

BOBP/REP/119

TRAINING MANUAL **on** **the construction of** **FRP beach landing boats**



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on

the construction of FRP beach landing boats

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GCP/GLO/200/MUL



This training manual is one of a series prepared during the course of the project GCP/GLO/200/MUL. The conclusions and recommendations given in the document are those considered appropriate at the time of its preparation. They may be modified in the light of further knowledge gained at subsequent stages of the project.

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Cover photo:

The first FRP IND-30 design beach landing boat under construction during the training course at Ayyappa Boat Builders in Kakinada, Andhra Pradesh, India, under the FAO project “Safety at sea for small-scale fisheries in developing countries” (GCP/GLO/200/MUL), funded by the Swedish International Development Cooperation Agency (Sida), the International Maritime Organization (IMO) and the Swedish Maritime Administration (SMA).

Preparation of this document

This manual has been developed from information collected during the FAO project “Safety at sea for small-scale fisheries in developing countries” (GCP/GLO/200/MUL), funded by the Swedish International Development Cooperation Agency (Sida), the International Maritime Organization (IMO) and the Swedish Maritime Administration (SMA).

The manual was partly developed from the FAO Fisheries and Aquaculture Technical Paper 507: *Fishing boat construction: 4. Building an undecked fibreglass reinforced plastic boat*, by Thomas Anmarkrud. It draws heavily from the experience gained during a training course conducted in Kakinada, India for FRP boatbuilders and from current practices in India and Sri Lanka in building beach landing fishing boats.

Two boats of the FAO IND-30 design were built during the training course. Øyvind Gulbrandsen, FAO Consultant Naval Architect, was responsible for the final IND-30 design.

Abstract

This manual on construction of fibreglass reinforced plastic (FRP) beach landing boats has been prepared primarily to assist small boatyards in Tamil Nadu, India that build beach landing fishing boats, but may also be used as a guide for making good quality FRP boats as well as for FRP training in the region.

The manual should be seen as a supplement to FRP boatbuilding manuals available in the Food and Agriculture Organization of the United Nations (FAO) and other international publications. It assumes prior knowledge of FRP hand lay-up processes and terms generally used in the industry.

Recommendations on working conditions, materials and quality control are based on tropical ambient conditions and the type of boatyards likely to build such boats.

Part I of the manual contains general information on FRP materials, handling and working conditions. Part II describes the building of a hull plug and a mould and Part III describes the building of a beach landing boat. Finally, Part IV contains information on manufacturing defects and repairs.

The manual has four annexes that provide further information related to FRP boatbuilding. Annexes 1 and 2 contain a bibliography and a glossary, respectively. All drawings for the FAO IND-30 boat design are provided in Annex 3. Finally, Annex 4 contains the draft recommended construction standards for FRP fishing vessels. These standards are a part of the FAO/ILO/IMO *Safety recommendations for decked fishing vessels of less than 12 m in length and undecked fishing vessels*, which are currently under development.

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Acronyms

BLC	Beach landing craft
BOBP-IGO	Bay of Bengal Programme Inter-Governmental Organisation
CIFNET	Central Institute of Fisheries Nautical and Engineering Training
CSM	Chopped strand mat
FAO	Food and Agriculture Organization of the United Nations
FRP	Fibreglass reinforced plastic
ILO	International Labour Organization
IMO	International Maritime Organization
MEKP	Methyl ethyl ketone peroxide
MEK	Methyl ethyl ketone
PVA	Polyvinyl alcohol
PVC	Polyvinyl chloride
Sida	Swedish International Development Cooperation Agency
WR	Woven roving

Acknowledgements

The authors gratefully acknowledge the important contributions of many experts with fiberglass reinforced plastic (FRP) boatbuilding experience, including V Babu Rao, National FRP Consultant, for his excellent support during the training and boatbuilding exercise in Kakinada, Andhra Pradesh, India, as well as Ayyappa Boat Builders for providing the infrastructure.

Special thanks are also due to BOBP-IGO and its Director, Dr Yugraj Singh Yadava, for their excellent logistic support to the FRP boatbuilding training courses in obtaining trainee nominations from the Department of Fisheries of the Governments of Tamil Nadu, Andhra Pradesh and the Union Territory of Puducherry, contracting Ayyappa Boat Builders and local backstopping.

Several of the photos and illustrations used in this manual have been provided by Thomas Anmarkrud during the preparation of FAO Fisheries and Aquaculture Technical Paper 507: *Fishing boat construction: 4. Building an undecked fibreglass reinforced plastic boat*. Photos were also provided by other authors, including V. Babu Rao, during the training course in Kakinada.



Introduction

Fibreglass reinforced plastic (FRP) as a material for fishing boatbuilding was introduced in South Asia in the 1960s. It grew in popularity over the following two decades for two reasons: the escalating cost of good boatbuilding timber and the relatively lesser skills required to build small FRP boats.

FRP is ideally suited for mass production and its popularity for mass-built recreational craft in the developed world is well known. In both India and Sri Lanka, an opportunity was recognized by a few entrepreneurs for manufacturing FRP boats on a large scale. Boatyards using the latest developments and conforming to international standards were set up nearly 30 years ago to cater to the increasing demand for larger harbour-based fishing boats as well as to meet an export demand for recreational craft. In Sri Lanka, nearly all boats built today are made of FRP.

Small-scale fisheries also suffered a steady decline of catch per effort and traditional boats could no longer provide adequate earnings because of their limited range. FAO, through its Bay of Bengal Programme in the late 1980s, developed a prototype fishing boat suitable for beach-based operations and capable of an extended range of operation. This was the forerunner of the beach landing craft (BLC) in India. The growing scarcity of suitable timber for traditional beach boats saw the rapid increase of FRP BLC of many sizes and types along the east coast of India in the past two decades.

The flipside to this rapid development was the growing number of FRP boatyards where occupational safety and health conditions as well as quality control was unknown. In addition, fishers were unaware of the need for strict quality.

The tsunami in December 2004 exacerbated the problem. The huge amount of humanitarian aid, the rush to provide needy fishers with replacement boats and the mushrooming of opportunistic boatyards resulted in FRP fishing boats of even poorer quality. Thousands of boats built after the tsunami were unserviceable after just a couple of years.

Through the FAO project “Safety at sea for small-scale fisheries in developing countries” (GCP/GLO/200/MUL), funded by the Swedish International Development Cooperation Agency (Sida), the International Maritime Organization (IMO) and the Swedish Maritime Administration (SMA), it was identified that the first corrective step required was to establish safety guidelines for construction and to promote good FRP boatbuilding practices. Development of a training manual addressing the key area of quality control and boat structure was seen as a priority.

This manual draws heavily from the experience gained during a training programme conducted in Kakinada, India for FRP boatbuilders, where two FRP BLC of FAO design IND-30 were built, and from current practices in India and Sri Lanka in building beach landing fishing boats.

Recommendations on working conditions, materials and quality control are based on tropical ambient conditions and the type of boatyards likely to build such boats. Many of the hand lay-up processes described are equally applicable to other FRP boats built in the region.

Using the manual

This FRP manual is prepared for Tamil Nadu, India, but could also be used as a guide for making good quality FRP boats in the Bay of Bengal region and other regions where appropriate. Many of the applications are general and will apply to most kinds of FRP boats. It should be a supplement to FRP boat building manuals and books already available in FAO and other international publications.

This FRP manual assumes that the boatbuilder has some FRP experience and will use good practices.

Parts I and II contain general information on FRP boatbuilding and on mould and plug building, respectively. Part III describes the construction of an FRP BLC, used for fishing. Part IV focuses on FRP maintenance and repair work. Finally, Annexes 1-4 provide a bibliography, glossary, drawings for the FAO IND-30 boat design, and draft recommended construction standards for FRP fishing boats, respectively.



PART I

GENERAL INFORMATION



1 - FIBREGLASS REINFORCED PLASTIC

What is fibreglass reinforced plastic, or FRP? It is a composite of several materials (mainly fibreglass fibres and resin) laid down in alternating layers and hardened to form a solid laminate. By way of comparison, wood fibres in a tree are held together by their natural glue, lignin. Similarly in FRP, layers of fibreglass material are glued together with polyester resin. Both in a tree and in FRP laminate, the fibres give strength to the structure, and lignin and resin hold the fibres together, creating stiffness and distributing the load among the fibres.

If put together correctly, the laminate can be both strong and stiff with good resistance to fatigue and the influence of water. If constructed poorly, the laminate might still look good on the surface, but due to its poor quality, could degrade and collapse in half the expected lifetime or even less.

This basic manual concentrates on the process of preparing the mould and constructing an FRP boat by gluing together layers of bonded fibreglass fibres called chopped strand mat (CSM) with a resin called general purpose (GP) orthophthalic polyester (“ortho-polyester”). The fibreglass could also be glued together with other resins, like vinylester or epoxy.

The chemical, oil-based resin is toxic and flammable: therefore, safety considerations are important when working with this material. These precautions are set out in the following section.



Figure 1

This boatbuilder is saturating the fibres of CSM with polyester resin, using a resin roller.

He is also using a face mask respirator as protection against inhaling toxic fumes.

2 - MATERIAL DESCRIPTION AND HANDLING

2.1 FIBREGLASS - CSM (CHOPPED STRAND MAT)



Figure 2

CSM consists of randomly oriented fibres from 25–50 mm (1–2 inches) in length, held together with a styrene soluble polyvinyl acetate binder.



Figure 3

Chopped strand mat-E (CSM-E) fibreglass specified for marine applications.

2.2 POLYESTER RESIN

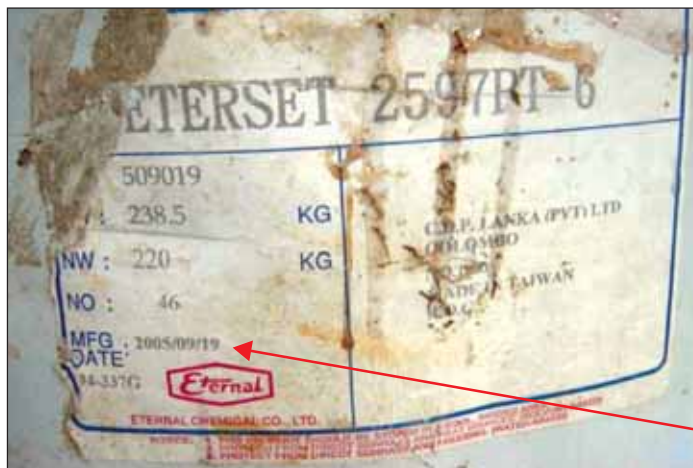


Figure 4

The most commonly used polyester resin is a general purpose (GP) orthophthalic-polyester ("polyester"). This resin, when mixed with 1% of methyl ethyl ketone peroxide (MEKP) catalyst, typically has a gel time of 8–15 minutes at 30 °C.

When stored in the dark and below 25 °C, the resin can remain stable for six months. When stored at standard tropical temperatures, stability will be reduced to three to four months from production date (as shown on the label attached to the drum).

2.3 GELCOAT / TOPCOAT

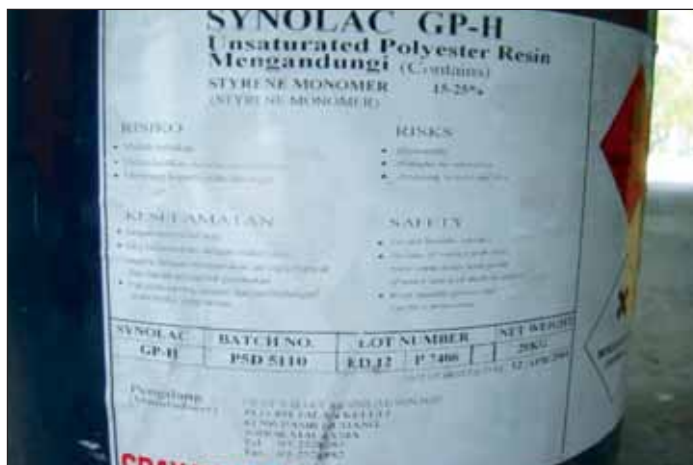


Figure 5

The date of production is written on the container label, and storing stability is the same as for polyester resin.

The gelcoat comes unpigmented, but colour can be added. Use no more than 10% and mix thoroughly at slow speed using a "blender" attachment on a power drill, prior to application. Add no more than 2% hardener to the gelcoat. The topcoat is made by mixing 4% of wax into the prepared gelcoat. The topcoat will air-dry on the surface and is often used as a finish coat.

2.4 HARDENER / CATALYST

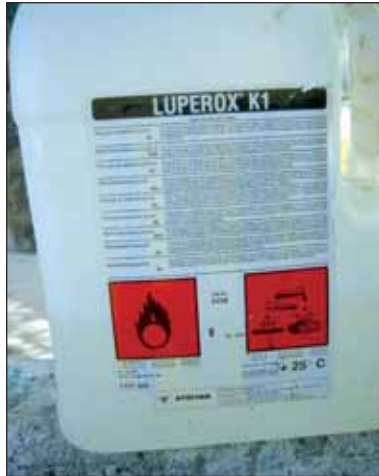


Figure 6

The hardener, or catalyst, is used to make the polyester cure. It is extremely corrosive, and special care must be taken in handling and storage. Wear safety glasses and rubber gloves for personal protection.

When hardener and resin are mixed, the chemical reaction generates heat (exotherm). If hardener is spilled in quantity, it may react quickly with other materials and cause a fire. Hardener should be stored separately from polyester.

If accelerator is used to make a fast-cure “fixing putty”, the accelerator must be mixed thoroughly with the putty before hardener is added. Mixing accelerator and hardener together will cause an explosion. When temperatures are near 37 °C, follow the manufacturer’s advice and use a minimum 0.8% of hardener, which will result in a shorter geltime. For ease of working, prepare this mixture in smaller batches.

2.5 WAX



Figure 7

When preparing a used mould for fibreglassing, a moderate amount of high quality paste release wax should be spread on the surface of the mould and then polished to a high gloss with a clean cloth.

When preparing (breaking-in) a new mould, apply five to ten layers of wax. Polyvinyl alcohol (PVA) may also be used as a mould release before starting the first five products. A good quality mould should not require use of PVA, and should need only a light waxing and polishing after each demoulding. This gives the best finished results.

2.6 BUFFING COMPOUND



Figure 8

The buffing compound, or paste polish, comes in different grades: coarse, fine or superfine. It is used when building up a new high-gloss finish in a mould or repairing an FRP hull. First, the surface is sanded with water and wet sandpaper in grits from 240 to 1 200 (Figure 15). Second, a coarse paste is used to polish the surface. Finally, after a thorough washing, the surface is buffed with fine grade paste and polished with wax.

When repairing a mould, the repaired spot has to be sanded, polished and then broken-in, as described above for a new mould.

2.7 ACETONE

Acetone is a liquid solvent, often used to dissolve and remove polyester from brushes, rollers and other tools before the polyester sets up or cures. Acetone can be absorbed through the skin and stored in the body. It also removes the natural oils that keep skin flexible and healthy. Extensive use of acetone over long periods without proper protection can have serious health implications. Direct contact should be avoided by using protective gloves when working with acetone. Hands should not be washed in acetone.

2.8 STYRENE

Styrene is a standard ingredient in polyester resin. It is also a solvent and can be used to lower the viscosity of polyester and gelcoat. While styrene is also necessary for the curing process, more than 5 percent should not be used. Higher amounts can unbalance the curing process and weaken the finished laminate. When repairing old laminates, a light styrene wipe prior to laminating can improve the bond between old and the new polyester laminates. Styrene is also effective for cleaning moulds.

**GOOD VENTILATION IS EXTREMELY IMPORTANT
WHEN WORKING WITH
POLYESTER RESIN, STYRENE AND ACETONE!
THE FUMES CAN BE HARMFUL TO HEALTH!**

2.9 POLYURETHANE FOAM

Pourable polyurethane foam (PU) may be used inside thwarts and other hollow cavities for floatation. To make the foam, two liquids, delivered in separate cans A and B, must be mixed in equal amounts (1:1) for proper expansion and cure. The amount of liquid needed to achieve the desired volume should be confirmed before use. Typically, 1.6 kg of mixed liquid expands into approximately one cubic foot of foam. PU foam also comes in blocks and sheets in variable densities.

Polyester resin can be applied directly onto cured PU foam.

**WHEN PU FOAM IS CURING,
ISOCYANATE GASES DEVELOP
THAT ARE HARMFUL IF INHALED!**

2.10 EXPANDED POLYSTYRENE (STYROFOAM)

This material can also be used for flotation. Styrofoam is generally the cheapest foam available and comes in blocks and sheets. However, it is easily damaged by solvents and melts on contact with acetone, styrene and gasoline. This means that it is not practical to laminate directly on styrofoam without isolating it with solvent-proof plastic. Expanded polystyrene also absorbs water when exposed for long periods. It therefore has to be waterproofed, for example, with bitumen emulsion.

2.11 MATERIAL HANDLING AND STORAGE

Precautions to be taken when handling and storing FPR materials include sections 2.11.1 to 2.11.5:

2.11.1 Ordering material

Choose a material supplier who is helpful and experienced. Build a good working relationship with him or her. Materials received should always be checked against those ordered from the supplier. It should never be assumed that what arrives is what was ordered. Lot number and date of production and/or expiry must be checked as soon as the containers arrive. If the product is old or of a different quality than ordered, it should be returned at cost to the supplier. Such cross-checking is important, because if the boat breaks down due to use of inappropriate raw materials, the boat owner will blame the builder, not the supplier.



Figure 9

Always check and write down the lot number and the production date when receiving storage time-sensitive products.

This information should always be given on the container.

This example shows a 20-kg bucket of gelcoat with required information on the label.

2.11.2 Documentation

The supplier should be asked for technical data sheets for each product, which should then be retained for future reference. Data sheets should give all the physical and technical properties required by the boat designer to produce a quality product. Resins can vary widely in characteristics such as viscosity and strength. Data sheets also provide key information such as proper mixing ratios and the critical temperature ranges suitable for laminating.

Always keep a record of all material used under the construction.

2.11.3 Fibreglass

Fibreglass (chopped strand mat) should be kept dry and clean. This is of great importance but difficult to achieve in a hot and humid climate. The fibreglass mat should be kept in a dry and ventilated room. If there is much dust or contamination in the air, or if there is a possibility of rain, cover the material in plastic.

2.11.4 Resin, catalyst and accelerator

Polyester and gelcoat should, if possible, be stored at less than 25 °C. The shelf life becomes greatly reduced at higher temperatures.

Resin, catalyst and accelerator should be stored separately, in a cool and dry place.

Thorough mixing of gelcoat and resins, in their original container, is required before use. According to current standards, resin is supposed to be mixed for 10 minutes every day to keep additives from separating and settling to the bottom of the drum. If not stirred before use, additives in gelcoat sometimes separate and rise to the top of the container.



Figure 10

If a drill with a proper mixing attachment is not available, the second best alternative is to roll the drum.

However, if the drum has been standing upright for some time, polyester resin near the bottom may already be of higher viscosity, and rolling the drum for a full 10 minutes might not be enough to fully mix the heavier and lighter resin. If not fully mixed, the first resin drawn from the drum tap may be of a different viscosity than that drawn later.

2.11.5 Temperature and humidity

For best results when doing the lamination, the raw materials, the mould and the working environment should all be at the same temperature.



Resin, catalyst and accelerator should be stored in a cool and dry place; the material will last longer if it is stored properly.

Figure 11

Even a simple workshop used for FRP construction should have a gauge showing temperature and relative humidity of air in the workshop.

The version shown here is sufficient and inexpensive.

If the temperature is much above 30 °C, for example 37 °C, geltime will be shortened. If the temperature is considerably lower than 30 °C, risk of insufficient curing is high. Lower temperatures and high humidity can also cause “aligating” (wrinkling) of the gelcoat.

If air humidity rises to above 80 percent, the binder in the CSM will absorb moisture and the reinforcement (CSM) will get “wet”, *i.e.* lose its strength.

A common solution to many of these problems is for lamination work to be done in the morning before the sun gets too hot or the humidity rises.

3 - WORKSHOP FACILITIES

The two main important things with FRP boat building is **the workshop** and **the quality**.

In the peak of summer in tropical countries, ambient temperatures may exceed 35° C. It is therefore very important that the premises are shaded from the sun and wind, dry and adequately ventilated to remove styrene fumes and dust from the moulds and laminating area. FRP materials must be stored in conditions as dark and cold as possible to ensure maximum shelf-life.



Figure 12

It is very important to protect the work area and FRP materials from the sun, wind and rain.

Similar care is important for storage of the raw materials.

If a workshop like the one shown at left is not possible, a temporary shelter should be constructed using, for instance, canvas.



Figure 13



Very important...

It is very important to have a reliable shelter to work in that protects the job from rain, sun, wind, dust (elements that can contaminate the laminate and retard the cure), moisture, heat and humidity (as much as possible).

A concrete floor is a good investment.

**Keep the work area tidy!
Don't get into sloppy habits!**

4 - TOOLS TO BE USED

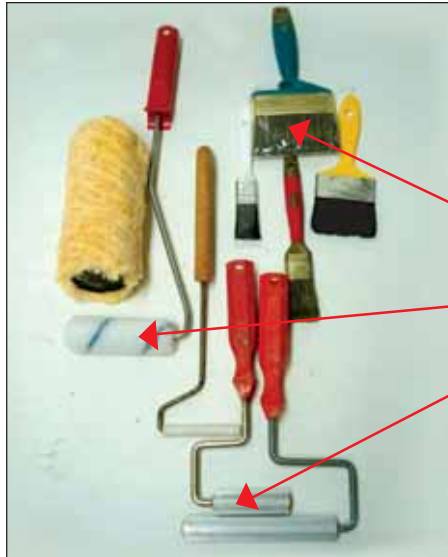


Figure 14

This photo shows examples of some tools used when building an FRP fishing boat.

The brushes are best for applying gelcoat, but can also be used for getting polyester resin into tight corners and onto small details.

Resin rollers of different sizes can be used. They should be made of materials that will not be damaged by solvents.

A variety of compacting rollers are employed for different applications.

The rollers must be used firmly but not too hard. Compacting must stop as soon as the resin starts to gel. Continued use of rollers at this time will only create air bubbles, not remove them.

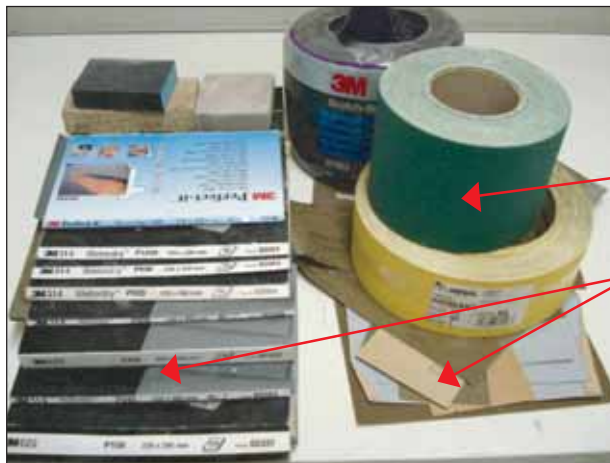


Figure 15

The 60- (or courser) grit sandpaper is used to sand the laminate first. The 80- and 120-grit sandpapers are used for medium finish work.

Wet sandpaper should be in these grits: 240, 400, 600, 800, 1 000 and 1 200. These are intended for finish work on the mould and on the gelcoat of the hull.



Figure 16

Funnels are handy for pouring polyester safely into smaller containers when larger buckets are not being used.

Transparent measuring containers of several sizes are useful for measuring polyester and gelcoat.

A weight scale is an alternative for measuring small amounts of gelcoat and polyester, and also for weighing fibreglass.



Figure 17

A variety of syringes can be used for correctly measuring very small amounts of hardener.

A typical cap from a soda bottle can usually hold around 5 ml of hardener.



Figure 18

Two sizes of masking tape are used for a variety of tasks. For example, it can be used to keep two different colours of gelcoat separate on the hull during construction or when isolating an area for repair operations. The tape is also handy for securing a plastic cover used for protection against dust or rain.

Scrapers with handles are used for spreading putty.

The wider, soft steel trowels typically used for bodywork on cars can also work well for this purpose.



Figure 19

A regular knife or utility-type knife with extra blades can be used for cutting dry reinforcement (CSM) or “soft” laminate from edges.

Screw drivers are needed for mounting stainless steel cleats and drain plugs.

CSM can also be cut with scissors or torn gently by hand.

A wood chisel is handy for removing bumps and cured strands of fibreglass.



Figure 20

Rubber mallets are useful for careful tapping of moulds to help with demoulding.

A regular hammer is more useful for driving in wooden wedges inserted around the edge of the mould.

Combination wrenches are used for mounting bolts and nuts on the fender and with cleats, eye bolts and u-bolts.

A spanner (adjustable wrench) is also handy for holding bolts and nuts during tightening.



Figure 21

A wood saw can be used for cutting foam.

A hack-saw can be used for cutting both cured laminate and stainless steel bolts.



Figure 22

An electric drill should be available with a full set of:

twist bits:

flat wood bits of different sizes for countersinking the 6 mm bolts for wooden fenders;

hard metal hole saw attachments are used with the electric drill for making larger holes in the FRP laminate.



Figure 23

Electric disc grinders are mainly used for sanding away damaged FRP, but also for abrading the laminate prior to assembly and to improve secondary bonding. They can be fitted with rubber backing discs for use with 40-grit sandpaper.

Carborundum cutting and grinding discs can be attached and used for cutting or grinding cured laminate and cutting off stainless steel bolts.

The machine at the right of the exhibit is excellent for flattening large areas.



Figure 24

Belt sanders are excellent for sanding in preparation for repairs and for getting into tight corners.



Figure 25

A power saw with a laminated hard metal blade, like the one shown here, is useful for cutting both wood and FRP laminate.

5 - BASIC LAMINATE BUILDING

5.1 PREPARING THE MOULD

Prepare the mould by either applying release wax and polishing, or applying mould release agent, as described in Figure 26. The next step in building an FRP boat is the preparation and application of gelcoat. After the gelcoat has been mixed with the right amount of hardener, as stated on the data sheet, it is important that the right thickness be applied either by rolling, brushing or spraying. An ideal total thickness of this layer of gelcoat is between 0.4 and 0.8 mm. Gelcoat thickness can be measured using a simple “wet film gauge” obtained from the gelcoat supplier. A gelcoat thickness gauge can also be made from a piece of metal. For practical reference, since a generous layer of gelcoat applied by brush is around 0.25 to 0.3 mm, two layers should be sufficient.



