaft Tunnel Plating		0.76			0.76
Shaft Tunnel Stiffeners		0.07			0.07
Store Flats Plating	0.64			0.15	0.79
Store Flats Beams	0.05			0.03	0.08
Store Flats Girders	0.02				0.02
Main Deck Plating	1.17	1.99	1.54	0.53	5.23
Main Deck Beams	0.23	0.45	0.34	0.10	1.12
Bottom Shell Stiffeners	0.06	0.10	0.11		0.27
Bulkheads Plating	1.76	0.71	1.16	0.62	4.25
Bulkheads Stiffeners	0.41	0.24	0.30	0.16	1.11
Main & Cant Frames	0.26	0.78	0.65	0.38	2.07
Chine & Transom Bar	0.22	0.23	0.19	0.05	0.69
Bulwark Rail	0.09	0.10	0.03		0.22
Fo'c's'le Deck Plating		0.35	1.28	0.79	2.42
Fo'c's'le Beams		0.05	0.19	0.18	0.42
Fo'c's'le Girders		0.02		0.05	0.07
Fo'c's'le Bulkheads Plt.		0.34	1.84	0.25	2.43
Fo'c's'le Stiffeners		0.03	0.24	0.04	0.31
Bkts. Breasthooks etc.	0.29	0.14	0.16	0.15	0.74
Main & Aux. Engine Seats			2.25		2.25
Total Weight	10.21	12.74	15.14	6.03	44.12
8% Allowances	11.03	13.76	16.35	6.51	47.65

Table 3
Summary of Wood Weight

Item	Unit No. & Weight (Tons)				Weight Total Tons
	1	2	3	4	
Decks	1.20	2.91	3.31	1.62	9.04
Shell and Keel	2.80	7.74	7.56	3.09	21.19
Bulkheads	4.18	0.46	1.34	0.46	6.44
Deck Beams	1.21	3.03	3.66	1.41	9.31
Rudder Steel	1.25	–	–	–	1.25
Frames	1.02	3.78	9.73	3.69	18.22
Flats	0.65	–	–	–	0.65
Flat Beams	0.20	–	–	–	0.20
Stringers	0.17	0.30	0.24	–	0.71
Stern Post	3.53	–	–	–	3.53
Transom Frames	0.35	–	–	–	0.35
Cant Frames	0.26	–	–	–	0.26
Bulkhead Stiffrs.	0.36	0.21	2.16	0.23	2.96
Bulwark Stays	0.19	0.28	0.06	–	0.53
Bulwark Rail	0.26	0.29	–	–	0.55
Whale	0.24	0.25	0.05	–	0.54
Waist	0.46	0.48	0.15	–	1.09
Bilge Ceiling	0.72	1.99	1.14	0.20	4.05

Table 3 (Cont'd)

Item	Unit No. & Weight (Tons)				Weight Total Tons
	1	2	3	4	
Shelf, Clamp + Lodger	1.08	3.58	2.92	2.34	9.91
Shaft Tunnel	–	1.54	–	–	1.54
F.O. Bunker	–	–	4.54	–	4.54
Eng. Seat + Keelson, Wood	–	1.45	3.15	1.29	5.89
Chocks	0.04	0.04	0.04	0.04	0.16
Chain Locker Flat	–	–	–	0.14	0.14
Fo'c's'le Bhds	–	–	1.47	–	1.47
Fastenings 5%	1.01	1.44	2.08	0.72	5.25
Weight	21.18	29.77	43.60	15.23	109.78

Table 4

Summary of F.R.P. Weight

Item	Unit No. & Weight (Tons)				Weight Total Tons
	1	2	3	4	
Decks	1.24	3.02	3.80	1.76	9.82
Shell	3.24	5.34	5.47	2.33	16.38
Bulkheads	0.50	0.22	0.62	0.17	1.51
Deckbeams	0.22	1.18	1.40	0.46	3.26
C Girder + Floors	0.39	–	–	0.15	0.54
Frames	0.46	1.47	1.54	1.01	0.46
Flats Beams	0.24	–	–	–	0.24
Transom Frames	0.14	–	–	–	0.14
Cant Frames	0.06	–	–	–	0.06
Beams + Webframes	0.20	0.74	0.74	0.10	1.78
Bulkhead Stiffeners	0.66	0.31	2.19	0.45	3.61
Skeg + Keel	0.95	–	–	–	0.95
Rudder + Stern Frame	1.61	–	–	–	1.61
Girders	0.58	1.04	0.86	0.34	2.82
Bulwark Stays	0.08	0.26	0.04	–	0.38
Bulwark Rail	0.09	0.10	0.02	–	0.21
Stringer Angle	0.26	0.27	0.22	0.08	0.83
Angles	2.02	1.54	2.23	0.66	6.45
Shaft Tunnel + Floors	–	0.82	–	–	0.82
Stringer	–	0.03	0.09	0.08	0.20
F.O. Bunker	0.98	–	0.54	–	1.52
Double Skin Deck	1.29	–	0.76	0.57	2.62
Engine Seat	–	–	1.75	–	1.75
Bulkheads (Accommod.)	–	–	0.44	–	0.44
Wood Bottom Chain Locker	–	–	–	0.13	0.13
Brackets	0.03	–	–	–	0.03
Gel Coat	0.24	0.25	0.35	0.13	0.97
P.V.A.	0.05	0.05	0.07	0.03	0.20
Epoxy-Grit	0.02	0.03	0.04	0.01	0.10
Total Weight	15.90	16.97	23.17	8.46	64.20

Table 5

Summary of Ferro-Cement Weight

Item	Unit No. & Weight (Tons)				Weight Total Tons
	1	2	3	4	
Keel and Stem Bar	0.07	0.24	0.20	0.32	0.83
Skeg	1.53	–	–	–	1.53
Rudder and Stern Frame	2.02	–	–	–	2.02
Shell Plating	8.63	12.93	10.64	6.31	38.51
Floors	0.78	0.89	1.72	0.17	3.56
Shaft Tunnel	–	1.80	–	–	1.80
Store Flats	1.17	–	–	0.15	1.32
Bottom Shell Stiffrs.	–	0.51	0.47	–	0.98
Main Frames/Cant Frames	0.82	1.75	1.25	0.63	4.45
Intermediate Frames	0.06	0.13	0.11	0.05	0.35
Bulwark Rail	0.18	0.19	0.05	–	0.42
Main Deck	3.08	4.92	3.86	1.40	13.26
Fo'c'le Deck	–	0.87	2.94	1.56	5.37
Bulkheads	6.97	3.11	4.35	2.17	16.60
Deck House Bulkds.	–	0.83	4.80	0.66	6.29
Bkts., Breasthooks, etc.	0.18	0.41	0.73	0.42	1.74
Main Engine Seats	–	–	3.97	–	3.97
Aux. Engine Seats	–	–	1.68	–	1.68
Main Web Frames	–	3.39	2.25	–	5.64
Total Weight	25.49	31.97	39.02	13.84	110.32

Table 6

COMPARISON OF WEIGHTS

Material	Total Weight	Percentage of Steel Weight
Steel	106.2 T	100%
Aluminum	47.65 T.	45%
Wood	109.78 T.	103%
F.R.P.	64.20 T.	60.5%
Ferro-Cement	110.32 T.	104%

MATERIAL COSTS BREAKDOWN

Table 7

Ordered Steel Weight + Material Cost

Material Form	Wastage Allowance	Weight	$/LBS.	Cost $
Sections	+8%	31.10	0.10	6,966
Plating	+8%	75.50	0.08	13,530
Castings	–	1.50	0.15	504
Welding + Gas	5% of hull weight	5.00	0.21	2,361
Gas	1½% total cost			
				$23,361

Table 8

Ordered Aluminum Weight and Material Cost

Material Form	Wastage Allowance	Weight	$/LBS.	Cost $
Sections	+8%	8.67	0.725	14,080
Plating	+8%	38.80	0.545	47,367
Welding + Gas	5% of hull weight	2.20	1.60	7,885
				$69,332

Table 9

Ordered Wood Weight and Material Cost

Material Form	Wastage Allowance	Weight	$/LBS.	Cost $
Steel Casting	–	1.50	0.75	504
Steel Plate	–	4.54	0.08	814
Fastenings	–	5.31	0.25	2,974
Oak	+20%	85.27	0.12	22,921
Fir	+20%	25.75	0.20	11,536
Birch	+20%	7.09	0.20	3,172
				$41,921

Table 10

Ordered FRP Weight and Material Cost

Material Form	Wastage Allowance	Weight	$/LBS.	Cost $
FRP Mat	10%	7.89	0.46	8,130
FRP Woven Roving	10%	8.55	0.56	10,725
Poly Urethene	10%	1.06	1.00	2,374
Resin (Polyester)	10%	48.42	0.25	27,116
Wood (Oak)	–	3.01	0.129	809
Gel Coats (2)	–	0.97	0.39	847
P.V.A.	–	0.20	0.40	179
Epoxy-Grit	–	0.10	10.00	2,240
				$52,420
Female Mould (Material Only)				$45,330
Total Material (One Hull)				$97,750

Table 11

Ferro-Cement Material Cost

Material Form	Wastage Allowance	Weight	$/LBS.	Cost $
Cement	+10%	25.96	25/T.	674
Aggregate	+10%	46.86	0.65 T.	30
Chickenwire	+10%	6.39	0.18	2,576
Hardward Cloth	+10%	4.94	0.54	5,975
Reinforcing Rods	+ 5%	8.40	0.07	1,317
Pipes	+ 5%	12.84	0.16	4,602
Tying Wire				100
				$15,274

HULL COSTS

Table 12 (A)

Steel	Weight of Hull	106.2 tons
	Man Hours at 140/ton	14,868 hrs.
	Wages at $3/hr.	$44,604
	Overhead 95%	42,374
	Material Cost	23,361
	Material Overhead 4%	934
	Total Building Cost	$111,273
	Profit 10%	11,127
	Purchase Price	$122,400

Table 12 (B)

Aluminum	Weight of Hull	47.65 tons
	Man Hours at 90% Steel	13,381
	Wages at $3/hr.	$40,143
	Overhead 95%	38,136
	Material Cost	69,332
	Material Overhead 4%	2,573
	Total Building Cost	$150,184
	Profit 10 %	15,018
	Purchase Price	$165,202

Table 12 (C)

Wood	Weight of Hull	109. 78 tons
	Man Hrs. at 120/T.	13,174
	Wages at $3/hr.	39,522
	Overhead 85%	$33,594
	Material Cost	41,921
	Material Overhead 3%	1,258
	Total Building Cost	116,295
	Profit 10%	11,630
	Purchase Price	127,925

Table 12 (D)

FRP	Weight of Hull	64.20 tons
	Wages at $3/hr.	$31,758
	Overhead 85%	26,994
	Material Cost	97,750
	Material Overhead 3%	2,933
	Total Building Cost	$159,435
	Profit 10%	15,944
	Purchase Price	$175,379

Table 12 (E)

Ferro-Cement	Weight of Hull	110.32 tons
	Wages at $3/hr.	$44,604 (as steel)
	Overhead 85%	$37,914
	Material Cost	15,274
	Material Overhead 3%	458
	Total Building Cost	$98,250
	Profit 10%	9,825
	Purchase Price	$108,075

Table 13

Comparison of Purchase Prices

	$ PURCHASE PRICE					
Material	1 Hull	%	5 Hulls	%	25 Hulls	%
Steel	122,400	100%	111,100	100%	97,500	100%
Aluminum	165,202	135%	150,000	135%	131,200	135%
Wood	127,925	104%	116,100	104%	101,200	104%
FRP.	175,379	143%	111,300	100%	87,720	90%
Ferro-Cement	108,075	88%	99,200	88%	86,000	88%

ADDENDUM

The following items have been revised anc incorporated in the text in the light of information and discussions since reading the paper.

Wood Construction

The construction suggested in the original text contained virtually an allowance in the scantings for ice reinforcement and a more accurate assessment is incorporated with the appropriate reduction in weight and cost.

Conclusion

On re-estimation of the hull cost as a percentage of the total ship cost a figure of 35% is substituted for the original 40%.

The Vessel

The displacement should be 500 tons.

Note:–

All weights are Long Tons (2240 lbs.)

All costs are Canadian Dollars.

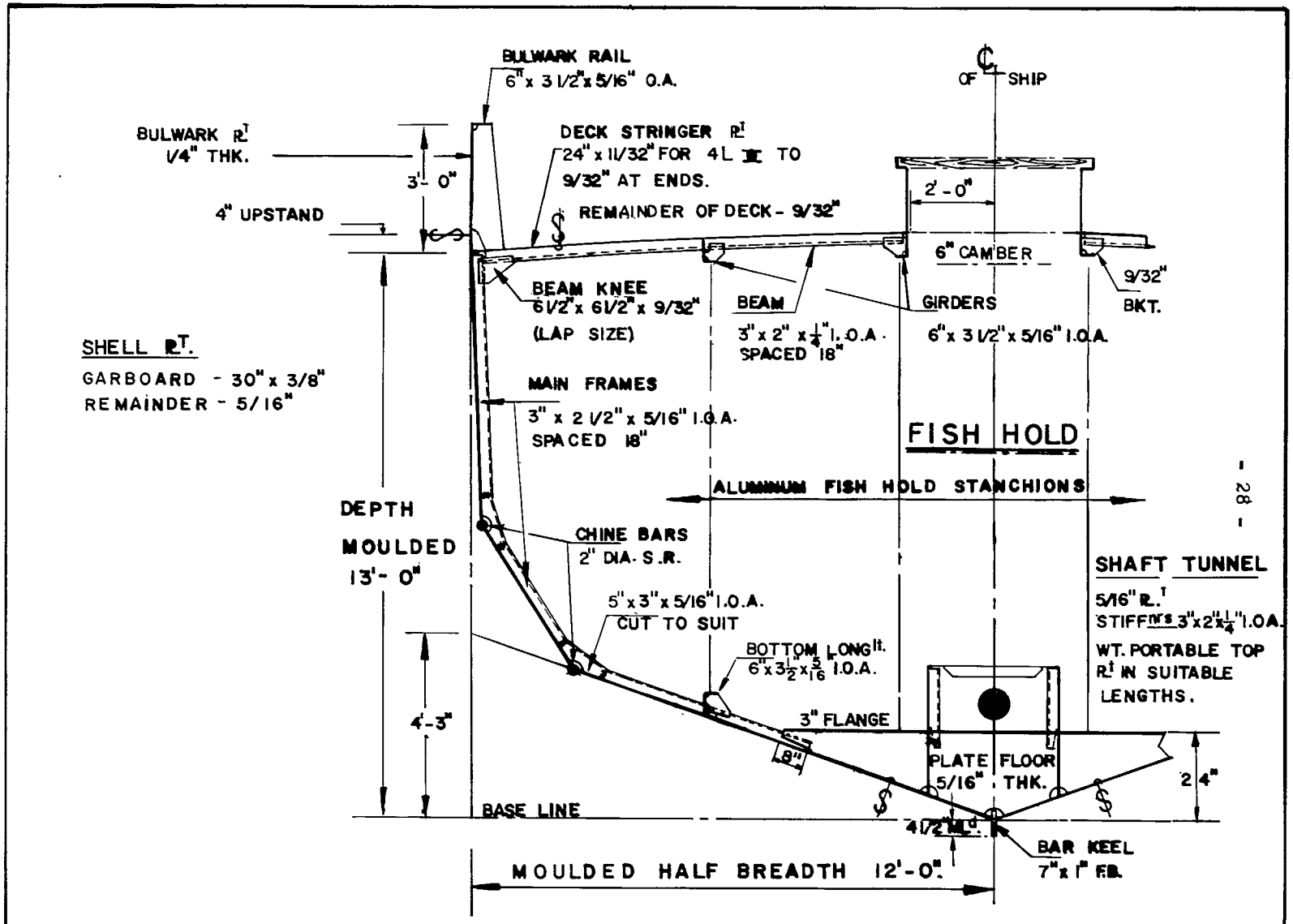


FIG. 1 - MIDSHIP SECTION FOR 100' STEEL COMBINATION FISHING VESSEL.