Figure 26

Brushing gelcoat on to the black surface of the mould is shown in the photo.



Figure 27

The photo shows the use of a gelcoat thickness or wet film gauge.

This initial layer of gelcoat must be properly cured before lamination can start. It is best to wait 3–4 hours for curing to be complete. If laminating starts sooner than one and a half hours after gelcoating, there is a danger that the polyester will soften up the gelcoat, causing it to wrinkle. This effect is called “aligating”.

To achieve a good primary bond between the gelcoat and polyester resin, the lamination process should be started as soon as possible after four hours and definitely within 24 hours of gelcoat application. This rule also applies for the “open time” (working time) of the polyester to ensure a good primary bond between laminate layers. (Primary bond is discussed in more detail in Part IV – Manufacturing defects and repairs). Precautions should be taken against contamination of the gelcoat surface. If a mould with fresh gelcoat is left overnight in an open shed, the mould should be covered with light plastic. This is especially important in wet or windy weather or other conditions that might result in gelcoat contamination.

All required materials should be prepared before starting to laminate over gelcoat. The fibreglass resin should be thoroughly stirred and at room temperature before hardener is added and mixed. Once resin is mixed with hardener, all steps needed to build a layer of laminate must be completed quickly as the mixture can be worked for only 10–15 minutes. Suppliers should provide a technical paper detailing how long polyester can be worked at a certain temperature with a specific amount of hardener.

Only mix as much polyester and hardener as can be applied to the fibreglass mat in the time available. A small amount of polyester mixed in large container, as shown in Figure 28, is less likely to start gelling early than if the same amount of polyester is mixed in a small container. The difference in gel time is caused by increased exotherm buildup. This problem can also occur if laminates are too thick.

5.2 MIXING POLYESTER RESIN

Follow the initial steps set out in the section on “Material Description and Handling”, make sure that you use the correct amount of hardener for a good cure.



Figure 28

A handy tool for measuring hardener can be made by attaching a piece of steel wire to a bottle cap. A syringe can be used to measure the exact amount contained in the bottle cap.

A typical cap from a soda bottle will hold 5 ml of hardener. To measure 1% of hardener by volume, one capful is sufficient for 500 ml (1/2 litre) of polyester.



A coat of polyester resin should always be applied before laying on the fibreglass mat. The metal roller is effective for working out any air bubbles and for compacting the resin and fibreglass layers together.

In case there is no scale for measuring polyester resin, one may assume that one kilogram equals almost one litre. For either measure, there will be no significant loss of quality when working with these materials on a sturdy structure such as the IND-30 boat.

5.3 THE FIRST LAYER, OR BACKUP LAYER

The first layer (backup layer) consists of resin and a 300 g mat. There should be no bumps or contamination on the cured gelcoat prior to starting the lamination. It is vital that all air bubbles are carefully worked out and the first layer is allowed to cure for 4 to 6 hours, maybe even overnight, before the next layer is added.

For the backup layer, it is especially important that the fibreglass mat be torn (Figure 29) rather than cut. For this layer, the pieces of mat should be placed edge to edge with no overlap. This technique provides a smooth transition between the skin coat and subsequent layers, and does not interfere with the structure of the boat. Since the skin coat is not a structural layer, joining fibreglass pieces together in this way does not interfere with the overall strength of the final product.

Iso-polyester should always be used in the backup layer to help waterproofing the hull and avoid osmosis.



Figure 29

This photo shows how the first layer (backup layer) of fibreglass is applied.

The gelcoat is completely covered with a generous layer of polyester to make sure no air is trapped close to it.

Fibreglass mat with torn edges is then applied carefully over the polyester layer and rolled thoroughly.

Figure 30

Proper use of compacting rollers is very important. They are used to ease fibreglass mat into the underlying polyester and remove all air trapped between the two. This process must be completed before the polyester begins to set up and cure.

This boatbuilder is using a small compacting roller to push fibreglass into a tight groove and ensure that any trapped air is removed.

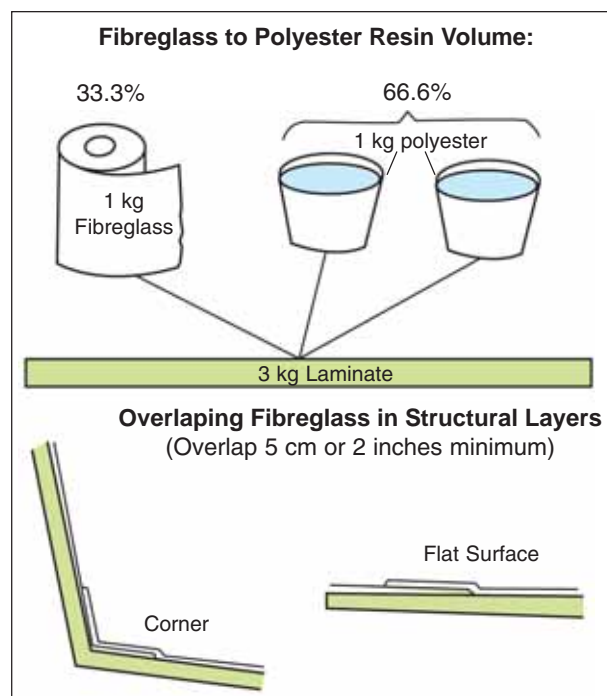


Figure 31

Shows the right amount of fibreglass (CSM) and polyester to use in a CSM laminate, and how to stagger/overlap the pieces of fibreglass mat in a structural layer.

5.4 INSPECTIONS

Continuous visual inspection is very important for quality control. A close watch must be kept to detect surface contamination and trapped air. If the fibreglass is too wet, the laminate will turn white. If the exotherm builds up too quickly, the colour of the laminate will change and appear aerated/foamy. If too much polyester has been used, wet puddles will occur. The boatbuilder is usually the only person who can detect and correct such faults, and when the next layer of laminate is in place, the faults will be invisible. If such faults are not corrected immediately, the finished new boat will already have weaknesses, minor or major.



Figure 32

This photo shows the results of poor quality control.

Large pockets of air have been left in the first fibreglass layer on top of the gelcoat.

5.5 LAMINATION OR MOULDING

For construction of the 8-m IND-30 BLC, both CSM and woven roving (WR) are being used. A main concern when laminating is to assemble each layer at the proper time interval. The laminate should be allowed to cool down after the curing process (exotherm) before starting on the next two layers. The topic of primary and secondary bonding and preparation of the surface to be laminated are set out in more detail in Part IV, Manufacturing defects and repairs.

6 - QUALITY

Quality is very important. Because the FRP boats are hand-made, the quality will always vary. Since you are the boatbuilding expert, you will probably be blamed if the quality suffers whenever a customer insists on cutting expenses.

FRP boats should comply with national safety legislation. For guidance, see also Annex 4 of this manual and the *Safety guide for small fishing boats* (BOBP/REP/112, 2009).

High quality starts with good design and drawings, and is greatly helped by being well organized.

The IND 30 is designed by an experienced professional naval architect who, as part of his training, has studied all aspects of boat design. It is for these reasons that the drawings should be understood and the boat built according to the drawings.

See the drawings for the IND-30 in Annex 3.

Air, moisture, dust and dirt in the laminate all contribute to quality problems with the boats.

Osmosis is one problem to be avoided as much as possible; cleanliness, thoroughness, correct material storage and choice will all help.

FRP is almost waterproof but not totally, and water will work its way through the gelcoat and cause osmosis, collecting in any voids or pieces of dust and dirt behind the gelcoat, and will begin to blister and rot the laminate.

FRP laminates with osmosis can lose up to 30 percent of their strength from osmosis.

**A good boatbuilder is a careful boatbuilder,
and the quality of the work can be judged
years after the job has been done.**



Four practices to avoid

1. The practice of laying dry glassfibre into a mould and wetting through is unacceptable. You must wet the job first to get the fibres wet out correctly.
2. The practice of laying all layers in one go is unacceptable due to problems of exotherm (laminate gets hot and turns white or purple, loses strength and pulls and shrinks the part in that area).
3. The practice of using unpromoted resin (pure resin without accelerator) as a solvent for storing brushes is dangerous. You will be using a brush with resin in it that will not cure properly.
4. Do not use less than 0.8% catalyst (8 ml to 1 kg polyester) or less than 1% accelerator, or the part may not cure properly. Check with your resin supplier.



Figure 33

Examples and consequences of bad practice:

- Avoid standing barefoot directly on the laminate. This is very dangerous to your body as well as to the construction. Sweat, talc and dirt will weaken the strength of the bond between the layers.
- Avoid wetting through the CSM mat, as mentioned above.
- While laminating and curing, never expose any part of the FRP boat to the sun.

AVOID BAD PRACTICES!

7 - HEALTH AND SAFETY ISSUES

Personal and environmental safety when working with FRP

7.1 PERSONAL SAFETY

7.1.1 Eye safety

In all industrial environments, protection is needed to prevent objects or chemicals from getting into workers' eyes. When working with FRP, care is needed to avoid both chemical hazards, including anything from eye irritation to severe corrosion and physical hazards such as irritation from airborne particles.

For example, the catalyst/hardener (**methylethyl ketone peroxide, or MEKP**) is a severely corrosive liquid. Grinders produce many dangerous airborne particles. In both cases, eye protection, mainly in the form of goggles, should be worn when working with FRP materials.



Figure 34

At left are examples of goggles for effective eye protection, ear protectors for hearing safety, and a dust mask for lung protection during grinding.

7.1.2 Hearing safety

Being exposed to loud sounds, constantly or even periodically, can eventually lead to permanent hearing loss. Ear protection should always be used whenever a power tool, such as a grinder or other noisy machinery, is in operation. For safety reasons, extra attention is necessary when communicating with and locating co-workers when ear protection is used; otherwise, it will not always be possible to hear a warning.

7.1.3 Breathing safety

Lungs are one of the most obvious and important organs to protect in a boatbuilding plant. Most boatyards have mechanical ventilation to keep the levels of volatiles, or hazardous fumes, and dust below an acceptable level. Even if fans/extractors are operating, a suitable respirator should be worn when there is direct exposure to hazards such as styrene fumes and fibreglass dust. There may be no immediate indication that exposure to such hazards is having an effect, but in the long-term, fibreglass dust will collect in the lungs, causing breathing problems and eventually result in lung collapse. The styrene fumes from polyester can cause nerve problems and possible brain damage, while the isocyanides released by the curing of polyurethane are poisonous and the amines released during the curing of epoxy have been linked to cancer.

When working with volatile fumes in a closed area with poor or no ventilation, such as inside a boat, respirators with an external source of fresh air must be worn for protection. Failure to use such protection can result in chemical lung inflammation.



Figure 35

The most commonly used respirator for protection against fumes is shown here. The filter in the front is disposable and should be replaced regularly.

Different filters are available for specific fumes and also for dust.

The filter must be clean and of the proper type.



Figure 36

This picture shows a battery-powered face mask. The battery pack is worn on the belt. Air is forced through the filters and pushed up into the mask, which provides protection for both eyes and lungs.

This apparatus is comfortable to wear and facilitates communication since only the eyes and nose are covered.

7.1.4 Walking and climbing safety

Uncured fibreglass and resin are very slippery. Spills on the floor, steps and scaffolding used for climbing can result in severe falls and other accidents. In particular, when working on larger boats, it is important not to cause damage when accessing wet laminate. Care is needed when constructing and when using steps and ladders. Electrical cables can also cause tripping.



Figure 37

Watch your step!

Great care is needed when walking on narrow planks and stepping on wet slippery fibreglass.

7.1.5 Hand and finger safety



Fibreglass boat construction requires fully functioning hands and fingers. Boatbuilding careers can be lost once hands and/or fingers are damaged or lost.

Disc grinders and power saws should always be equipped with a suitable guard.

Although wearing gloves is a very important protection from chemicals and abrasion, they can sometimes hamper the ability to work safely with power tools. It is necessary to balance work needs with maximum protection against chemicals and power tools.

7.1.6 Skin safety



Invisible threats can be just as dangerous as visible ones.

Direct contact with solvents like styrene and acetone must be avoided. They can be absorbed into the skin and, ultimately, the bloodstream. This absorption can result from directly touching the liquids or the air when heavily polluted with solvents during the use of spray equipment. The effects of repeated, direct contact with solvents are cumulative and long-term.



Figure 38

This photo shows the proper use of long-sleeved gloves when applying resin.

These workers are also wearing half-mask respirators for protection against volatile fumes like styrene.

Boatbuilders should always have available a generous supply of industrial gloves capable of withstanding the solvents being used.

7.1.7 Fire hazard safety



Smoking and open fire should not be permitted in a boatbuilding plant or boatyard.

Most materials used for FRP construction are highly volatile and flammable. Everyone in the workplace must take responsibility for eliminating fire hazards. The combined effect of smoking cigarettes and inhaling volatile fumes greatly increases health risks. At least one fire extinguisher should always be available in a boatyard.

Electrical appliances and power tools must be used with care. Electrical cables represent major risks, including poor wire condition and loose contacts that can cause explosions or start fires. Air-powered tools are safer.

Any leakage or spillage of catalyst can pose a significant fire hazard whether spraying or hand laminating.

When too much catalyst is used or when too much time is spent on some laminating details, resin may begin to set up in the bucket (early “kick off”). In such circumstances, the exotherm can quickly build up causing a fire unless the bucket is removed to a safe place and water is poured on top of the resin.

Abnormal exotherm buildup can also occur when saturated wet fibreglass is discarded into a waste container. Rags, wet with solvent, should not be discarded into the same container.

Mixing accelerator and catalyst (promoter and initiator) together causes explosions.

7.2 WORKSHOP SAFETY

7.2.1 Controlling dust and fumes

When sanding, the most effective way of controlling dust is at the source. An extraction fan/dust collector with a large hose diameter, or a vacuum cleaner (preferably a “HEPA VAC”) connected to a hose attachment on the grinder itself, is required.

Because it is very difficult to eliminate all dust at the source, a combination of approaches can be useful in maintaining good working environment in a workshop where several operations are being carried out at the same time.

In a boatbuilding plant, the most effective approach is to carry out as much of the sanding and grinding as is practically possible in a separate room.

To control fumes, there should always be some sort of air extraction and ventilation in the painting, gelcoat or laminating work areas. This arrangement minimizes the part of the boatbuilding plant where respirators are required.



Figure 39

The man on the left is spraying gelcoat and has a respirator with an external air supply. This is good practice. The man on the right is preparing CSM and wearing no respirator, even though the air is heavily loaded with styrene. This is bad practice.

In addition, since the activities are carried out so closely together, the gelcoat overspray will contaminate the fibreglass on the cutting board. This could reduce the quality and strength of the resulting laminate.

7.2.2 Controlling fire hazards



Figure 40

One example of very dangerous conditions in a workshop.

The electric grinder is shown sitting on top of a full barrel of polyester, which is highly flammable!

The shop manager has overall responsibility for maintaining a safe working environment and reducing the risk of fire!

7.2.3 Reducing waste and disposal of material

Plans and good routines for waste disposal are necessary to minimize fire hazards and pollution. Local authorities have regulations on how to handle the hazardous waste. Money can often be saved by separating hazardous and non-hazardous waste.

Careful management of raw materials to avoid wastage also saves money

Note that discarded chemicals, hardened resins and foams all have short- and/or long-term negative effects on the environment.

7.2.4 Raw material storage

Ideally, all raw materials should be stored in separate rooms to retain quality prior to use and for safety reasons. In particular, it is important to keep the catalyst in a separate room from the polyester and gelcoat in order to reduce the potential hazard of fire.

7.2.5 Documentation

All technical data sheets provided by the supplier for each material purchased should include everything needed to handle the chemical safely. It is recommended that all technical data sheets be collected in a binder, kept in a safe place and be available to all personnel who may potentially be exposed to these chemicals.

PART II

BUILDING OF PLUGS AND MOULDS

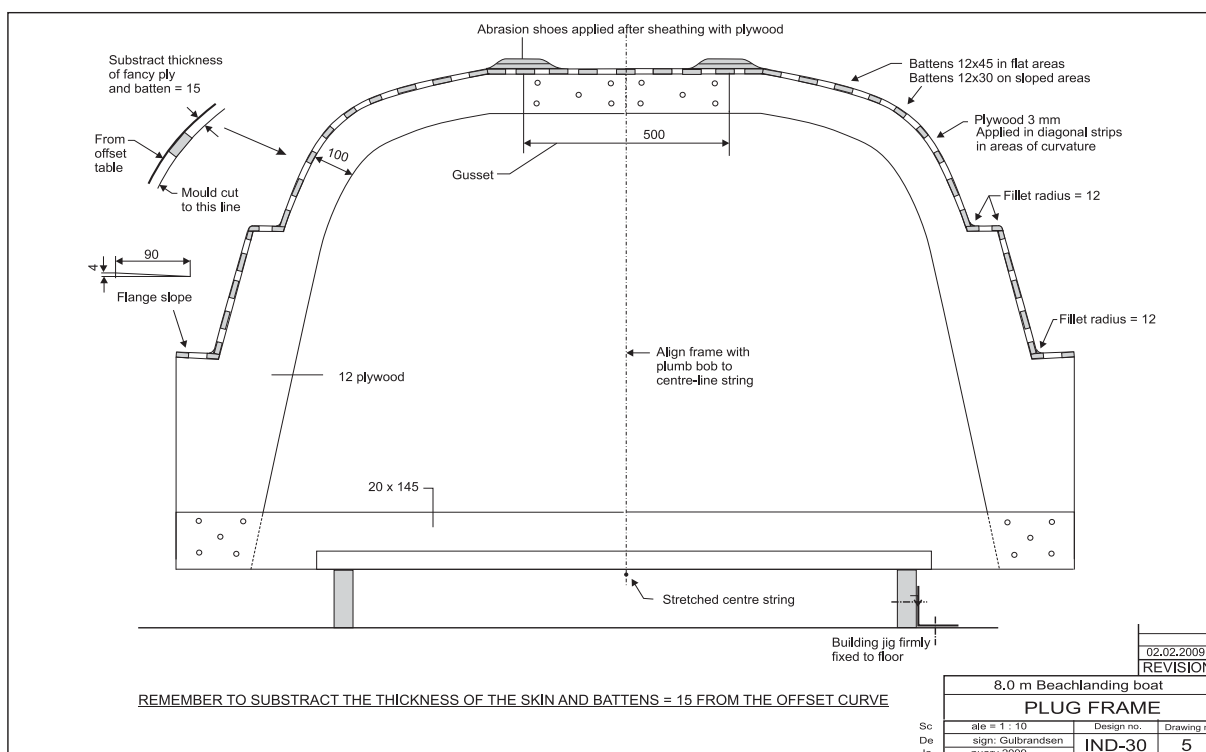
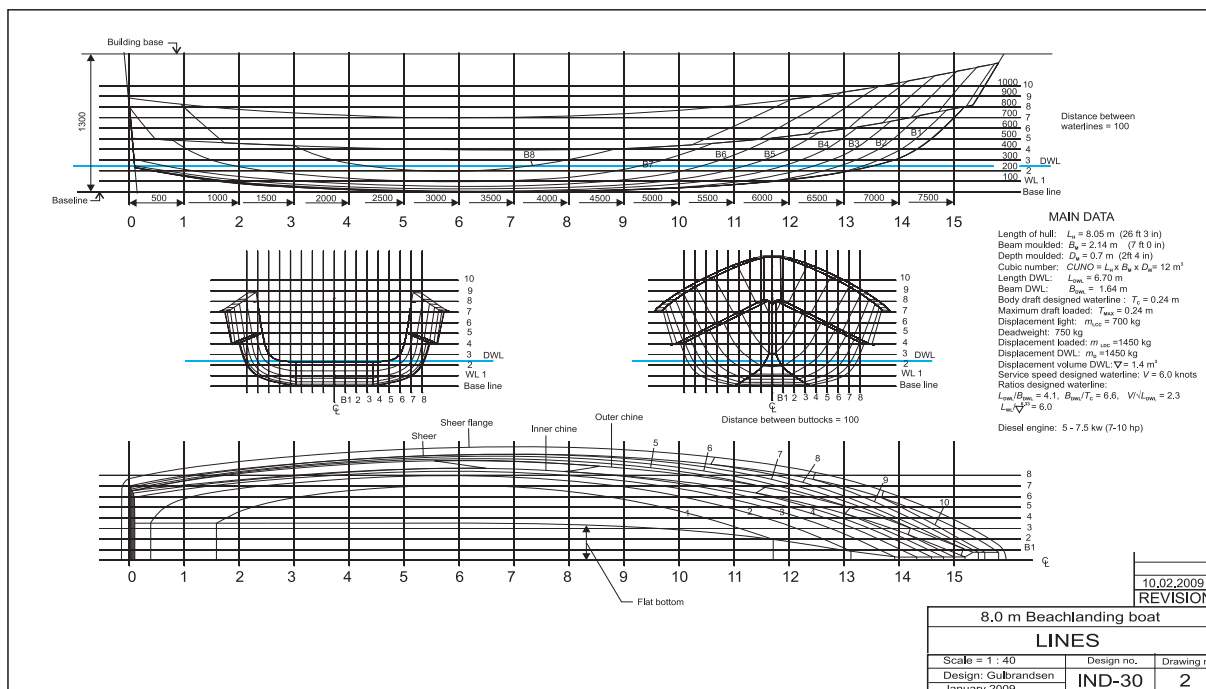
8 - MAKING THE HULL PLUG

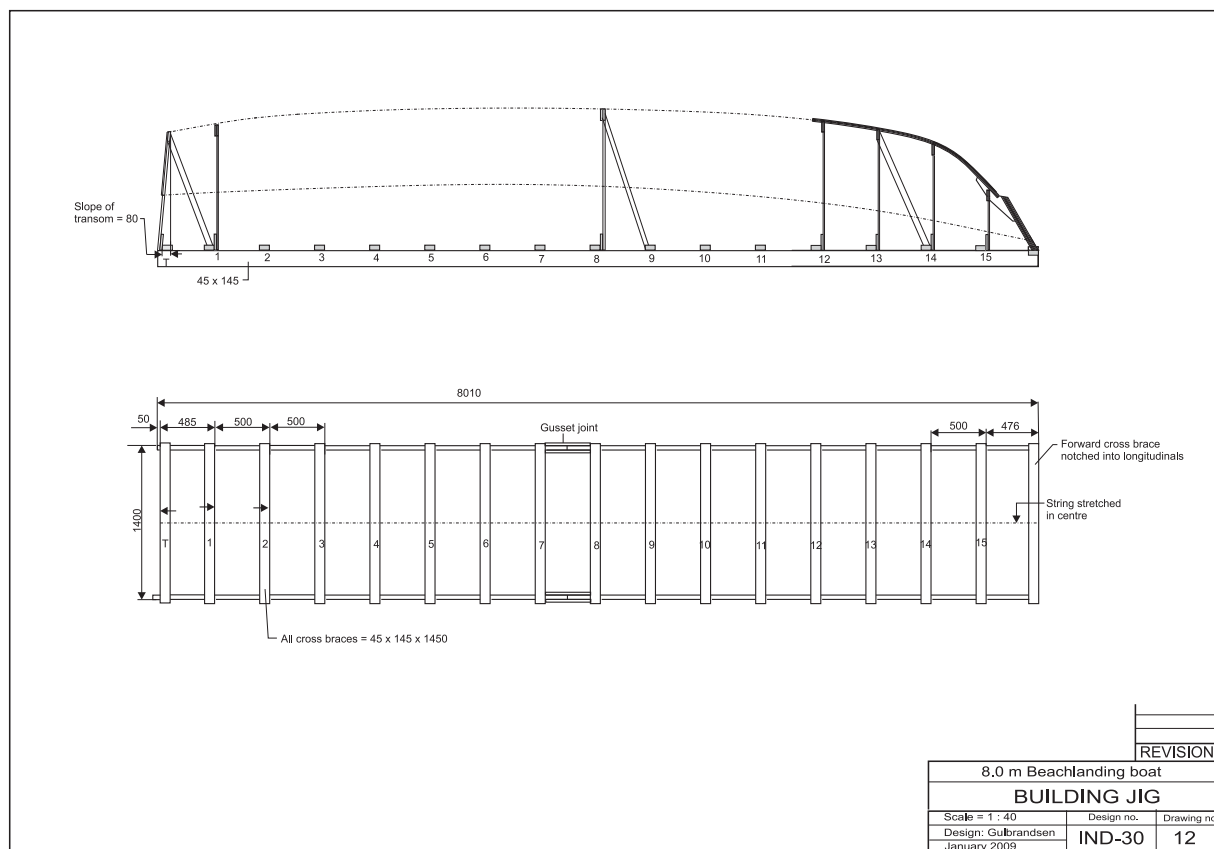
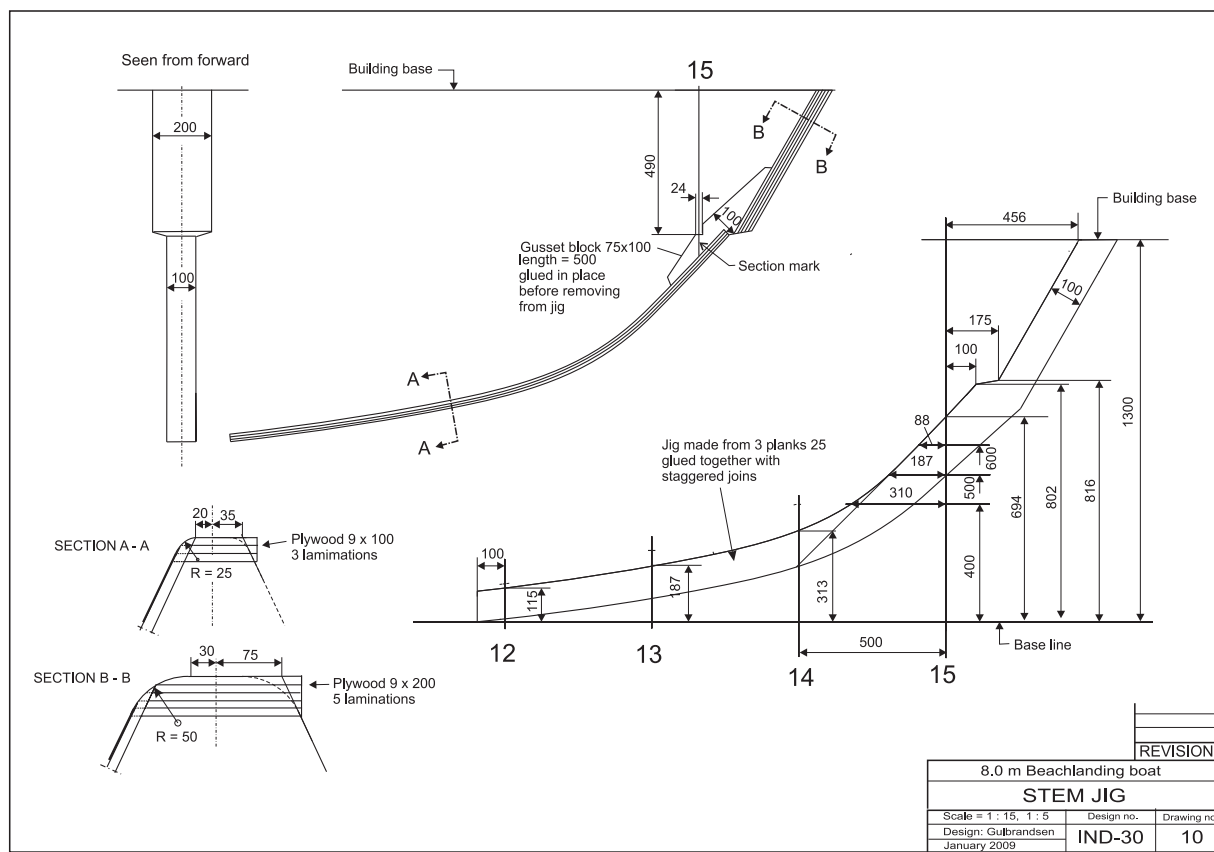
If the mould already exists, Part II can be skipped. The building of the beach landing boat is described in Part III.

The following section illustrates the sequence of building a hull plug.



Remember! Drawings must be studied carefully and the dimensions specified by the designer should be adhered to (Annex 3).





8.1 LOFTING AND FRAMES

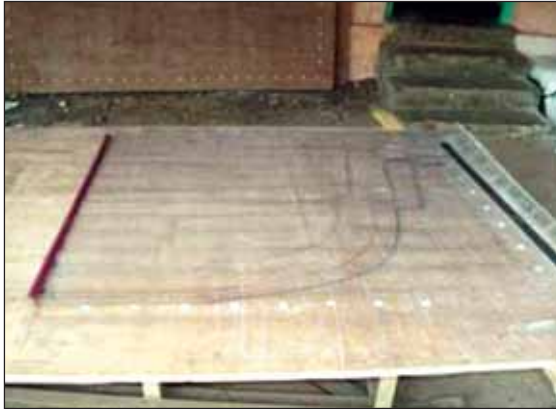


Figure 41

Lofting on plywood – mylar film transfer.



Figure 42

Sample plywood frame.



Figure 43

Frame assembly on jig.



Figure 44

Plumbline check.



Figure 45
Frame assembly.



Figure 46
Applying veneer ply skin.

8.2 HULL SKIN



Figure 47
Topside skin.



Figure 48
Diagonal strips for a curved surface.



Figure 49
Skin complete.



Figure 50
Preliminary fairing.



Figure 51
Applying autograde putty.



Figure 52
Hull plug ready for painting.



Figure 53

Spray painting – first coat.

A two-component paint should be used that will resist the solvents in the tooling gelcoat that will be applied.



Figure 54

Spray painting and rubbing down.



Figure 55

Finished plug.

**THE PLUG FINISH WILL DETERMINE
THE MOULD FINISH**

9 - MAKING THE MOULD

Useful tips when making a mould are:

- Use large flanges for stability.
- Use plenty of framing to add stability, either plywood on edge or FRP top-hat.
- Restrict all secondary bonding on the outside of the mould to light laminates in order to avoid shrinkage and pulling the mould,
- Ensure that mould thickness is 6 mm thick for a boat up to 3 m in length, then add 2-mm thickness for each metre of length.
- Use a proper tooling gelcoat that is light-coloured to reduce the heat of the mould. Do not lay up the mould too quickly.
- For a better result, do one lay up in the morning and one lay up in the afternoon until the required thickness is obtained. Thickness can be obtained with a core material.
- Avoid print through by using no roving or core material closer than 6 mm from the gelcoat.



Figure 56

The buffing compound used to polish the mould after release from the plug as a step after wet sanding and before waxing, or to polish the plug surface.

Read the instructions on the can.



Figure 57

Flange on transom.



Figure 58

Gelcoat on transom.



Figure 59
Transom lay-up completed.



Figure 60
Centre flange on hull plug (the purpose of which is to make a split mould).



Figure 61
Gelcoat on starboard half.

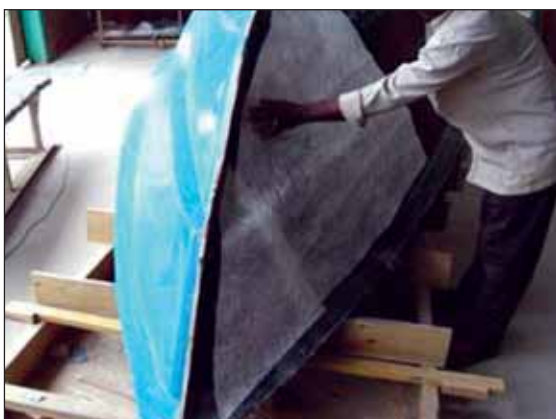


Figure 62
Mould lay-up.



Figure 63
Mould lay-up.



Figure 64
Mould framework. The shape of the frame is for tilting of the mould (See Figure 80).



Figure 65
Mould framework.

Figure 66
Rubbing down with water emery.



Figure 67
The completed split mould (without the transom).

PART III

BUILDING AN FRP BEACH LANDING BOAT

10 - BUILDING AN FRP BEACH LANDING BOAT

10.1 PREPARATION

The following is a practical guide to building an FRP boat, using an IND 30 8-m BLC as an example.

A beach landing boat operating from surf-beaten beaches is subject to a much harsher environment than a boat operating from a creek or harbour. It is subject to tremendous impact forces when crossing breakers and landing on the beach. In addition to impact, a BLC is also subject to severe abrasion when it is hauled up on to the beach each day. These operating conditions must be taken into account when deciding hull lay-up and structural arrangements.



Figure 68

Before starting, study the drawings thoroughly to understand the details of the lay-up schedule and structural details.

Typical drawings required are given in Annex 3.



Recommendations for determining FRP scantlings are given in Annex 4. These are the recommended guidelines for FRP fishing boats and form Annex III of the draft *FAO/ILO/IMO Safety recommendations for decked fishing vessels of less than 12 m in length and undecked fishing vessels*, which are under development.

On the IND 30 hull, we are using two layers of woven roving in the bottom, combined with CSM. The CSM builds thickness and the WR is good for impact strength.

On impact, the forces will be spread over a wider area if WR is used. WR layers are put as close to the laminate surfaces as practical. If it is too close to the gelcoat, the pattern of the WR will be visible.

The structure of the IND 30 is designed by an engineer to a formula for good strength to weight. The boat has four longitudinal stiffeners, two chines and two top-hat sections in the bottom. These longitudinals allow us to use less frames or bulkheads. The bulkheads also support the deck.



Figure 69

Finished internal structure. Note the bulkhead stiffeners to keep the bulkheads from buckling. The gunwale will also be reinforced.

10.2 A TYPICAL LAMINATING SCHEDULE

A typical laminating schedule is given below for the IND-30A.

Layer	Material	Area to be covered
1)	Gelcoat	Full cover
2)	Gelcoat	Full cover
FIRST LAMINATION		
3)	300 g/m ² (CSM)	Full cover
SECOND LAMINATION		
4)	Fill keels with sand / resin slurry	
5)	300 g/m ² (CSM)	Local, to cover slurry
THIRD LAMINATION		
6)	300 g/m ² (CSM) surface mat (optional)	Bottom only
7)	and 610 g/m ² (WR)	Bottom only
8)	and 450 g/m ² (CSM)	Full cover
FOURTH LAMINATION		
9)	450 g/m ² (CSM)	Keel reinforcement (see drawings)
10)	450 g/m ² (CSM)	Keel reinforcement (see drawings)
FIFTH LAMINATION		
11)	600 g/m ² (CSM)	Full cover
12)	610 g/m ² (WR)	Full cover
13)	300 g/m ² (CSM)	Full cover

10.3 MOULD PREPARATIONS

Ensure that the mould sits level and flat in the workshop to avoid building a twisted boat or the hull from pre-releasing.

Wax the mould 3 times (10 times for a new mould): wax on, wax off approximately half a square metre at time.



Figure 70

Before applying PVA, fit the centreboard case and drive tunnel moulds. Ensure that the centreboard case goes in straight or the boat will go around in circles.



Figure 71

Modelling clay is used to fill the joins of the parts of the moulds before the PVA is applied.

Read the instructions from the manufacturer.



Figure 72

Apply the PVA by hand with a sponge. Thin the PVA with water to give a consistency that gives an even coating.

Although a high gloss finish and wax application may be sufficient for small boats, it is always safer to use PVA when complex curvature is involved.

Read the instructions on the can.

10.4 TESTING



Figure 73

It is a good idea to build a smaller part first before beginning the hull in order to understand the performance of the resin.

10.5 APPLYING THE GELCOAT

Use only **iso-gelcoat** to improve the waterproofing and reduce osmosis.

Check that the PVA has cured by scraping with your fingernail. If it scrapes like cellophane tape, it has cured.



**MAKE SURE THAT THE PVA FILM IS
TOTALLY DRY BEFORE APPLYING
THE GELCOAT!**



Figure 74

Mix the pigment and accelerator well into the gelcoat with an electric drill or mixer, if possible. Let it stand for some time to let the air bubbles in the gelcoat escape. Mix small batches and keep a wet edge when applying the gelcoat. Brush horizontally and then vertically to help avoid runs.



Figure 75

For the first coat, apply the gelcoat at 500–700 g/m² and around 300–500 g/m² for the second coat.

Brush horizontally then vertically to avoid runs.

Mix small batches and work keeping a wet edge.

THE FIRST COAT MUST BE THICKER THAN THE SECOND COAT.

**HAVE A RELIABLE PERSON
DO THE MIXING AND RECORDING**



Ratios for gelcoating	
Pigment	6 to 10%
Accelerator	1.5 to 2%
Catalyst	Max. 2%
Gelcoat coverage	500–700 g/m ² first coat. Wait a minimum of three to four hours between coats. Apply 300–500 g/m ² for the second coat when the first coat has set but is tacky when touched.

The variables for setting time are the ratios of catalyst and accelerator to gelcoat, as well as air temperature and working time needed. Consider working at the coolest time of day and resting when it is hottest. Make sure that you have a plan for a laminating sequence that all workers are aware of and that the person mixing the resin is reliable and works in a consistent manner. Recording the use of resin accelerator and catalyst is a good practice.

After the second coat has also cured to a tacky film, you can start to laminate. To test the cure, drag your finger over the gelcoat in a low part of the mould. If no gel sticks to your finger but it is tacky to the touch, you can start to laminate. If in doubt, wait a little longer. If you laminate too soon, the styrene in the resin will attack the partly cured gelcoat and wrinkle it like an alligator's skin.

10.6 MIXING OF THE RESIN

The most commonly used polyester resin is a general purpose (GP) **ortho-polyester**. This resin, when mixed with 1% of MEKP catalyst, typically has a gel time of 8–15 minutes at 30 °C.



Figure 76

If a drill with a proper mixing attachment is not available, the second best alternative is to roll the drum.

However, if the drum has been standing upright for some time, polyester resin near the bottom may already be of higher viscosity and rolling the drum for a full 10 minutes might not be enough to fully mix the heavier and lighter resin. If not fully mixed, the first resin drawn from the drum tap may be of a different viscosity than that drawn later.



Figure 77

A variety of syringes can be used for correctly measuring very small amounts of hardener.

A typical cap from a soda bottle can usually hold around 5 ml of hardener.



Figure 78

In the case that there is no scale for measuring polyester resin, one may assume that one kilogram equals almost one litre. For either measure, there will be no significant loss of quality when working with these materials on a sturdy structure such as the IND-30 boat.

Follow the initial steps set out in the section Material Description and Handling and make sure you use the correct amount of hardener for a good cure.

Iso-polyester with superior resistance to sea water should be used for the backup layer. Cheaper **ortho-polyester** may be used for the main lay-up.



Maximum and minimum ratios		
Catalyst	Min. 0.8%	Max. 2%
Catalyst for gelcoat	Min. 1.5%	Max. 2%
Accelerator	Min. 1.5%	Max. 2%

Keep the catalyst level above the minimum so you can easily adjust the working time as the day gets hotter.

Be careful!
Catalyst levels 0.8 to 2% MAX!

10.7 APPLYING THE BACKUP LAYER

The gelcoat must be backed by a layer of E 300 CSM mat. Catalyse this layer quickly to avoid alligating. Be careful to work out all air bubbles from this layer as this is the layer most affected by osmosis. Avoid a buildup of extra resin or fibre on this layer. A uniform layer of 300 g/m² CSM is required.

For the backup layer it is especially important that the fibreglass mat be torn (section 5.3). Always use **iso-polyester** for the backup layer.



Figure 79

The backup layer is a non-structural lightweight laminate.

Tilting the mould would make this job easier and release the styrene fumes, which slow the cure of polyester.

The chine will be used to ground the edge of the deck.



A coat of polyester resin should always be applied before laying on the fibreglass mat. The metal roller is effective for working out any air bubbles and for compacting the resin and fibreglass layers together.

10.8 SUBSEQUENT LAYERS

Follow the laminating schedule and be thorough; roll all layers with a metal roller. Continue to laminate, not leaving the open laminate for more than 24 hours.

In the tropics, be aware of weather changes. You may need to stop laminating and cover the job if it rains.



Figure 80

Tilting the mould is a good way to obtain access to all parts of the mould and also to avoid contamination with dirt.

The tilting mould releases the styrene, which is heavier than air. Styrene fumes slow the cure of polyester resin. On thin laminates or gelcoat, lower areas of the job may cure more slowly than higher areas.

Figures 64 and 65 (see page 40) shows how the framing of a mould could be constructed in order to make the titling of the mould possible.

As mentioned earlier, it is wise to have a WR close to the surface. A surface mat can be used to help fill the weave of the roving and prevent the resin draining out of the laminate immediately before gelling. The resin gets warm just before gelling, thins and runs. Using a filler up to 5 percent of resin weight to thicken the resin has the same effect as a surface mat. Surface mat is the stronger alternative, as fillers tend to weaken the bond between layers.

The below chine area actually starts 50 mm above the chine to give an overlap to the topsides and add strength. Overlap all layers a minimum of 50 mm except the backup layer, as this layer is not considered structural. Staggering of overlaps should ensure that there is no buildup of thickness at panel joints.



Figure 81

All corners must be reinforced and any sharp corners filleted with roving strands after the gelcoat to prevent voids or resin-rich areas that will be brittle. Build up a double laminate at the corner of the hull/transom and the stem.

10.9 BONDING IN STIFFENERS AND BULKHEADS

The internal structure is built before it is needed and laminated into the hull before the hull is released to guarantee that the hull shape is kept.



Figure 82

Longitudinals are in position ready to be tabbed in place, then laminated over. Longitudinal stiffener formers must be shaped to fit fairly over the hull laminate. Use a hacksaw and file to obtain satisfactory seating.

Use weights and resin putty to hold them in place. Laminate over the formers and on to the hull after proper surface preparation to ensure a good secondary bond.



Figure 83

Longitudinals are finished with a web bracket on to the transom.

Reinforcement patches are for the rudder and towing eye connections.

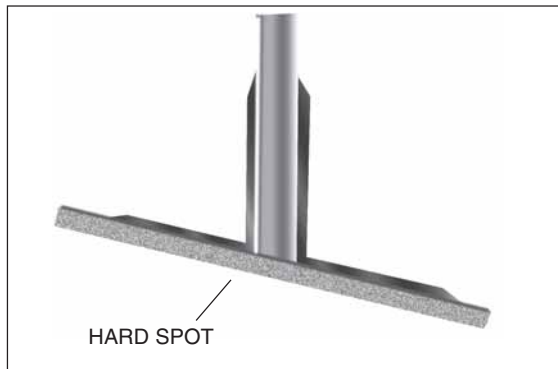


Figure 84

Bulkheads should not fit tightly against the hull.

See Figure 85 and Annex 4, Appendix 2, section 4.4.19 for recommended practice.

Hard spots cause stress concentration and subsequent laminate failure caused by fatigue.

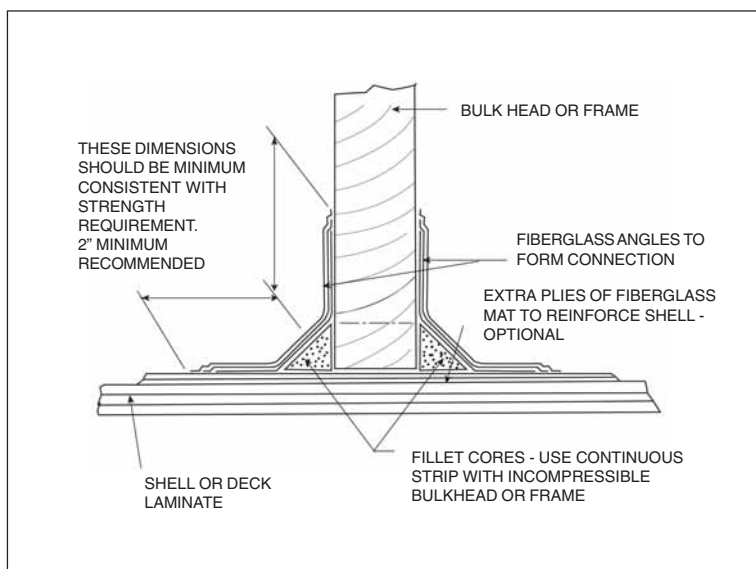


Figure 85

Apply a polyester filler fillet before laminating as has been done here.

Fit a foam fillet so that the frame will not print through on the hull.



Figure 86

Bulkheads are filleted into place before laminating.

A clamp ensures the correct height of the bulkhead, which is vital for a good hull to deck bond later.

Note that the fitting of the bulkhead to the hull could have been better; having accurate moulds or templates for the bulkheads will help this.



Figure 87

Tabbing of the bulkheads and floors to the hull should be as specified. Prior to bonding bulkheads and stringers, the area should be well ground to ensure a good secondary bond.



Figure 88

The bottom longitudinals are pre-moulded in one piece with 1 x 450 g/m² CSM, fitted and laminated over with 2 x 450 g/m² CSM from each side, giving a total of 5 x 450 g/m² on top to give best effect and 3 x 450 g/m² on the sides. Limberholes are fitted before laminating the frame into the hull.

Stiffeners are added to the bulkhead to stop them buckling.



Figure 89

This is an example of a bad fit and should be rectified.



Figure 90

An example of a poorly designed and built framing system.

Well thought-out use of longitudinal stiffeners and transverse framing will result in a better and cheaper structure.

See Figure 91 below.



Figure 91

Example of well-designed framing system.

10.10 RELEASE

Release the hull as gently as possible. The use of many small wedges around the mould edges is better than a few big wedges that will stress the product locally.

PVA release agent can be dissolved if water is used to release the piece.

Use a rubber mallet if necessary.

Remember that the mould is an investment that should be treated gently.



Figure 92

The starboard half of the mould after the release.

**Don't release the part too soon!
Make sure it has cured!
Avoid the risk for print through or pulls from
post-curing as polyester shrinks 2% as it cures.
24 hours at 40° C is good for
post-curing parts.**

10.11 DETAILS

Plywood is an excellent structural material. If plywood frames are used instead of the specified FRP frames, be sure that they are marine-grade plywood. Seal the edges properly.



Figure 93

If you decide to use plywood instead of FRP for the bulkheads, then keep the fibreglass longitudinals as they are.

Keep the hull skin as designed.

See scantling tables for details.



Figure 94

Tunnel for a liftable propulsion system (the BOB drive).



Figure 95

Gelcoat on the centreboard slot plug.

Ensure that the centreboard slot plug goes in straight or the boat will go around in circles.



Figure 96

Mats being applied.



Figure 97

Plug being removed.



Figure 98

Mixing of sand and resin for the abrasion layer.



Figure 99

A 10-mm abrasion layer applied with a sliding mould after removal from the mould.

Note: It is easier to apply the abrasion layer in the mould after the first layer of CSM 300, as shown in construction drawing no. 4 (Annex 3).



Figure 100

Resin being applied on top of an abrasion layer that consists of sand and resin.



Figure 101

While the resin is still wet, a CSM mat is applied.



Figure 102

Finally, the abrasion layer is covered with two layers of topcoat.

10.12 DECK PLUG, MOULDING AND ASSEMBLY

Decks for FRP boats can be built either by using FRP-sheathed marine plywood or as an FRP moulding suitably stiffened. Compared with the hull moulding, an FRP deck is simpler. However, the deck to hull joint is crucial. The deck needs to be seated on a shelf attached to the hull at sheer.

In the IND 30, the outward flange at sheer and the flat of chine provide seating of the deck. The deck assembly is of three separate pieces: the fore and aft decks at sheer level and the lower cockpit deck in between.

Deck to hull connection may be of the bolted type or by bonding to the hull with FRP angles. Prior to assembly, the seating surface and underside of the deck edge must be well ground and cleaned. The deck should be set in place over at least two layers of wet mat of E 450 g/m² to ensure a leakproof joint.



Figure 103

Building of the deck plug (inside the hull of the first boat).



Figure 104

Hatch coamings attached to the plug.



Figure 105
Application of modelling clay.



Figure 106
Topcoat being applied.



Figure 107
Note the metal plates on the deck to prevent a slippery surface.



Figure 108
Cockpit deck mould complete.



Figure 109

The cockpit deck in front and the mould behind.



Figure 110

Stiffeners being attached to the underside of the deck.

Some good tips for hull to deck bonding:

- Use a slurry of premixed resin and waste CSM pieces as glue. Make it thick enough to stay where put and wet enough to bond properly.
- It is important to do a “dry fit” to check that the hull and deck fit.
- The IND 30 has deck hatches so the interior of the boat can be easily checked and worked on, which is a good feature in any boat.
- Mount any fittings that will be difficult to mount after the deck is on.
- Use fibreglass tapes to bond the deck to the hull and bulkheads wherever possible.
- Bond the deck to hull outside with 3 x 450 g/m² CSM 120 mm wide. Stagger the layers.
- Hatches must be properly secured to the boat for safety.



Figure 111

Cockpit deck seated on chine flat. Using temporary thwarts and vertical struts to exert pressure, the deck is bonded over wet mat.



Figure 112

The deck edge is also connected with FRP tabbing to the hull after the seating has set.



Figure 113

Note the proper seating of the deck over the transverse bulk-head.



Figure 114

The plugs for the fore and aft decks under construction.



Figure 115

Antiskid plates on the fore deck plug.
Note the mast step.



Figure 116
The mast step.



Figure 117
The engine hatch coaming on the aft deck plug.



Figure 118
The first layer of gelcoat being applied on the deck plug.



Figure 119
Final stage of the making of the mould for the aft deck.



Figure 120
Detail of the rudder for the BOB-drive.



Figure 121
Detail of the emergency rudder to be used with sail.

10.13 FITTING OF BUOYANCY MATERIAL AND FENDERS

Wooden blocks may be laminated to the hull or deck to fix the strapping for securing the buoyancy in place. Strap the buoyancy blocks in securely. Sealing these foam blocks by painting them with water-based paint or bagging them in plastic will make them more effective and stop them from getting mouldy.



Figure 122
The fore and aft decks are assembled the same way by seating the decks on the hull flange after placing the required polystyrene buoyancy blocks under the deck.



Figure 123

Polystyrene buoyancy blocks under the aft deck.



Figure 124

The deck is stiffened with top-hat stiffeners and doubling pads moulded in to take deck fittings.



Figure 125

The sheer rail is bonded with a former to take a PVC pipe fender.



Figure 126

PVC pipe fender.



Figure 127

PVC pipe fender being put in place



Figure 128

The finished boat.



Figure 129

The deck layout of the finished boat.



Figure 130

The BoB-drive in a lower position to the left and in an upper position to the right.



Figure 131

Sea trials should be carried out together with the buyer before the delivery of the boat.



Figure 132

Sea trials to test the stability in surf crossing.

PART IV

MANUFACTURING DEFECTS AND REPAIRS

11 - MANUFACTURING DEFECTS

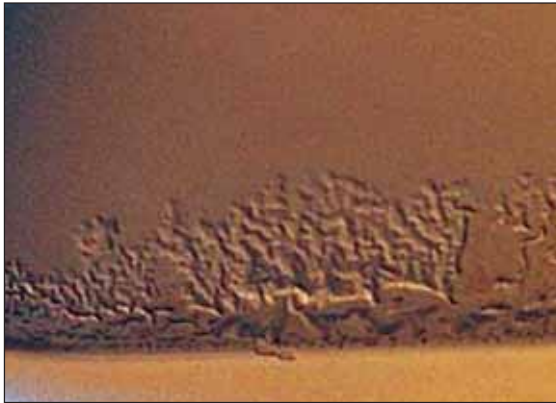


Figure 133

Wrinkling or “alligatoring” is a gelcoat fault caused by:

- insufficient catalyst in gelcoat.
- gelcoat too thin.
- backup layer applied too soon.



Figure 134

Fibre pattern is a result of:

- gelcoat too thin.
- high exotherm because of bulk curing.



Figure 135

Star crazing is caused by:

- gelcoat too thick.
- reverse impact.
- crack pattern transferred from mould.



Figure 136

Blisters are caused by:

- moisture contamination.
- rapid cure of gelcoat.

12 - REPAIRS

Damages to the hull depend on the type of accident or the severity of conditions. They may be minor hairline fractures of the gelcoat, severe grazes caused by abrasion or scratches by a sharp object or through-hull puncture resulting from impact fracture.

12.1 HAIRLINE FRACTURE AND GRAZES

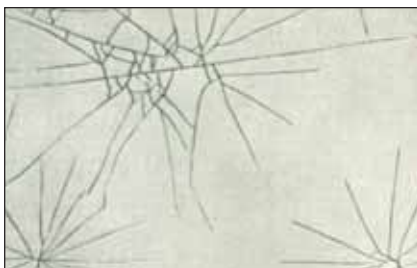


Figure 137

Hairline fracture and grazes.



Figure 138

Severe grazing caused by scratching.