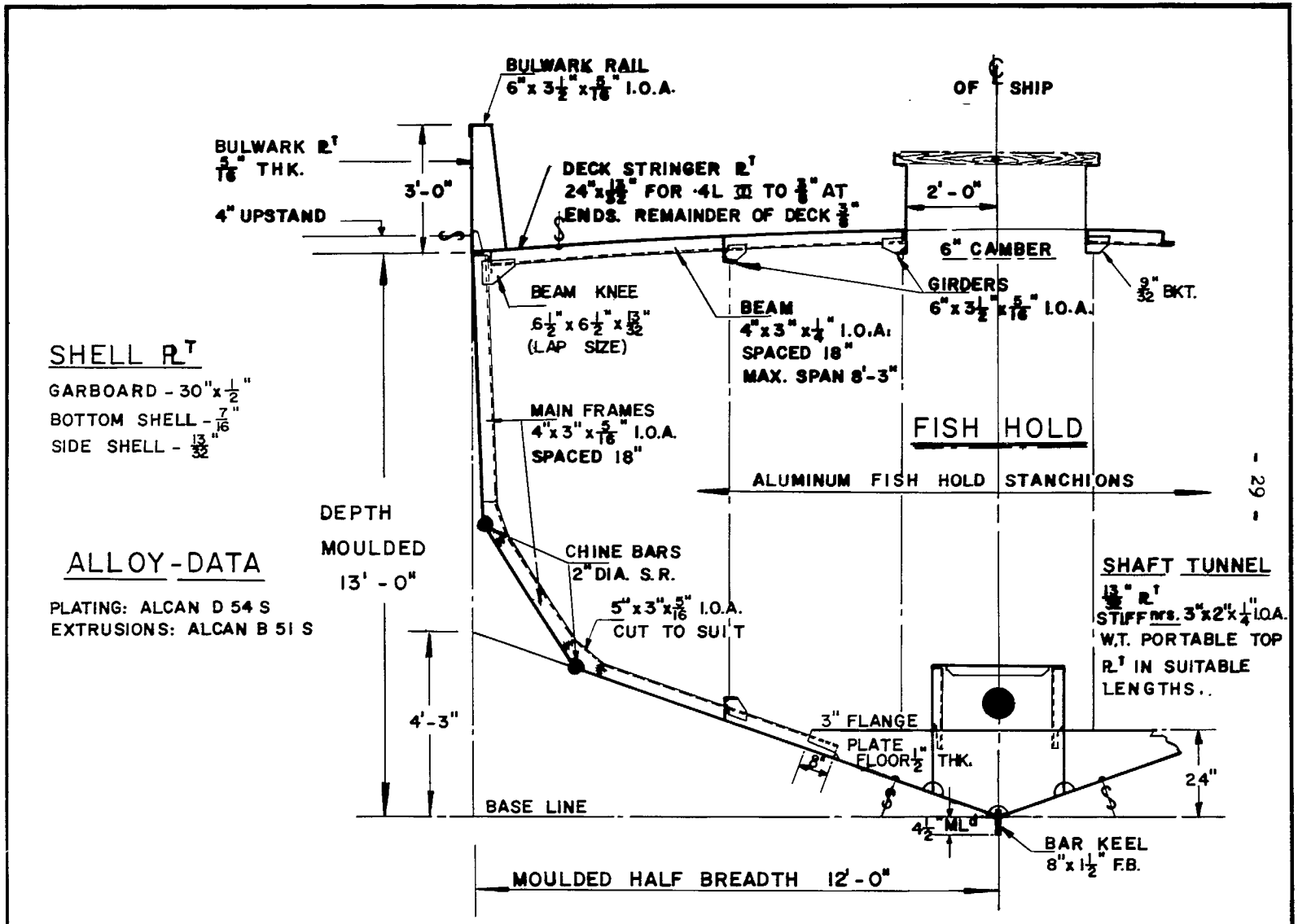


FIG. 2 - MIDSHIP SECTION FOR 100' ALUMINUM COMBINATION FISHING VESSEL

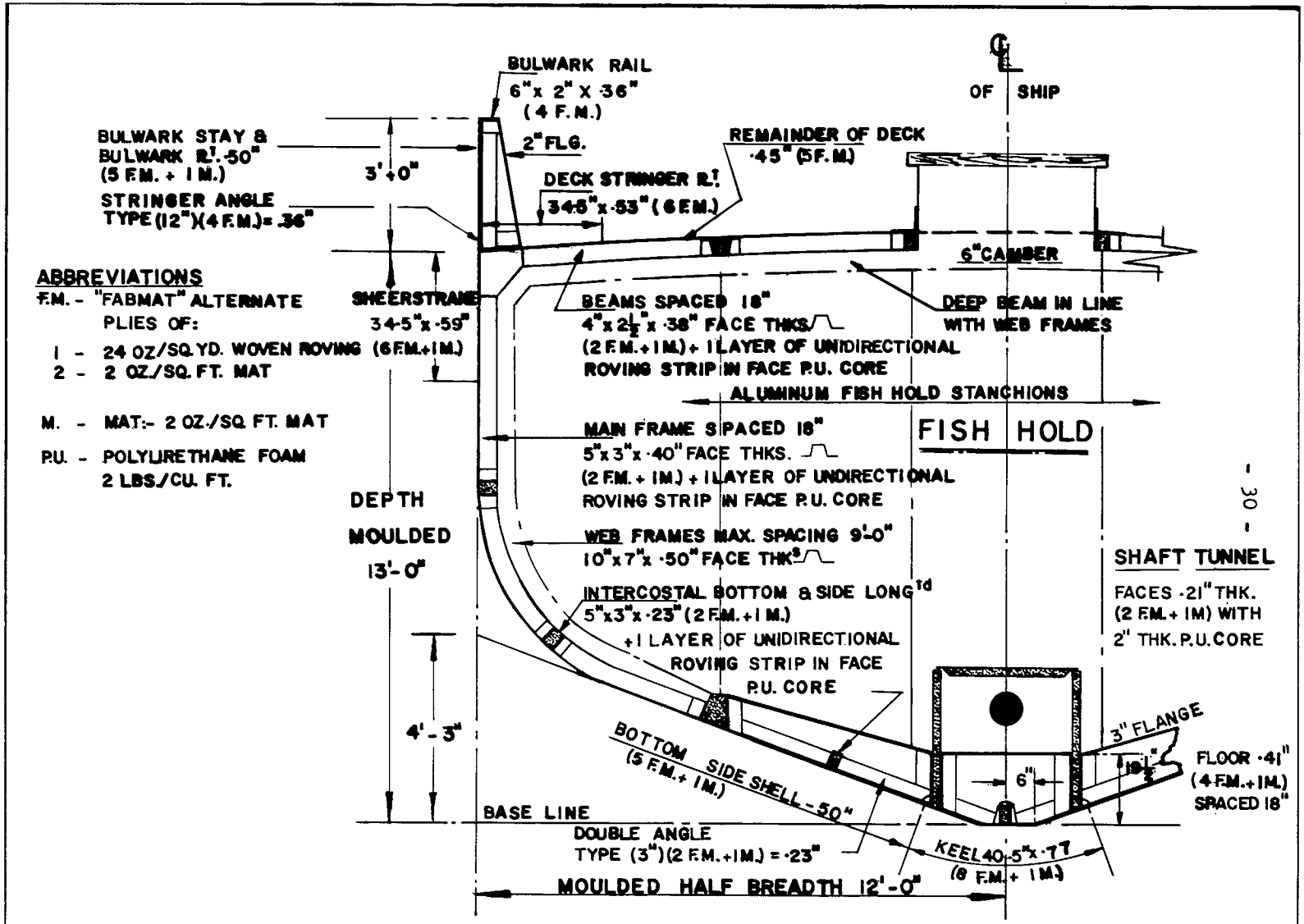


FIG. 3- MIDSHIP SECTION FOR 100' FIBERGLASS COMBINATION FISHING VESSEL

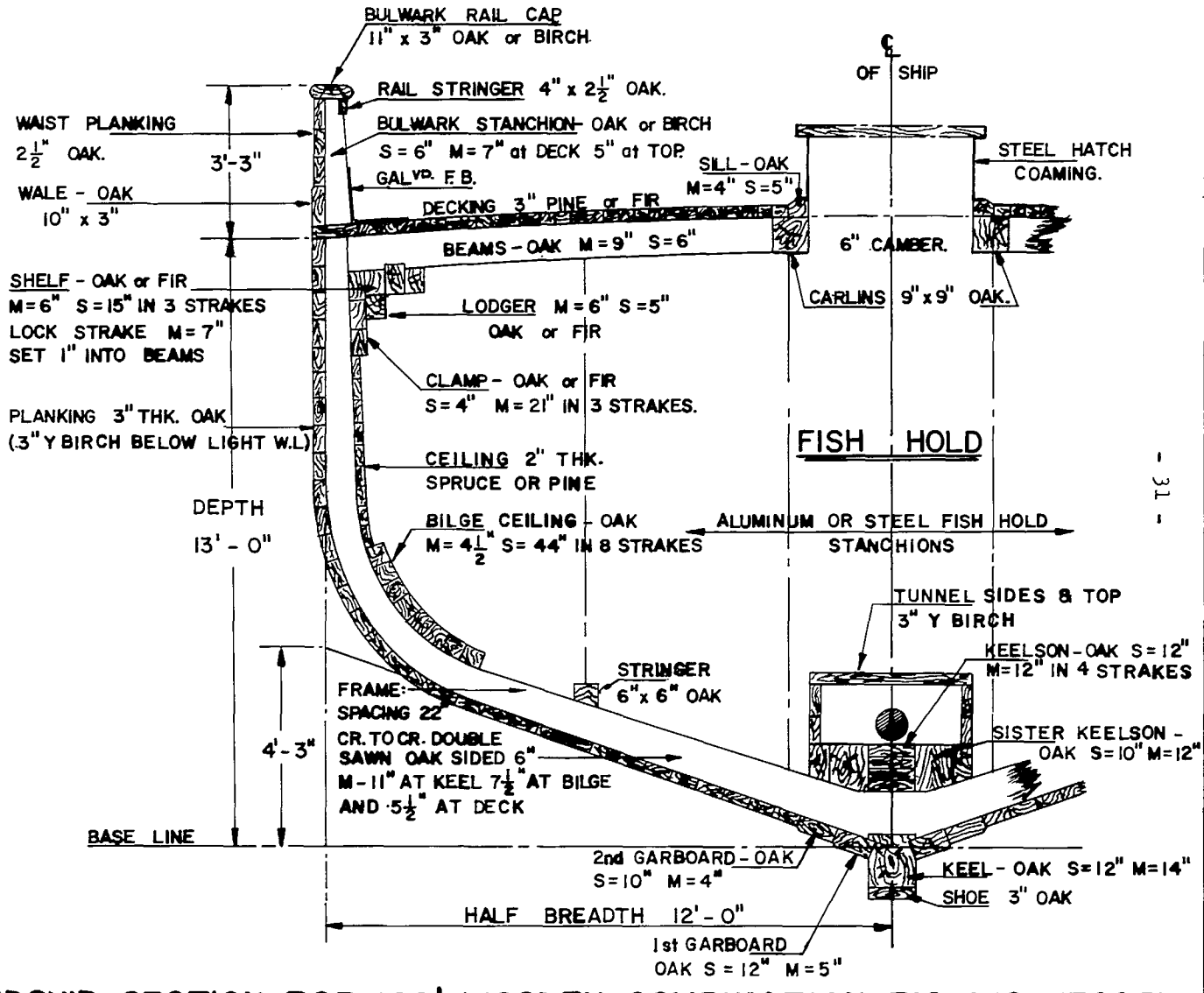


FIG. 4 - MIDSHIP SECTION FOR 100' WOODEN COMBINATION FISHING VESSEL

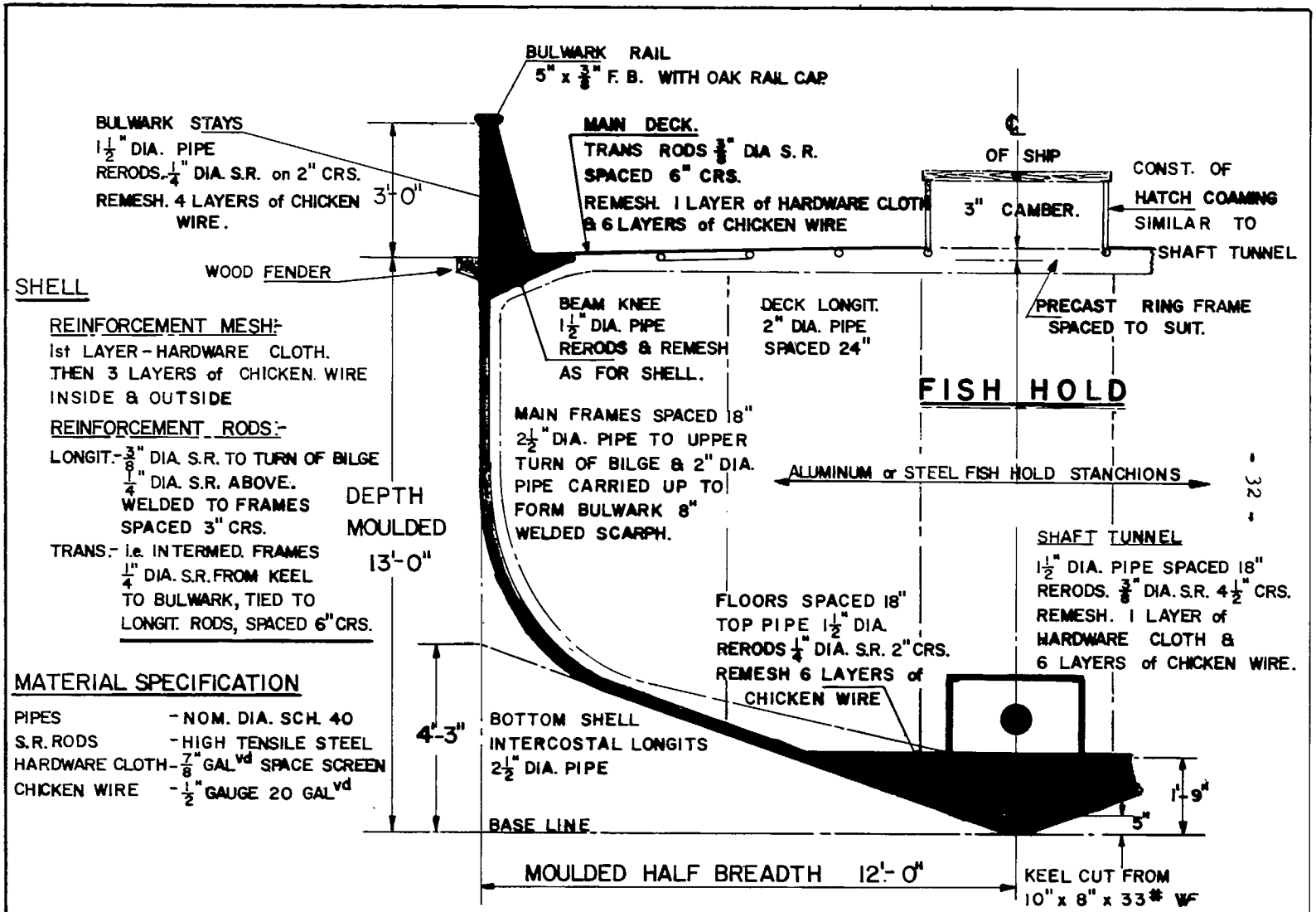
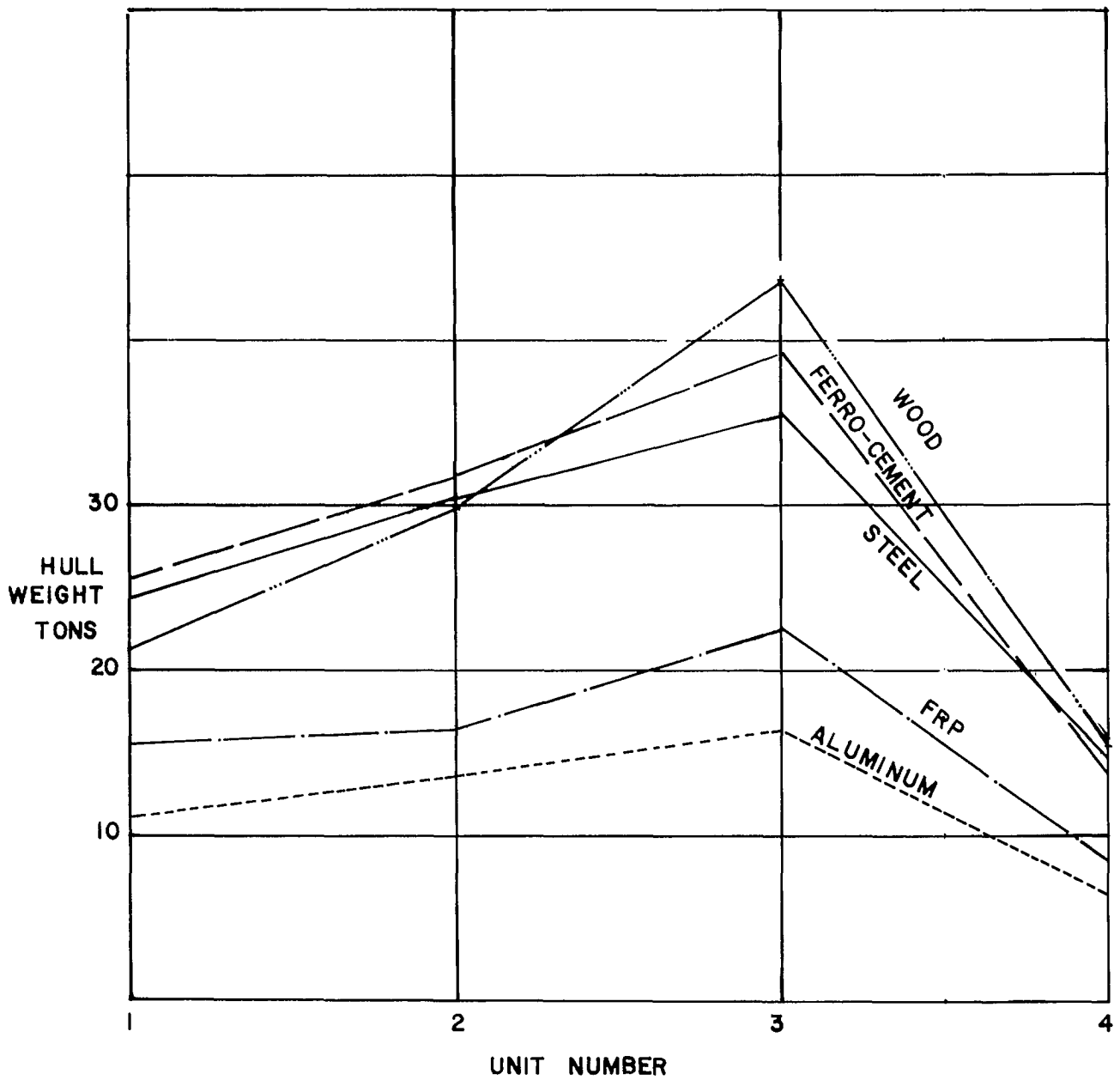
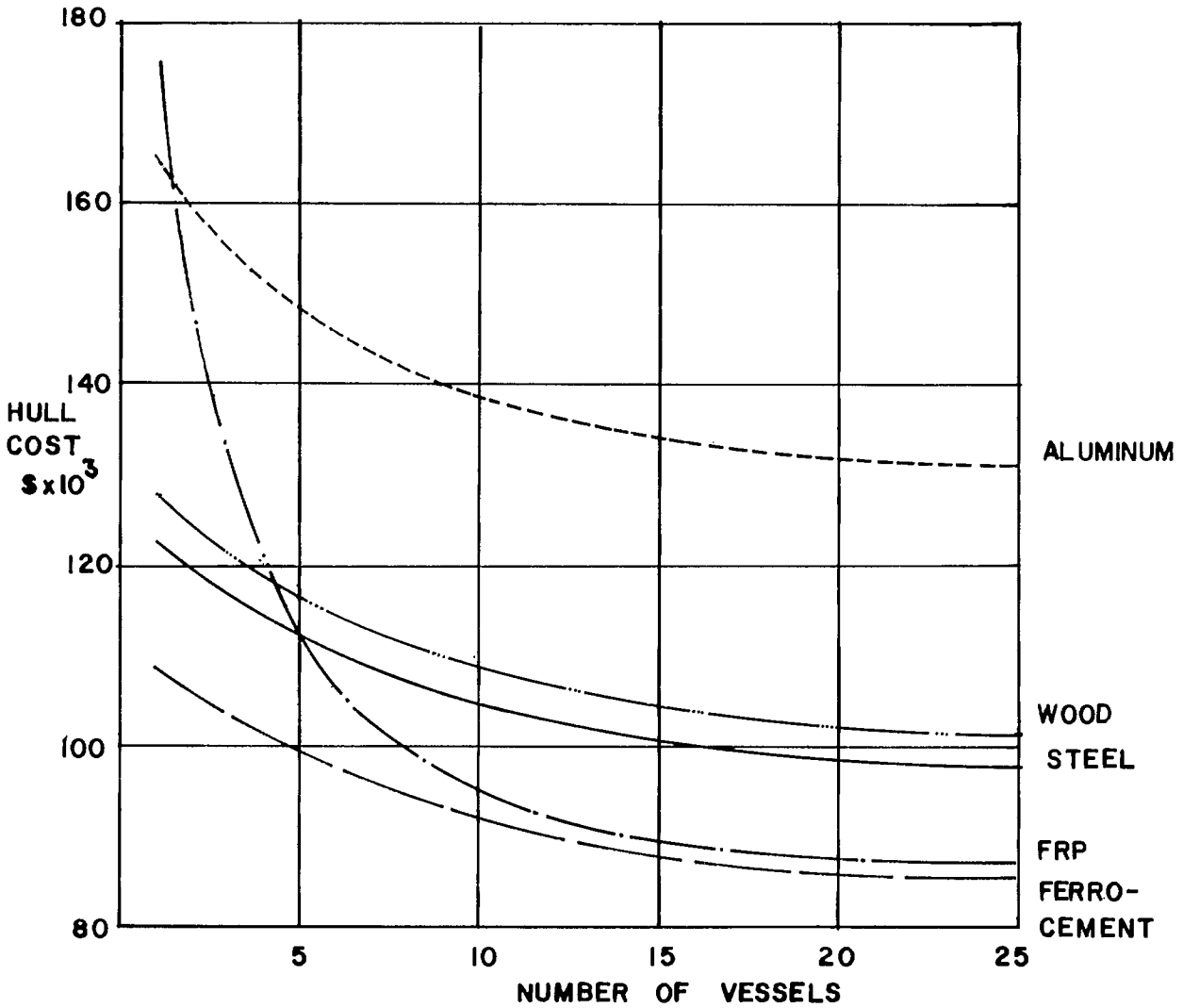