Enlarge the hairline fracture into a definite V-shaped groove, using the corner of a chisel or a file. The groove must be deep enough to penetrate the gelcoat completely and expose the main laminate below.

Prepare and activate a small quantity of resin. A filled resin is best for this type of repair. Failing this, a general-purpose resin can have filler powder added. Work this into the groove, using a broad knife, until it is slightly proud of the external surface. Leave the repair to cure completely.

After the repair has cured, fair in the surface with grade 320 wet-and-dry abrasive, used wet on a rubber block. Rub lightly in one direction only to prevent the area surrounding the repair from becoming depressed. If the rubbing down is too vigorous, the original gelcoat surrounding the repair may be depressed or even removed, exposing the reinforced laminate underneath the gelcoat.

12.2 PUNCTURES

Punctures may or may not be accessible from both sides. Different methods are needed for each case. Note that the scarf should be at least 1:20.

Figure 139

Damage accessible from both sides

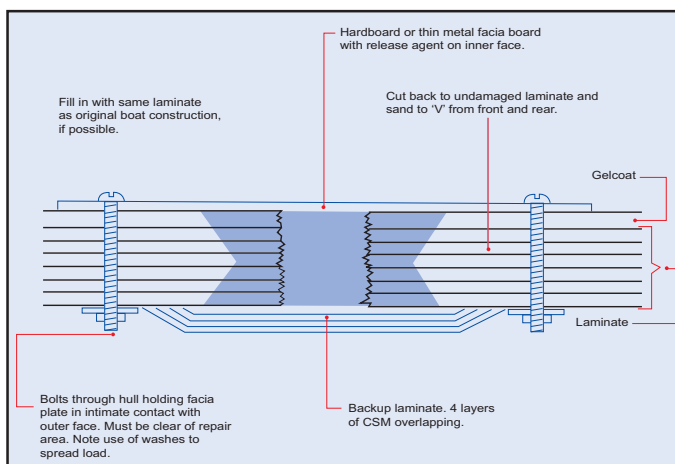
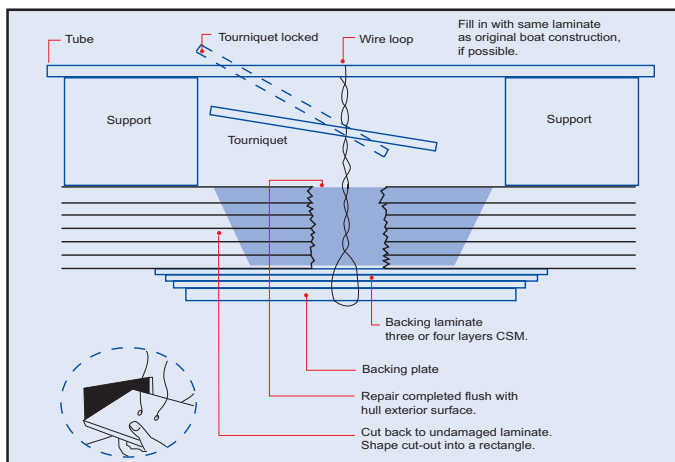


Figure 140

Repairing a puncture with only outside access



The following section explains the common types of damages found in beach boats and details the various steps in a proper repair procedure.

12.3 TYPICAL DAMAGES TO BEACH LANDING CRAFT

For everyday use, FRP generally does not need much maintenance, although this does not mean that a boat will last forever. Wear and tear and the absorption of water affect the lifespan of an FRP boat. The challenge is to determine whether what can be observed on the surface is merely cosmetic or constitutes more serious structural damage.

Remember the following important points:

1. A good secondary bond is essential.
2. The area of the repair should be made slightly stronger than what it was originally.
3. Access to both sides is often needed, so you must not hesitate to tell the customer that you need to cut a new hatch in the deck to repair the hull.

When a boat is left constantly in water, the water is absorbed by the polyester laminate. Gelcoat or topcoat does not stop water absorption. This absorption is not visible, but the laminate can absorb 1.5 to 2 percent water and become less stiff. After a certain number of years (5 to 15), the laminate may also react chemically with the water to produce hydrolysis, which is comparable to rust in steel. The speed and extent of hydrolysis depend, on the combination of water conditions, temperature, use of the boat and how good the quality control was when the boat was built.



Figure 141

In this figure, old laminate showing typical results of hydrolysis can be seen. The polyester becomes depolymerized and is washed out of the laminate.

The results are visible as dark spots on the surface and white pockets deeper in the laminate.

If the gelcoat is intact, osmosis blisters might occur.

Old laminate is weaker and less stiff than new laminate, even if damage is not visible.

Water absorption will be slowed and the working life of the boat improved if the hull laminate below the waterline is treated with several layers of epoxy barrier coat when the boat is new. Anti-fouling material applied to the hull to reduce marine growth improves fuel economy, but has no effect on water absorption.



Figure 142

Many boats have laminates that are just too thin.

On this boat, the laminate was 4 mm but the layers separated easily because of the excessive use of pigment and too much polyester with respect to glass.

The boat would have survived had the gunwale been made tougher.

The polyester to fibreglass volume percentage should be approximately 67 percent polyester to 33 percent fibreglass.

The coaming had layers of putty in between the laminate layers.

The fibres do all the work.



Figure 143

In addition to the iron posts working their way out, the area where the posts are connected to the hull is in itself a “stress riser” and many boats have failures here.

It might be easy to think that the boat breaks at this point because of the pull in the steel bars, but the truth is that it breaks because the rest of the boat is soft and this is a stiff and weak point.



Figure 144

Since the structure of the boat is somewhat “soft”, the bending of the laminate will concentrate in “hard spots” where cracks and delaminations will develop.

All corners should be well rounded and areas with stress risers should have additional layers of FRP to absorb and distribute the stress and strain.



Figure 145

At the bottom of the boat, there are wear-and-tear failures caused by abrasion, as well as cracks and delaminations resulting from thin laminates and local stress risers, such as the leeboard holes and poor detailing in internal structural supports.

Additional strips of prefabricated FRP laminates could be glued on for additional stiffness and abrasion resistance.

In order to enable readers to understand the importance of dealing with a crack in an FRP laminate and not underestimate the strain and stress of a loaded area, the following sections address basic structural repairs. The figures in the following section show that a small crack can have major consequences and proper repair work takes a long time.

No shortcuts should be taken if a repair is meant to last!

12.4 PRACTICAL GUIDELINES FOR STRUCTURAL FRP REPAIRS

In general, repairing FRP boats is easier than repairing boats built of other materials. However, proper preparation of the site, a dry working environment and the correct air temperature are critical.



Figure 146

This figure shows a typical fatigue fracture inside the transom on a boat powered by an outboard engine.

In this case, an attempt has been made to repair the crack, but putty and gelcoat cannot mend structural damage.

Ideally, a boat should be repaired indoors to protect the work from rain and sun, and to ensure a stable temperature. If working indoors is not possible, a tent should be erected over the boat. All hardware and equipment that prevent access to the damaged area must be removed. A dust mask and eye and ear protection should be worn before any grinding starts. The grinding dust should be extracted at source. A commercial dust extractor or vacuum attached to the grinder can be used..



Figure 147

Prior to grinding, all surface contamination such as oil and silicone should be washed off and removed with an appropriate solvent. For grinding, 40-grit sandpaper is a good choice.

In the example shown here, grinding has uncovered deep delaminations. To ensure a lasting repair, the full extent of the delaminated fibreglass must first be removed, no matter how far or deep it extends

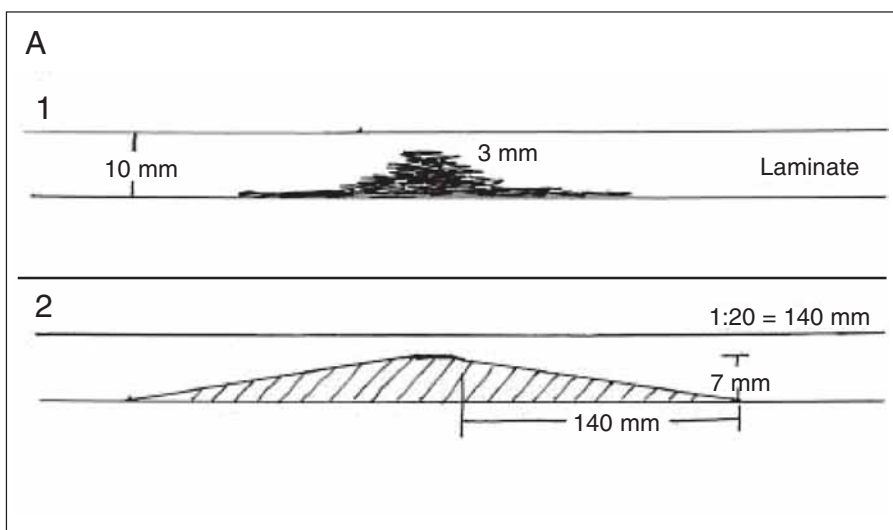
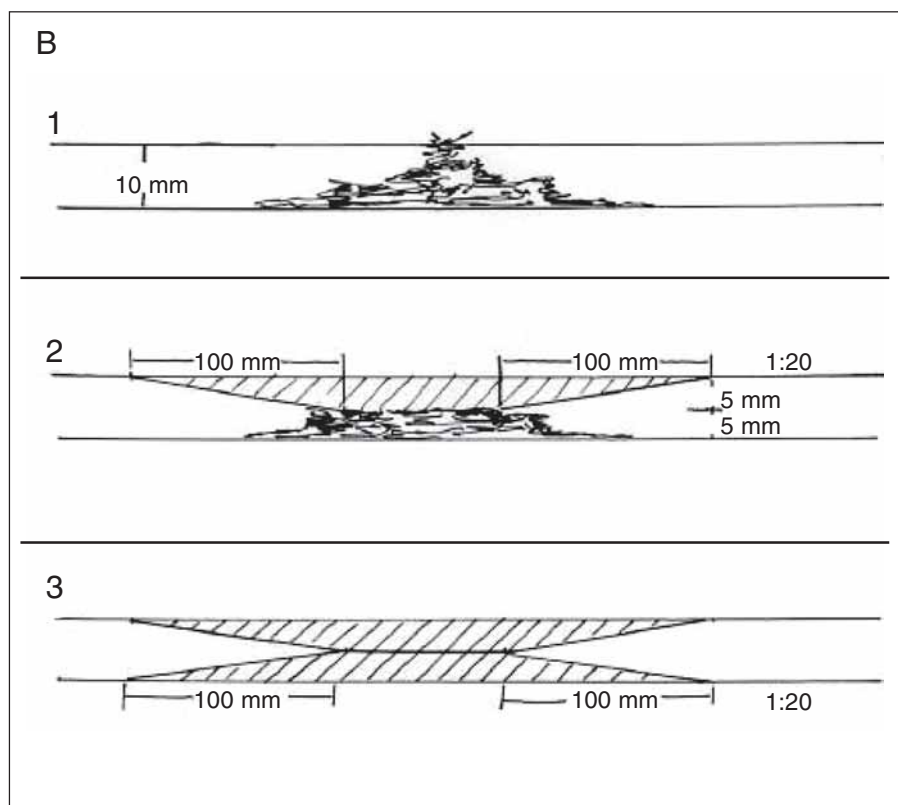


Figure 148

These schematic drawings illustrate the principle of laminate repair.

The first two images [A1 and 2] show damage that has not penetrated the whole laminate. The next three show a two-sided repair [B1-3].



Many manuals state that a scarf of 1:12 is sufficient for fibreglass repairs. This may be true for unloaded areas with thick laminates; however, for thinner laminates and loaded areas, the scarf should be at least 1:20.

In many cases, a scarf of 1:40 or more must be used to ensure adequate adhesion and absorption of stresses in loaded areas.



Figure 149

When grinding has been completed, the area to be laminated will probably be much larger than suggested by the initial visual inspection.

For example, in this boat, tiny cracks in the gelcoat were visible on only one side of the engine well, but grinding revealed that the delamination was just as deep on both sides.

A decision must be taken on what kind of materials to use for laminating once the repair area has been identified and prepared. The following text is a guide to making this choice.

12.5 PRIMARY BONDING

Primary bonding occurs when two surfaces are connected directly to each other, forming a chemically homogenous laminate containing no weak bond line.

A fresh or “green” polyester laminate has active molecules on the surface that will bind chemically to a new laminate. Laminating on to a green laminate gives a primary bond.

Except for sanding off bumps and fibres that could cause defects and air pockets in the laminate, a fresh green polyester laminate requires no other preparation before adding another layer.

How long the laminate surface remains active depends on a combination of the technical properties of the resin and the temperature during curing. Generally, the open time for polyester resin is 24-48 hours.

When building a medium-sized boat, primary bonding can usually be achieved. When building larger FRP boats, more time is needed to complete a layer of laminate, which makes operating within open time windows more difficult. Even so, achieving primary bonding between laminates in the main hull is crucial. In most cases, only secondary bonding will be achieved when laminating frames, stringers and bulkheads into larger boats.

An older polyester laminate is rarely completely cured. It will still have some reactive molecules that might, if properly sanded first, bond with the repair laminate. Wiping a sanded laminate lightly with styrene, immediately before applying a fresh polyester laminate, may also improve the bonding properties.

12.6 SECONDARY BONDING

All repair work relies on secondary bonding. Consequently, stronger or additional replacement material will be needed to bring the damaged area back to its original strength.

When laminating over a cured laminate, the cross-linking reaction does not occur to a significant degree across the bond line. Since the polymer networks are discontinuous, the bond relies mainly on the adhesive strength of resin.

12.7 CHOOSING A RESIN FOR STRUCTURAL REPAIRS

In general, iso-polyester, vinylester or epoxy resins are preferable to general-purpose polyester resins for FRP repairs and alterations. After considering strength, cost and ease of processing for each, iso-polyester and vinylester resins are usually recommended for most repair work.

For more critical structural repairs, laminates made with epoxy resin are generally stronger (but not stiffer). Epoxy resins are highly adhesive and have a longer shelf-life than polyester and vinylesters. These characteristics make epoxy ideal for emergency repair kits. As it requires no solvents, epoxy resin does not contaminate the surface of the original laminate and shows no shrinkage when curing (less tension).

Epoxy resins do not hydrolyse and this, together with good adhesion, low shrinkage and high ratio of elongation to break, make them more liable to perform well as a primary bonded laminate. However, they are intolerant of bad mix ratios and the setting time cannot be shortened or lengthened by altering the amount of hardener. In addition, an epoxy surface is definitely not active with styrene; therefore, any further work on an epoxy boat or an epoxy repair will have to be done with epoxy. Avoid using 5 minute or very fast epoxy for structural repairs.

A thorough cleaning and preparation of the bonding surface is very important to achieve good epoxy adhesion.

12.8 CHOOSING REINFORCEMENT FOR STRUCTURAL REPAIRS

If practical, the same reinforcement used when building the original boat should be used in the repair, especially if the part being repaired is heavily loaded and operating near its design limits. Use of lighter weight reinforcement will allow for better contact with the surface, but the importance of this feature should be weighed against the importance of using the original reinforcement for maximum support.

Meanwhile, it should be remembered that there will be no continuous fibres attaching the old to the new laminate, and the strength of the join will depend solely on adhesion of the new laminate to the old. Almost 100 percent of stiffness can be recovered if the laminate is built up to its original thickness; however, the strength and fatigue properties of the repaired laminate will be weaker than the original. The dimension of the fibre bundles is critical for the repair to perform well, because large bundles and heavy mats/fabrics obscure air and resin-rich pockets that are more likely to form at the borderline between the old and new laminates.

It is important to take all these matters into consideration when designing the repair laminate (see Figure 150). If additional reinforcement is required to maintain the boat's overall strength, care should be taken to avoid excessive laminate buildup, since this can increase the risk of developing stress concentrations.



Figure 150

In this example, the resin chosen for use was epoxy, but vinylester might also have performed well.

It should be borne in mind that this was a single-sided repair and the original polyester laminate was already showing weakness from fatigue.

The reinforcement was a mix of 290-g woven twill and 450-g double-bias fibreglass, chosen because of drape ability and good performance with epoxy.

12.9 SURFACE PREPARATION

It is important not to clean a freshly sanded, porous, fibre laminate with acetone or solvent prior to lamination, unless it has been contaminated with oil or grease. If cleaning is necessary, a light grinding with clean sandpaper after washing is required, followed by sufficient time for the solvent to “air out” (evaporate). When the solvent is absorbed by the porous surface, it “contaminates” the surface laminate and can dilute the new resin, preventing optimum adhesion.

When using polyester, a light styrene wipe prior to laminating is the only acceptable procedure. A small amount of styrene will activate the surface slightly and improve adhesion. Too much styrene will weaken the bond line.

For repairs under the waterline, fresh styrene in the new polyester laminate is also liable to trigger hydrolysis (absorption of water) at an earlier stage than in the original laminate and cause premature failure in the borderline area between the old and the new laminate.

An important issue when making repairs is to check the water content of the laminate with a moisture meter. If the laminate contains too much water, the bonding will fail sooner than it should and the new laminate will separate from the old one prematurely.

When it comes to the actual laminating, the same procedures as for making a new boat should be followed, including the maintenance of high quality control standards.



Figure 151

At this stage, the laminate buildup has been completed and the surface has been ground flat to a nice “finish”. Use of any form of putty on structural repairs is to be carefully avoided.

Putty has a low ratio of elongation to break, and will break up and crack much more quickly than a laminate.



Figure 152

This figure shows the finished product. Gelcoat has been applied, water-sanded, buffed and polished to a decent gloss.

Polyester gelcoat can be used on top of epoxy as long as the epoxy is cured properly and the epoxy surface has been fully sanded before the gelcoat is applied.

In this case, a 5-mm aluminium plate has also been attached to distribute pressure from the bolts over a larger area.

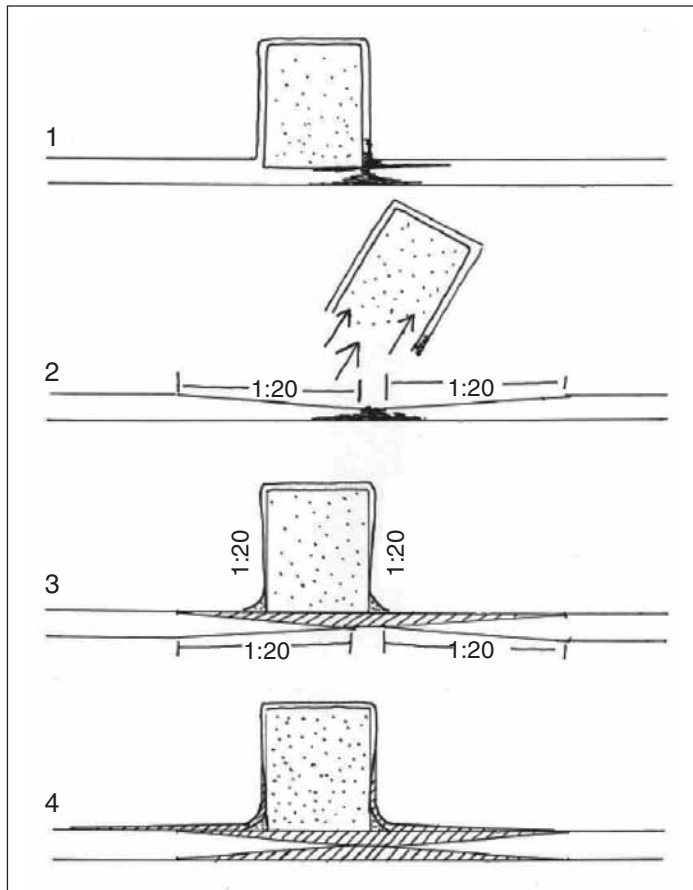


Figure 153

Cross-section showing structural damage to the frame of an FRP boat and the proper method of repair.

1. A fracture in the outer skin has penetrated the whole laminate and caused delamination in the framework.

2. For the repair to be effective, the wooden frame must be cut and removed. Next, the hull laminate must be repaired as described earlier.

3. The frame has to be ground to a scarf wherever it will be joined with other laminates and then bonded down with putty/glue and finished with a radius fillet.

4. All lamination work on the frame is best done with easily drapable fabrics or 450 g/m² and lighter CSM.

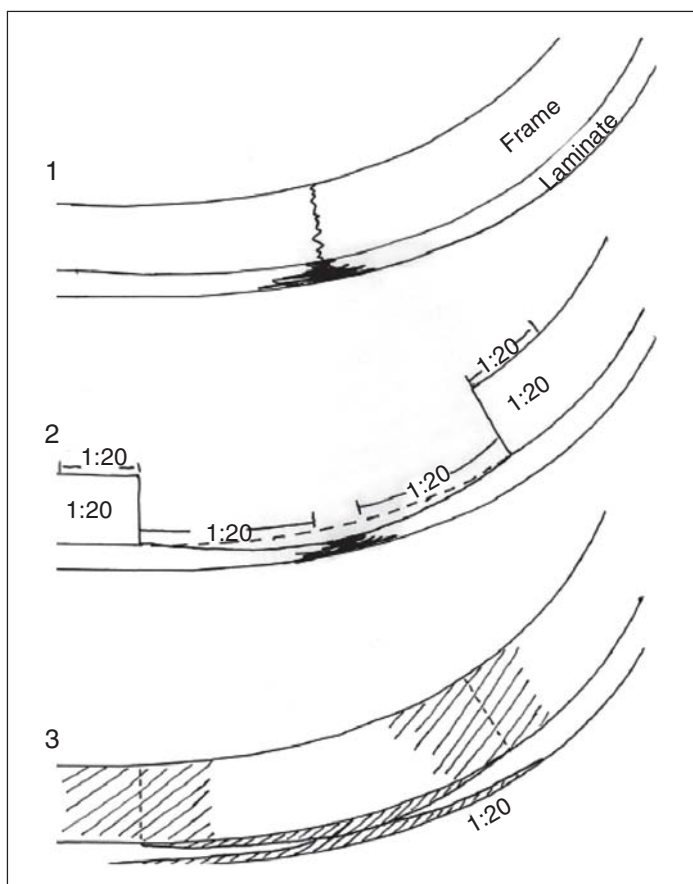


Figure 154

Side view

1. This represents almost the same structural damage as shown in the previous figure, but viewed from the side.

2. The frame is shown cut and taken away, making the damaged laminate accessible. In this case, no scarf in the core of the frame is required as it would be on a wooden boat, because this frame is filled with foam or air, which is not a structural member.

3. The place to cut and how to cut the frame will vary depending on the damage and will have to be estimated carefully in each case. Sometimes, when structural foam is involved, it is necessary to make a scarf in the same way as with a wooden frame. In some cases, "stepping" the scarf may also be an alternative. Using additional extra length reinforcement, such as unidirectional fibres along the top of the frame, must also sometimes be considered to add strength to the repair.

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Annex 2: GLOSSARY

Backup layer or skin coat	The first layer next to the gelcoat.
Bulkhead	Structural interior panel set across the boat.
Accelerator (or cobalt)	Reduces gel time in polyester resins.
Acetone	Solvent for removal of uncured resin from equipment.
Alligatoring	Wrinkling of the gelcoat.
Barcol hardness	Used to measure hardness of a laminate and degree of cure.
Bidirectional	Type of sewn glassfibre mat, having fibres oriented in two directions.
Binder	Used to hold chopped strand mat (CSM) together until the binder is dissolved by the resin when laminating.
Bleeding	The softening of the back side of a gelcoat by a resin, allowing the pigment to escape the gelcoat.
Bond strength	The strength of the join between two surfaces.
Catalyst	Hardener.
Chalk powder	Talc.
CSM	Chopped strand mat. Its weight is expressed in grams per square metre.
Cobalt	See Accelerator.
g	Grams.
Consolidation	Rolling of glassfibre laminate to remove air.
Continuous roving	Unwoven uncut glassfibre.
Core	Central part of sandwich construction.
Crazing	Cracking of resin from internal stress.
Cure	The process of resin from gelation to full mechanical properties.
Delamination	The separation of a laminate into two layers.
Drain out	The leaking, sagging or puddling of resin from a laminate.
Exotherm	Heat produced from the cure of resin.
Fatigue	Repeated stress on a material over or near its limit of mechanical properties.
Fibre content (of a laminate)	Weight expressed as a ratio to resin.
Fillers	Aerosil, milled fibres or talc to thicken resin.
Frame	Structural member set across the boat.
FRP	Fibreglass reinforced plastic.
Gel	Partial curing stage of resin.
Gelcoat	Surface coating.
Gel time	Working time of a resin.
GRP	Glass reinforced plastic, same as FRP.
Humidity	Air moisture content.
Inhibitor	Chemical designed to increase working time of resin.
MEKP	Methyl ethyl ketone peroxide – Hardener or catalyst for polyester resin.
MEK	Methyl ethyl ketone – A solvent.
Milled fibres	Very short lengths of glass used as a filler powder to thicken resin.
Osmosis	When water creeps straight through the gelcoat and into the laminate causing blisters and other problems.
PVA	Polyvinyl acetate (wood glue).
PVA	Polyvinyl alcohol (mould release agent)
Pigment	Used to colour gelcoat.
Plug	Original part from which to take a mould.
Pre-release	When a part releases from the mould prematurely.

Print through	Visible glassfibre pattern on gelcoat.
Promoter	See Accelerator.
Release agent	Wax or PVA.
Resin rich	Too much resin in the laminate.
Roving	Continuous bunch of glassfibre.
Scantlings	Designed structure of the hull and deck
Shelf-life	The time an unused resin can be kept.
Skin coat	See Backup layer.
Surface mat	Very light tissue mat usually used next to the gelcoat.
Talc	Chalk powder.
Tooling gelcoat	Used for making moulds.
Viscosity	Thickness of the resin.
Voids	Air bubbles in the laminate.
Wax	Mould release agent.
WR	Woven roving – woven glassfibre cloth. Its weight is expressed in grams per square metre.