FIG. 5 - MIDSHIP SECTION FOR 100' FERRO-CEMENT COMBINATION FISHING VESSEL

UNIT WEIGHT DISTRIBUTION FIG 6

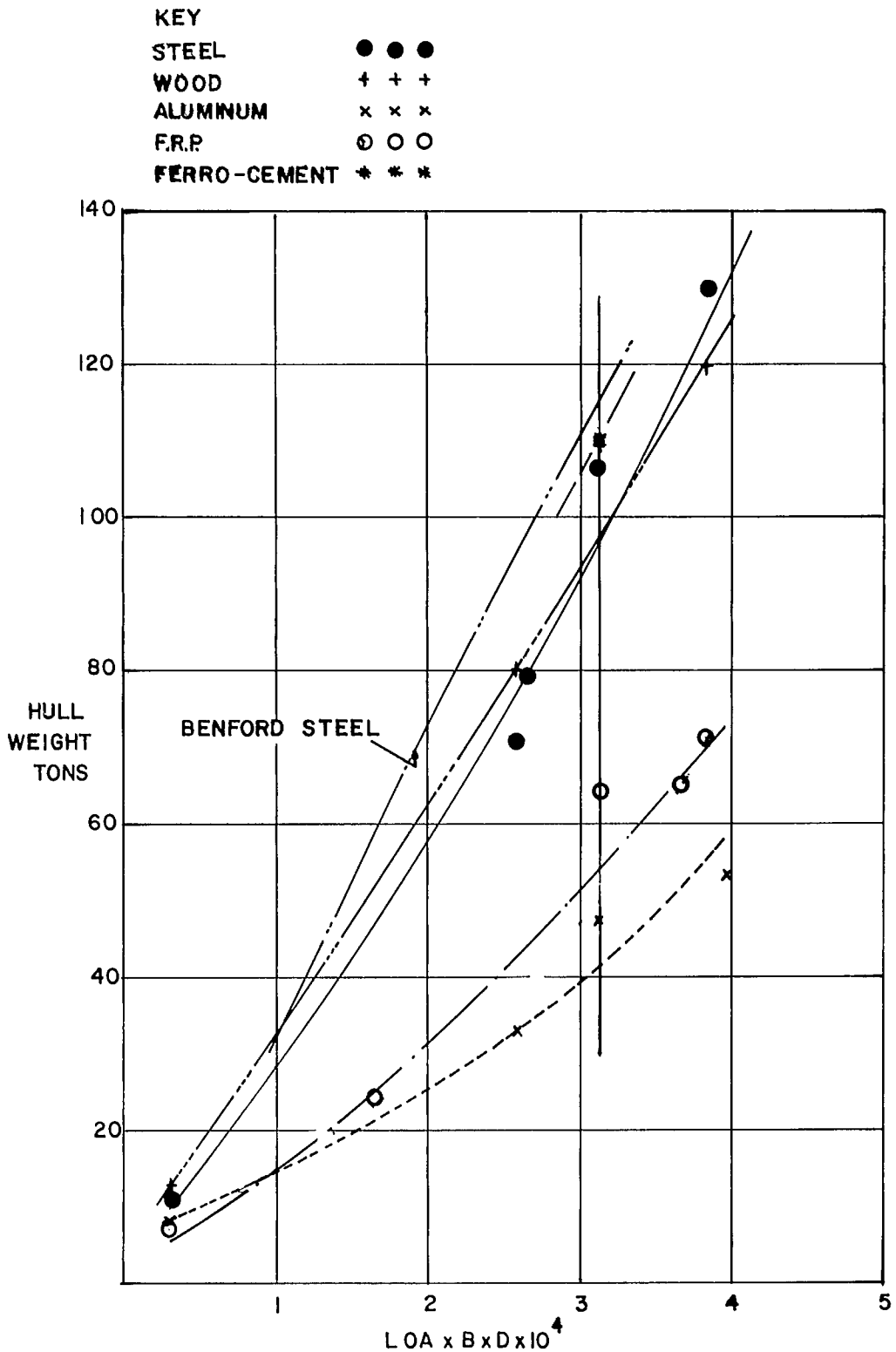


COST COMPARISON SERIES
PRODUCTION 100 FT LOA HULL FIG 7

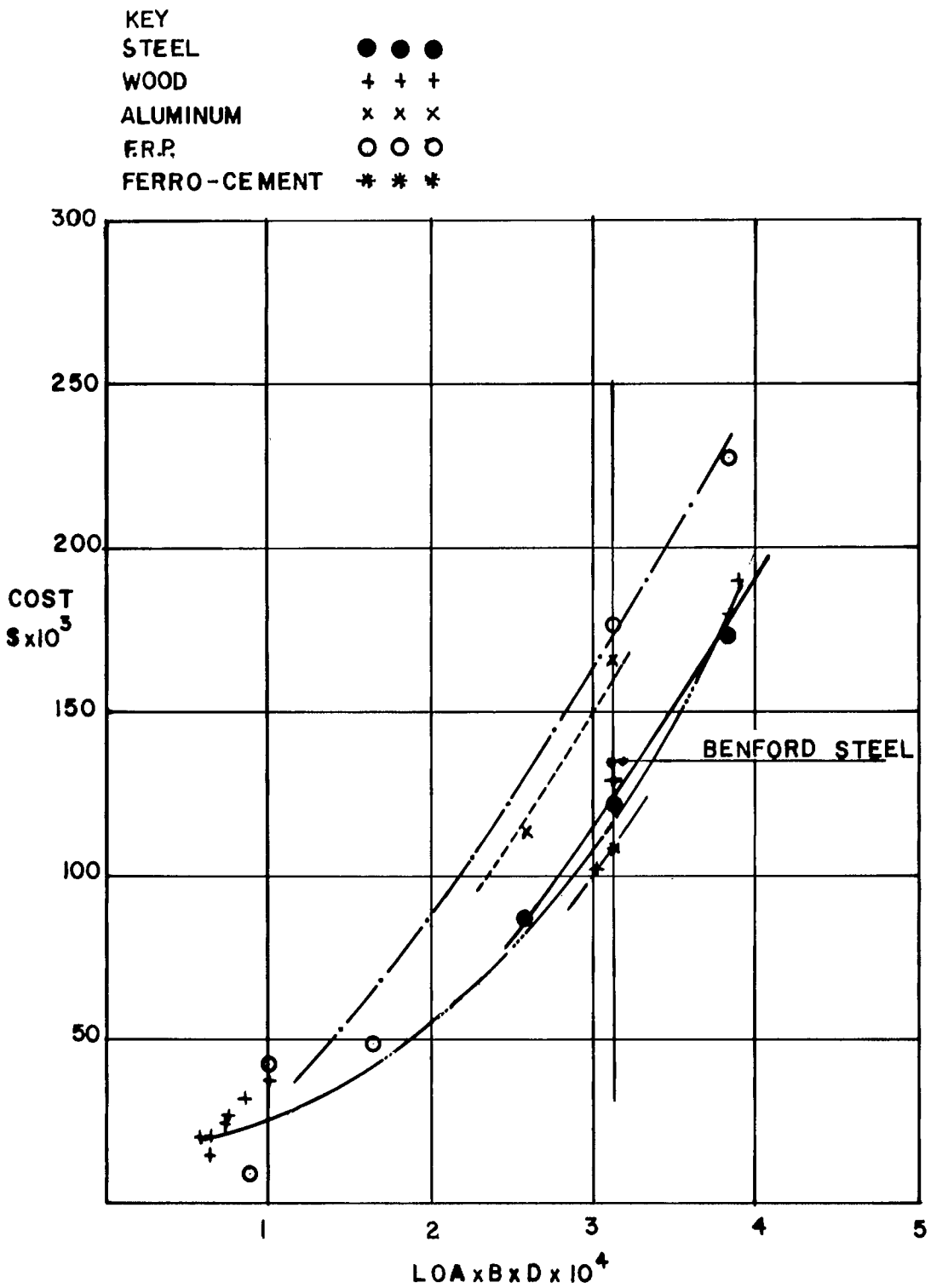


WEIGHT COMPARISON

FIG 8



COST COMPARISON FIG 9



Economic Criteria in Fish Boat Design



Prof. Benford

by

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ABSTRACT

This paper introduces fishing craft designers to practical economics. It explains some of the more useful economic measures of merit and discusses the suitability of each under various circumstances. Although particular reference is made to decision making in the selection of fish boat materials, the ideas expressed in the paper are actually applicable to all kinds of design decisions. A brief section explains also how these ideas may be applied to decisions in operating an existing vessel.

PREFACE

I am writing this paper in response to a request for a contribution pertaining to economic factors in selecting materials for fish boat construction. Being an authority on neither fish boats nor materials, I must confine myself to the general principles of economic analysis. Since these principles can, however, be applied to all sorts of decisions in fish boat design, I shall not confine myself to the question of material selection – important though that is.

Analyzing the economics of fish boats is a complicated matter. Authorities such as Chaplin, Haywood, Proskie, Doust, and Bogucki (1 – 5)* have presented carefully thought-out approaches to the problem, and there is no intent to duplicate their work here. I would point out, however, that the referenced studies tend to be sketchy in their treatment of economic measures of merit. My primary intent, then, is to supplement those references with this exposition on economics as a tool in fish boat design.

In closing this preface, I want to thank Mr. Walter Scott and Mr. John Proskie, both of the Department of Fisheries of Canada, for the willing advice and assistance they gave me during the preparation of this paper. Numerical values of interest factors are taken from Reference (15).

THE TIME-VALUE OF MONEY

A fish boat is an investment that earns its returns as an integral part of a system for finding, catching and selling fish. It involves someone (the investor) giving up the immediate pleasure of spending his spare cash, in hope of regaining it plus a profit in the years ahead. If we want to understand the economics of fish boats, then, we must understand how to weigh the relative merits of cash

*Numbers in parenthesis are reference numbers.

amounts that flow into or out of the organizational unit at different times. Cash flows in the far future are not as important as cash flows near at hand. We are not talking here about inflation or deflation. What we are talking about is the fact that normal human beings would just as soon have $100 to spend today as $110 a year from now, or $250 ten years from now.

We handle the time-value of money with the six standard interest formulas summarized in Tables 1,2, and 3. Table 1 defines the basic abbreviations.

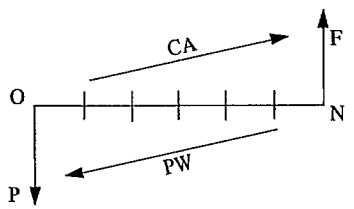
Table 1

Definitions and Symbols for Parameters

Definitions	Symbols
Effective interest rate per interest period	i
Number of compounding periods	N
Present sum of money, or present value (or a single investment)	P
Future sum of money	F
End-of-period cash flows (or equivalent end-of-period values) in a uniform series continuing for a specified number of periods. The letter A implies annual or annuity.	A

Table 2

Single Payment, Compound Amount Relationships



$F = (CA - i\% - N)P$

CA = compound amount factor (single payment)

$CA = (1 + i)^N$

$P = (PW - i\% - N)F$

PW = present worth factor (single payment)

$$PW = \frac{1}{(1 + i)^N}$$

$$CA = \frac{1}{PW}$$

Table 2 shows interest relationships for single-payment cash flows. These can be used to transpose any given cash flow from one point in time to any other. For example, the equation:

$$P = (PW - 8\% - 10)\ 0.463\ \$1000 = \$463$$

can be read: The present worth of $1000 10 years hence, assuming 8% interest, is equal to the present worth factor for 8% interest and 10 years (which has a numerical value of 0.463) times the future amount of $1000; which equals $463.

Table 3 shows values of the present worth factor for various interest rates and numbers of years. The compound amount factor CA, is the reciprocal of the present worth factor.

Table 4 shows the standard interest relationships for uniform series of cash flows. These can be used to convert a single cash flow, P or F, into a uniform annual amount, A, of equivalent desirability – as measured by some interest rate. For example, if you borrow $1000 and agree to pay it back in equal annual amounts over a 10-year period at 8% interest, you could find the annual amount to be paid back as follows:

$$A = (CR - 8\% - 10)\ 0.149\ \ \$1000 = \$149$$

Conversely, an expected cash flow of $149 per year for each of the next 10 years has a present value of $1000.

Table 5 shows values of the capital recovery factor for various interest rates and numbers of years. The series present worth factor, SPW, is the reciprocal of the capital recovery factor, CR.

The sinking fund factor, SF, and series compound amount factor, SCA, relate uniform annual amounts to future single amounts. The sinking fund factor can be found by subtracting the interest rate from the capital recovery factor found in Table 5. The series compound amount factor is the reciprocal of the sinking fund factor. By way of illustration, annual investments of $149 earning 8% interest for the next 10 years would accumulate:

$$F = (SCA - 8\% - 10)\frac{1}{0.069}\ \$149 = \$2160$$

The denominator, 0.069, is derived by subtracting the interest rate, 0.08, from the capital recovery factor, 0.149, read from Table 5.

Table 3

Present Worth Factors

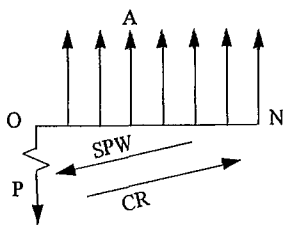
(Single Payment)

$$PW = \frac{1}{(1+i)^N}$$

N (Years)	i=1%	i=5%	i=8%	i=9%	i=10%	i=11%	i=12%	i=13%	i=15%	i=20%	i=25%
1	.9901	.9524	.9259	.9174	.9091	.9009	.8929	.8850	.8696	.8333	.8000
2	.9803	.9070	.8573	.8417	.8264	.8116	.7972	.8731	.7561	.6944	.6400
3	.9706	.8638	.7938	.7722	.7513	.7312	.7118	.6931	.6575	.5787	.5120
4	.9610	.8227	.7350	.7084	.6830	.6587	.6355	.6133	.5718	.4823	.4096
5	.9515	.7835	.6806	.6499	.6209	.5935	.5674	.5428	.4972	.4019	.3277
6	.9420	.7462	.6302	.5963	.5645	.5346	.5066	.4803	.4323	.3349	.2621
7	.9327	.7107	.5835	.5470	.5132	.4817	.4523	.4251	.3759	.2791	.2097
8	.9235	.6768	.5403	.5019	.4665	.4339	.4039	.3762	.3269	.2326	.1678
9	.9143	.6446	.5002	.4604	.4241	.3909	.3606	.3329	.2843	.1938	.1342
10	.9053	.6139	.4632	.4224	.3855	.3522	.3220	.2946	.2472	.1615	.1074
11	.8963	.5847	.4289	.3875	.3505	.3173	.2875	.2607	.2149	.1346	.0859
12	.8874	.5568	.3971	.3555	.3186	.2858	.2567	.2307	.1869	.1122	.0687
13	.8787	.5303	.3677	.3262	.2897	.2575	.2292	.2042	.1625	.0935	.0550
14	.8700	.5051	.3405	.2992	.2633	.2320	.2046	.1807	.1413	.0779	.0440
15	.8613	.4810	.3152	.2745	.2394	.2090	.1827	.1599	.1229	.0649	.0352
16	.8528	.4581	.2919	.2519	.2176	.1883	.1631	.1415	.1069	.0541	.0281
17	.8444	.4363	.2703	.2311	.1978	.1696	.1456	.1252	.0929	.0451	.0225
18	.8360	.4155	.2502	.2120	.1799	.1528	.1300	.1108	.0808	.0376	.0180
19	.8277	.3957	.2317	.1945	.1635	.1377	.1161	.0981	.0703	.0313	.0144
20	.8195	.3769	.2145	.1784	.1486	.1240	.1037	.0868	.0611	.0261	.0115
25	.7798	.2953	.1460	.1160	.0923	.0736	.0588	.0471	.0304	.0105	.0038
30	.7419	.2314	.0994	.0754	.0573	.0437	.0334	.0256	.0151	.0042	.0012
50	.6080	.0872	.0213	.0134	.0085	.0054	.0035	.0022	.0009	.0001	–

Table 4

Uniform Series, Compound Amount Relationships



$P = (SPW - i\% - N)A$

SPW = series present worth factor

$$SPW = \frac{(1+i)^N - 1}{i(1+i)^N}$$

$A = (CR - i\% - N)P$

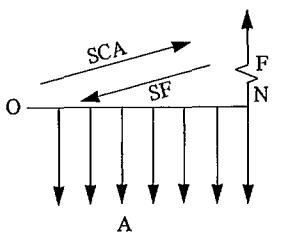
CR = capital recovery factor

$$CR = \frac{i(1+i)^N}{(1+i)^N - 1}$$

$$SPW = \frac{1}{CR}$$

Table 4 (Cont.)

Uniform Series, Compound Amount Relationships



$F = (SCA - i\% - N)A$

SCA = series compound amount factor

$$SCA = \frac{(1+i)^N - 1}{i}$$

$A = (SF - i\% - N)F$

SF = sinking fund factor

$$SF = \frac{i}{(1+i)^N - 1}$$

$$SCA = \frac{1}{SF}$$

Table 5

Capital Recovery Factors

$$CR = \frac{i(1 + i)^N}{(1 + i)^N - 1}$$

N (Years)	i = 1%	i = 5%	i = 8%	i = 9%	i = 10%	i = 11%	i = 12%	i = 13%	i = 15%	i = 20%	i = 25%
1	1.0100	1.0500	1.0800	1.0900	1.1000	1.1100	1.1200	1.1300	1.1500	1.2000	1.2500
2	.5076	.5376	.5606	.5685	.5760	.5839	.5917	.5994	.6150	.6545	.6944
3	.3401	.3671	.3880	.3951	.4021	.4092	.4164	.4236	.4380	.4747	.5123
4	.2564	.2820	.3019	.3086	.3155	.3223	.3292	.3362	.3503	.3863	.4234
5	.2062	.2309	.2505	.2571	.2638	.2706	.2774	.2843	.2983	.3344	.3719
6	.1724	.1970	.2163	.2229	.2296	.2364	.2432	.2501	.2642	.3007	.3388
7	.1486	.1728	.1921	.1987	.2054	.2122	.2191	.2261	.2403	.2774	.3163
8	.1307	.1547	.1740	.1807	.1874	.1943	.2013	.2084	.2228	.2606	.3004
9	.1167	.1407	.1601	.1668	.1736	.1806	.1877	.1949	.2096	.2481	.2888
10	.1056	.1295	.1490	.1558	.1627	.1698	.1770	.1843	.1993	.2385	.2801
11	.0964	.1204	.1401	.1469	.1540	.1611	.1684	.1758	.1911	.2311	.2735
12	.0888	.1128	.1327	.1396	.1468	.1540	.1614	.1690	.1845	.2253	.2684
13	.0824	.1065	.1265	.1336	.1408	.1481	.1557	.1634	.1791	.2206	.2646
14	.0769	.1010	.1213	.1284	.1357	.1432	.1509	.1587	.1747	.2169	.2615
15	.0721	.0963	.1168	.1241	.1315	.1391	.1468	.1547	.1710	.2139	.2591
16	.0679	.0923	.1130	.1203	.1278	.1355	.1434	.1514	.1680	.2114	.2572
17	.0643	.0887	.1096	.1171	.1247	.1325	.1404	.1486	.1654	.2094	.2558
18	.0610	.0855	.1067	.1142	.1219	.1298	.1379	.1462	.1632	.2078	.2546
19	.0580	.0827	.1041	.1117	.1195	.1276	.1358	.1441	.1613	.2065	.2537
20	.0554	.0802	.1018	.1095	.1175	.1256	.1339	.1424	.1598	.2054	.2529
25	.0454	.0710	.0937	.1018	.1102	.1187	.1275	.1364	.1547	.2021	.2510
30	.0387	.0651	.0888	.0973	.1061	.1150	.1241	.1334	.1523	.2008	.2503
50	.0255	.0548	.0817	.0912	.1009	.1106	.1204	.1303	.1501	.2000	–

Finally, to round out these examples, find the present worth of the future amount ($2160) found above:

P = (PW - 8% - 10) 0.463 $2160 = $1000

Note that the $1000 found here is exactly equal to the amount of the loan that requires annual installments of $149, which were then shown to be equivalent to $2160 10 years hence.

TAXES

There are circumstances where analyses of before-tax returns will lead to the same technical decisions as those indicated on the after-tax basis. This is not always the case, however, so we need to understand the impact of the income tax on after-tax returns. The principal complication here is that Canadian tax laws allow considerable flexibility in assigning depreciation credits. Proskie (6) explains the alternatives, and I shall not repeat his work here. I merely point out that, whereas predicted before-tax returns may be uniform, after-tax returns frequently will not.

Figure 1 shows the distribution of gross revenue from a typical year of operating a corporate-owned fishing vessel. The main thing worth noting is that the measures of merit (that we discuss later) are nearly all based on after-tax returns. A′; net profit is less meaningful and can be ignored. Thus we find that depreciation is recognized only as a step in computing the tax and is thereupon forgotten.

We won't say much else about the Canadian tax structure except to note that the current corporate income tax rate, t, is 21% on the first $35,000 of taxable income, and 50% on taxable income in excess of that (7). In figuring taxable income, two depreciation methods are allowed: either straight-line or declining balance (6). In the latter case, the maximum allowable factor is 15%, and it may be reduced at the owner's option in years when its maximum value would lead to a negative taxable income.

Figure 1 shows the following relationship between before-tax and after-tax returns:

$$A' = A(1 - t) + tD + t\,I_b \qquad (1)$$

Let us assume that the before-tax returns, A, are uniform, that the period of the bank loan equals the depreciable life, and that straight-line depreciation is

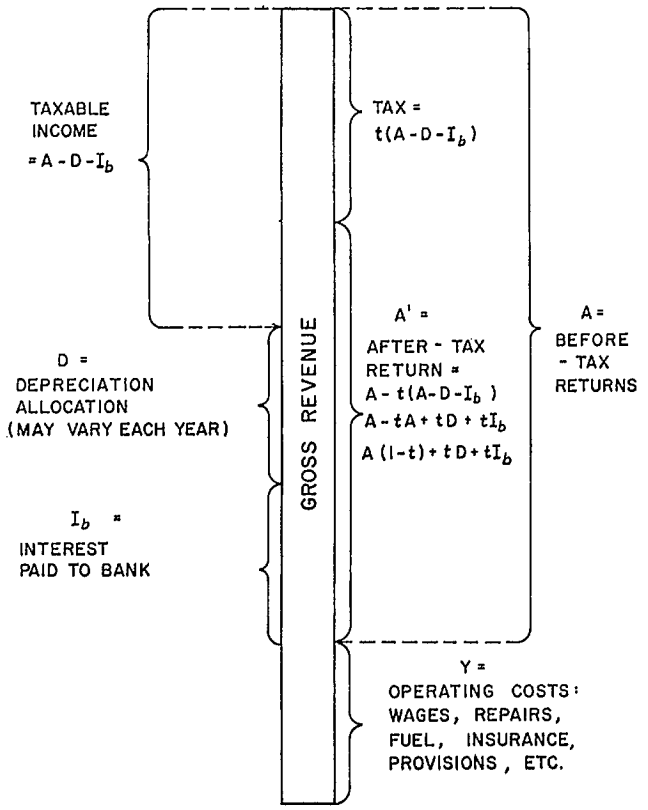


FIGURE 1: DISTRIBUTION OF GROSS REVENUE

applied. If we then divide both sides of the equation by the initial investment, P, we find the relationship between the capital recovery factors before (CR) and after tax (CR′):

$$CR' = CR(1-t) + \frac{tD}{P} + \frac{tI_b}{P} \qquad (2)$$

Equation (2) and Table 5 are used to convert from after-tax interest rates (i′) to before-tax rates(i).

The annual interest payment, I_b, on a bank loan can be approximated as follows:

$$I_b = (CR - i_b - H)P_b - \frac{P_b}{H}$$

or

$$I_b = P_b\left[(CR - i_b - H) - \frac{1}{H}\right]$$

where P_b = Initial amount borrowed from bank
i_b = Interest rate on bank loan
H = Period of the bank loan, years.

MEASURES OF MERIT

Selecting a method for comparing the economic merits of alternative design will hinge on whether those alternatives promise equal income-producing capabilities. The rest of this chapter, then will be divided into three sections: one on measure of merit for boats of equal capability, and one dealing with related miscellaneous topics.

Boats of Equal Capability

When studying the merits of competing technologies (such as different hull materials), we should normally compare the relative economics of proposed boats of equal functional capability. Let me be specific. Suppose we want to introduce some new hull material whose chief advantage is lightness in weight. We may then succumb to the temptation of designing a challenger boat that will be just like the defender except that its hull is aluminum instead of steel. Even if this were technically feasible, our economic comparison might not be altogether convincing Why not? Because our line of reasoning would presumably be to the effect that lighter hulls mean bigger payloads, which mean bigger incomes, etc. The flaw here is that there is no straight correlation between increased capacity and increased annual income. Fish-catching rates fluctuate and there would be many voyages when the two boats would return with identical catches.

Of course, we could recognize the complications just mentioned and resort to Monte Carlo techniques (1) or other complicated solutions. These would not, however, offer unarguable evidence of the merits of the proposed new material *per se*. A more convincing case can be built around a redesigned challenger whose functional capabilities are exactly equal to those of the defender. Relative income then disappears as a worrisome factor. The task is strictly technical in nature. It involves several cycles of design, which lead to a challenger that can exactly match the defender's income-producing capabilities – notably in speed and fish storage capacity. While this may be a lot of work (unless you have access to a computer and suitable program), it is an altogether more satisfactory technique for analyzing comparative technologies. It generates a more defendable outcome because the technical parameters that produce the differences are less open to debate than are the economic parameters that govern in situations where functional capabilities differ.