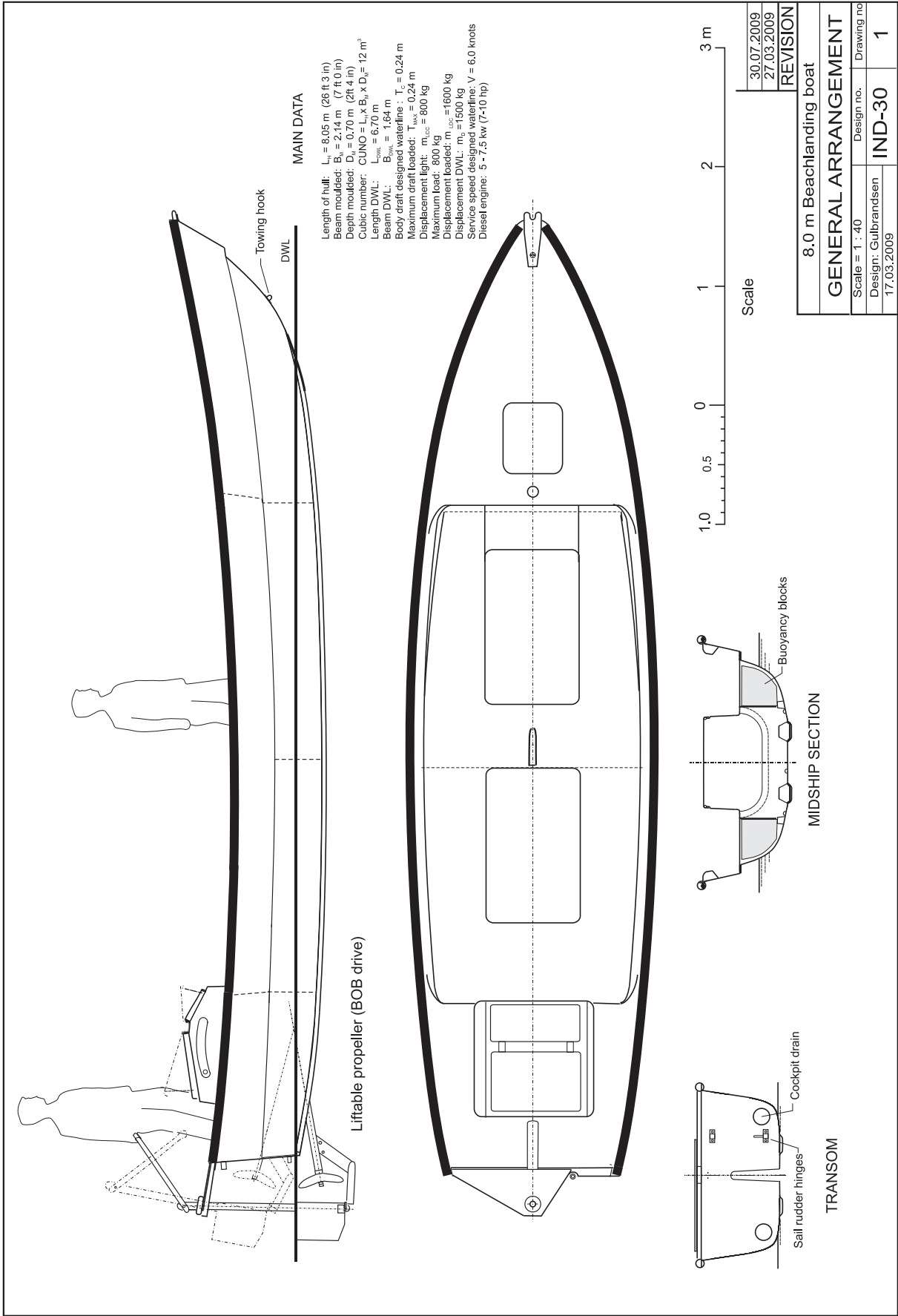


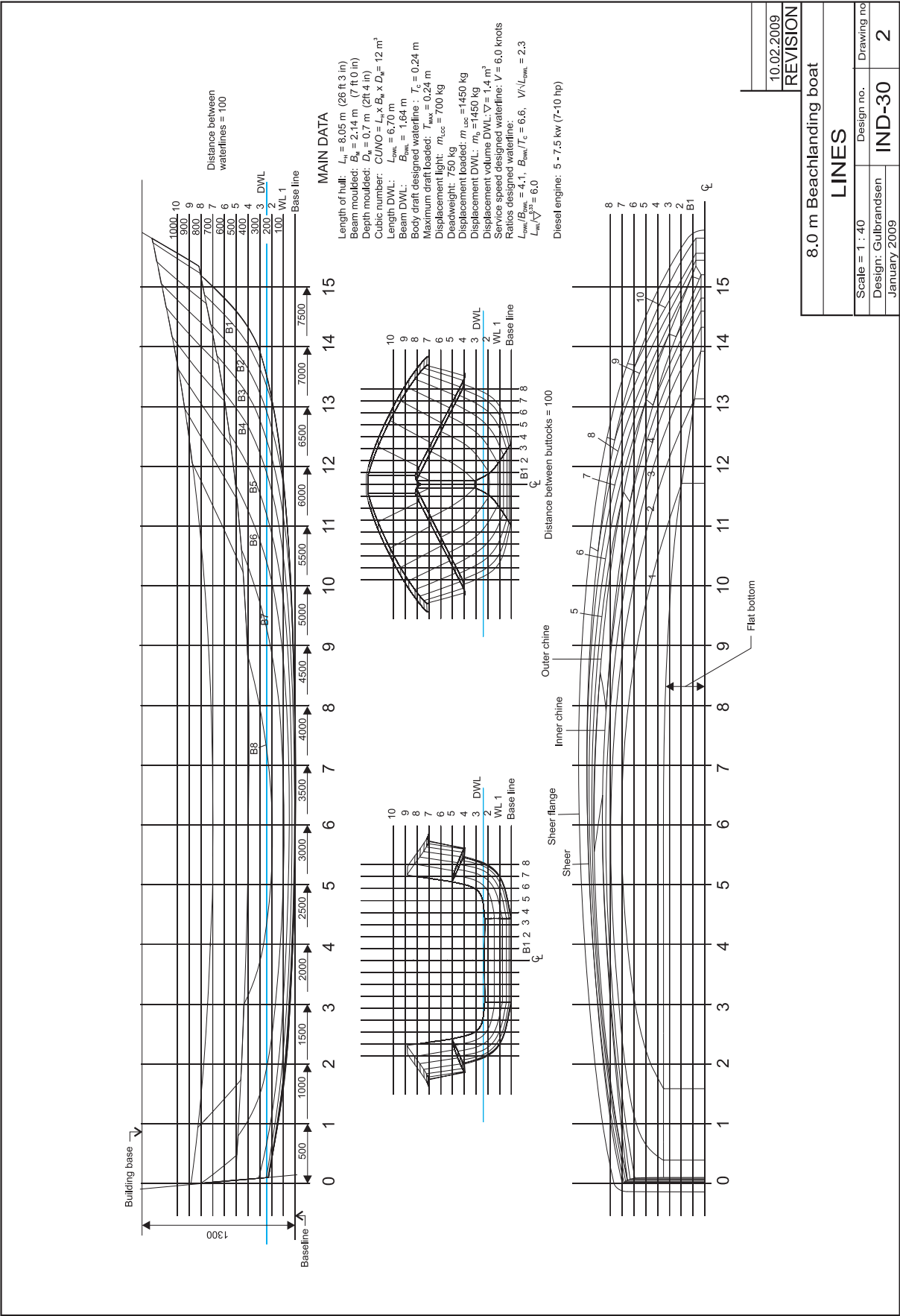
Annex 3: DRAWINGS

IND - 30 8 m BEACH-LANDING BOAT – THE PLUG

1. GENERAL ARRANGEMENT
2. LINES
3. OFFSET TABLE
4. TRANSOM
5. PLUG FRAME
6. FRAME 12
7. FRAME 13
8. FRAME 14
9. FRAME 15
10. STEM JIG
11. STEM ASSEMBLY
12. BUILDING JIG
13. RUBBING SHOE



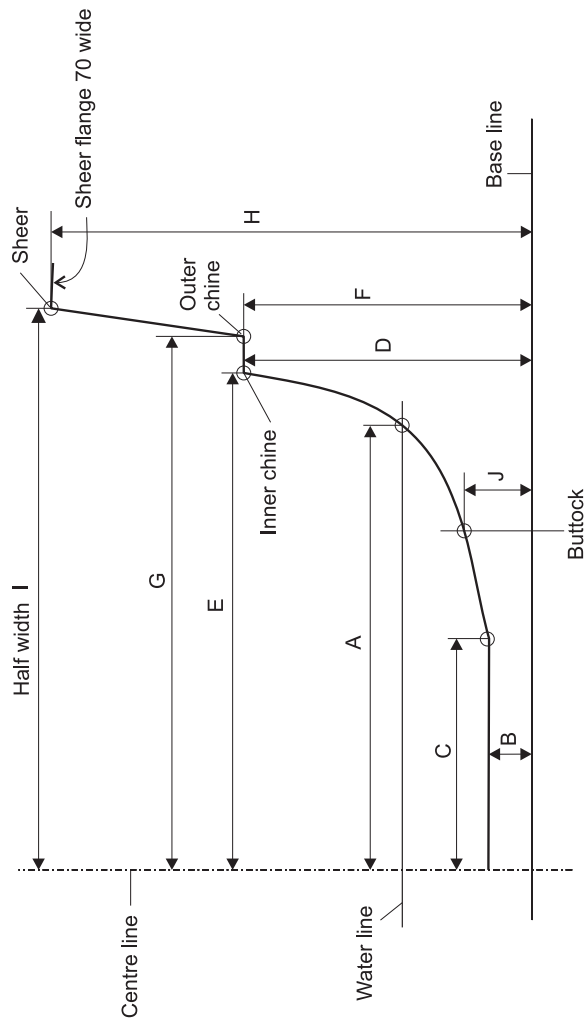




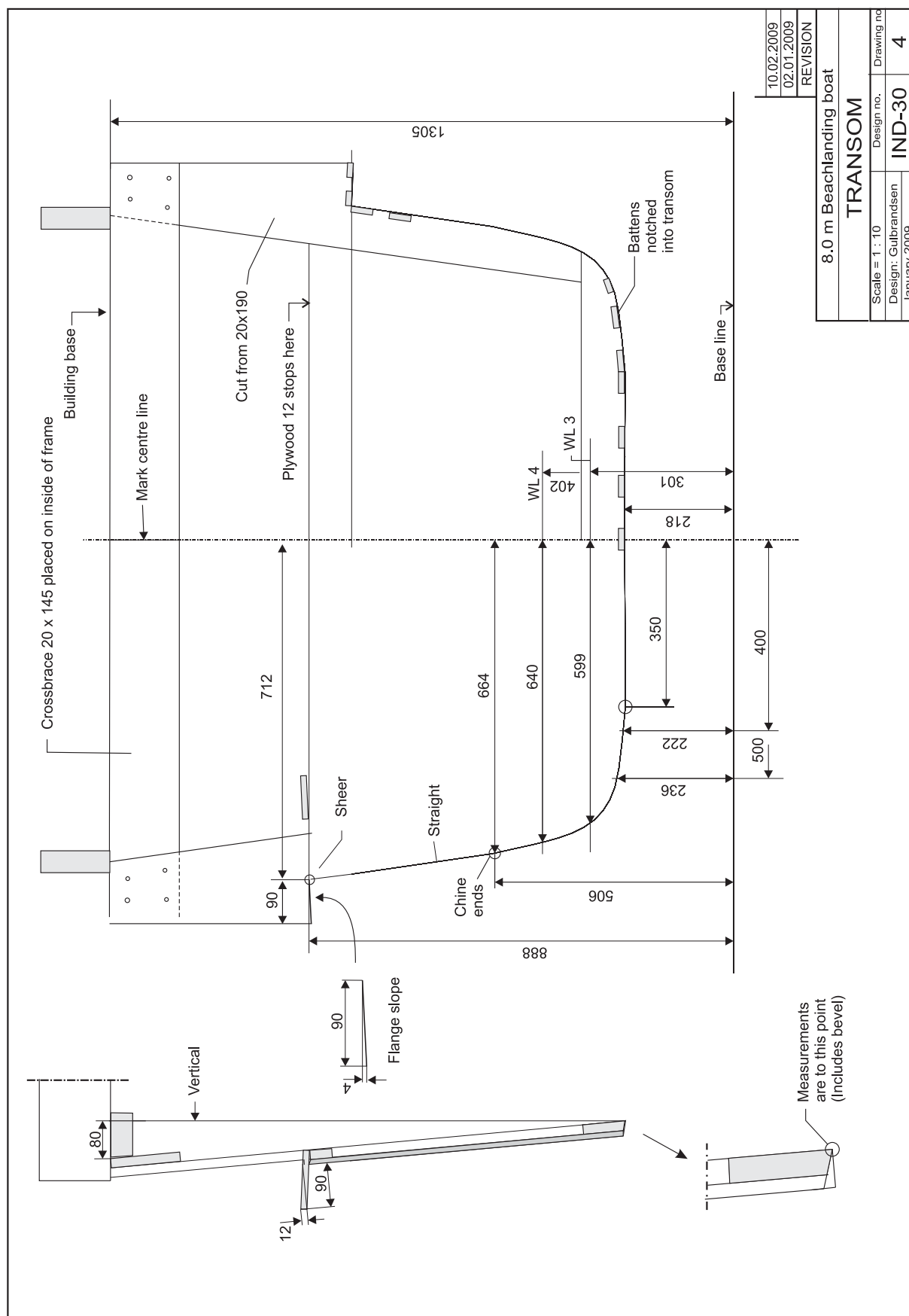
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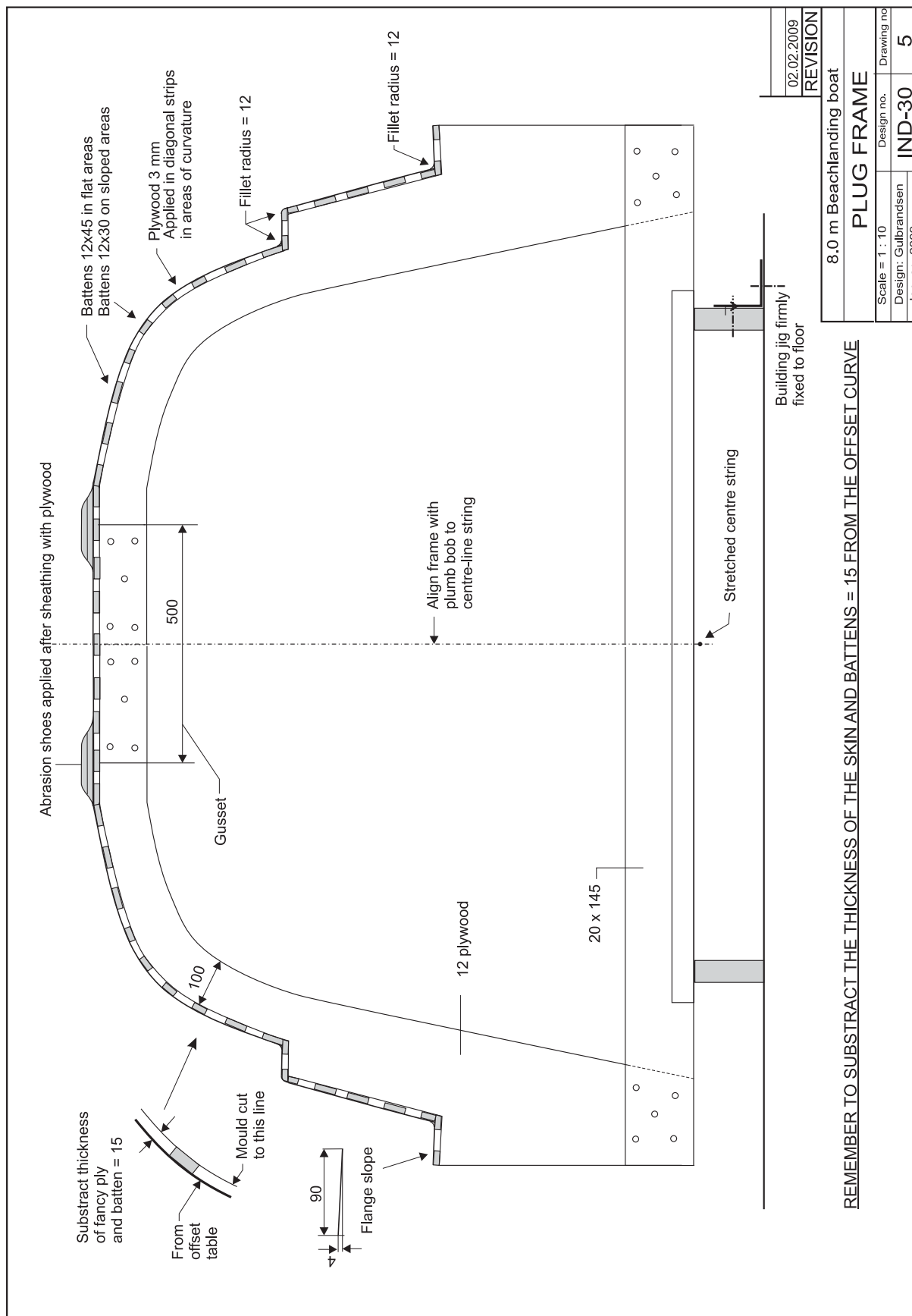
IND - 30 OFFSET TABLE

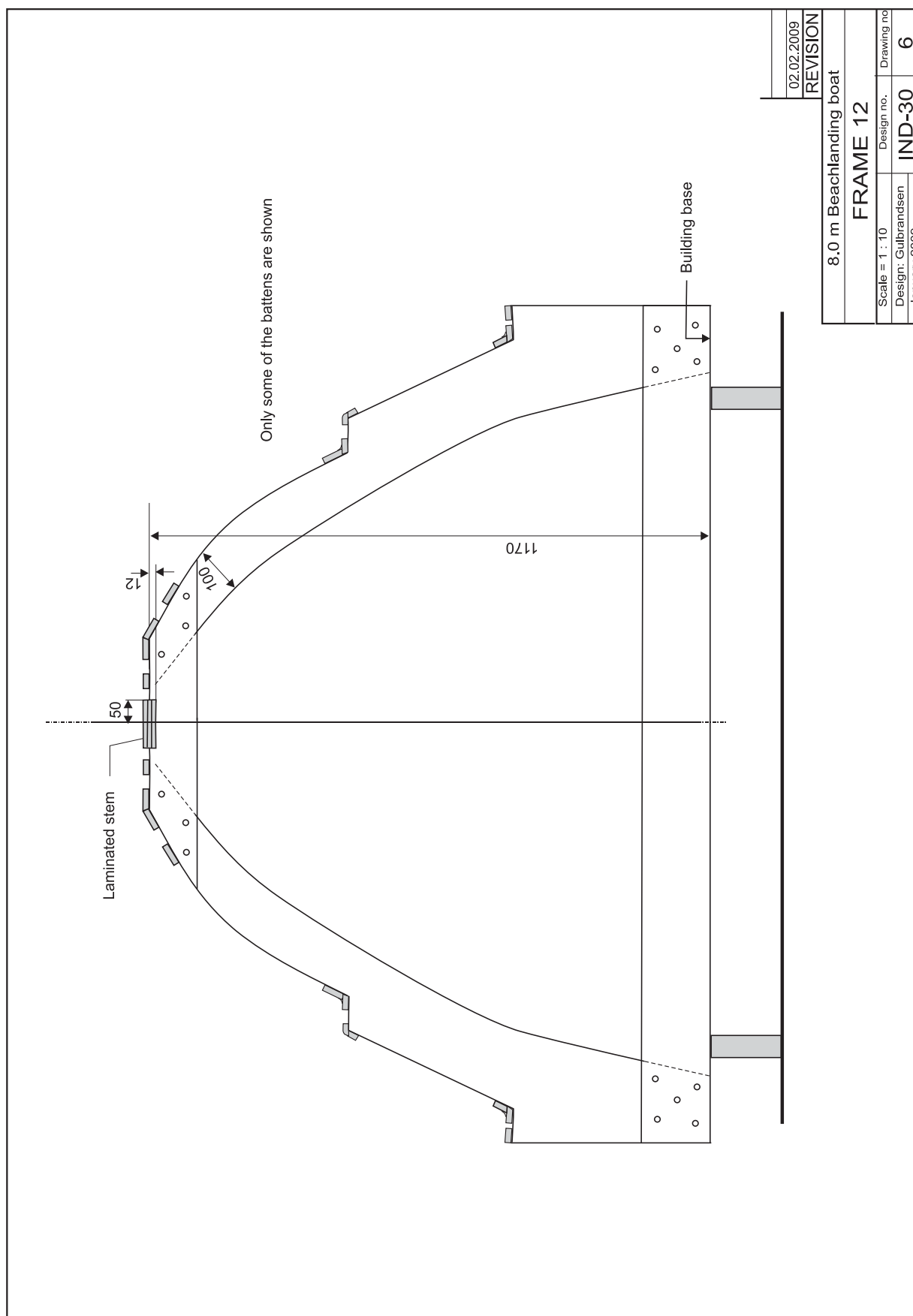
Drawing no. 3

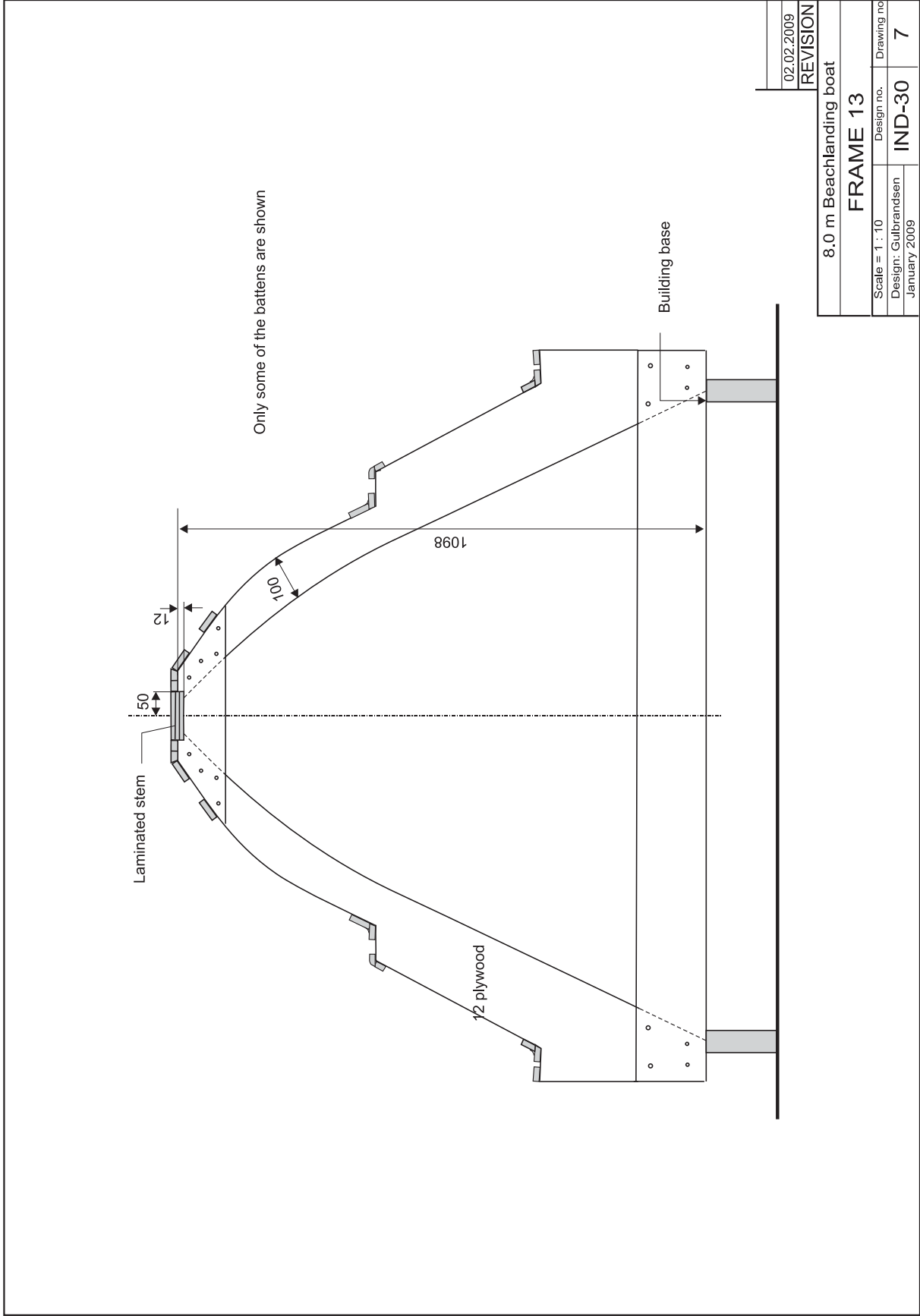


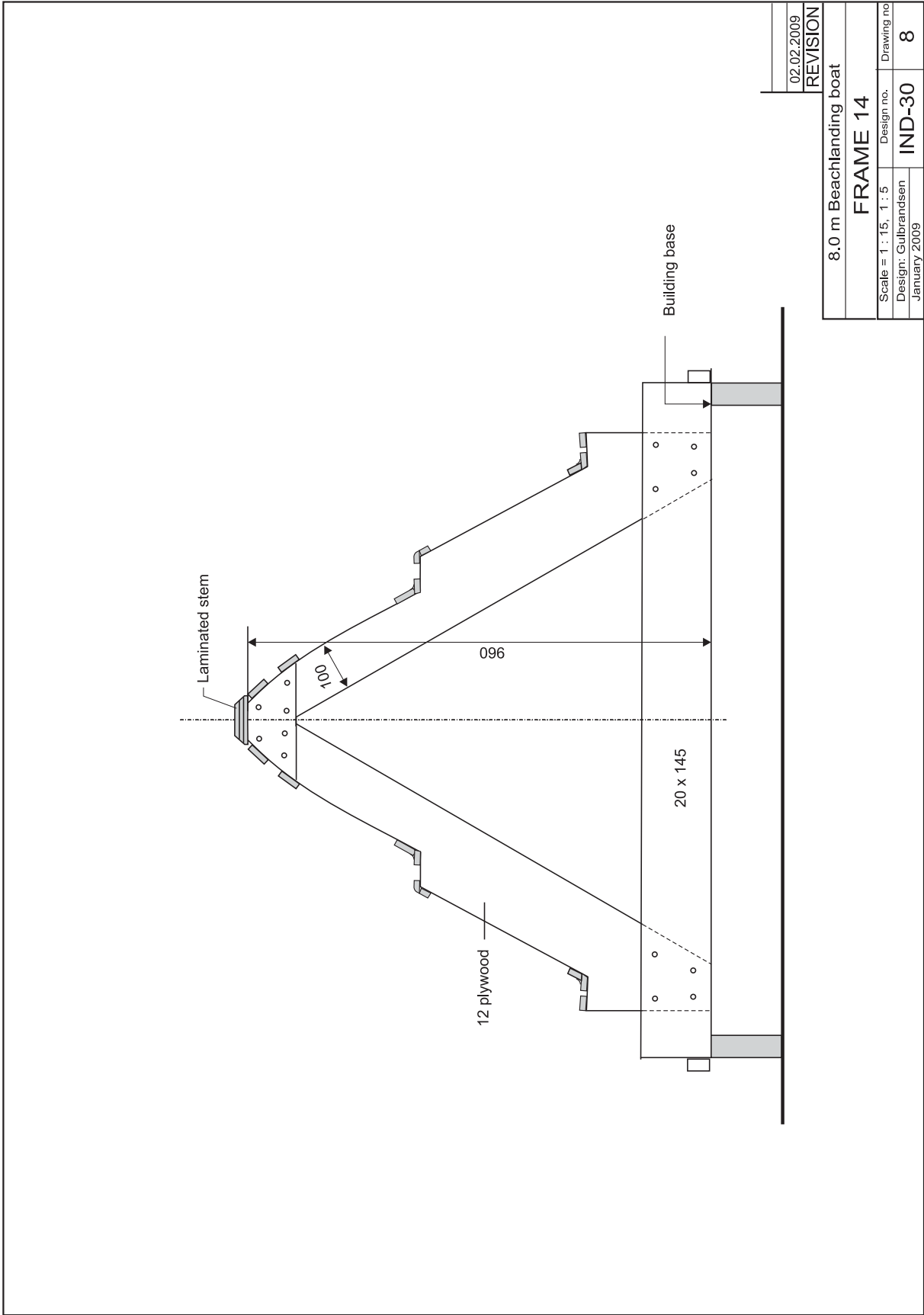
Section	1/2 WIDTH A						FLAT BOTTOM		INNER CHINE		OUTER CHINE		SHEER		BUTTOCK HEIGHT J			
	WATERLINES						B	C	D	E	F	G	H	I	1/2 Width	B4	B5	B6
	1	2	3	4	5	6												
1	0	582	669	697	751	768	147	350	476	711	476	747	822	804		149	170	
2	459	674	729	751	823	838	79	350	453	760	453	816	776	864		86	110	147
3	589	728	774	794	876	890	43	350	435	800	435	867	743	912		53	73	105
4	657	768	810	830	917	931	20	350	418	833	418	905	720	948		29	50	77
5	693	794	834	857	945	960	7	350	406	859	406	930	707	976		16	35	60
6	706	800	841	840	958	975	0	350	399	870	399	938	702	993		10	30	54
7	694	785	829	932	955	977	0	348	394	860	394	930	705	1000		10	30	57
8	653	750	798	908	936	964	7	337	397	835	397	906	719	994		21	43	74
9	576	693	749	790	898	929	20	317	411	796	411	868	743	972		40	68	113
10	466	609	677	726	839	874	38	287	438	744	438	815	777	935		74	116	
11	319	486	572	630	753	794	67	243	475	672	475	741	819	880		139		
12	0	328	436	502	555	674	115	174	527	571	527	640	872	806				
13	0	117	254	339	394	516	187	95	594	442	594	512	941	696				
14	0	0	0	0	180	230	313	35	681	276	681	345	1030	534				
15	0	0	0	0	0	0	694	35	786	74	786	144	1132	315				