When comparing competing proposals for boats of like income-producing capabilities, we can ignore income and

concentrate our analysis on the life-cycle costs of the systems. In this, we must recognize invested costs as well as operating costs, and we also must recognize taxes and the time-value of money. Two widely accepted (and practically equivalent) economic criteria are used for this purpose: average annual cost, AAC, and present value, PV. If we assume uniform annual costs of operation, Y, then finding the average annual cost simply involves adding those costs to the annual cost of capital recovery:

$$AAC = Y + (CR)P$$

where P = initial investment
and CR = capital recovery factor based on expected life of the boat, owner's stipulated yield, and tax.

In calculating annual operating costs, we specifically exclude depreciation allocations and any interest paid to a bank; both are recognized, however, in arriving at the capital recovery factor (as explained in the section on taxes). Establishing a suitable yield, i', is an important first step and one that deserves elaboration. It involves some matters of opinion and its value has a strong bearing on the final outcome. Reference (8) discusses the question of reasonable levels of yield. This requires business judgement and would normally be set by management. Considering the risks of the fishing industry, I should judge that the stipulated level would normally fall between 12% and 20%, the latter figure being appropriate to countries where investment capital is relatively scarce.

The present value criterion, as its name implies, is found by taking the present value of all projected costs discounted to the present. To simplify our work, we may define "the present" as the time of delivery of the ship. Thus, the initial investment, P, occurs at time zero and is used without discounting. All other costs are discounted, however, in a degree commensurate with their time of occurrence and with some appropriate interest rate. If we again assume uniform annual costs, we would have this expression for present value, PV:

$$PV = P + (SPW)Y$$

where Y = uniform annual costs of operation
and SPW = series present worth factor.

As before, the operating costs are exclusive of any allocations for depreciation or interest. The series present worth factor is simply the reciprocal of the capital recovery factor, the derivation of which has already been explained. Again, the numerical value of these factors must recognize the owner's need for reasonable profits after tax.

Boats of Unequal Capability

The preceding section deals with cost studies in which competing designs promise equal incomes. There will be cases, however, where we must recognize differences in annual income. We then consider each proposed boat as an investment and aim our study at finding the one that promises the highest yield. By "yield", we refer to the profitability of the operation, expressed as an equivalent rate of interest. This is a widely-used concept, which goes under many other names, such as discounted cash flow rate of return, DCF; profitability index PI; and equated interest rate of return, EiRR. In those cases where after-tax returns are uniform (as they may be with straight-line depreciation), finding yield is very simple in principle – if we are also willing to assume that the entire investment is made in a lump sum upon delivery of the boat. First we divide the after-tax returns, A', by the initial investment, P. This gives us the venture's after-tax capital recovery factor, CR':

$$CR' = \frac{A'}{P}$$

We then go to Table 5 and find the yield, i', that corresponds to the derived value of CR' and number of years, N. If, in addition, all alternatives have equal lives, we can skip the last step; the alternative with the highest CR' will automatically have the highest i'. Indeed, to make the task even simpler, we need only find the capital recovery factor *before* tax, CR:

$$CR = \frac{A}{P}$$

in which A = annual return before tax. This shortcut is valid under our assumptions of equal lives and uniform after-tax returns. The alternative promising highest CR then also promises highest CR', which in turn promises highest i'.

There will, of course, be many cases where after-tax returns are *not* uniform. Finding yield then requires trial and error to determine that interest rate that will bring the present value of all cash flows (including the investment) to zero. Figure 2 and Table 6 (columns 1 and 2) show an imaginary cash flow forecast for a proposed fish boat. The investment is spread over two years and the annual after-tax returns vary because of such factors as declining-balance depreciation, non-uniform trends in revenue or operating costs, occasional major rehabilitation costs, and income from disposal after 15 years of operation. Let us assume that we want to find the resulting yield for comparison with other proposed designs. As shown in Table 6, columns 4 and 5, we first guess at an interest rate (in this case 10%) and use Table 3 to find the corresponding present worth

factors for entry into column 4. The individual present values in column 5 (which equal column 2 times column 4) add up to a positive net amount. This indicates that the initially guessed-at interest rate of 10% was too low. So we next try a higher figure: 12% (columns 6 and 7). The net present value is still positive, so we try yet higher: 13% (columns 8 and 9). Now the net present value is negative, so we know that the yield must fall between 12% and 13%. The interpolated value is 12.1%. We are now ready to repeat the process with the next alternative design, seeking that which promises the highest yield.

The dashed line in Figure 2 shows the cumulative cash flow. Its intersection with the baseline indicates the payback period, or time required to regain the investment. Payback period is a crude measure of merit at best, but it deserves consideration when future conditions are particularly unsettled.

Another popular economic criterion is the net present value, NPV. If you will refer back to Table 6, you will notice that we found the net present value of the projected cash flow for each of three arbitrary interest rates. In normal use, NPV involves the use of an assigned interest

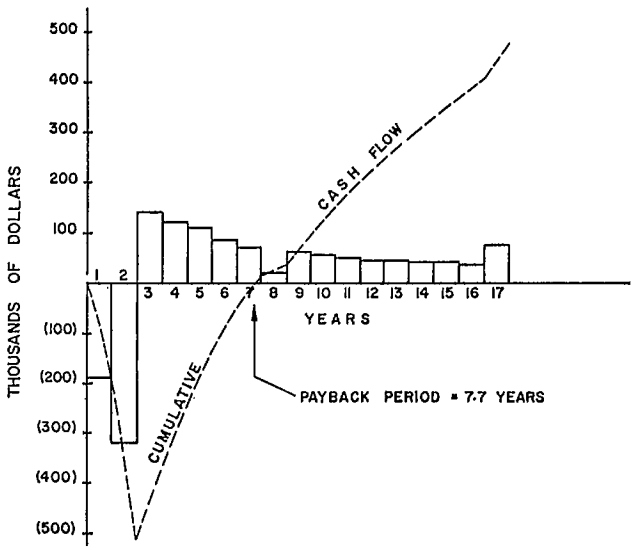


FIGURE 2: CASH FLOW DIAGRAM

Table 6

Cash Flow Summary for a Proposed Fishing Vessel

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
			$i' = 10\%$		$i' = 12\%$		$i' = 13\%$	
Year	Cash Flow	Cumulative Cash Flow	(PW-i'-N)	Present Value	(PW-i'-N)	Present Value	(PW-i'-N)	Present Value
	$	$		$		$		$
1	(190,000)	(190,000)	0.909	(172,710)	0.893	(169,670)	0.885	(168,150)
2	(320,000)	(510,000)	.826	(264,320)	.797	(255,040)	.783	(250,560)
3	140,000	(370,000)	.751	105,140	.712	99,680	.693	97,020
4	120,000	(250,000)	.683	81,960	.635	76,200	.613	73,560
5	110,000	(140,000)	.621	68,310	.567	62,370	.543	59,730
6	85,000	(55,000)	.564	47,940	.507	40,560	.480	40,800
7	70,000	15,000	.513	35,910	.452	31,640	.425	29,750
8	20,000	35,000	.467	9,340	.404	8,080	.376	7,520
9	60,000	95,000	.424	25,440	.361	21,660	.333	19,980
10	55,000	150,000	.385	21,175	.322	17,710	.295	16,225
11	50,000	200,000	.351	17,550	.287	14,350	.261	13,050
12	45,000	245,000	.319	14,355	.257	11,565	.231	10,395
13	45,000	290,000	.290	13,050	.229	10,305	.204	9,180
14	40,000	330,000	.263	10,520	.205	8,200	.181	7,240
15	40,000	370,000	.239	9,560	.183	7,320	.160	6,400
16	35,000	405,000	.218	7,630	.163	5,705	.142	4,970
17	75,000	480,000	.198	14,850	.146	10,950	.125	9,375
Net Present Value				45,700		1,585		(13,515)

Note: Parentheses indicate cash outflows.

rate that represents management's opinion of what constitutes a minimum acceptable level of profitability. This is often called the cut-off rate. Its value is somewhat arbitrary. As a minimum, it will be at least as high as the organization's cost of capital. Some managers will set it perhaps 2% higher. Cost of capital is simply the weighted average of interest paid for debt capital (bank loans) and equity capital (from sale of stock). Typical figures for the cut-off rate in Canada and the United States range from 8% to 11%.

Solving for NPV is not difficult. If the assigned cut-off rate is 10%, for example, we need only go through the routine shown in columns 1, 2, 4 and 5 in Table 6. If the after-tax returns, A′, are uniform, and if we assume a single investment, the calculation is even simpler:

$$NPV = (SCA)\, A' - P$$

where SCA = series compound amount factor.

Despite its superficial similarity to the present value criterion, the net present value is altogether different in concept. In place of a target rate, NPV uses a minimum acceptable interest rate. Moreover, NPV involves future returns rather than future cost, and subtracts rather than adds invested costs. Finally, we try to maximize NPV but minimize PV.

Unfortunately, NPV and yield frequently lead to conflicting conclusions. This is because NPV has a bias toward bigger investments. If the owner has more investment opportunities than he has investment dollars, he should probably use yield as his criterion. If he has excess investment dollars, NPV would make more sense.

A variant on NPV is the net present value index, or net present value per dollar invested:

$$NPVI = \frac{NPV}{P}$$

The net present value index removes the NPV's bias toward large investments.

References (8 – 16) may be consulted for further elaboration on the controversial issue of yield vs net present value in weighing alternative investment decisions. References (9, 12, and 16) are particularly directed toward that particular topic. Be warned, however, that every authority has a somewhat different opinion.

Miscellaneous Considerations

There are several important comments that apply to any of the aforementioned methods of economic analysis:

1. A most important calculation is that of the initial cost. You will, however, find surprisingly little help in the literature. References (17 and 18) are of some benefit, but leave many questions unanswered. If we are to make meaningful progress in systems analysis, we must persuade cost estimators to publish the contents of their little black books. We must also carry out research in new ways to estimate costs.
2. Working capital is the money that a boat owner has tied up in his operations but which he will regain when the business is closed down. In most design studies, this kind of capital can be ignored.
3. Economic studies compare alternatives. In comparisons, the differences are what count. Cost factors that are the same for all alternatives can be overlooked. Said in another way, cost studies should examine only those cash flows that will result from the decision under question.
4. Economic studies are based almost entirely on estimated future costs and incomes. Accuracy is impossible. Do not waste your time with more than three or four significant figures.
5. Most optimization studies produce curves of a measure of merit plotted against some technical parameter such as speed or capacity. An almost universal attribute of such curves is their flatness in way of the optimal point ("flat laxity"). Because every real life situation involves intangible considerations, you should consider a fairly wide range of the technical parameter as being just as acceptable as that indicated by the exact point of optimality.
6. All cost studies are based on estimates or guesses of future conditions: costs, incomes, tax rates, operating life, etc. In all of the examples cited in this paper, we have used single, most likely values of each input. In more sophisticated studies, risk and uncertainty should be recognized. This subject, as it applies to fishing craft, is worthy of a complete conference in itself. Reference (1) shows one approach; further studies deserve support.
7. We have specifically ignored the division of after-tax returns between owner and bank (where bank loans

are involved). The reasoning behind this simplification is explained in Reference (9).

OPERATIONS

To this point we have specifically directed our attention to fish boats that are still in the design stage. Once the boat is built, our principles of economic decision making are still much the same. The big difference is that the invested cost is no longer a variable. Simply stated, we then try to maximize our yield by maximizing the annual after-tax return.

If you are considering adding a new item of equipment to an existing boat, you no longer ask whether its yield is greater or less than that of the boat (based on its initial cost). The boat's initial cost is past history and any decision about the new equipment can in no way change it. You need only look at the first cost of the equipment and the resulting increase in after-tax returns. Then compare the resulting yield with alternative investment opportunities of equal risk.

In questions of when to retire an older boat, the initial cost is again inconsequential. Nor is the book value significant, except as it may affect your tax liability (6). As a boat gets increasingly decrepit, the owner should periodically consider selling it. He then estimates whether the discounted gains of keeping the boat for one more year would more than offset the foregone opportunity of an immediate sale. The net present value approach might be appropriate. The gains implicit in keeping the boat for one more year would include the year's after-tax returns and the predicted resale value 12 months hence. It might also include "inferiority": a subtracted amount based on the predicted increase in returns attainable by a more modern boat.

At this point I cannot resist pointing out that the most economical life for fishing craft shortens as technological progress accelerates the impact of inferiority. One way shipyards can increase business is to promote inferiority in existing vessels. This, of course, can best be done through encouraging maritime education and research. And nothing is more encouraging than cash. What better way to close this opus?

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Presentations and Symposium on Various Materials

Introduction by Prof. Harry Benford

Professor Benford: "I will have to start out by confessing that I am not sure if my role is that of peacemaker or rabble rouser. I think that our general aim in having this round table will not be to reach any final conclusions except in a very general sort of way. Don't feel that you are going to see a knock-down, drag-out battle and then a champion announced at the end.

"I would like to point out one important factor that has been overlooked, I beleive, and that is the historical and classical literature background of this controversy; it actually dates back to the story of the three little pigs in which it was conclusively proved that wood is a better material than straw, and bricks are even better than wood. Now in case the Canadian Association of Brick Builders is about to conclude that I am on their side let me point out that the Big Bad Wolf was boiled in an iron kettle that was heated over a wood fire.

"There are three or four rules that I would like to tell you about for your presentations. Keep it short. I don't want any obvious sales pitches, no references to one another's ancestry, and no physical attacks.

"I would like to make an initial presentation on this myself, and that is that there are many many factors, obviously, that are going to influence our decision on choice of material. I would like to advance the hypothesis that there is room for all here, that there are different combinations of circumstances that are going to dictate the use of other materials. Also, and I think Mr. Traung pointed this out, there are many cases where we can use several materials in one boat. I believe that yesterday someone showed a midship section of a plastic boat's steel keel, with concrete filler. I think that was a pretty good ecumenical approach.

"I have made what is perhaps an arbitrary breakdown of the pertinent factors that would influence the decision in the choice of material, but I put it up to you as something to inspire a little thought and stimulate some discussion on the part of the panel. There are the physical properties, the things that perhaps you can't argue about too much; the strength to weight ratio, whether the thing is durable, whether it is easily maintained, whether it is easily fabricated into shipshape form, ease of joining. Then there are insulation properties. Mr. Traung makes a very important point about not only a heat insulation but also sound insulation in his paper.

"Uniformity, that is if the physical properties fall within a narrow band or is there a wide spread in them?

"Dimensional stability, does it swell up when it gets wet? There are the production circumstances—the availability of skilled labour to work in this kind of material, the labour rates and productivity. I can see that if you have highly paid labour that is not very productive it is going to influence your choice of material. The size and complexity of the boat is going to influence it. The production run, whether you are building one or many, is something pointed out by various authors. Then there is the capital for facilities – do you have the money to go into the steel fabricating business

or don't you? Weather protection is a factor; some materials have to be dealt with under a roof, while others don't. The availability of the material, and the delivered cost are very, very important. Then we have certain operating circumstances. Geographic factors, that is whether you have got to run into ice, or torredo worms or whatever, fresh water or salt water; it's all going to make a difference. If you have to pay a lot of money to borrow money then you are going to be more interested in saving money in the future. Then there are the intangibles. First of all, they are probably as important as everything else here put together. I will have to admit when I saw the slides of that wooden boat yesterday I was all ready to go for wood, just because it looked so beautiful. The availability of cost and technical data – now there is something that is probably holding back the development of ferro-cement right now–it's too new and we don't know enough about it, so people are hesitant to use it. And then finally, another intangible, the general appearance.

"I will ask each of you on this panel to come up and make a brief formal presentation and then later I will ask you to give me your opinion on where you think your material is best suited for what combination of circumstances, and also, let's be frank. We have been giving nothing but the pros, let's be frank and give the cons as well."

Steel Fishing Vessels



Mr. Elder

by

Robert McArthur,
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(Paper presented by James R. Elder, Naval Architect,
Saint John Shipbuilding and Drydock Co., Ltd.,
Mr. McArthur having been unable to attend the
Conference because of business commitments.)

Mr. McArthur is a native of Scotland, where he has worked in various shipyards. During World War II he served with the Royal Engineers, and came to Canada in 1951. At present he is the Assistant General Manager of the Saint John Shipbuilding and Drydock Co., Ltd., Saint John, N.B. For the past seven or eight years he has been closely associated with trawler design and development.

Mr. Elder received his education in naval architecture at what is now Sthrathclyde University, Glasgow, Scotland. He started his shipbuilding career with the Fairfield Shipbuilding and Engineering Company and while with that company was transferred to the staff of the British Ship Research Association, London, England. He has worked with Charles Connell and Co., Ltd., Glasgow, and the Sun Shipbuilding and Drydock Co., Ltd., Chester, Penn. He is a chartered engineer and an Associate Member of the Royal Institution of Naval Architects, and a member of the Society of Naval Architects and Marine Engineers. He is now a naval architect with the same company as that of Mr. McArthur.

ABSTRACT

The author outlines the versatility of steel as a construction material describing several aspects of its use as they apply to hull design, construction and maintenance.

It is emphasized that the steel shipbuilder has at his disposal, considerable amount of valuable information obtained from actual sea-going experience. Also, by virtue of this experience, good use could be made of further technological improvements as they become available to the industry.

In conclusion, the paper summarizes some of the main characteristics of steel as a construction material.

STEEL FISHING VESSELS

During the earlier sessions of this Conference, the various materials, together with their associated construction techniques, have been described and discussed in considerable detail, and in making this final assessment, it is intended to examine some of the more general aspects related to the use of steel as a high-quality, versatile, uniform, and inexpensive medium for fishing vessel construction, with a particular thought for the future.

DESIGN

The fast-changing trend of recent years has been towards larger and more powerful vessels and, apart from replacement of present fleets of the inshore fisheries, the greatest potential for expansion appears to be offshore – perhaps further offshore than many now consider practical.

While fishing vessels become more complicated and the costs of machinery, gear, and electronics assume major proportions of the total cost, the hull cost remains a considerable factor, and the hull design is correspondingly important.

Economic hull design requires careful choice of scantlings for the main strength members and special consideration of local strength at points of unusual stress. This can only be undertaken successfully if we are dealing with a material of uniform quality and known physical properties. If we are not sure of the material's capability, then we must increase these members till the potentially weakest piece of material will do the job, thus increasing the weight and cost of the material and contributing nothing to the performance of the hull.

The techniques of making steel of uniform quality and connecting the pieces to form the complete hull with good quality assurance, may seem simple today but they have not been achieved without many failures of varying degrees over the years.

The records of the world's Classification Societies show that, in many cases, the general strength of the material and structure were sound but the defects occurred due to improper understanding or treatment of local strength requirements.

No program of development can be carried on successfully on the basis of theory without corresponding practical results to prove the rules and it would therefore appear that the designers of vessels in some of the newer materials, at least in the immediate future, may be at a disadvantage in having to develop vessels in the larger categories of their anticipated size range without sufficient practical results from actual service at sea.

CONSTRUCTION

The cost of constructing the hull is a major factor in the total cost of any vessel. Custom-built ships are expensive in any material but the benefits to be gained from multiple hulls are considerable and multiple hulls appear to be mandatory when using some materials.

Steel offers significant savings on standard hull forms placed in one shipyard for multiple construction.

Steel fishing vessels delivered in Canada during 1967, according to published figures, totalled some 40 vessels with an aggregate tonnage of about 23,000 tons. Of this group, 29 vessels were trawlers designed principally for ground fishing. In this group, we find vessels of eleven different lengths, all designed to fish the same grounds, the owners of each size group having gone through a difficult and expensive period of design development to arrive at the final design which they hoped would produce a vessel just a little more competitive than their rivals.

When we consider the variables which contribute to a fishing vessel's productivity—such as the skipper's knowledge of the fishing grounds, his ability to handle the gear, his crew, and his ship, the quality and design of the fishing gear, the manoeuvrability and sea-kindliness of the ship, luck, weather, and various other conditions – why, then, is it so important to have a vessel which is 1 ft., 5 ft. or 10 ft. longer than the other? Canadian shipyards have contributed their share in the last few years in bearing the high cost of this type of development.

The various comparisons in construction costs which have been made in support of newer materials under discussion, have been made on a basis of present steel construction costs and, it would seem, have been made without bias in respect to the steel costs quoted except in the area of installation costs of machinery and deck gear. However, they have been made on the basis of present practice in steel construction.

The various demonstrations of what has been done and what can be done in the newer materials are filled with the enthusiasm of new ventures, but in thinking of the future, we must also recognize that steel shipbuilding everywhere is presently undergoing a bit of a revolution which invokes radical change in the concepts of a few years ago and indicates some completely new approaches to this complicated industry.

Steel shipbuilders, with their basic material versatile in capacity, stable in quality, and proved in service, are in an excellent position to take full advantage of the benefits to be derived from the use of the computer and the tremendous advantages which can be achieved through automation.

It is admitted that this development will depend on other factors, such as monetary environment which will control the atmosphere of shipbuilding markets and which will either stimulate or suffocate the shipbuilding industry in any particular area. This, of course, may be said to be common to the builders of some other materials.

QUALITY CONTROL

Parallel to the requirements for efficient hull design, the need for good quality control or quality assurance to the

owner, is equally important. In the case of a wood hull, the quality of the material is only as good as the skill and the eye of the craftsman; and in other materials, how is the work of the "plasterer" or "laminator" gauged? In the case of steel vessels, the control of material quality is a matter of record, each batch of material having been carefully tested before leaving the mill. During construction, the plates are cut, formed, and welded, using procedures that have been tested; the welding operators are qualified by means of statutory tests; and the final work is checked by X-ray examination. These procedures are then documented to give uniform quality assurance. This may sound expensive but, in actual fact, it gives assurance which reduces the element of risk and justifies the use of more sophisticated materials and methods.

OPERATIONS AND MAINTENANCE

In operation, a steel hull has a potential life of up to 50 years, if given reasonable annual care and maintenance. It should, perhaps, be noted here that steel hull scantlings include an allowance for normal corrosion and, in most cases, a vessel becomes obsolete for various reasons long before the steel hull is worn out.

Advances have been made in corrosion control through the application of protective coatings. These new coatings offer the owner a wide variety of good quality coatings which can be used at his discretion to give long-lasting protection and reduced maintenance cost.

With a steel-hulled fishing vessel, if the owner decides to change the run of his gear, or add to the vessel's equipment, then it is a simple matter to weld on a few lugs or stiffen the structure to take the new equipment.

CONCLUSION

In summary, steel as a material for construction has versatility in physical properties and uniform quality on a controlled basis. The designer has at his disposal well-defined, constantly up-dated rules for the use of the material which enable him to develop a hull structure which is economic in the use of material and, at the same time, provides the necessary strength to meet service requirements.

In construction, the steel shipbuilder, generally, has a backlog of experience on vessels of many other types which may be used to advantage in fishing vessel construction. He is working with a material which he knows, using tools which he is familiar with and, even with continuing technical improvements, he is basically using methods and producing structures which have stood the test of time.

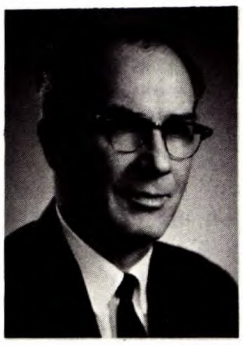
In the area of quality control, systems and methods originally devised to control the production of much more critical structures, have been easily adapted to the shipbuilder's use, giving the required degree of control at minimum cost.

When the steel ship owner requires maintenance, or hull repair service, he can usually find someone in his home port who has the equipment and ability to carry out minor repairs and, for major jobs, there is usually a ship repair establishment within a reasonable distance.

To make a complete assessment of comparative hull cost on a basis of different materials, is extremely difficult. Each case would have to be considered on its own merits in relation to geographical situation, type of vessel, type of gear, availability of materials and labour, and ability of the shipyard concerned to meet delivery requirements.

With the foregoing comments in mind, it is felt that steel, at least in the foreseeable future, offers the most attractive medium for fishing vessel construction.

Nova Scotia Wood for Shipbuilding



Mr. Hines

by

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Mr. Hines was born in East Noel, Hants County, Nova Scotia. He attended the University of Manitoba and McGill University, from which he received a Bachelor of Science degree in Electrical Engineering in 1931. From 1940-44 he served with the Aeronautical Inspection Directorate of the R.C.A.F. In 1944-45 he worked for Canadair Limited in Montreal on design of aircraft electrical systems.

Mr. Hines joined the Fishermen's Loan Board as Engineer and Technical adviser in 1945, and was appointed Director, Marine and Engineering Services, Nova Scotia Department of Fisheries, Halifax, in 1965.

ABSTRACT

Without reciting in detail the mechanical and physical properties of wood, all of which can be found in tabular form in architectural and engineering handbooks and other publications and papers, this paper endeavours to explain in laymen's terms why wood continues to be used so extensively for building boats in Nova Scotia.

In support of these explanations are a brief history, a list of types of wood and uses, reference to building experiences in Nova Scotia and a review of the characteristics which support its use.

WOODEN SHIPS

Wood has pioneered the shipbuilding industry. It was there in the beginning and remains today. The Great Architect of the Universe designed the Ark which was built of Gopher Wood.

Wood supplied the material from which the Romans and other nations built their ships. These ranged in size from 500 tons to 1000 tons in measurement and were capable of carrying many persons besides a considerable cargo. That in which Saint Paul was wrecked had on board 276 passengers as well as a cargo of wheat.

The romantic saga of the sea is not complete without a look at the Viking ships, the Norman ships, the English ships, the Spanish ships and the French ships. These were created from wood for the purpose of commerce, exploration, war, and plunder.

The long open galley, with oars and a square sail, which was set when the wind was favourable, remained for hundreds of years. In the 15th Century, ships were equipped with rudders instead of steering oars. They were built larger with two, three and even four masts. These improvements increased efficiency and thus enabled them to cross oceans – and so it was that daring voyages were made into unknown oceans.

When the earliest explorers from Europe first reached Canada, they were not looking for timber. Though they did not seek them, the forests were here. The flag of the King

of France was hoisted by Jacques Cartier in 1534; in 1604 the first logs were cut in Nova Scotia to erect the fortifications at Port Royal. It was a hundred years later that the French government realized that these Canadian forests were a source of material for the construction of the King's ships – ships of war to wage the battle for the mastery of the seas.

And so it happened that the development of Canada's forest industries was closely associated with war. The best oak, pine, birch and spruce were earmarked for the building of ships. After the British conquest, this policy was continued and for many years timbers from Canada's forests went into ships of the Royal Navy.

These towering trees standing in the primeval forests were marked with the broad arrow in token that they were reserved for the Royal Navy.

"Masts for the King's Own Navy,
"Yards for the Royal Shrouds
"Tall, lithe spars that raked the stars
"And whipped the billowy clouds." – H.A. Cody

Nova Scotia, a Maritime Province, is almost completely surrounded by water. The primeval forest of its land has been depleted but there still remains timber in quantity and size suited to the building of ships. The clipper ships and sailing vessels, for which the province was noted, have been replaced by larger ships of another material. There still remains the fishing industry, the third largest industry of the area, which requires working stages from which the harvests of the sea can be taken.

It is a matter of record that in the ten-year period from 1958 to 1967, of the more than 1,000 fishing craft financed by the Nova Scotia Fishermen's Loan Board only 13 were constructed of a material other than wood. This can be attributed to an abundant supply of the raw material, wood, with its miracle properties and the existence of many boat yards and their capable personnel. I note here that Nova Scotia has 91 yards concentrating on the building of wooden craft.

Without reciting in detail the mechanical and physical properties of wood, all of which may be found in tabular form in architectural and engineering handbooks and other publications and papers, this report will endeavour to explain in laymen's terms why wood continues to be used so extensively for building boats.

One of the many factors, which has contributed to the continued usefulness and popularity of wood, is its high strength to weight ratio and its capacity to withstand shock from suddenly applied loads. These characteristics impart flexibility and resilience to a structure which seems to come alive in a seaway with an ease and gracefulness not to be found in other materials.

Wood has a high insulating value with respect to heat and sound. It does not burn unless heated to 450°F or more, and is more heat stable than its competitors. This adds to physical comfort within the structure and makes it less prone to severe icing on the outside.

For marine use, the fact that wood is not subject to rust or corrosion is of singular importance.

If properly treated and maintained wood is a durable, long-lived material. Preservatives for protection against fungi and insects should be used and all parts of the structure should be well ventilated. Shipping records of Great Britain have shown 24 English wooden ships over 100 years old and 13 over 95 years old. The oldest wooden trawlers in Nova Scotia were built in 1945 and are still operating very successfully. There are several saltfish schooners approaching 60 years of age. To further support this claim one should also mention the "Cutty Sark" and the "Victory".

The builders of these boats would quickly state that wood is easy to work and handle. It has beauty of figure. It may be bent. It may be fastened by screws, dowels, nails or glue. It readily takes a variety of finishes – paints, stains, varnishes, waxes and plastics.

The Nova Scotia forest offers the boat builder a variety of trees which may be used for many purposes: –

Gray Oak may be used for frames, stanchions, deck beams, stems, rim timbers, finish wood, planking and shaft logs;
Yellow Birch for keel, stern post, fore-foot, deadwood and for planking below the water line;
Spruce (Black and Red) may be used for ceiling, auxiliary beams, shelves, clamps, bilge stringers, spars, keelsons, sister keelsons, fish hold dividers, bulkheads and deck house framing;
Black Spruce is used in small boats for planking in tidal areas where boats are left on stoney beaches;

Pine (Native White) used in decking, interior finish and for planking of small boats;
Beech and Rock Maple for keels;
Ash as framewood for small boats;
Hackmatack (Juniper) for ships knees, and as framewood for small boats.

It should be noted here that the Plywood used in Nova Scotia comes from other parts of Canada.

It is well to note that when selecting the material for certain parts of the boat the following physical and mechanical properties should be considered, namely: strength, ability to held fastenings, and resistance to rot. With the advent of laminates, timber sizes are no longer restrictive and, with our existing stocks, it is possible in Nova Scotia to build wooden ships up to 125 feet in length without having to resort to fabricated components.

While maintenance costs and operating costs for boats of a size built from different materials do not vary a great deal, this cannot be said of the building costs. The wooden boat is at a decided advantage in this respect. The experience of the Nova Scotia Fishermen's Loan Board and the results provided by economic studies done by the federal Department of Fisheries will bear out this point. It can also be said that boats of a size regardless of the materials of construction produce about the same quantity of fish. The low capital cost is very important at this time because of high interest rates and high insurance rates. It would then appear from this short resume that there is every justification for the use of wood in the construction of fishing boats and this situation is likely to continue.

A Comparative Assessment and Future Outlook for Materials in Fishing Vessel Construction, with Particular Reference to Plywood

by

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(see also page 111 for Mr. Brandlmayr's Paper on behalf of the Plywood Manufacturers of British Columbia)

ABSTRACT

A comparative assessment of commonly used materials is given in tabular and descriptive form. It is suggested that no one material has dominant advantages. Plywood is considered lowest in cost for one-off construction and molded fiberglass for multiple building. Aluminum alloys are best for strength to weight ratio although plywood and fiberglass are close behind.

Future cost reductions will result more from quantity production than from new materials or combinations of materials. Various forms of composite and sandwich structures are discussed and a low cost composite plywood and fiberglass hull is proposed for single unit construction.

The future use of plywood is considered, emphasizing its suitability for secondary structural components in all types of construction, applications for molds and for the construction of small quantities of one hull design.

PLYWOOD BOATS

The strength to weight advantage of plywood structures over metal fastened solid wood structures or anything but high strength alloys has been clearly demonstrated in the case of aircraft and in applications for hydroplanes where only plywoods and high strength alloys are used. When a single boat or relatively small numbers of one design are required, plywood usually offers the most economical construction either as the basic material or supplementary to the basic material.

Figure 1 gives a comparative assessment of materials used for fishing vessels to about 100 feet in length.

Plywood construction covered with adequate layers of fiberglass mat and woven roving is compared with solid wood of the typical west coast Douglas Fir planked type; single skin fiberglass as commercially molded; welded mild steel; and welded aluminum alloys. In all cases commercial rather than experimental building results are considered and for this reason concrete, high strength and corrosion resistant steels, and special plastics are not included.

It is impossible to obtain meaningful comparative statistics, so the author's opinion and observations form the basis of these statements. Each hull material is rated as first, second, third or fourth with respect to each of seven significant qualities. A choice of material would be determined partly by the qualities required in a particular vessel or series and partly by the construction facilities and skills available.

Strength to Weight Ratio

Aluminum will produce the best strength to weight ratio making it particularly desirable for small, fast craft.

Fiberglass and plywood are about equal and second to aluminum. With great care they can approach the strength to weight ratio of aluminum but commercially they are some 10 per cent to 20 per cent poorer.

Steel and solid wood are third in order and about 50 per cent heavier than aluminum.

Rot, Corrosion and Fatigue

Within a 25-year useful life there appears to be no appreciable loss of material or loss of strength in fiberglass. This cannot be said for any of the other materials. Aluminum is nearly as immune but must be handled with care as to dissimilar metals, impressed electrical currents and anti-fouling coatings. It is usually left uncoated.

Steel, solid wood and plywood fall into the third category and all require considerable protection.

Even with the best care localized loss of metal occurs on a steel hull and neglect can be disastrous. An equal degree of care must be taken to protect solid wood from both rot and marine borers. Plywood has a similar rot problem but it is assumed that the outer surface is protected from borers by the fiberglass sheathing.

Fatigue failures sometimes occur in plastic and metal hulls around shaft log, engine beds or keel and these can be attributed to faulty design more than to the characteristics of the material. There is no question that the elastic properties of the material in relation to the structure must be adequately understood.

Weathering

One of the principal reasons for the growing use of fiberglass in pleasure boats is its resistance to weathering. A fiberglass boat can be left in the weather including exposure to fumes from chemical plants with less deterioration than any presently considered material.

Aluminum runs a close second or equal.

Plywood covered with fiberglass is further down the list since the changes in atmospheric conditions including temperature will affect the wood in spite of its fiberglass covering.

Steel and solid wood are at the bottom of the list. Both require an unbroken protective film which is impossible to maintain without frequent attention.

Abrasion

In the tugboat field steel is preferred partly because of its superior ability to withstand abrasion which is of prime importance in tug service. On fishing vessels of other materials, steel is often used to protect high wear areas. Stainless steel is worth consideration for localized abrasion problems to minimize rust stains.

Aluminum is a poor second to steel for abrasion.

Fiberglass and hardwood sheathing are approximately equal and generally inadequate in heavy wear areas.

Usual solid wood such as Douglas Fir is the last in order.

Maintenance Costs

Some comparative figures are probably available for specific applications but this rating is based strictly on the properties of the material assuming operating conditions to be equal.

Fiberglass and aluminum can be considered about equal and the best of available materials. Neither requires a surface coating.

Because of the relatively thin coating of fiberglass, plywood construction requires more maintenance than solid fiberglass. If sufficient glass is used so that the plywood becomes a core then the hull's durability approaches solid fiberglass. Other sandwich structures using foam will also fall slightly below solid glass because of the thinner skins involved.

There is some doubt as to comparative maintenance costs of steel and solid wood. As for the other materials suitable design and good building and coating practices are overwhelming factors but more than for other materials they require frequent expensive attention.

Initial Cost

Solid wood construction is no longer the cheapest on the west coast of Canada and the trend is against it. However,

the actual differences in hull construction costs are small and the difference that hull material makes to the total vessel cost is never more than 10 per cent.

For one-off construction it is suggested that plywood is cheapest, solid wood and steel slightly more expensive with fiberglass and aluminum following in that order. In the case of 30′ to 50′ vessels equally well built by experienced people the difference in cost is so slight that we have west coast gillnetters built of plywood, glass, solid wood and aluminum all at nearly the same end price.

When considering multiple building, molded single skin fiberglass has the cost advantage, followed closely by plywood or other sandwich construction. Currently steel, aluminum and solid wood all experience economies from quantity production but cannot match the low labor content of quantity molded fiberglass.

Designs by naval architects and quotations by large shipyards cannot be used to determine construction costs of small vessels. Rather a comparison must be made between the products of a builder with a highly developed production ability in a certain glass boat and another in aluminum and so on.

Future Material:

Quantity production of fishing vessels is the chief avenue to reduced costs and compared on a multiple basis no foreseeable materials including plastics, composites or ferro cement can achieve a substantial reduction in costs relative to others.

Improvements in physical properties are foreseeable through the use of various plastic and metal sandwich materials and through the use of adhesives at joints rather than welds or other fasteners.

An ideal sheet would be produced under controlled conditions with hard strong outer surfaces and a light core between. The sheets would be formed into a hull by bending them into place and fastening together with an adhesive. Such a surface might have the characteristics of stainless steel but with greater strength and the core might have the density and strength of plywood.

Molded in place sandwich structures are commonly used in pleasure boat construction with the skins of fiberglass and the core of wood or foam. The space industry has developed metal faced structures supported by foam filled honeycomb spacers. Here we have a sophisticated three component structure with a hard thin sheet on each surface, closely spaced stiffeners in the form of the honeycomb material and then buckling support for the honeycomb and the skin by the light foam filler.

Thermal insulation materials can be used as part of a vessel's structure as in sandwich construction or in short blocks of insulation that give added buckling support to what is basically single skin construction.

The Future of Plywood

Principal applications of plywood are enumerated as:

(1) Patterns for all types of construction.

(2) Low cost molds for fiberglass vessels.

(3) Ceiling and joinerwork in accommodation spaces.

(4) Supplementary structural members such as bulkheads and decks.

(5) Construction of one-off hulls, experimental craft and building of boats in areas where skills are inadequate for other types of construction. In these cases a simple plywood structure sheathed in fiberglass is assumed and the cost will be less than anything else.

(6) Composite construction where the plywood is a mold that finally becomes a core totally enclosed in fiberglass has possibilities for limited production where the quality of surface finish is not important.

It is suggested that a hull could be built by setting up transverse station molds upside down and bending on sufficient ribbands. Sheets of plywood would then be laid over the hull with the joints butted. An outer skin of fiberglass of adequate thickness would be applied after which the hull would be turned right side up and the molds and ribbands gradually removed as glassing of the inside proceeded. Other members can then be installed as in any single skin fiberglass boat.

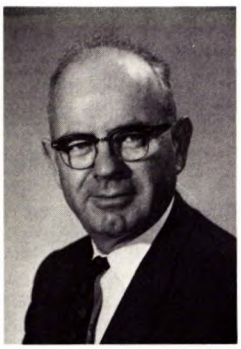
Such a hull would not have particularly smooth surfaces without the expenditure of excessive labor in sanding but accepting this it would be one of the cheapest in materials and labor and at the same time rate with the best for strength to weight ratio, rot and corrosion resistance, weathering and maintenance. It would approach the quietness and thermal insulation characteristics of a wooden hull. Single or double chine hull forms could be readily adapted to this construction.

Figure 1

Comparative Assessment of Materials of Construction for Vessels to 100 Feet in Sea Water

	Strength / Weight	Rot Corrosion and Fatigue	Weathering	Abrasion	Maintenance Costs	Initial Cost	
						One-off	Multiple
Plywood (covered with fiberglass)	2	3	3	3	2	1	2
Solid Wood	3	3	4	4	3	2	3
Fiberglass	2	1	1	3	1	3	1
Steel	3	3	4	1	3	2	3
Aluminum	1	2	2	2	1	4	4

Shipbuilding with Aluminum



Mr. Campbell

by

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Mr. Jenks

Mr. Campbell, for over 20 years with Alcan, mainly concerned with developments in the transportation industry in Canada, the U.S.A., Europe, Australia, South America, Japan, India and Africa, has a degree of Bachelor of Engineering in Metallurgy from McGill University and a Bachelor of Arts from Loyola University.

He is a member of The American Society of Mechanical Engineers, the Engineering Institute of Canada, the Professional Engineers of Quebec, an Affiliate Member of The Society of Naval Architects and Marine Engineers, and a Member of the Task Group HS-6-1, Aluminium, of the Society of Naval Architects and Marine Engineers.

He has presented papers in Canada, the U.S.A. and Europe and has had papers published in The Engineering Journal and the Transactions of The American Society of Mechanical Engineers, The Institution of Locomotive Engineers of London (England), as well as in various trade magazines.

Mr. Jenks holds degrees in both Arts and Science from Mount Allison University, Sackville, New Brunswick. He has worked at Arvida, Quebec, for the Aluminum Company of Canada, Limited, as a chemist and as a supervisor of chemical analysis. In 1945, he transferred to Alcan Research and Development Limited, Kingston, Ont., where he became Head of the Publications Division. For more than 20 years he has been concerned with writing, editing and producing internal and external technical reports, papers, and other communications. He has written several handbooks connected with the technology of aluminum and numerous papers and reports.

Mr. Jenks is a member of the Chemical Institute of Canada, the American Chemical Society, the American Documentation Institute, and is a Fellow of the Society of Technical Writers and Publishers, of which he was at one time President.

ABSTRACT

This paper briefly outlines some applications of aluminum in the shipbuilding industry, and puts forward reasons for choosing aluminum as a construction material. The design and performance of an all-aluminum 300-ton

cargo vessel, M.V. "Independence", is then considered in detail—as a practical example of how aluminum might be adapted to the building of fishing trawlers.

In February 1966, Sprostons (Guyana) Limited of Georgetown, launched an all-aluminum cargo vessel of 316 tons deadweight to operate in the Demerara River and nearby coastal waters. This vessel, the M.V. "Independence", shown in Figure 1, has many structural characteristics in common with a typical fishing trawler and exemplifies the benefits of all-aluminum construction. I shall devote most of my paper to a description of this vessel, but first I shall outline briefly aluminum's contribution to the shipbuilding industry in general.

Shortly after aluminum became commercially available in the late 1880 s, the 40-foot French-built steam yacht "Mignon" took to sea with an aluminum hull. The French and Russian governments began building torpedo boats with pure aluminum hulls and deckhouses, and European and American boat designers started to explore the potentialities of the new lightweight metal. In 1895, the America's Cup Races were won by the United States entry "Defender" which had aluminum topsides.

However, for many years the use of aluminum in boats was spasmodic because some of the seagoing properties of the metal had not been perfected and there was no easy fabrication method. Then, in the 1930s, new aluminum alloys containing magnesium became available. These new alloys, combining high strength with excellent corrosion resistance (even in salt water), are described by Mr. H. Svenkerud in his paper "Aluminum as a Fishing Vessel Construction Material". Collectively known as "marine aluminum", they are alloys that are readily adaptable to such joining techniques as MIG and TIG welding, and have proved to be excellent materials for building ships hulls and superstructures.

Presently, one of the major applications of marine aluminum is that of superstructures for large passenger ships – using aluminum it is possible to equip such ships with one or more extra passenger-carrying decks. Examples of passenger vessels with aluminum superstructures are S.S. "United States", the French liner "France", the Italian vessels "Michelangelo" and "Raffaello", the P. & O. liners "Oriana" and "Canberra", and most recently, the "Queen Elizabeth II".

At the other end of the size scale, aluminum has become the most popular material for building pleasure boats, and it is fast becoming established for sizes in between, sizes that include fishing trawlers. In 1965, one of the U.S. shipyards equipped to build fishing vessels launched the first of many 165-foot all-aluminum patrol motor gunboats. Tankers with aluminum hull include the 223-foot German tanker "Alumina" (launched in 1959). Over 500 aluminum crew boats are in service in the U.S.A. as well as aluminum barges up to 195 feet in length. Some of the most successful small fishing vessels are those presently being built in aluminum on the West Coast by Mr. Matsumoto, of Matsumoto Shipyards Ltd. in Vancouver.