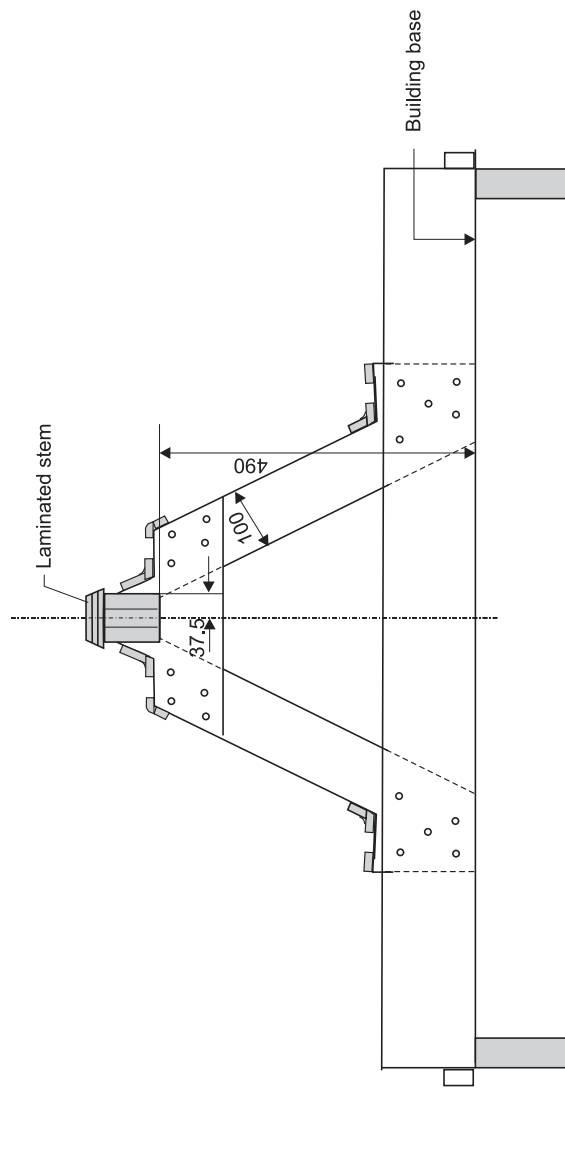




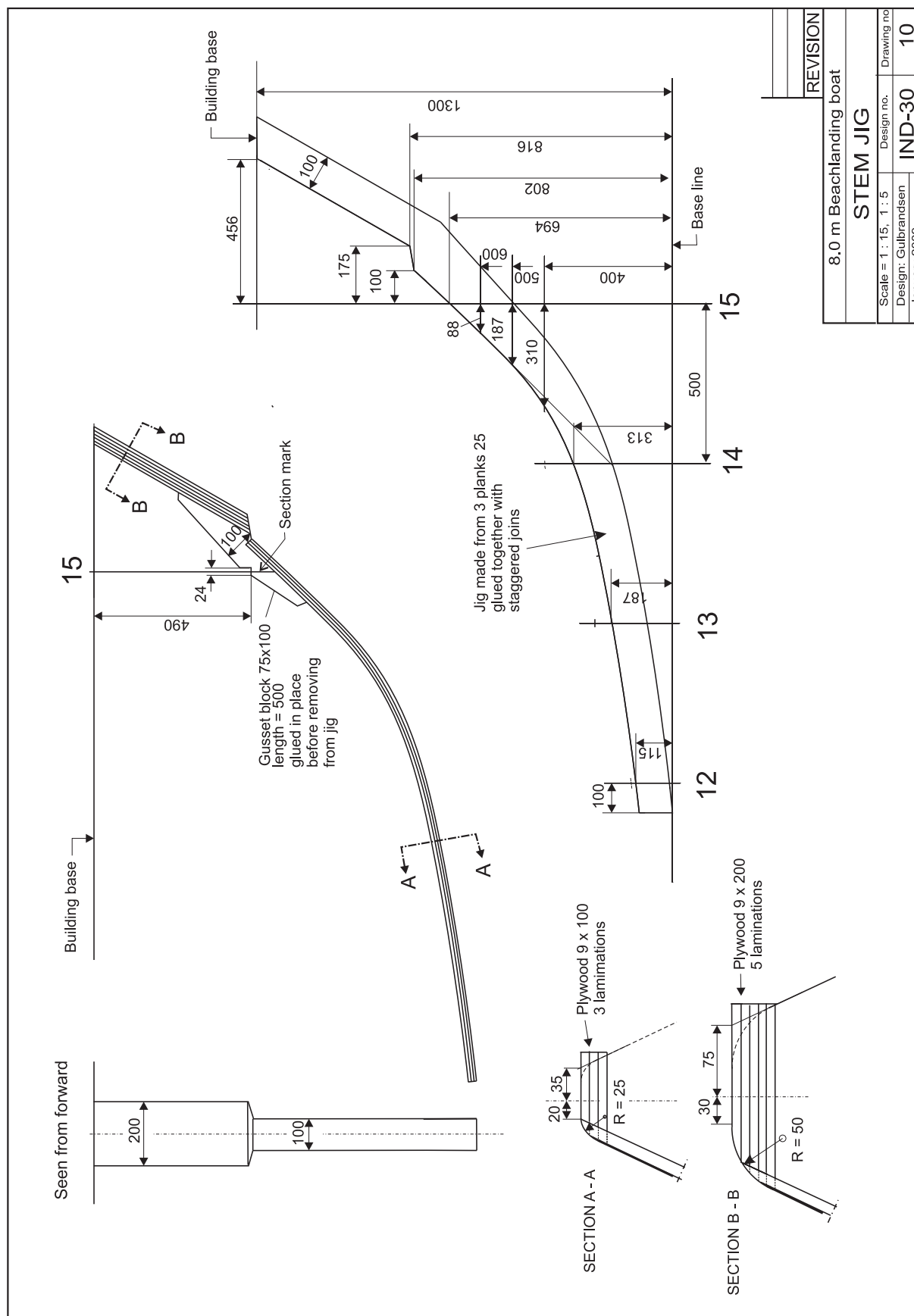


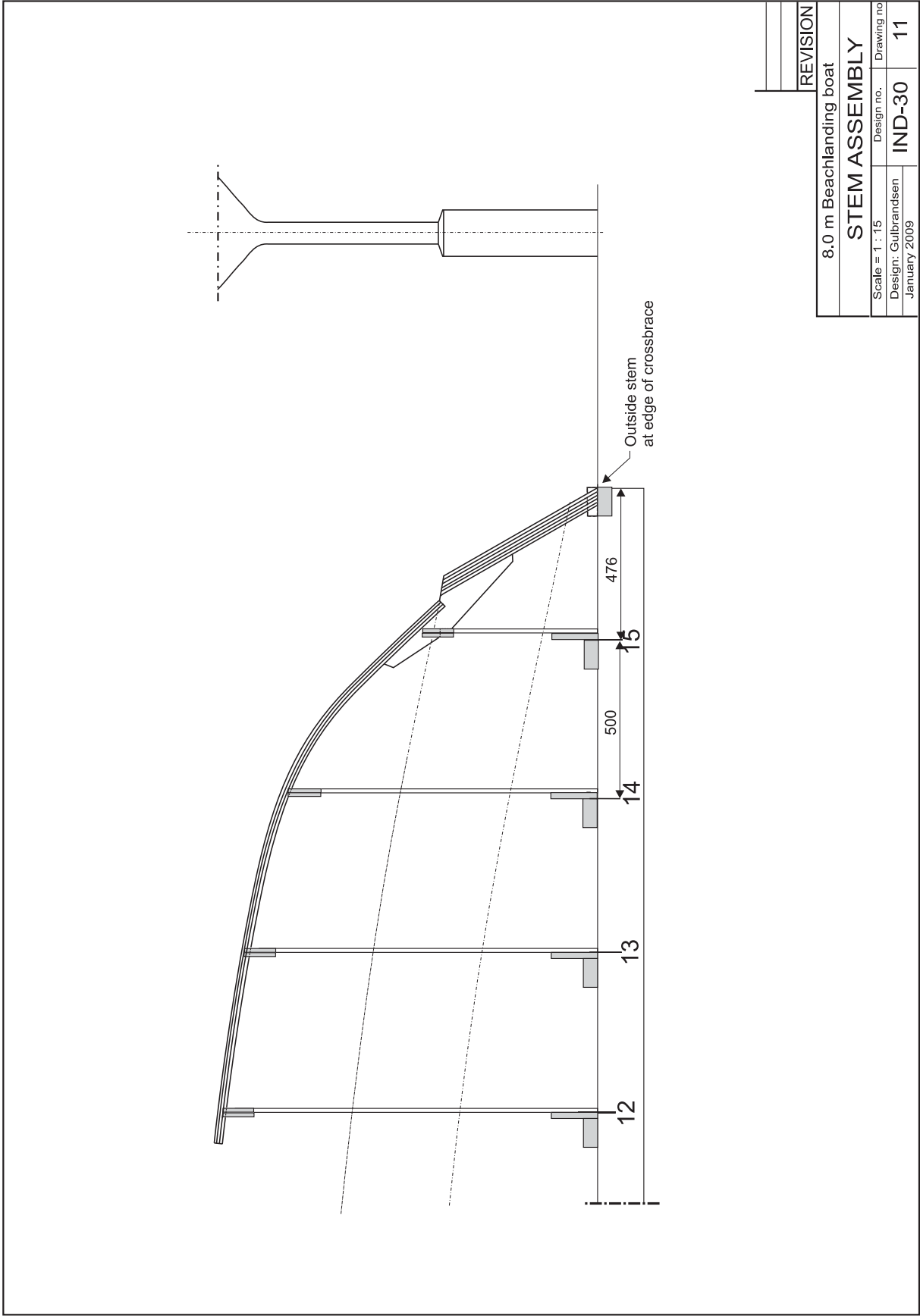


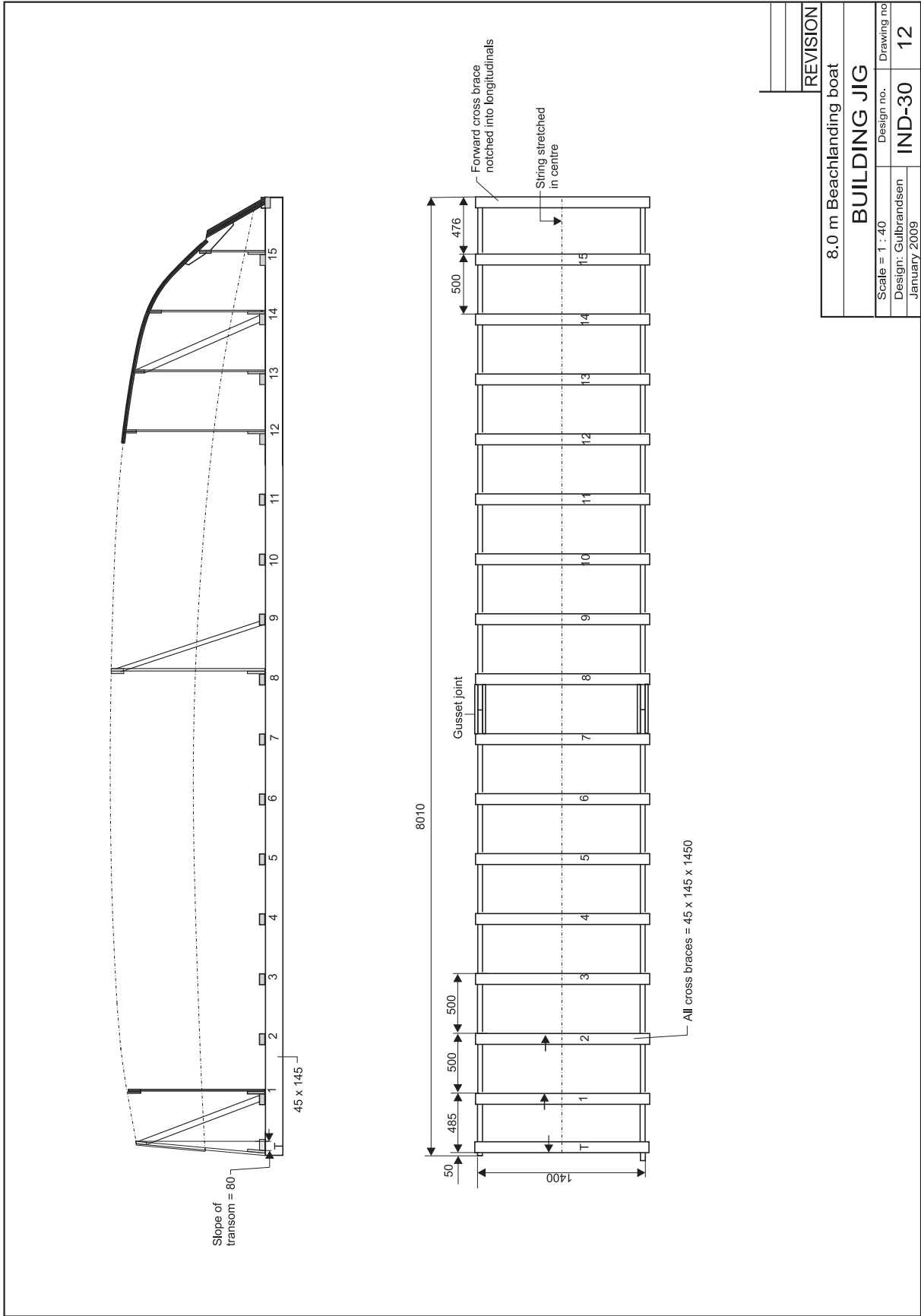


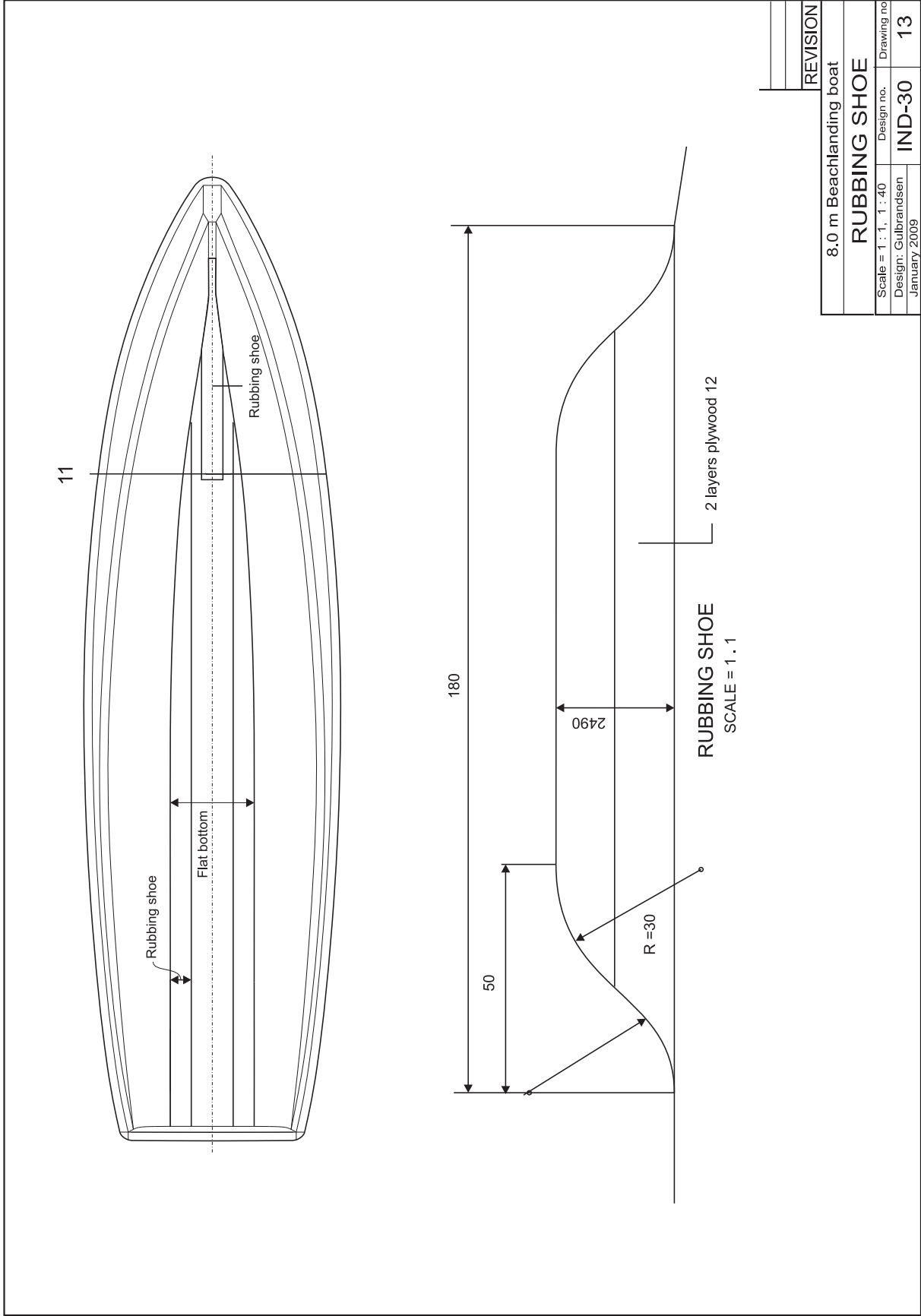


02.02.2009	
REVISION	
8.0 m Beachlanding boat	
FRAME 15	
Scale = 1 : 10	Design no.
Design: Gulbrandsen	IND-30
January 2009	Drawing no.
	9