CHOICE OF ALUMINUM

When planning a new vessel, the owner of a trawler fleet should consider aluminum as a construction material in light of the substantial money savings to be realized over the ship's expected lifetime of some twenty-five years. Several factors contribute to these savings.

Marine aluminum alloys have a high strength-to-weight ratio—about three times that of ordinary shipbuilding steel. The weight of an aluminum hull is about one-half that of an equivalent steel hull and, hence, the owner can obtain a 50 per cent weight saving at a cost which represents the difference in material value between aluminum and steel. Interest from this weight saving can be calculated in one or more of the following ways:

> Each pound saved can be added to the deadweight capacity of the trawler and make room for an extra pound of fish, or fuel or fresh water.
>
> Greater speeds are possible with the same power and consuming the same amount of fuel. This means more fishing time, more cargo trips per year, and less idle manhours.
>
> Travelling at the same speed, less power is required and less fuel is consumed than with a comparable heavier vessel.
>
> With the same power and the same fuel consumption, an aluminum vessel can travel greater distances and so extend her range of operations. This feature has strongly influenced the choice of aluminum applications in building Japanese fishing vessels.

To sum up, aluminum allows the designer to select from larger payload, greater speed, reduced horsepower, or from a combination of these advantages.

Another compelling reason for choosing aluminum is the saving in maintenance, stemming in particular from the fact that metal above the waterline does not require painting.

Many vessels bear witness to the corrosion resistance of marine aluminum. Fishing vessels built by Matsumoto Shipyards Ltd., Vancouver, have not been painted above the waterline, yet have maintained their new appearance for many years. The R.C.M.P. Patrol Cruiser "Interceptor", built by Marine Industries Limited, Sorel, P.Q. in 1934 was taken over by the Royal Canadian Navy during the second World War; she had lost about 60 per cent of her paint covering yet remained in excellent condition, and later went unpainted into extensive service in Guyana. On many ocean-going vessels aluminum superstructures and hatch covers have weathered to a dull grey, but remain in excellent condition even after years at sea.

Designwise, draft is important for vessels operating in shallow waters, and a lightweight aluminum hull draws substantially less water than a steel hull. Lightweight aluminum construction also permits a lower vessel center of gravity than steel and so adds to stability, as endorsed by the crews on the vessels "Cape Fourchu" and "Cape Scatari" which have aluminum superstructures.

Aluminum, then, can prove itself both in theory and, more important, in practice. As yet, all-aluminum construction is still something of a novelty and I can, perhaps most easily, point the case for aluminum by describing in detail the construction and performance of an all-aluminum vessel – as I mentioned at the beginning – the M.V. "Independence".

At the time the "Independence" was first envisaged by her owners, Sprostons (Guyana) Limited of Georgetown, the choice of aluminum as the material of construction was based on savings to be realized over the ship's expected lifetime.

In the first place, aluminum alloys readily met all strength requirements, yet conferred a weight saving of some sixty tons as compared to steel. This weight saving, in turn, made possible an increase in deadweight carrying capacity without serious modifications in the general design of the ship. An increase in cargo capacity without increased draft is particularly important in this part of the Caribbean where a combination of tides and sand bars often impedes the operation of deep-draft vessels. Moreover, by reason of changes in displacement and dimensions, a reduction in power, and hence fuel consumption, could be achieved. It was estimated that, in the case of the "Independence", fuel savings could easily be 12-1/2 per cent without jeopardizing schedules. In addition to this, because of the reductions in power requirements, smaller engines could be specified, thus leading to a substantial saving in first costs. Originally two Caterpillar D343 engines rated at 320 horsepower each were felt necessary, but it became apparent that two D333 engines rated at 180 horsepower each (280 less horsepower) would be sufficient because aluminum was to be used for the hull.

Aluminum's proven resistance to attack by brackish water such as that of the Demerara River, even in tropical temperatures, and to salt water when in coastal service, permits elimination of customary painting programs for both superstructure and hull. The savings to be realized in this way have been estimated at several thousand dollars during the service life of the ship.

Lastly, even after 25 years in these waters, the plates of the hull should not have diminished in thickness to any appreciable extent and other structural members should be similarly unaffected. Thus, at the end of the normal 25-year lifetime of a cargo carrier, before which the hull plates of steel ships have usually been repaired frequently or replaced, the aluminum hull of the "Independence" should have a very high resale value.

The owners, in consultation with sister companies in the Alcan Aluminium Limited Group which are suppliers of aluminum alloys, suggested high strength, seawater-resistant alloys Alcan D54S and A56S for plate and structural components. These alloys are non-heat-treatable and are approved by Lloyd's Register of Shipping for welded ships structures. They are readily formed and lend themselves to welding by the highly efficient inert gas metal arc (MIG) method. The owners planned to build the vessel in their own shipyard at Georgetown where experienced personnel and most of the necessary facilities were available. Furthermore, in order that welding might be performed under most modern and efficient conditions, the owners consulted Alcan Research and Development Limited with respect to equipment, welding procedures, and for training and qualification of welders and supervision of initial construction phases.

SPECIFICATIONS

General

The owners commissioned the naval architectural firm of Burness, Corlett & Partners Ltd. of Basingstoke and London, England, to design the ship and write the specifications. This firm has a wide experience in aluminum

in shipbuilding. Major points from the "Outline Hull Specification" and "Machinery Specification" are summarized in this and the next sections.

The general arrangement plan for the "Independence" is shown is Figure 2. Details of the midship section are shown in Figure 3, and the arrangement of machinery in Figure 4. Dimensions are shown on the drawings.

The vessel is of welded construction in aluminum alloys supplied by Alcan Industries Limited, London, England. Some details of the materials are shown in Table 1.

The use of aluminum alloys as designated above was agreed upon among the owners, the naval architects and Lloyds Register of Shipping. Structural plans and load line certificate were to Lloyd's Register of Shipping approval.

As will be seen from Figure 2, the hydroconic, 2-chine vessel is planned as a cargo-carrier with three holds. The center hold has water-tight doors in the transverse bulkhead and thus serves also as a midship fresh water ballast deep tank. The single bottom is overlaid with an approved wood to act as a cargo platform and is suitable for fork-lift trucks. The other two cargo holds are fitted with aluminum hatch covers of slab type for supporting cars, trucks and similar cargo. The main deck also is suitable for a variety of deck cargo, including steel rails, and the forecastle is fitted out for carrying cattle. Ballast tanks (fresh water) are located forward and aft, together with midship and forepeak deep tanks. All piping, both domestic and hull, is of Alcan GB-A57S; air sounding, filling and discharge piping is available for all tanks.

Table 1

Major Materials for M.V. "Independence"

	Alcan G.B. Alloy	Main Uses	Tons	
1. Plate	D54SM	(a) Shell, stem & keel	14.8	
		(b) Hull, bulkheads, girders, webs, machinery bases, etc.	22.9	
		(c) Main & forecastle decks, tank top plating	5.5	
		(d) Superstructure	8.0	51.2
2. Extrusions	D54SM	Framing & stiffeners		8.5
3. Piping & Welding Wire	A57SM A56S			7.3
		Total Tonnage of Aluminum:		67.0

Accommodation is provided for a crew of seven persons, including the officers. Ventilation is adequate for the vessel's intended service, and the forward end of the main deckhouse incorporates two standard cold storage cabinets. A small aluminum work/lifeboat is located aft of the bridge deck and can be launched to port or starboard. A full set of navigation lights and flags is provided.

The vessel has not been painted except for finishing aluminum-to-steel joints and for some decorative items.

The details of capacity, deadweight and draft are as follows:

(a) River Condition (fully loaded)

Underdeck cargo @ about 100 cu ft/ton	150 tons
Refrigerated deck cargo	5 "
Miscellaneous deck cargo (car, cattle, etc.)	20 "
Oil Fuel	10 "
Fresh Water	3 "
Crew & Stores	2 "
	190 tons

Corresponding mean draft – 5′6″

(b) Coastal Condition (fully loaded)

Underdeck bagged cargo @ about 50 cu ft/ton	300 tons
Oil Fuel	10 "
Fresh Water	3 "
Crew & Stores	3 "
	316 tons

Corresponding mean draft – 7′6″

(c) Ballast Condition & Maximum Consumables

Fresh water ballast including midship deep tank	175 tons
Oil fuel, fresh water, crew & stores	15 "
	190 tons

Corresponding drafts – 6′6″ aft
4′6″ forward

Steel and Wood Parts

The hull and superstructure of the ship are all-aluminum in construction. However, hawse pipes, bollards and fair-

leads are steel, the propellers and shafts are of stainless steel, and much of the machinery is steel or cast iron. Cabin fittings, some flooring, etc., are of conventional wood construction. Such instances of other than aluminum construction were so designed that problems with bi-metallic joints or aluminum-to-timber connections might be minimized.

Aluminum-to-steel joints, in general, have the following detail:

(1) The insertion of a Tufnol or equal sleeve in the bolt hole. The sleeve is a tight fit, inserted under pressure when necessary, and reamed to as close a tolerance as possible.

(2) Stainless steel bolts are used, the diameter generally on the generous side, to reduce bearing loads on the sleeves and to allow the normal thrust on the washers to be increased so as to intensify the frictional resistance to relative movement of the two parts of the joint.

(3) Tufnol or equal washers are inserted under the heads of bolts and under the nuts.

(4) Tufnol or equal chocks or gaskets are inserted between the two faying surfaces. In way of the rudder coupling, a Tufnol or equal key is inserted.

Deck machinery is mounted on aluminum ground bars fitted with Tufnol insulating pads. Stainless steel bolts are used, fitted with Tufnol washers under heads and nuts.

The owners gave special attention over and above the requirements of the specification to see that aluminum-to-steel joints were watertight. An elastomeric sealing compound was applied to the faying surfaces as deemed necessary by the owners. The edges of the joint were sealed by exuded compound or by a fillet of this or similar material, or by applications of aluminum or bituminous paint.

Generally speaking, the specification required that there should be no direct, uninsulated joints between aluminum and other metals. However, isolated cases of riveted aluminum-steel connections may occur in the vessel. In these, gaskets of Neoprene tape were inserted between the faying surfaces. Steel rivets are used, backed up on the aluminum side and hammered down on the steel side. The gaskets are left slightly proud around the edges and the joints are sealed along the edges by the application of a fillet of approved sealing compound. Such joints are completed by several coats of zinc chromate paint.

The installation of all fittings, large or small, including name plates, was considered equally carefully to avoid any possibility of attack.

Where aluminum-timber connections occur in exposed places, or where moisture is likely to collect, the wood faying surfaces are painted with aluminum or bituminous paint and Neoprene jointing is inserted between the faying surfaces. All wood fittings, where in contact with bare aluminum, are painted with aluminum or bituminous paint.

MACHINERY SPECIFICATIONS

Main Engines

The vessel is twin-screw, powered by two Caterpillar D333 turbo-charged and after-cooled marine engines, developing a continuous horsepower of 180 at the continuous rating of 2,000 rpm, and coupled to a reverse reduction gear box having a ratio of 1.47: 1, and delivering a speed of 9 knots.

The engines are arranged for bridge control with Morse MD24 pilot house-mounted single lever remote control for twin-engine installations, complete with pilot house-mounted instruments, with oil and water temperature actuated alarm.

Other equipment includes engine-mounted service indicators, pilot house-mounted electric tachometers, exhaust fittings, 30-volt alternator charging system and batteries, and a bilge and deck wash pump.

The engines are each equipped with jacket and seawater cooling pumps. Engine starting is by battery, each being complete with battery charger and charging board. Exhaust silencers discharge over the ship's side via water-cooled exhaust silencers of non-metallic type. Exhaust pipes rise in a vertical direction above the main deck level and bend downwards and go through the ship's side well above the deep load waterline, and the exhaust silencer is placed between the ship's side and the exhaust pipe. The tail pipe through the ship's side is of aluminum, but the remainder of this piping is of steel, with the water connection led into the exhaust pipe on the engine side of the silencer.

Vee Drives

The engines are coupled direct to a Walter vee drive, type RV 90, having a reduction ratio of 3:1. The unit is arranged with a standard 15° vee angle and is lined up to the propeller shaft with a solid shaft connecting to the vee drive and the engine reverse reduction gear box.

Seatings

Strong, fabricated, aluminum seatings are built into the ship to support the engine and gear box. Engine and gear box chocks are made of an approved compression-resistant material having a high insulation property. The units are bolted down with stainless steel bolts with Tufnol ferrules fitted to the engine and gear box seatings. Thrust chocks are welded to the seatings at the forward end of the Walter vee drive seating flanges and a Tufnol wedge is secured in position to relieve the holding-down bolts from shear stresses.

Fuel Tank System

Two fuel tanks are built into the vessel, one port and one starboard. The fuel tanks are cross-connected by a pipe having a diameter of 1-1/4 times the area of the deck filling connection, with valves arranged at each tank. The engines draw their fuel direct from the pipe connecting each tank, each engine having a separate supply line from the cross main. Each tank is fitted with flush deck filling connections and air pipe. Access manhole doors are provided for cleaning, etc., and self-closing drain cocks are located at the bottom of the tank, with internal pipes down to 1/4 inch above the bottom of the tank. Shut-off valves on each tank have extension spindles to above deck level.

Marine Auxiliary

One Lister Blackstone marine auxiliary engine, Model SL4MA, developing 19 horsepower at 1,500 rpm, and arranged for air-cooling, provides power for lighting and refrigeration. This engine is directly coupled to a 9 KW 127/220 volt 3-phase Arthur Lyon alternator. A vee-belt drive from the flexible coupling through a pulley-type clutch powers a Desmi, Model FA80, self-priming pump having a capacity of 200 gallons per minute at 40-ft head. This engine is started from a 12-volt battery system complete with charging board, charging dynamo and battery. The engine has a 25-gallon fuel tank, giving gravity supply to the engine, and is filled by a semi-rotary hand pump from the main supply tanks. Sufficient space is allowed for fitting a second auxiliary set.

Propellers and Stern Gear

The propellers are of stainless steel and are driven by stainless steel shafts supported in Cutlass rubber bearings with Ebonite Shells. The "A" bracket and stern tube are of aluminum construction and a water supply is led to the Cutlass rubber bearings in the stern tube. An inboard gland of the soft, greasy, packing type, has been fitted and secured by stainless steel studs and nuts. As a corrosion preventive measure, anodes of Alcan 420 alloy were fitted when the vessel was first dry docked in the latter part of 1966.

Ballast System

Ballasting is by fresh water and the tanks previously mentioned are filled from deck connections via stand pipes arranged port and starboard on each tank. The tanks can be pumped out by the engine-driven bilge pump or alternatively by the auxiliary-driven ballast pump. Ballast pipes are of aluminum with diaphragm-type valves of aluminum construction.

Electrics

The generator is coupled to a switchboard, complete with voltmeter, ammeter, earth warning light, main switch and fuses, and is arranged so that two generators can be coupled to one set of bus bars. Distribution is subdivided to No. 1 Refrigerator, No. 2 Refrigerator, navigation lights, deck and cargo lights, and accommodation lights.

Particular attention has been given in the installation of electrics to avoid stray currents and grounding that might cause corrosion to the hull. The vessel is wired on two-wire system and cables are butyl insulated and fireproof braided. No lead-sheathed cables are used.

CONSTRUCTION

The nature of the aluminum alloys chosen for the vessel facilitated welding by the inert gas metal arc (MIG) process. A scheme to build the ship in sub-assemblies was adopted. Further, the MIG equipment available, supplemented by some additional equipment, was adapted to machine welding. Combination of these factors greatly increased speed and efficiency in building the ship.

The welding equipment used consisted of four Airco 35A pull guns, 1 West-ing-gun with Caterpillar twin-arc diesel-driven power sources of the drooping characteristic type, and one Linde Sigmatic SWM-11S unit with ST-5 torch and Lincoln SAE 600 motor-generator power source modified for CAV operation. A Linde CM-37 machine carriage with track was used for machine welding. All electrode wire was Alcan G.B. A56S alloy.

A picture story of the welding of the various sub-assemblies and fit-up to the ship is depicted in Figures 5 to 14.

After set-up and adjustment of the welding equipment, and qualification and training of welders, welding of the skeg and bottom floor sub-assemblies proceeded simultaneously (Figures 5, 6, 7). The next sub-assemblies to be prefabricated were the bottom shell panels, one of which consisted of the keel plate with "A" and "B" strakes for the port side and the other with "A" and "B" strakes for the starboard side.

All prefabricated sub-assemblies were transported by crane from the bay in which they were fabricated to the building berth and fitted, tacked and welded in place in the ship. Where advantageous, the machine welder was transferred temporarily to the building berth from the prefabrication bay and returned after use. Figure 8 shows manual MIG welding of the skeg to the bottom shell. Figures 9 and 10 show prefabrication of the shell plating and fore unit, and Figures 11 to 14 show other successive welding operations in building the ship. As mentioned above, the machine welding technique was used wherever possible and, in fact, approximately 75 per cent of all welded footage was laid down by this method. In this way, Sprostons, who have built some eighteen vessels ranging from motor vessels to tugs, carried out construction of this all-aluminum ship expeditiously.

PERFORMANCE TO DATE

The vessel was launched on 23 February 1966 and underwent all dock and speed trials required by the specification, including proof of stability by inclining test, with flying colors. She was put into service by the owners in the same month.

It is interesting to note, as can be seen in Figure 13, that cavitation plates are fitted above the screws. These are required because the draft is very shallow in the light condition. The extremely low weight of the vessel produces a very low deadweight displacement ratio when loaded, but conversely, at the light draft possible in some ballast conditions, air must be prevented from entering the propellers. The cavitation plates have proved very successful for this purpose.

While the ship plies the Demerara River between Georgetown and Mackenzie, in Guyana, she can be used when required in a number of ways in coastal service in Caribbean waters. To date, the "Independence", so named to commemorate Guyana's emergence as an independent nation, is performing efficiently, and to the satisfaction of her owners.

She was inspected after a year's service by the designers, Burness, Corlett & Partners Ltd. and the following is a quotation from "The Motor Ship" of August 1967 giving the results of the inspection.

> "Since entering service in mid-March 1966 the ship has been employed between Georgetown and Mackenzie, a round trip of 114 nautical miles. To enable readers to form an idea of the arduous nature of the service, the vessel made 83 round trips in 1966 carrying 19,260 tons of cargo and approximately 1,575 passengers. In 1967 up to the end of April, she has made 34 round trips carrying 7,700 tons of cargo and 893 passengers (deck).
>
> When recently inspected, the vessel was found to be in very good condition. In spite of experiencing minor collisions the hull is undented and this is undoubtedly due to the extremely good shock absorbing qualities of aluminum due to its low modulus. There has been some minor damage to the deck rails but this type of injury is experienced by all small working ships.
>
> The most impressive aspect of the ship is the condition of the hull decks and deckhouses which are unpainted. The surfaces are as good as when she entered service, a very pleasing result to the owners. There is no chipping, no painting, no rust or staining of paint. Only hosing down with a solution of water and detergent is required to wash off any dirt. These qualities are much sought after in tropical climates where steel vessels quickly show signs of deterioration due to solar heat affecting the paint."

The owners advise that this information is still valid. The number of round trips from January to December 1967 was 106, carrying 28,347 tons of cargo and 3,243 deck passengers. From January to August 1968 she has made 67 round trips, carrying 18,793 tons of cargo and 2,062 deck passengers.

Except for drydocking and a short period when the crew was supporting a strike, the "Independence" has been in continuous service since her commissioning in March 1966.

Examinations at the drydockings reveal no wastage nor pitting of shell plating although in the early life of the vessel there was cracking of the starboard cavitation plate and a section of shell plating in the same vicinity. This may have been due to stresses from action of the propeller. The defect has been remedied.

As mentioned in the "Motor Ship" article, the rails do suffer damage and those on the main deck have been replaced with stanchions and chains.

Regarding economics, the vessel requires no painting, except in the accommodation for aesthetical reasons, and a washdown with fresh water is sufficient to keep the decks and shell in clean condition. This in itself is a considerable saving in painting costs taken over the lifetime of the vessel.

Financial results are satisfactory and although some of the overheads have naturally increased since the vessel entered service, the owners have been able to maintain the freight rates at the 1966 level.

CONCLUSION

The experience that one can gain by examining the M.V. "Independence" prior to specifying an aluminum trawler can be valuable. The condition of the hull, superstructure, machinery and fittings are there to be examined. When designing an aluminum trawler, extra precautions will have to be taken to prevent damage from heavy equipment that must be handled and here there is sufficient, extensive experience within the aluminum industry to solve such problems.

Table 2
(Guyana Dollars)

	Mar.-Dec. '66		Year 1967		Jan.-July '68	
	Amount	Per Hr	Amount	Per Hr	Amount	Per Hr
	$	$	$	$	$	$
Operating Expenses incl. wages and salaries	97,879	67.09	153,509	88.38	77,267	77.89
Supplies incl. fuel	8,784	6.02	10,843	6.24	6,652	6.70
Repairs and Maintenance	19,140	13.12	14,109	8.12	8,198	8.26
Overhead	25,488	17.47	33,295	19.17	19,195	19.35
Cash Cost	151,291	103.70	211,756	121.91	111,312	112.20
Depreciation	16,950	11.62	20,594	11.86	12,113	12.21
	168,241	115.32	232,350	133.77	123,425	124.41
Running Hours	1,459		1,737		992	

Capital Cost: $515,000

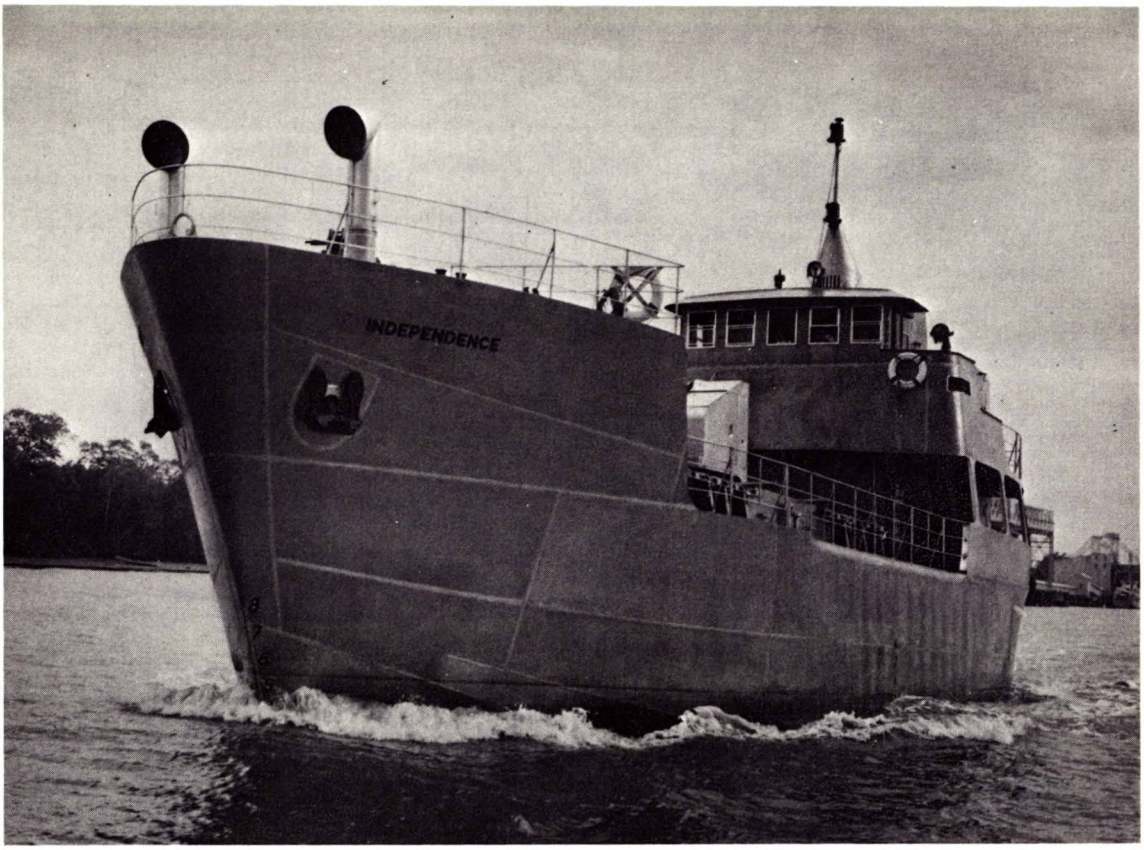


Figure 1. The M. V. "Independence"

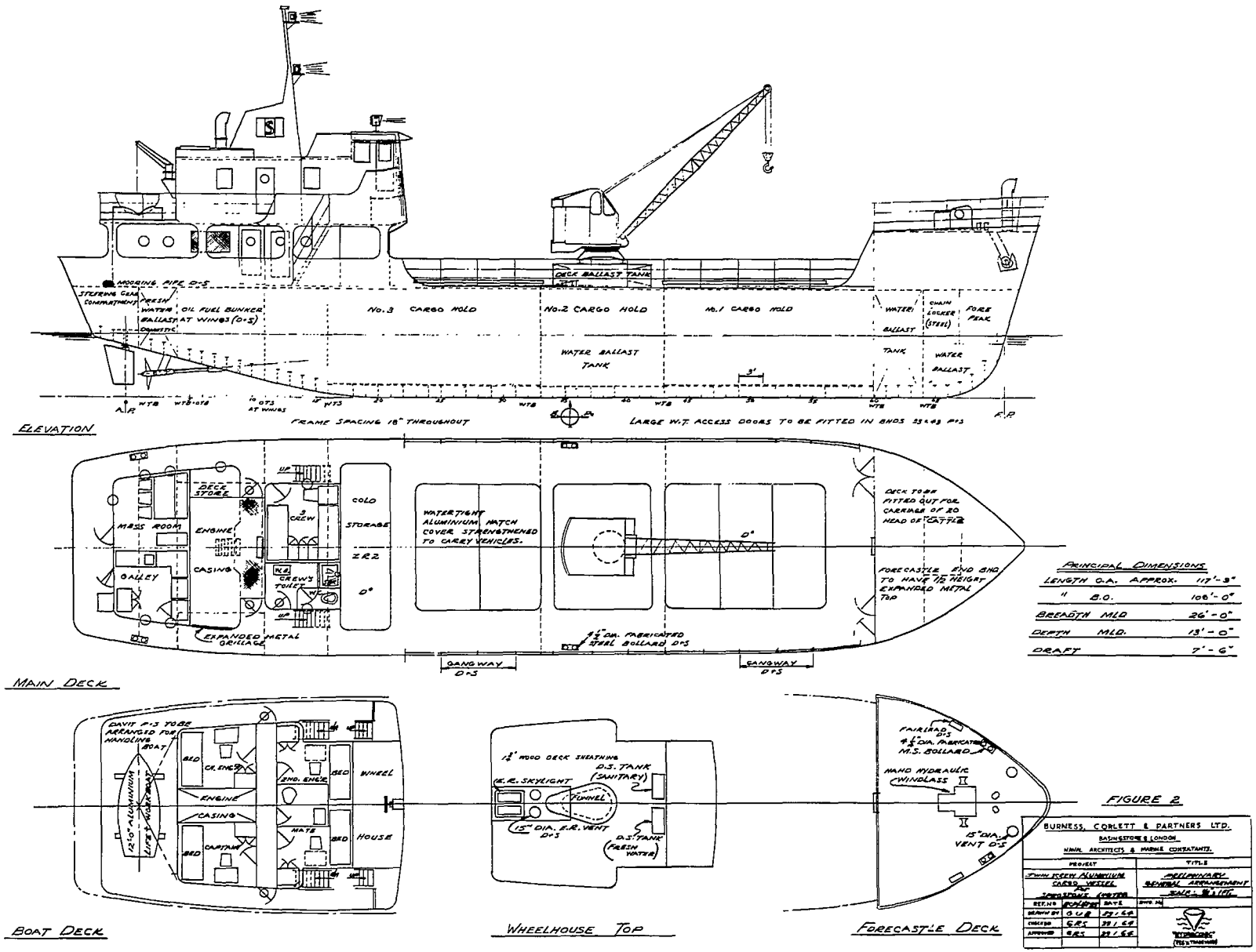
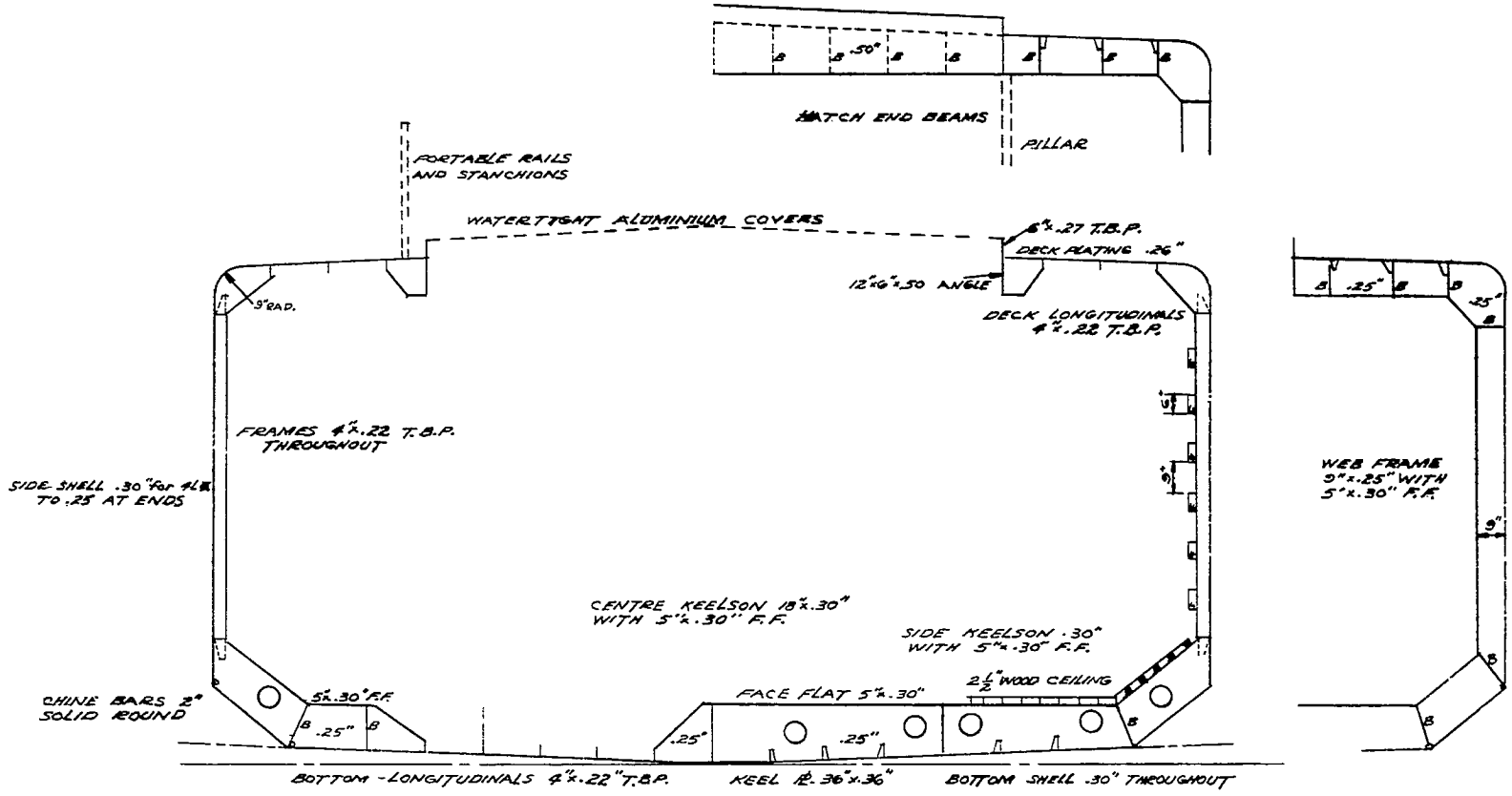


FIGURE 2

Figure 2. General arrangement plan for M. V. "Independence".

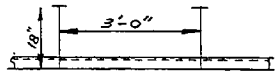


T.S. ALUMINIUM CARGO VESSEL

MIDSHIP SECTION (PRELIMINARY)

SCALE ½" = ONE FOOT

LENGTH OVERALL	117'-9" (APPROX)
LENGTH B.P.	106'-0" "
BREADTH	26'-0" "
DEPTH	13'-0" "
DRAFT (DEEP LOAD)	7'-6" "



SECTION THROUGH LONGITUDINALS

FIGURE 3

BURNESS, CORLETT & PARTNERS LTD.			
BASINGSTOKE & LONDON			
NAVAL ARCHITECTS & MARINE CONSULTANTS			
PROJECT			TITLE
TWIN SCREW ALUMINIUM CARGO VESSEL			MIDSHIP SECTION (PRELIMINARY)
REF No.	BCH 1/255	DATE	DRG NO. 2
DRAWN BY	A.G.B	23-1-64	
CHECKED BY	G.R.S.	23-1-64	
APPROVED BY	G.R.S.	23-1-64	
ISSUED TO			"HYDROCONIC" (REGD TRADE MARK)

Figure 3. Midship section of M. V. "Independence".

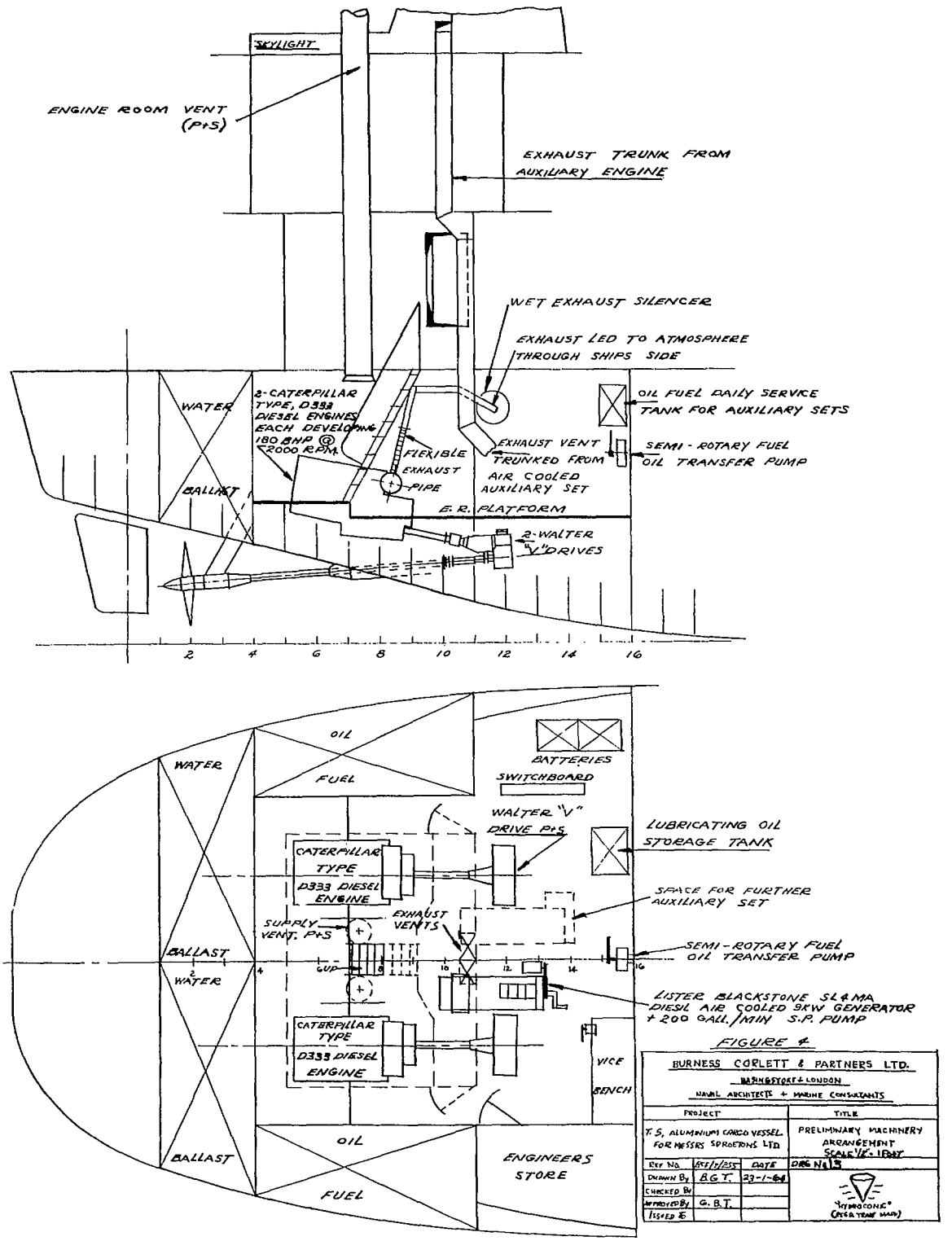


Figure 4. Machinery arrangement for M.V. "Independence".



Figure 5. Prefabricated skeg and keel plate

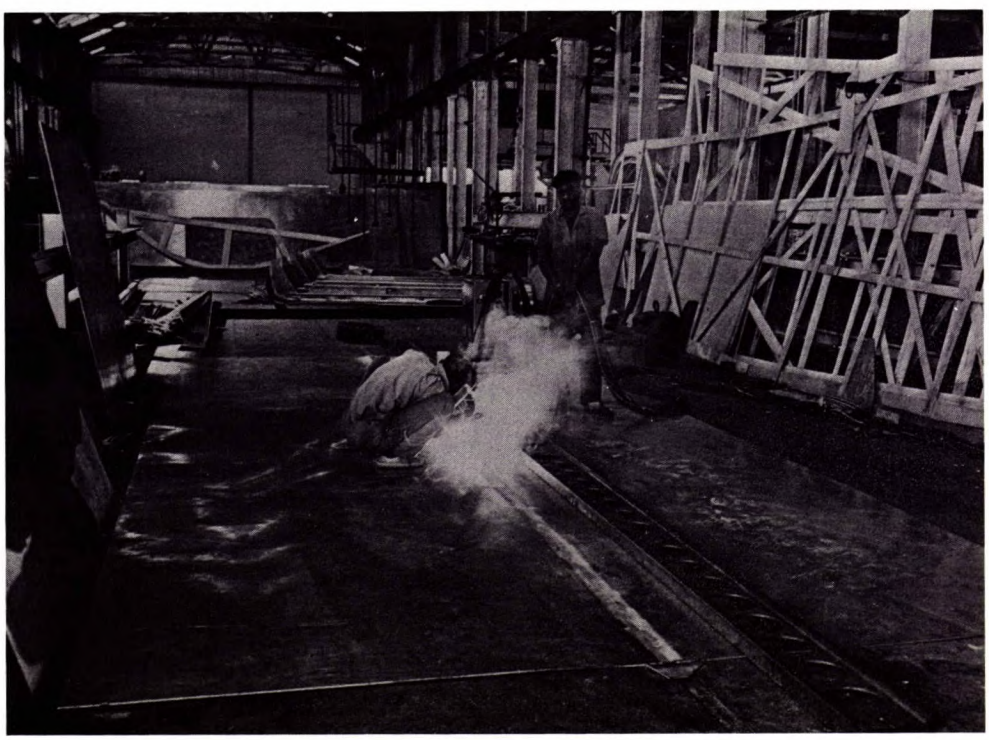


Figure 6. Linde Sigmatic machine welding equipment in operation welding deck plate seam

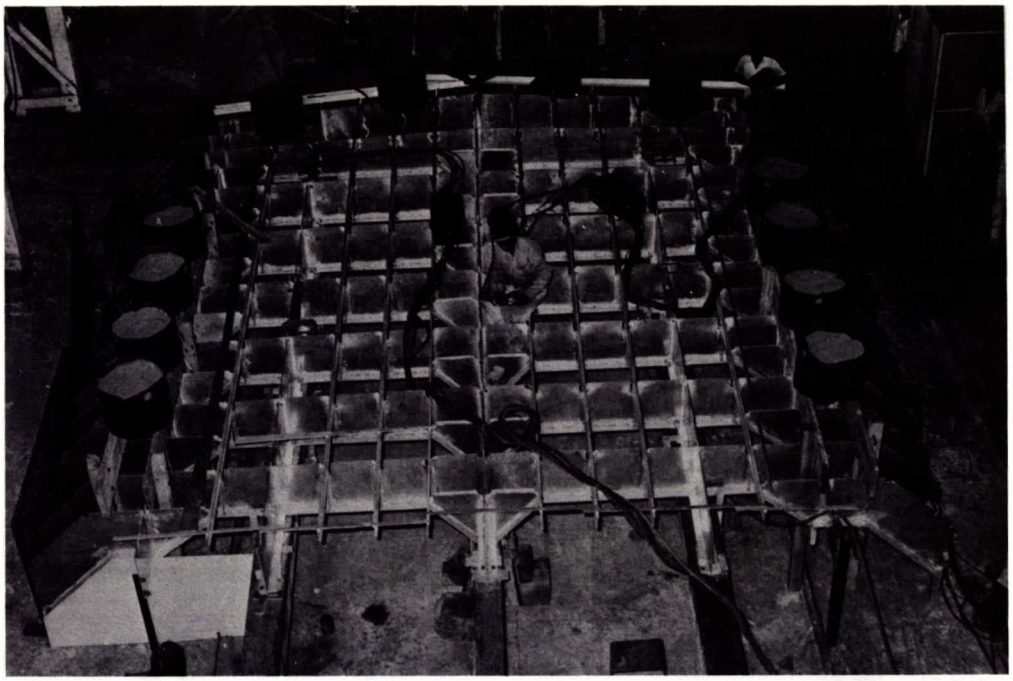


Figure 7. Bottom floor unit from bulkheads 16 to 33, complete with floors, longitudinal girders and longitudinal stiffeners. Note the oil drums filled with sand placed to prevent rise of unit, and wooden shores to prevent sinking due to welding. Also shows sub-assembly in background of bottom floor unit bulkheads 33 to 43.