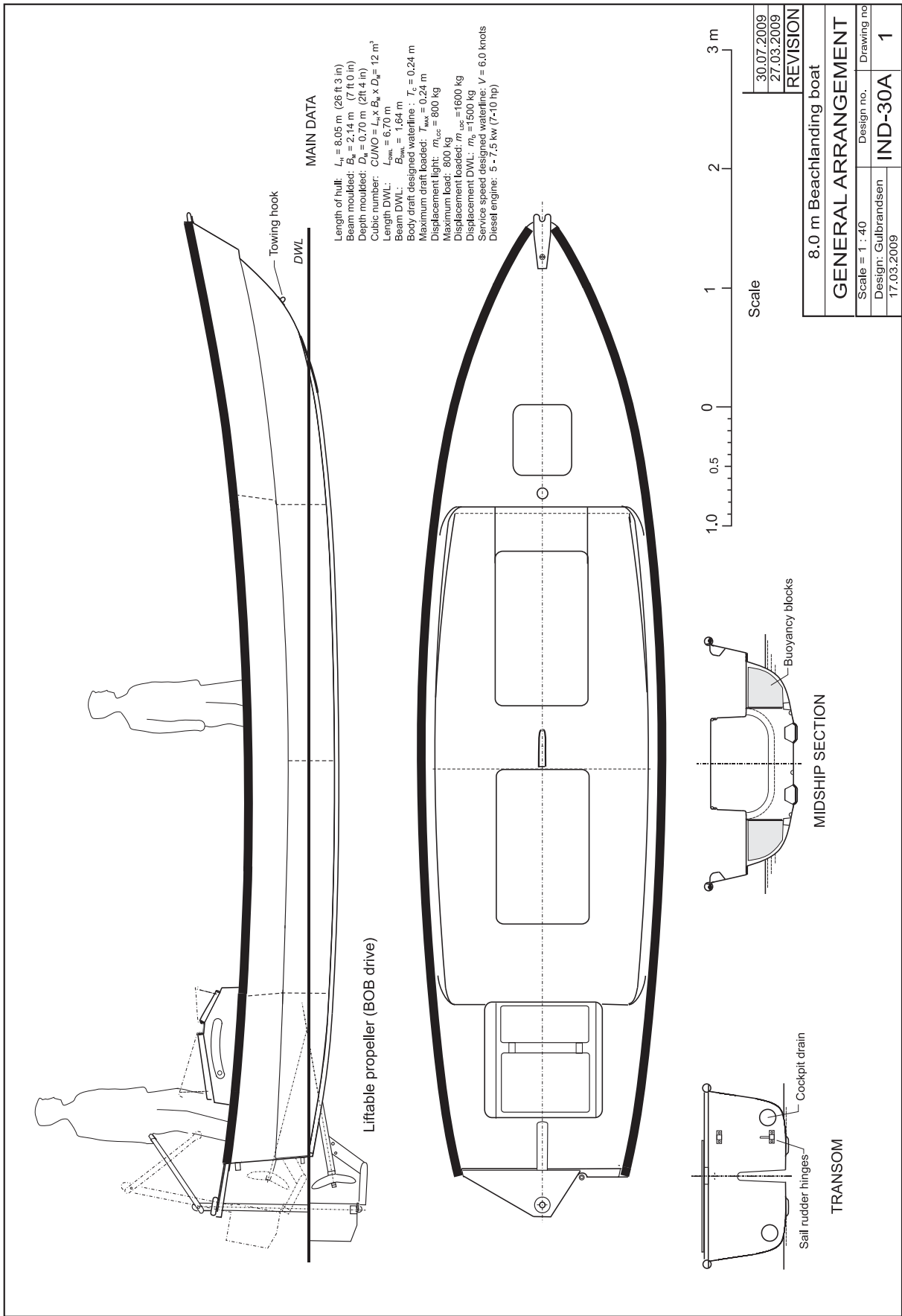


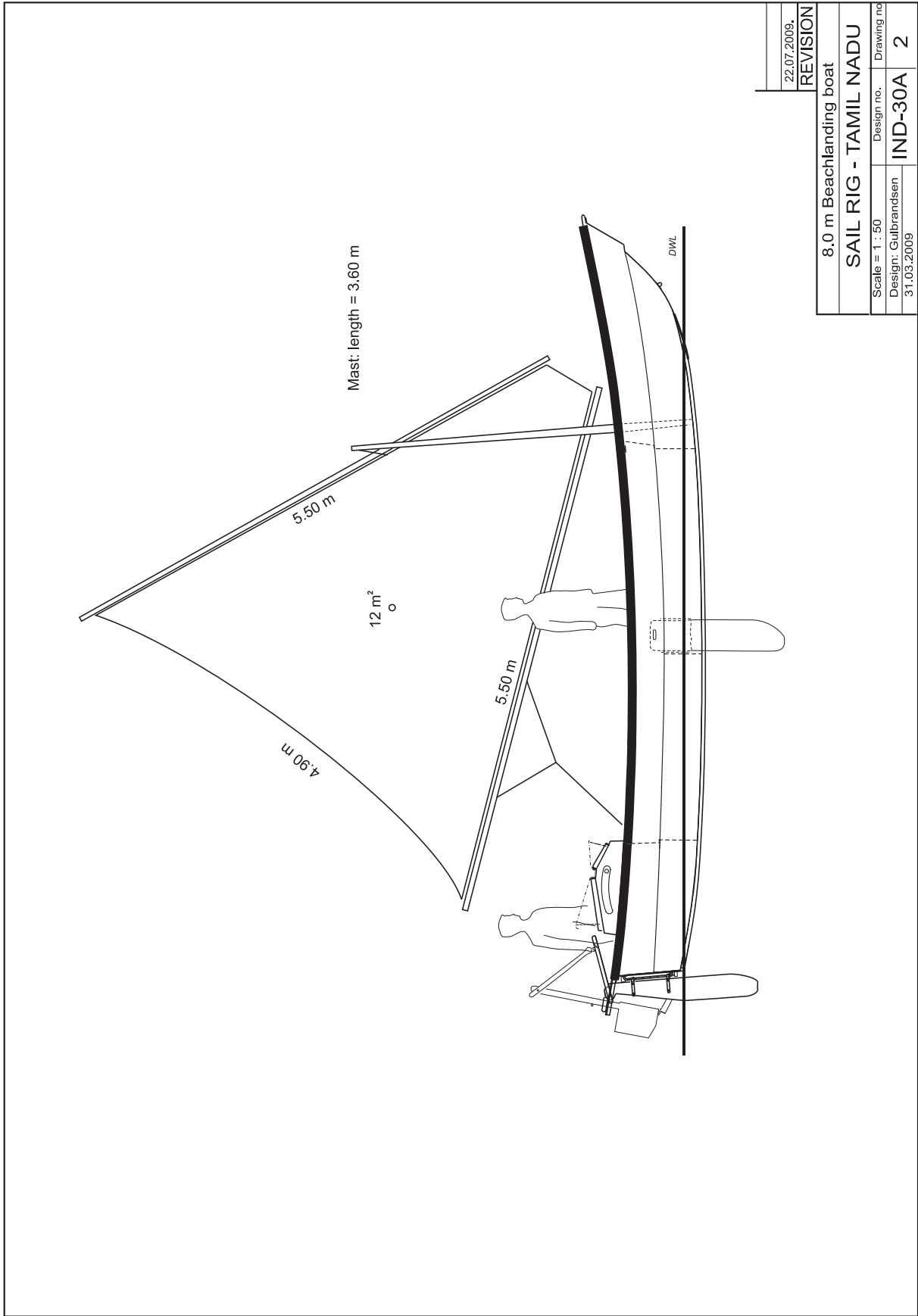




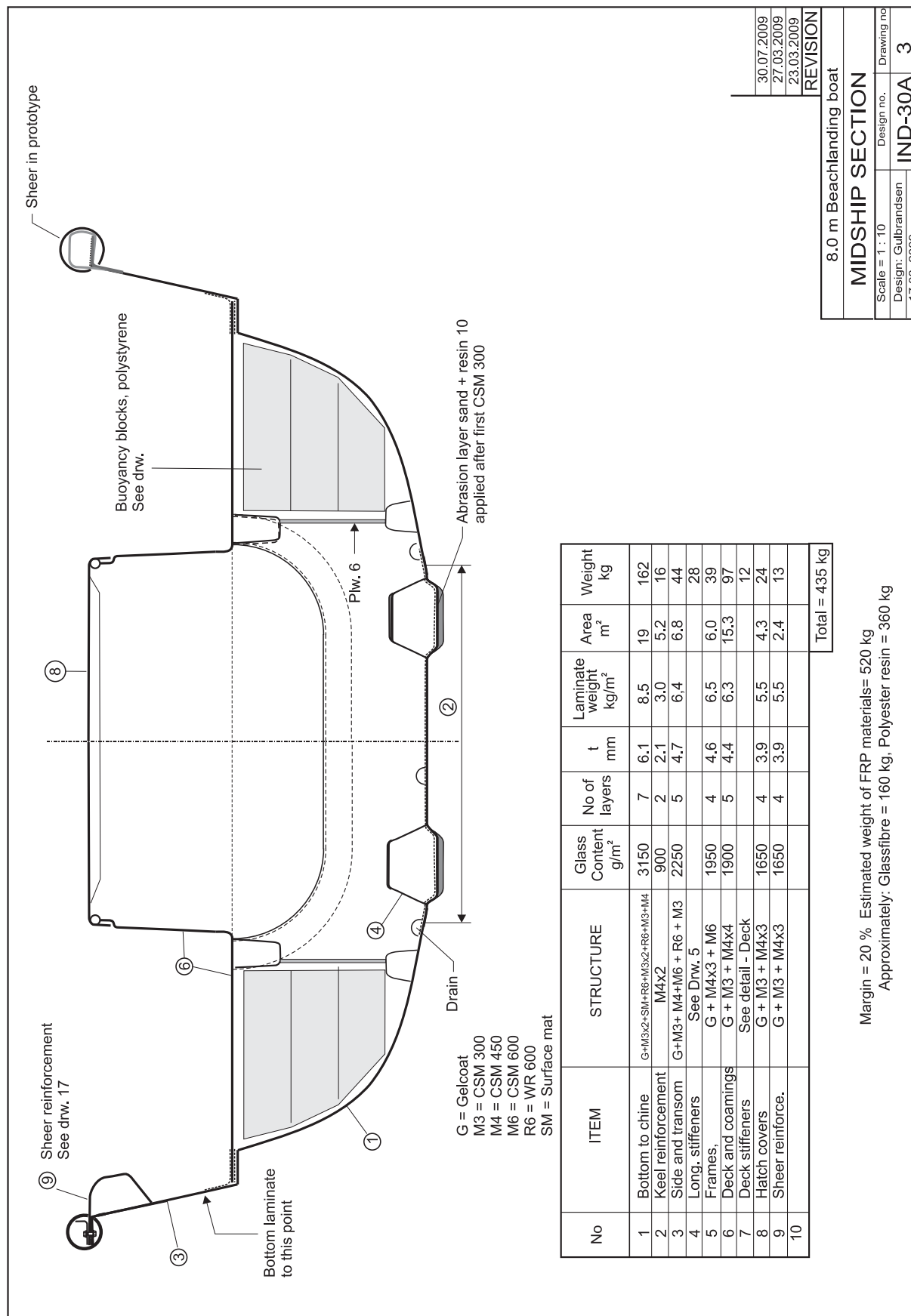
IND - 30A
8 m BEACH-LANDING BOAT

- | | |
|---------------------------|---------------------------|
| 1. General arrangement | 18. Hatch lock 1 |
| 2. Sail rig - Tamil Nadu | 19. Hatch lock 2 |
| 3. Midship section | 20. Sailing rudder |
| 4. FRP layup | 21. Rudder hinge |
| 5. Bottom stiffening | 22. Transom assembly |
| 6. Propeller shaft tunnel | 23. Centreboard |
| 7. Centreboard case | 24. Towing hook |
| 8. Frame 1 | 25. Mooring bitt |
| 9. Frame 2 | 26. Buoyancy blocks |
| 10. Frame 3 | 27. Right after capsize |
| 11. Frame 4 | 28. Engine installation A |
| 12. Frame 5 | 29. Engine installation A |
| 13. Lower deck | 30. Side view |
| 14. Coaming details | 31. Engine installation B |
| 15. Upper deck | 32. Engine bed |
| 16. Non-skid and details | 33. Engine hatch cover |
| 17. Rail | |



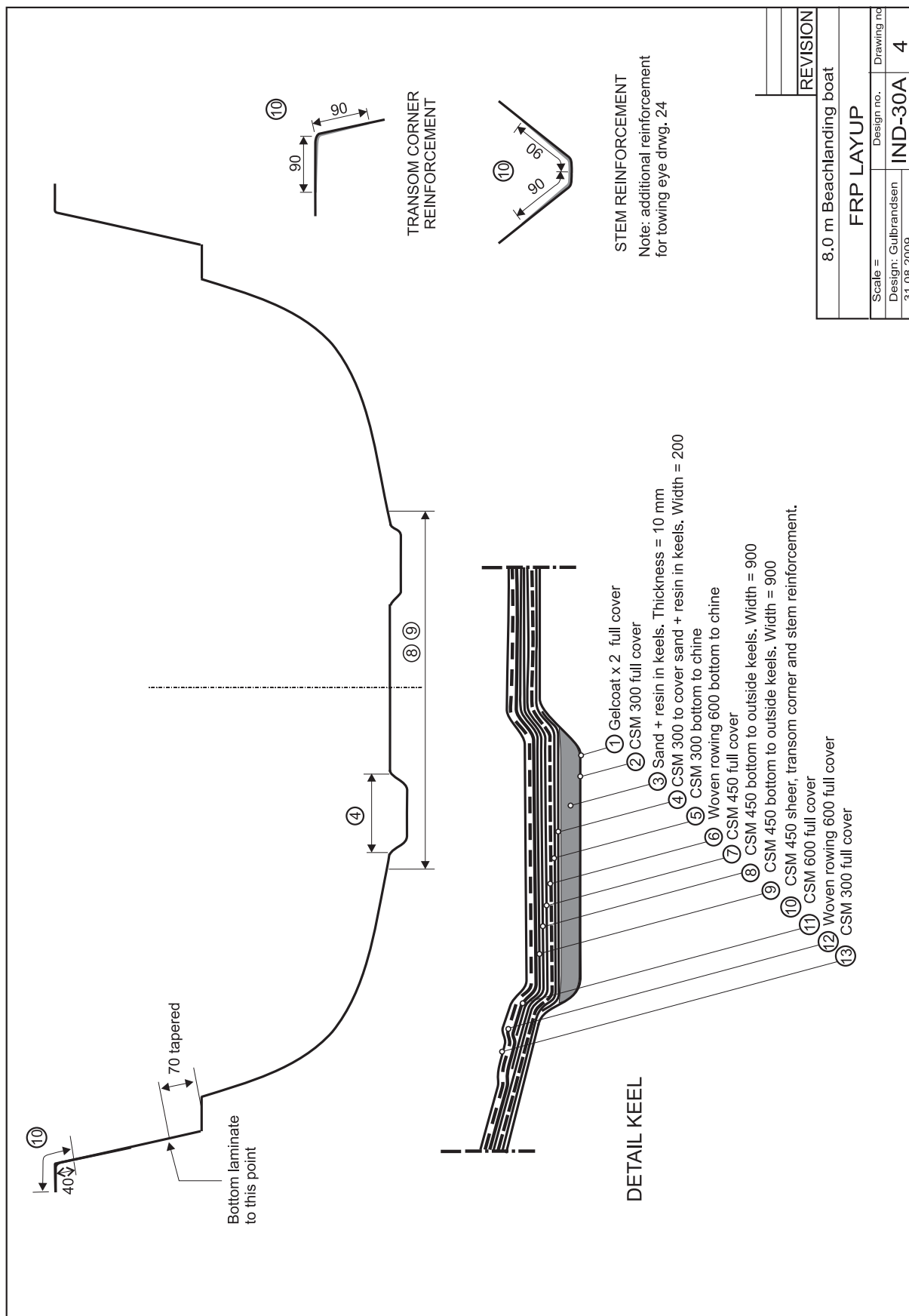


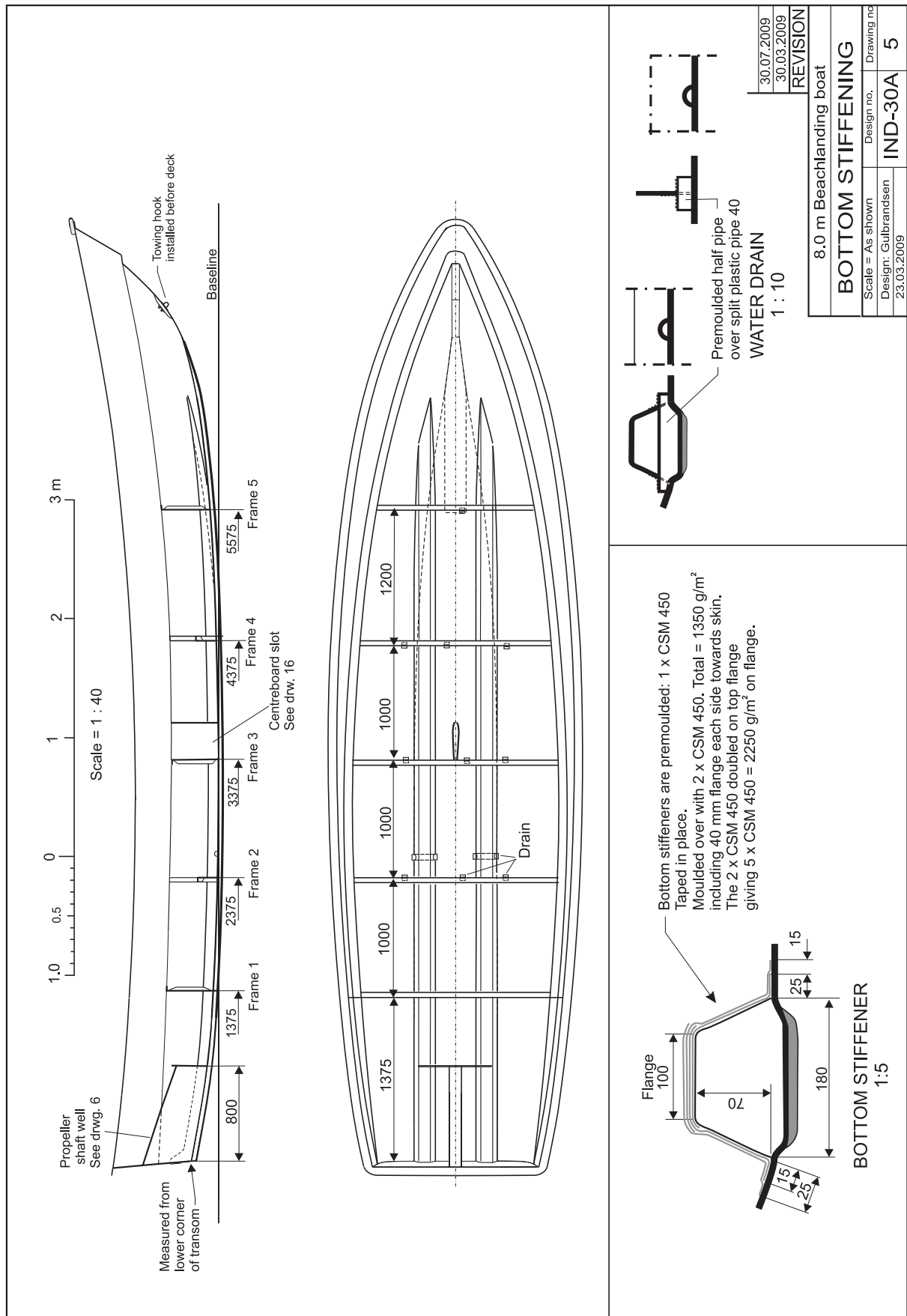
22.07.2009.		REVISION	
8.0 m Beachlanding boat		SAIL RIG - TAMIL NADU	
Scale = 1 : 50	Design no.	IND-30A	Drawing no.
31.03.2009			2



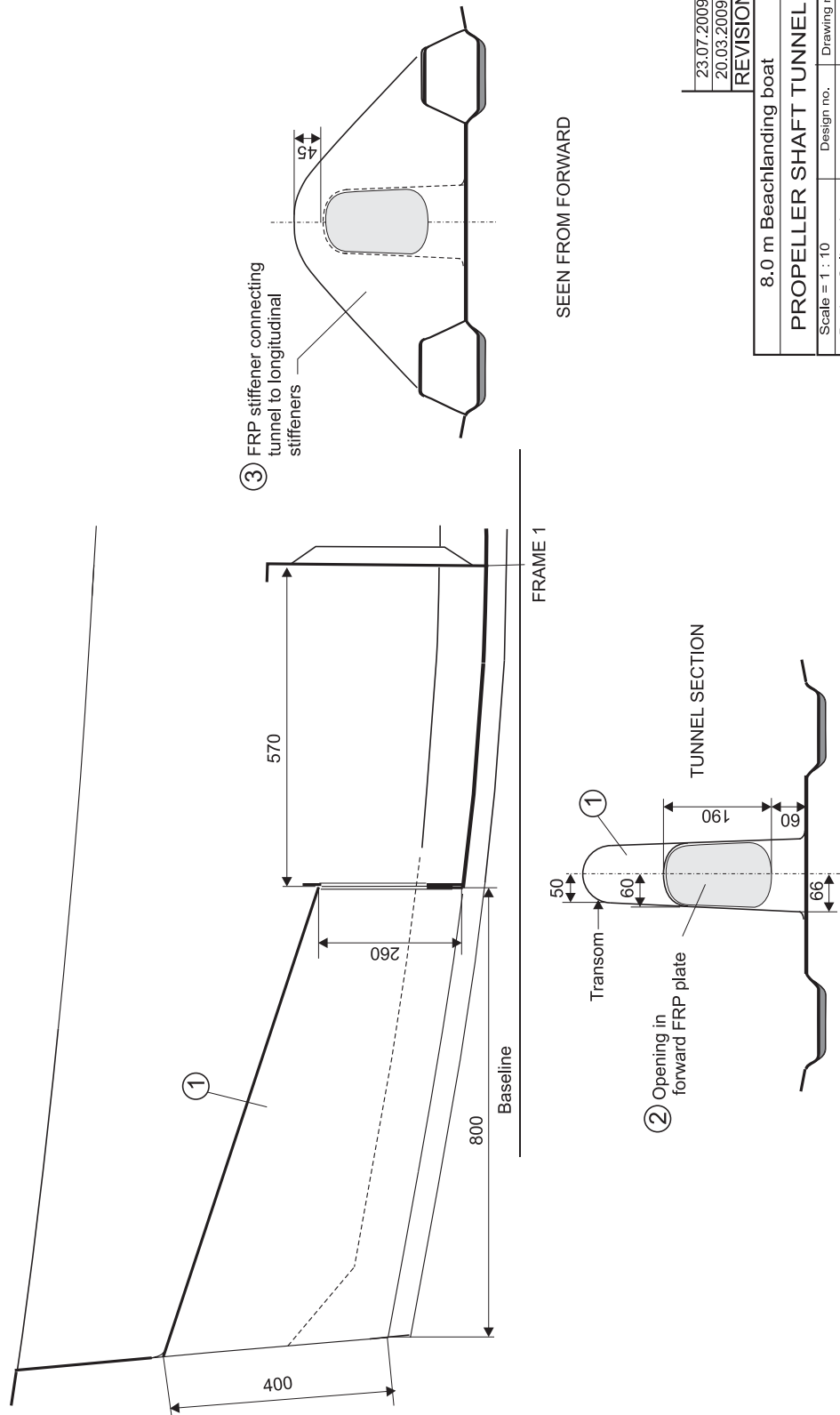
8.0 m Beachlanding boat		
MIDSHIP SECTION		
Scale = 1 : 10	Design no.	Drawing no.
Design: Gulbrandsen	IND-30A	3
17.03. 2009		

REVISION
30.07.2009
27.03.2009
23.03.2009

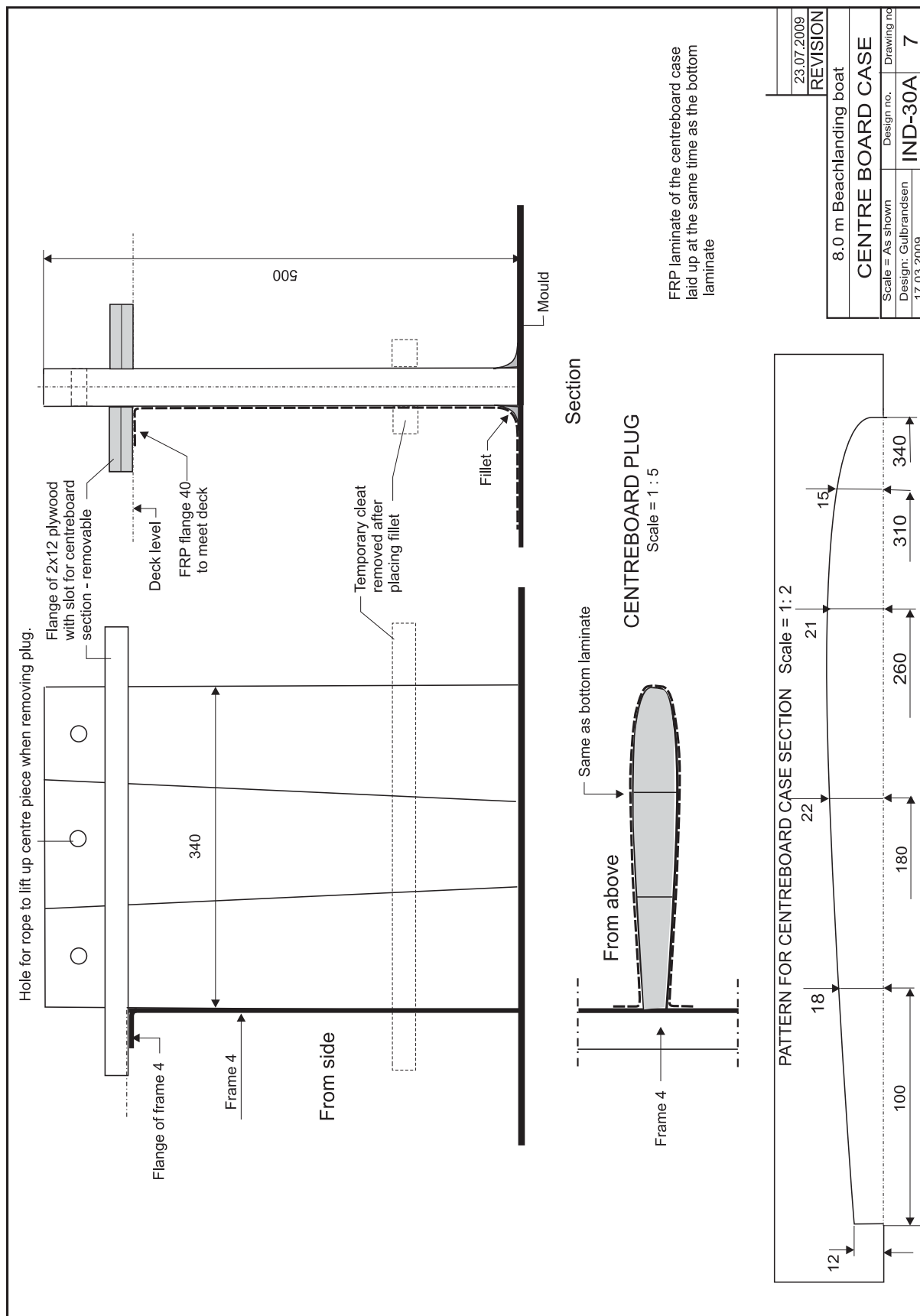


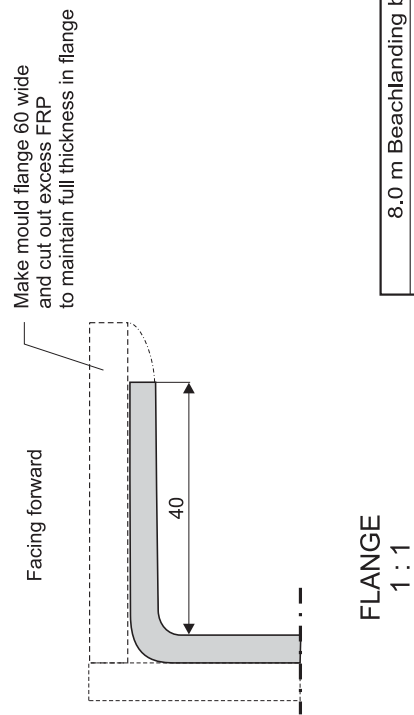
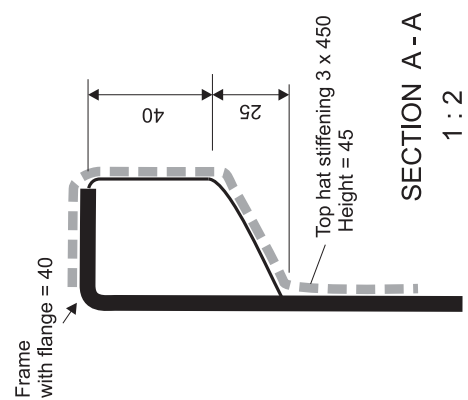
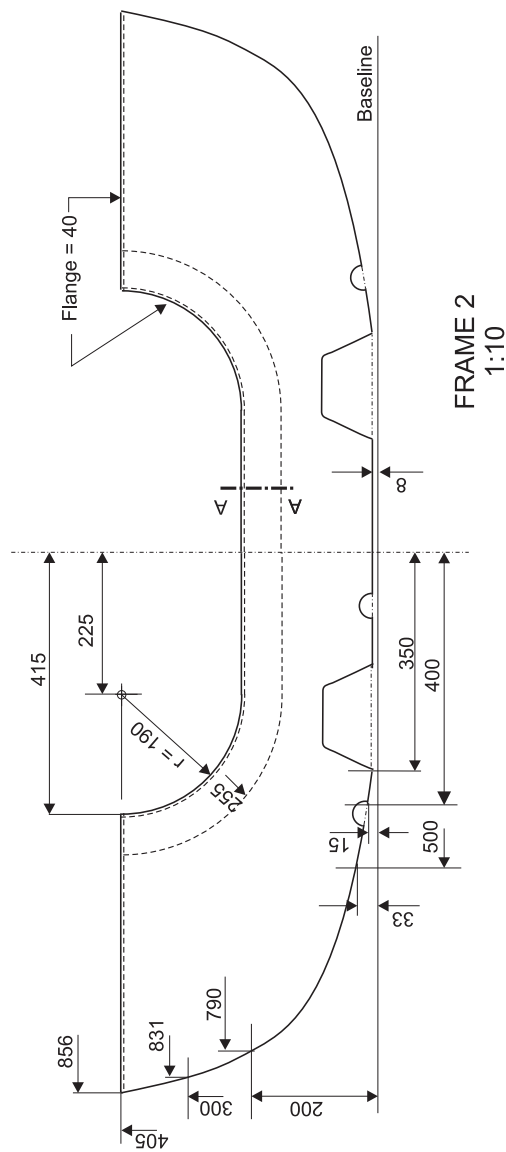


- ① The tunnel including the front end should be part of the mould and laid up at the same time as the skin laminate.
- ② An opening to be cut in the forward part of the tunnel according to the dimensions shown.
- ③ The transverse stiffening should be laid up on a flat panel, cut to shape including opening and tabbed to the tunnel, the bottom laminate and the stiffeners.