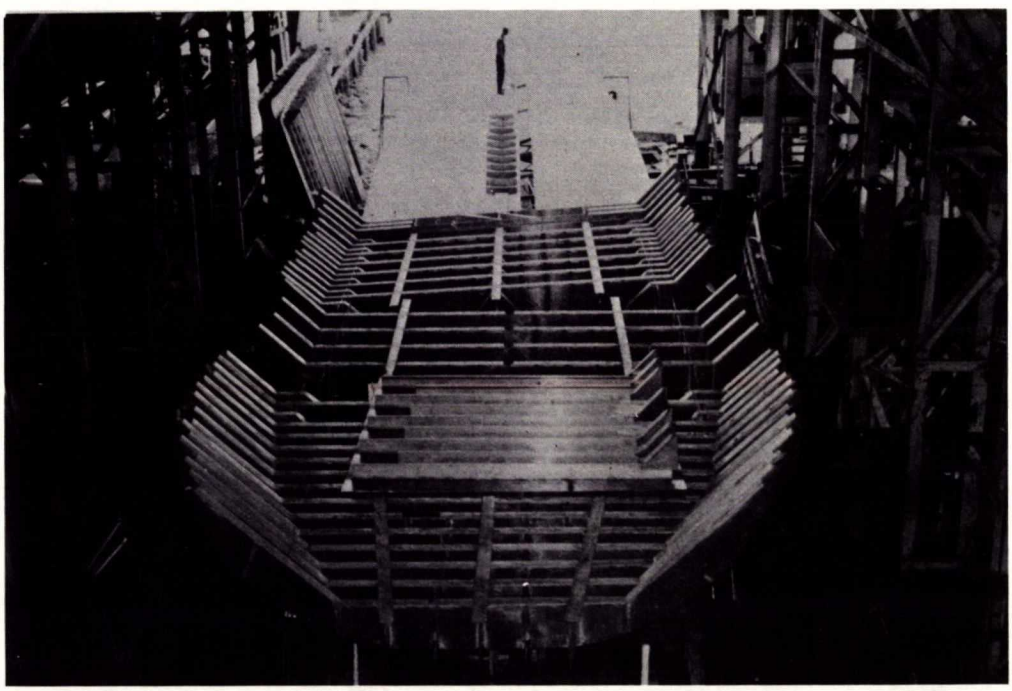


Figure 8. Aft-end bottom shell plating abutting to skeg keel plate. Bottom floors and longitudinal girders from 16 to 60. Note section of centreline bulkhead in foreground. Thwartship bulkheads Nos. 16, 33, and 43 can be seen in left background.

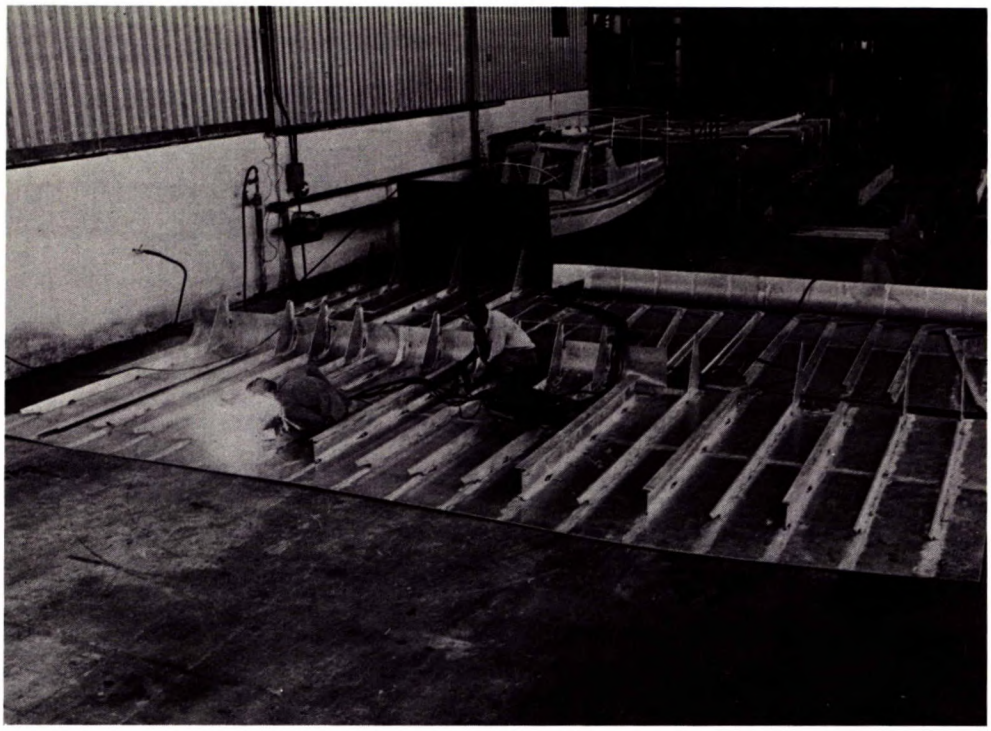


Figure 9. Prefabrication of side shell plating with frames and beam knees attached.

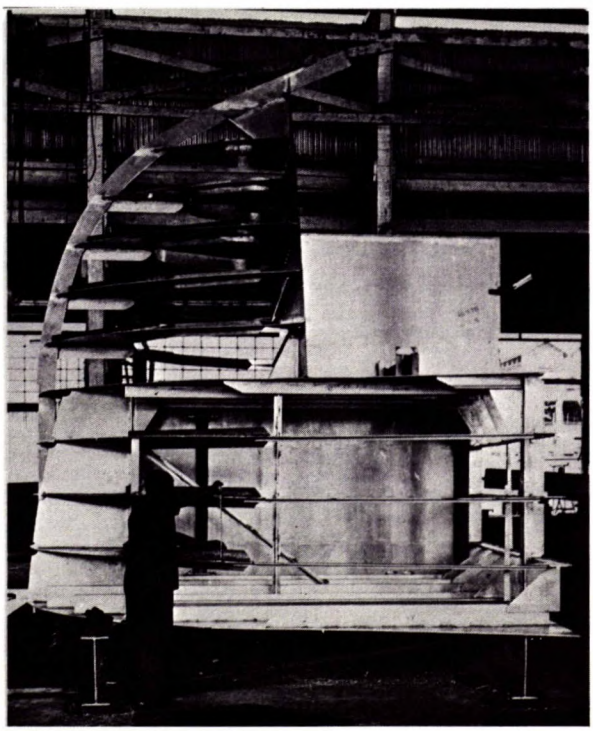


Figure 10. Prefabricated fore-end unit erected from bulkhead No. 60 to No. 64. Chain locker and stringer flat can also be seen.

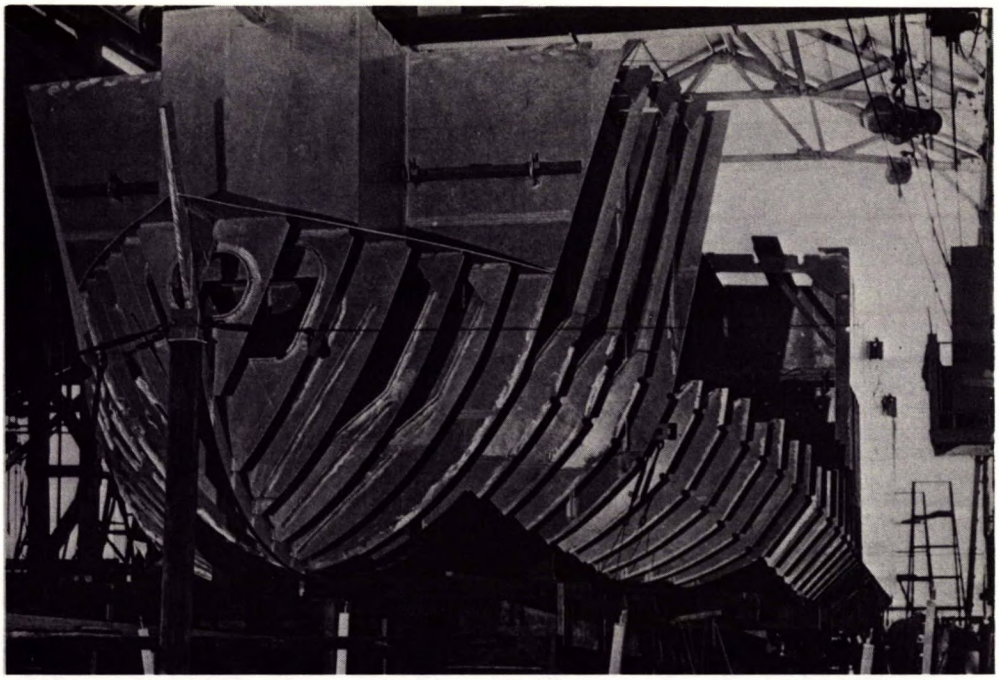


Figure 11. View from forward end showing fore-peak tank, anchor chain locker, port side amidship plating panel, bottom floor wing brackets of No. 3 unit and forward ballast tank.

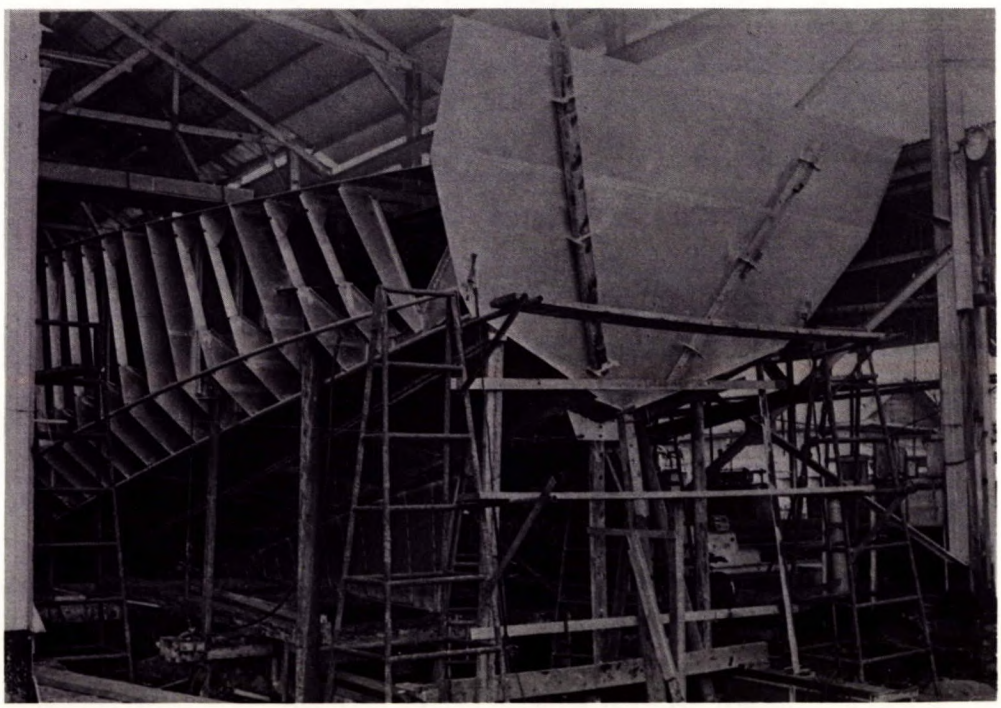


Figure 12. View of transom, bottom stern, shell plating, skeg, after-end framing, with 2-inch chine rods in position.

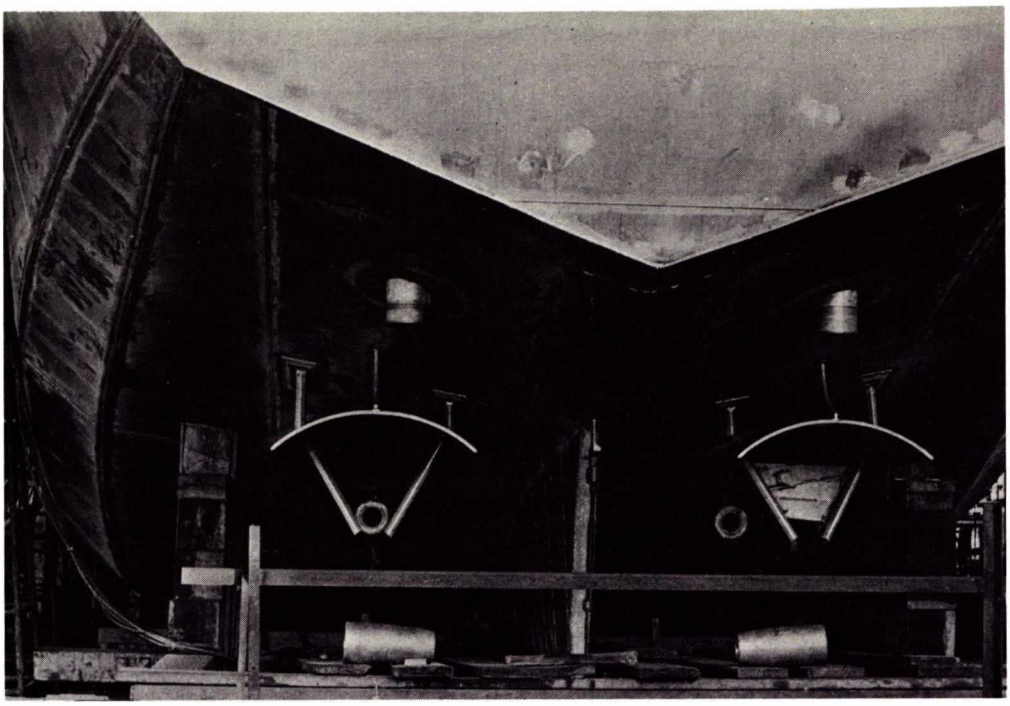


Figure 13. View looking to stern of vessel showing propeller cavitation plates, propeller boss "A" brackets, and stern tube.

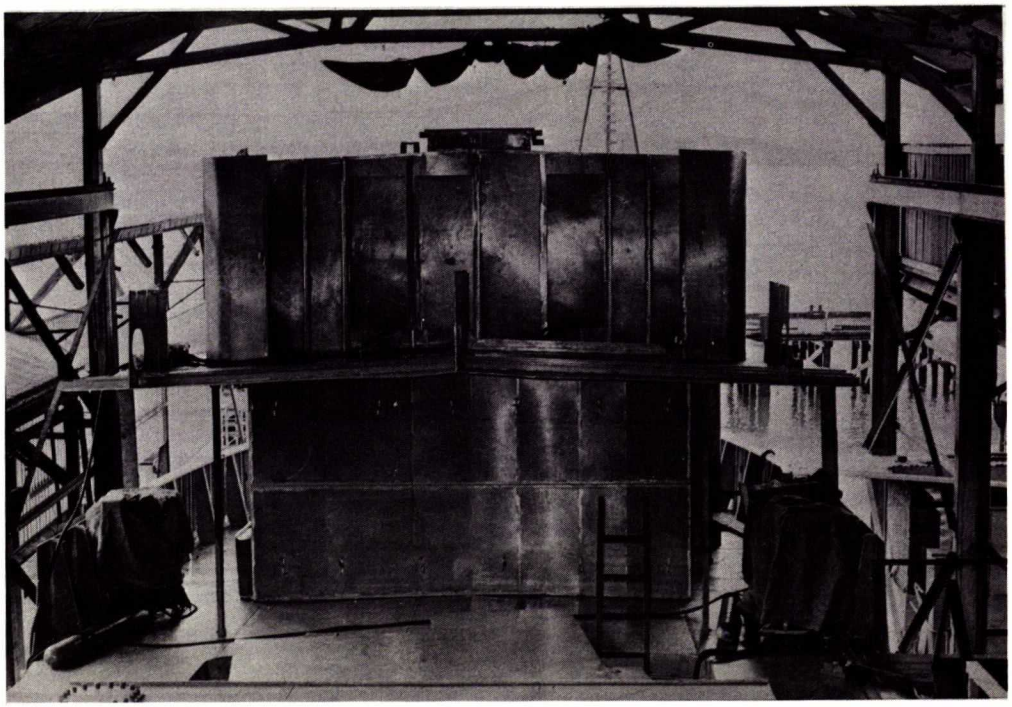


Figure 14. Showing erection of bridge and main deck accommodation, engine room skylight hatch, section of main deck and after bulkhead can also be noted. Plates in foreground are bridge deck roof plates.

Ferro-Cement Boats



Mr. Hagenbach

by

T.M. Hagenbach,
Managing Director, Seacrete Ltd.,
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Mr. Hagenbach (M.A. Cantab) the 58-year old Managing Director of Seacrete Ltd. and Windboats Ltd., Wroxham, Norfolk, England, took an honours degree in Law at Cambridge University and subsequently qualified and practised as a lawyer in the West Riding of Yorkshire. Feeling that "Boats were a more congenial way of making a living" he acquired a Norfolk Broads boatyard in 1946, which soon gained a national and later an international reputation. Starting the manufacture of ferrocement (Seacrete) boats some nine years ago, his company is now regarded as the world leader in this sphere. (Editor's Note: The author prefers the use of "ferrocement" as one word.)

ABSTRACT

After tracing the history and development of ferrocement as a boatbuilding material and drawing comparisons with the physical properties of competitive materials, the author contends that ferrocement – of which "Seacrete" is a specialized form – is the logical material from which to build fishing and commercial craft for the following main reasons:

1. The ability to build hull, decks, bulkheads, floors and engine bearers, fish tanks and bulwarks in one piece, resulting in a monolithic structure of immense strength which actually increases in strength with age.
2. Due to low cost of raw materials and the type of labour that can be employed, a ferrocement hull will generally cost less than an equivalent hull in other material.
3. Because it has great resistance to abrasion, will not corrode, has proven aging properties and is immune to marine borers, maintenance costs with a ferrocement hull are less than any other.
4. The ease with which a ferrocement hull can, in the event of damage, be repaired by unskilled labour in any climatic conditions except freezing.

Brief details will be given in the paper of approximately 150 ferrocement craft built by the Seacrete company and acceptance of the material by Lloyds Register of Shipping, Bureau Veritas, the United Kingdom White Fish Authority and the Food and Agriculture Organization of the United Nations in Rome.

FERROCEMENT BOATS

It is my intention today to present to you the case for ferrocement boats. Whilst these are frequently and popularly referred to as "Concrete Boats" nothing is really further from the truth.

It is of course true that in both cases sand, cement, water and steel reinforcement are used, but beyond that there is a real and fundamental difference, which I will explain later.

First let me point out that using concrete in the marine field is certainly not new. Between 1917 and 1922, due to the shortage of steel during and just after World War I, over 150,000 tons of concrete shipping was built on both sides of the Atlantic. The vessels ranged in size from 7,500 ton oil tankers to small tugs and lighters, and the hull thickness was usually between 4 inches and 6 inches.

The main point that I wish to make in regard to these old concrete craft is that in the light of tests carried out recently on panels cut from them, it was found that they are stronger today than when they were built. This is a normal characteristic of almost any cement product – it increases in strength with age.

The material that we shall discuss is ferrocement. Probably the inventor of the technique was M. Jean Louis Lambot, a Frenchman who was born in Montford in 1814. In the Museum at Brignoles, France, there is a ferrocement boat built by Lambot over 120 years ago. The boat is 11 feet 8 inches long and 4 feet 4 inches across the beam. The sides are approximately 1 3/8 inches thick and there is a bulwark of approximately 2 5/8 inches in breadth with an iron strip on top. It is still in fairly good condition and the metal pins to be used as rowlocks are still in position.

The name "ferrocement" was coined by Professor Pierre Luigi Nervi, to describe a new material consisting of cement mortar and reinforcement in multiple layers of light mild steel mesh.

Nervi showed that if there was a high percentage of mild steel evenly distributed throughout the cement mortar, the result was a marriage of the steel and mortar, resulting in a waterproof homogeneous material with a high degree of elasticity and a high resistance to cracking.

This is the vital difference between concrete and ferrocement. In the case of reinforced concrete there is no marriage of the metal to a concrete mix and normally reinforced concrete is not waterproof.

Nervi made slabs of up to 2 1/2 inches thick without losing any of the particular qualities of ferrocement. In 1943 ferrocement as a hull material was accepted by the Italian Naval Register and the Department of Marine Engineering of the Italian Navy.

Following this various craft were built in ferrocement in Italy, including a 165-ton motor yacht "Irene" – with a hull thickness of 1 3/8 inches, a 20-ton crane pontoon "Toscana", a trawler "S.Rita", and a 41-foot ketch "Nennele".

So far as the marine field was concerned, the data and technique appeared to lie dormant until 1959 when Mr. Paul Hagenbach, D.I.C., A.M.I.C.E., A.M.I.E.Aust., A.M.I.Struct.E., at Civil Engineer who had taken degrees both in Zurich, Switzerland, and in London, England, persuaded me, his uncle, with the boatbuilding company of Windboats Ltd of Wroxham, Norfolk, England, to embark on ferrocement boat construction.

Many of you hearing this paper may be sceptical. Believe me, positively no-one was more sceptical than me. I regarded concrete as something that one used for making a garden path and which cracked if anything dropped on it. My nephew was a very persuasive young man, so we got under way.

With the knowledge that I now have, perhaps the most remarkable thing about ferrocement is the length of time that it has taken for interest in it on a worldwide scale to be aroused to its present pitch. However, to those who know the world of ships and boats and the nature of the people who buy them, this is not altogether surprising.

A boat of any size represents to the buyer, particularly if he is a fisherman or commercial user, a sizeable long term investment. He is, therefore, naturally somewhat conservative in his outlook, with a strong leaning towards materials with which he is familiar and whose qualities – even if some of them are undesirable – he knows well.

I confess that it took some time for me to become absolutely convinced that ferrocement was logically right. Immensely strong, maintenance free, easy to repair and economical to build. I realised however that there was bound to be incredible prejudice against it.

We developed our own specialised form of ferrocement, called it "Seacrete" and formed a company, Seacrete Ltd., especially to develop it. The first three hulls were made by Seacrete Ltd. for their parent company, Windboats Ltd, for use in Windboats' Fleet of Norfolk Broads hire craft. There were three reasons for this, apart, of course, from the fact that at that time it would have been practically impossible to find any other buyer.

The first was that a Norfolk Broads Holiday Hire Fleet is as good a testing ground as you will find for materials whose claims for attention include toughness and durability. A cruiser let for 25 weeks each season will have many holiday skippers, most of them inexperienced and liable to submit a boat to more ill-treatment in a week than a professional would in a year.

The second was that it would enable us to compare the wear and tear suffered by the Seacrete boats with that to