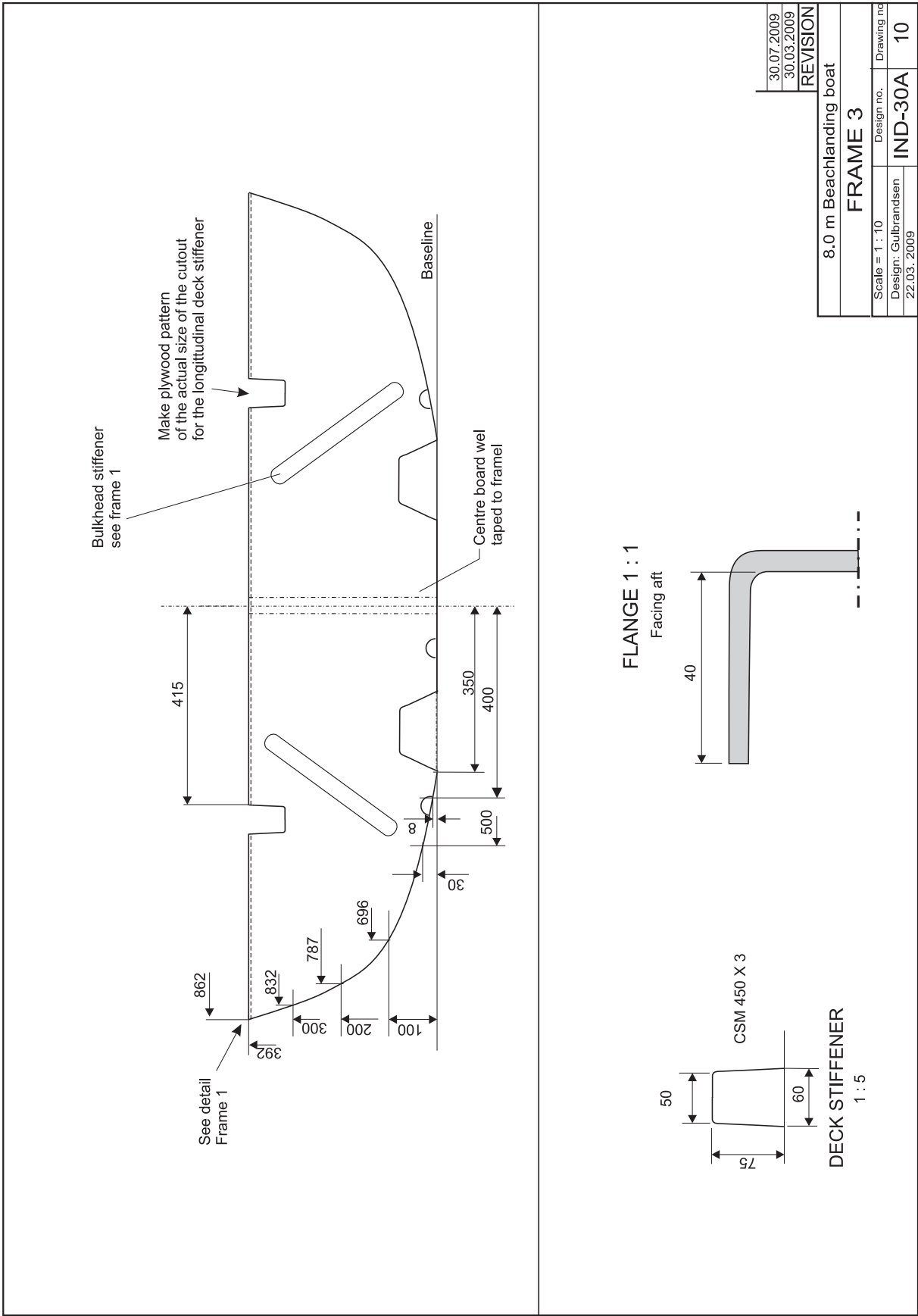


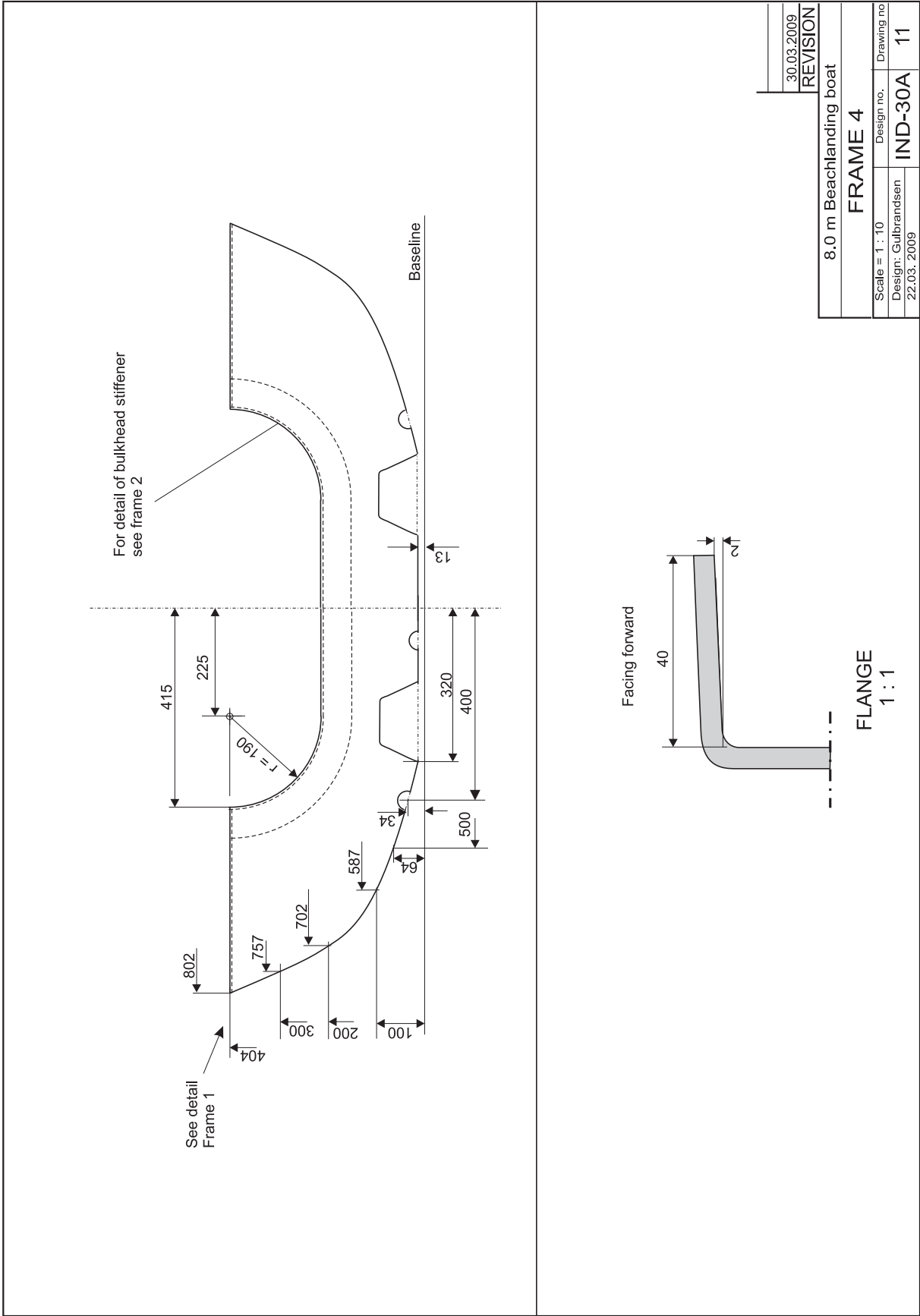
23.07.2009	REVISION	
20.03.2009		
8.0 m Beachlanding boat		
PROPELLER SHAFT TUNNEL		
Scale = 1 : 10	Design no.	Drawing no.
Design: Gulbrandsen	IND-30A	6
18.03.2009		

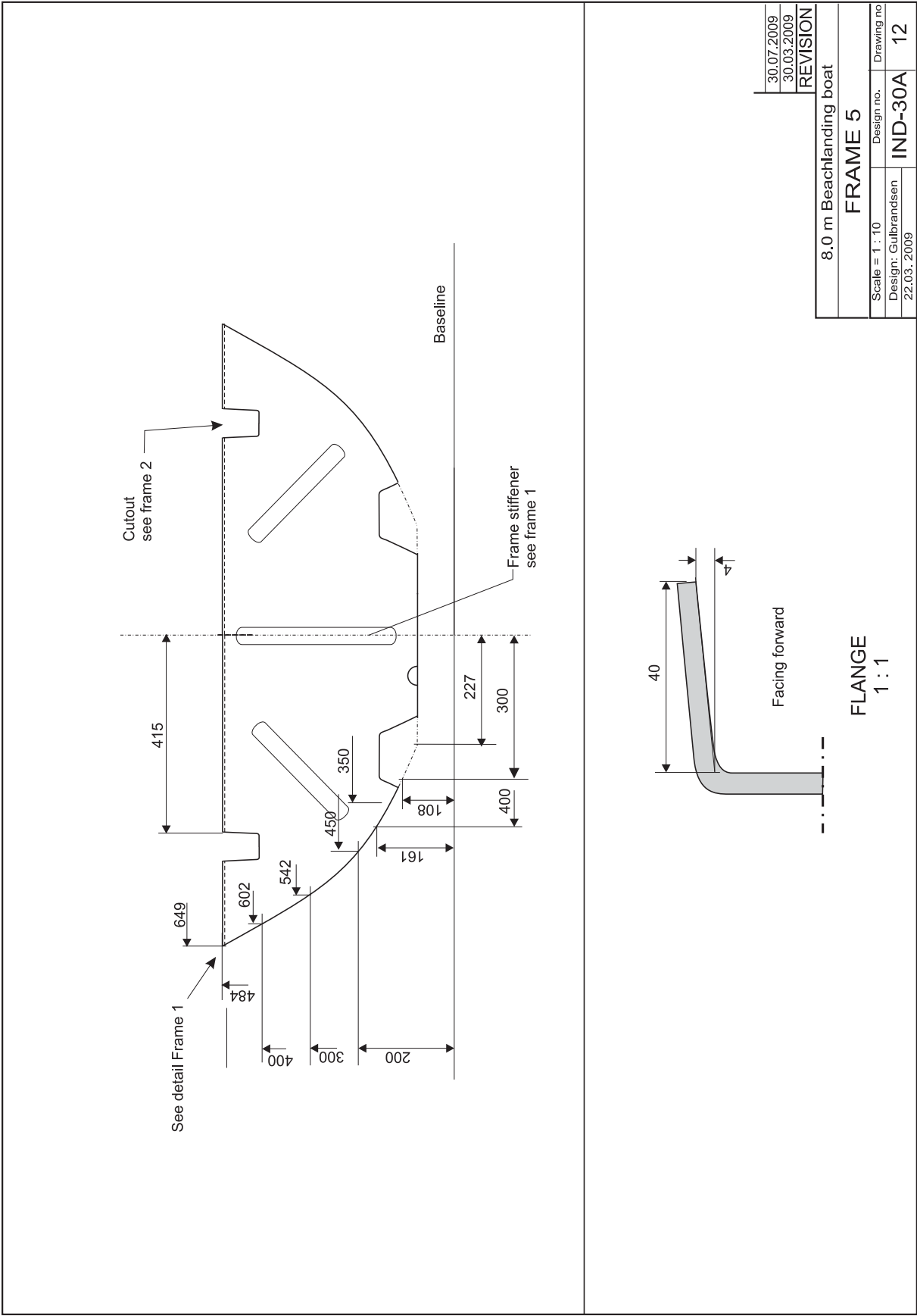


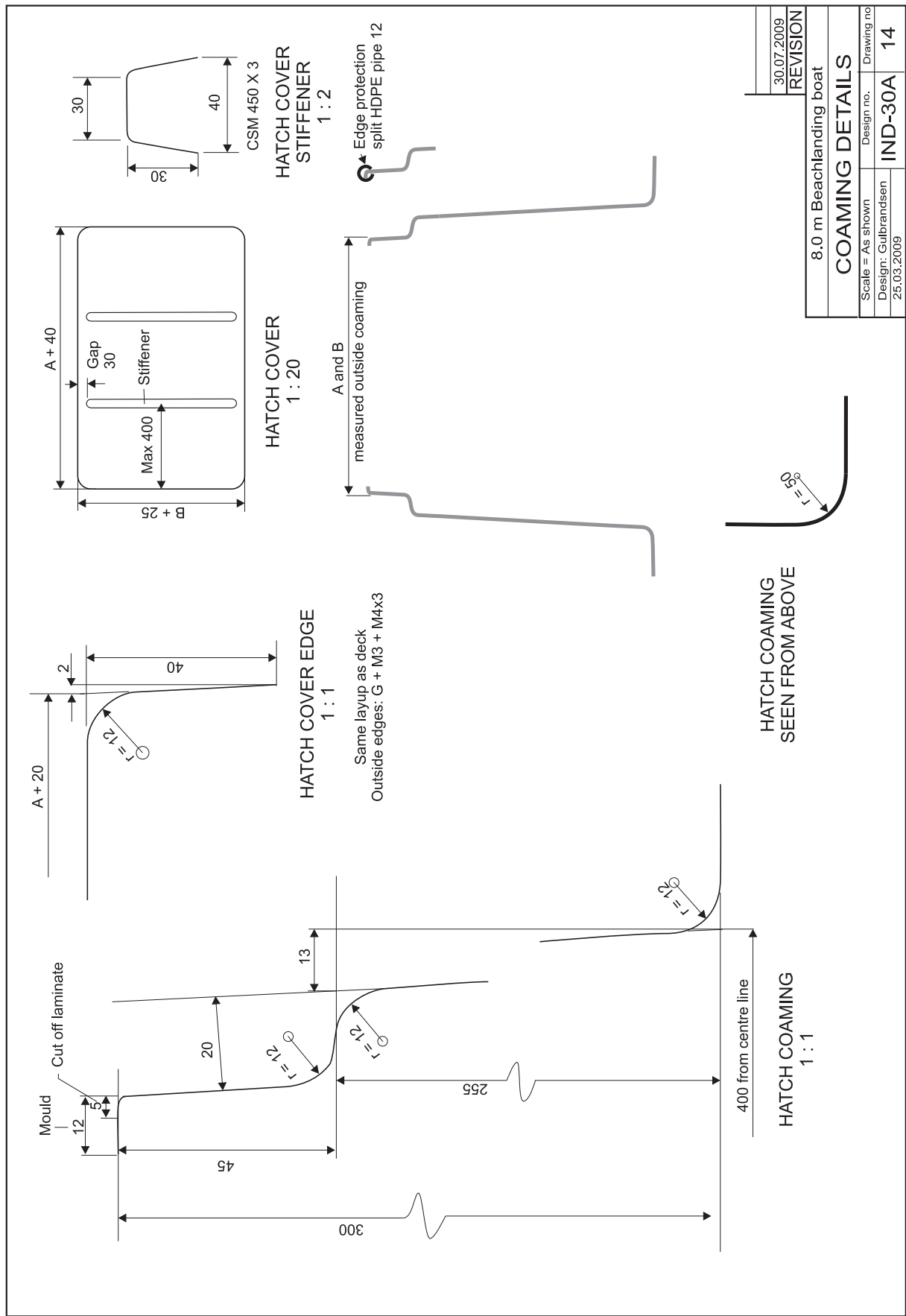


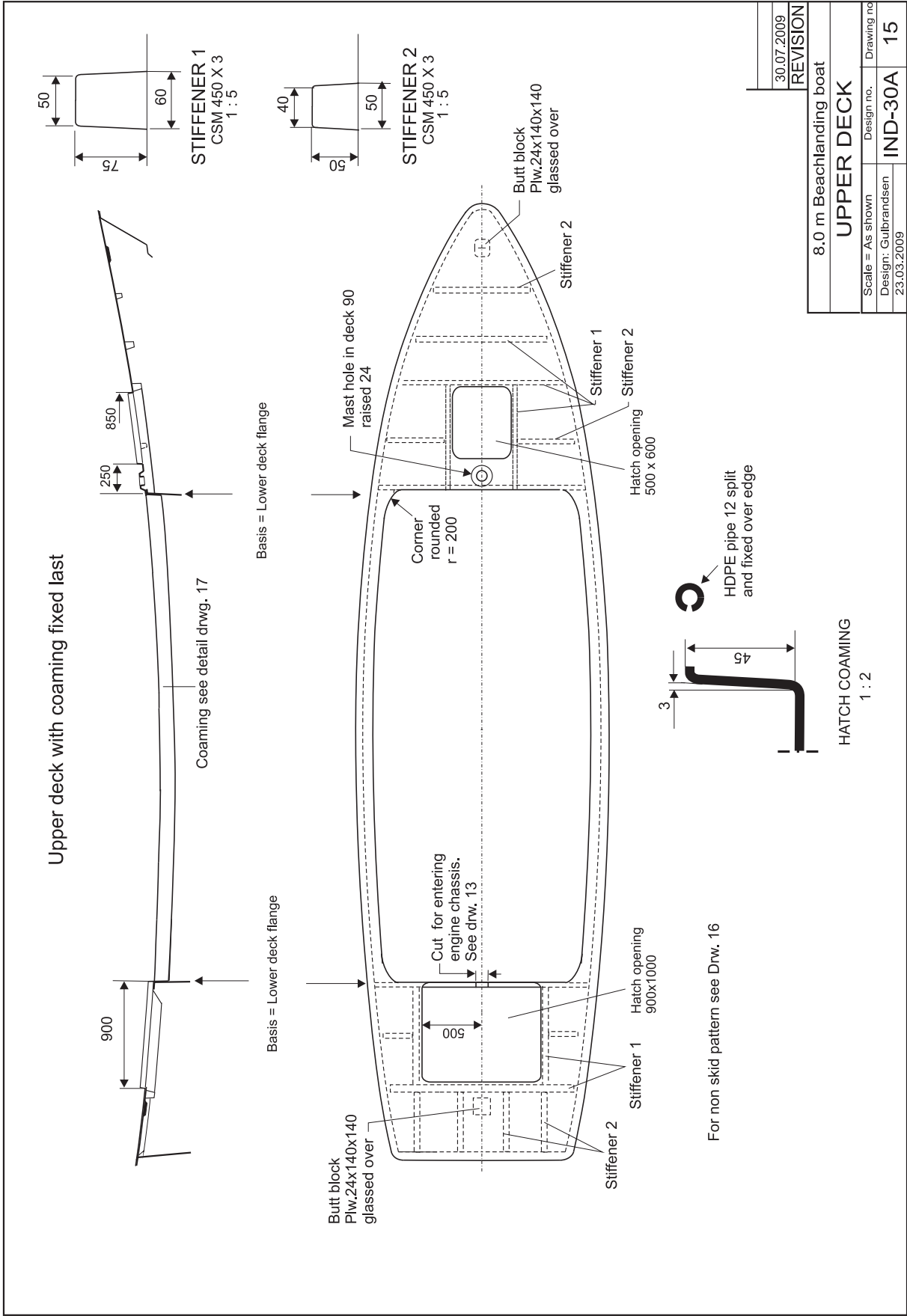
		20.07.2009
		REVISION
8.0 m Beachlanding boat		
FRAME 2		
Scale = As shown	Design no.	Drawing no.
Design: Gulbrandsen	IND-30A	9
22.03.2009		

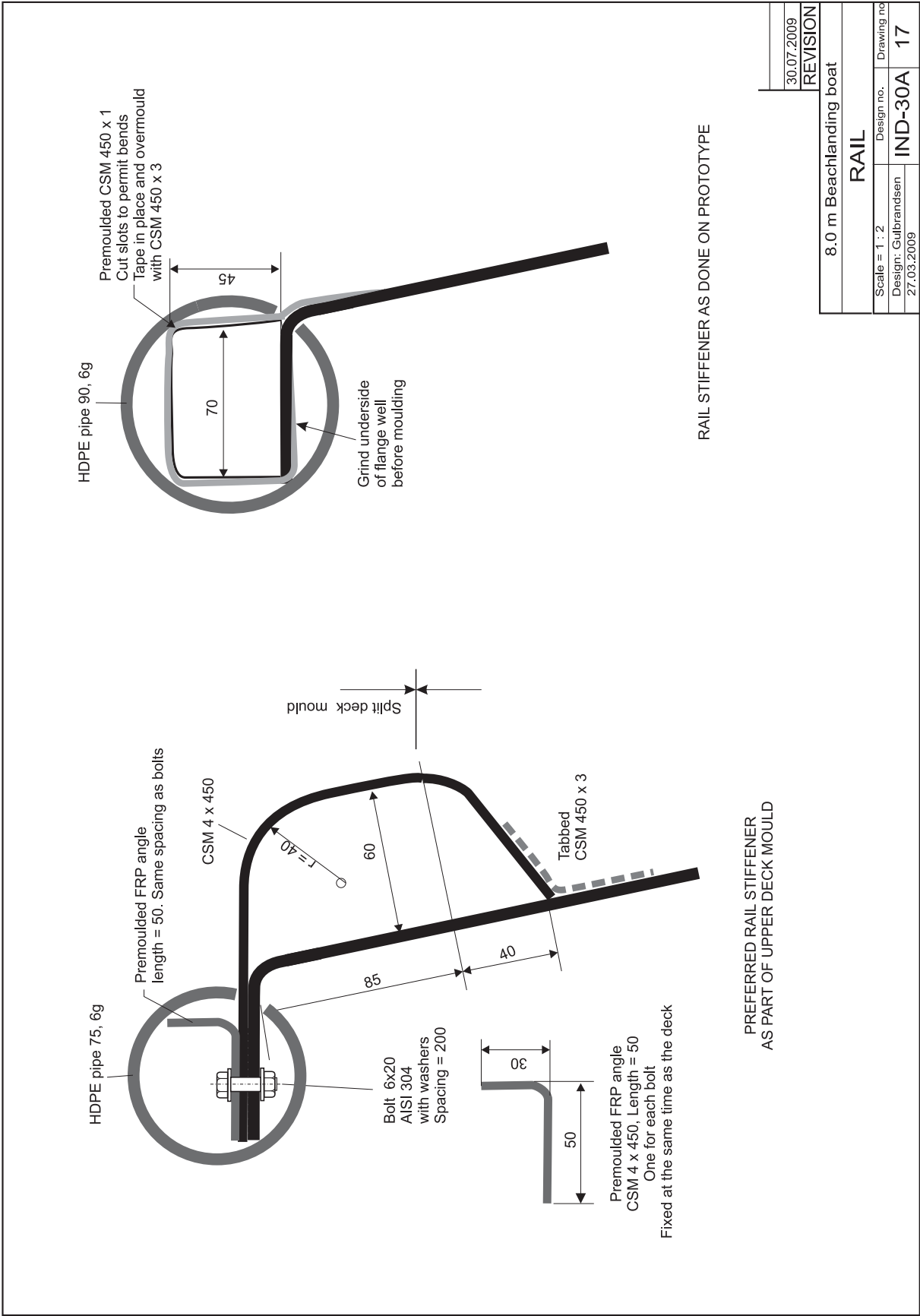


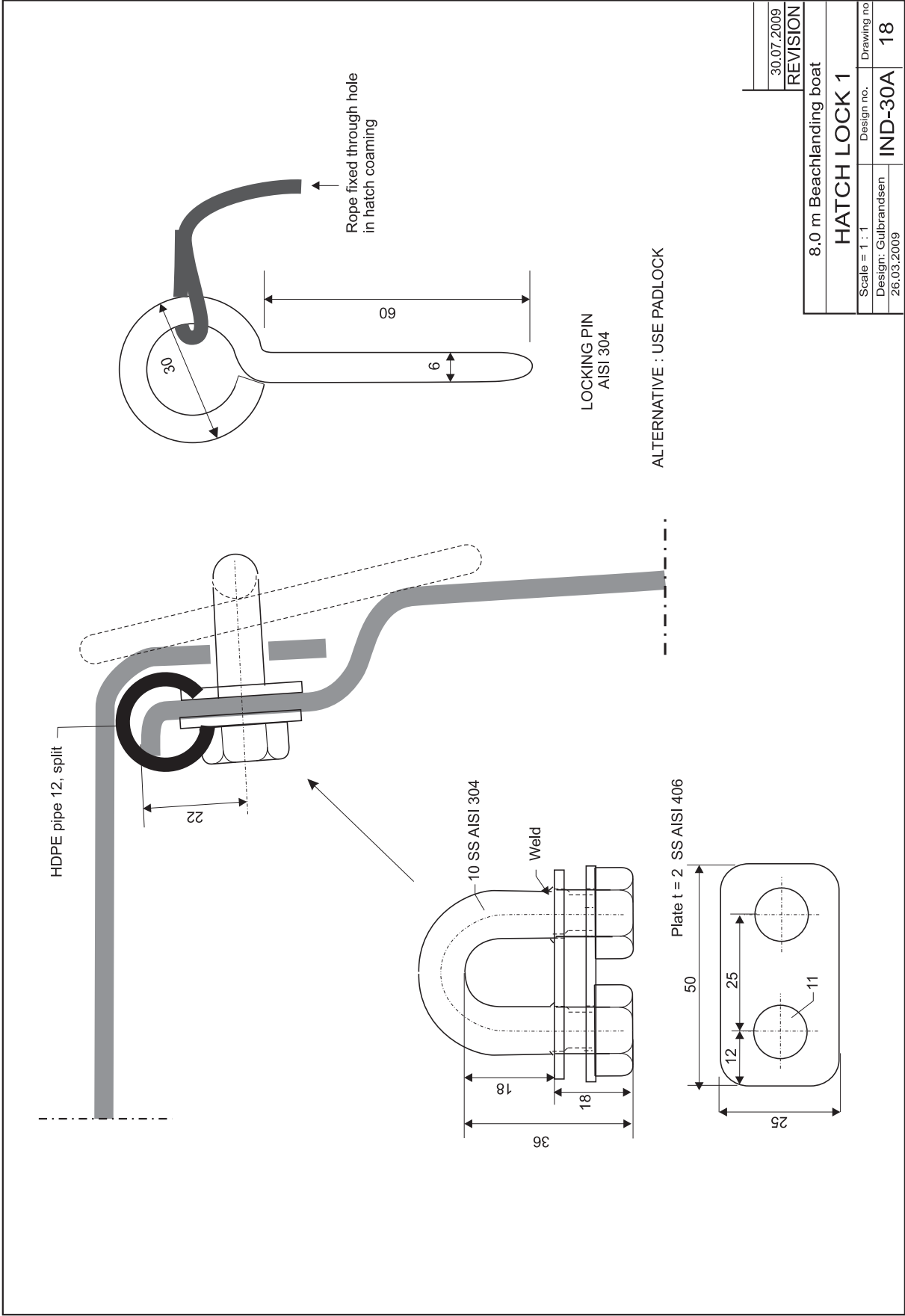


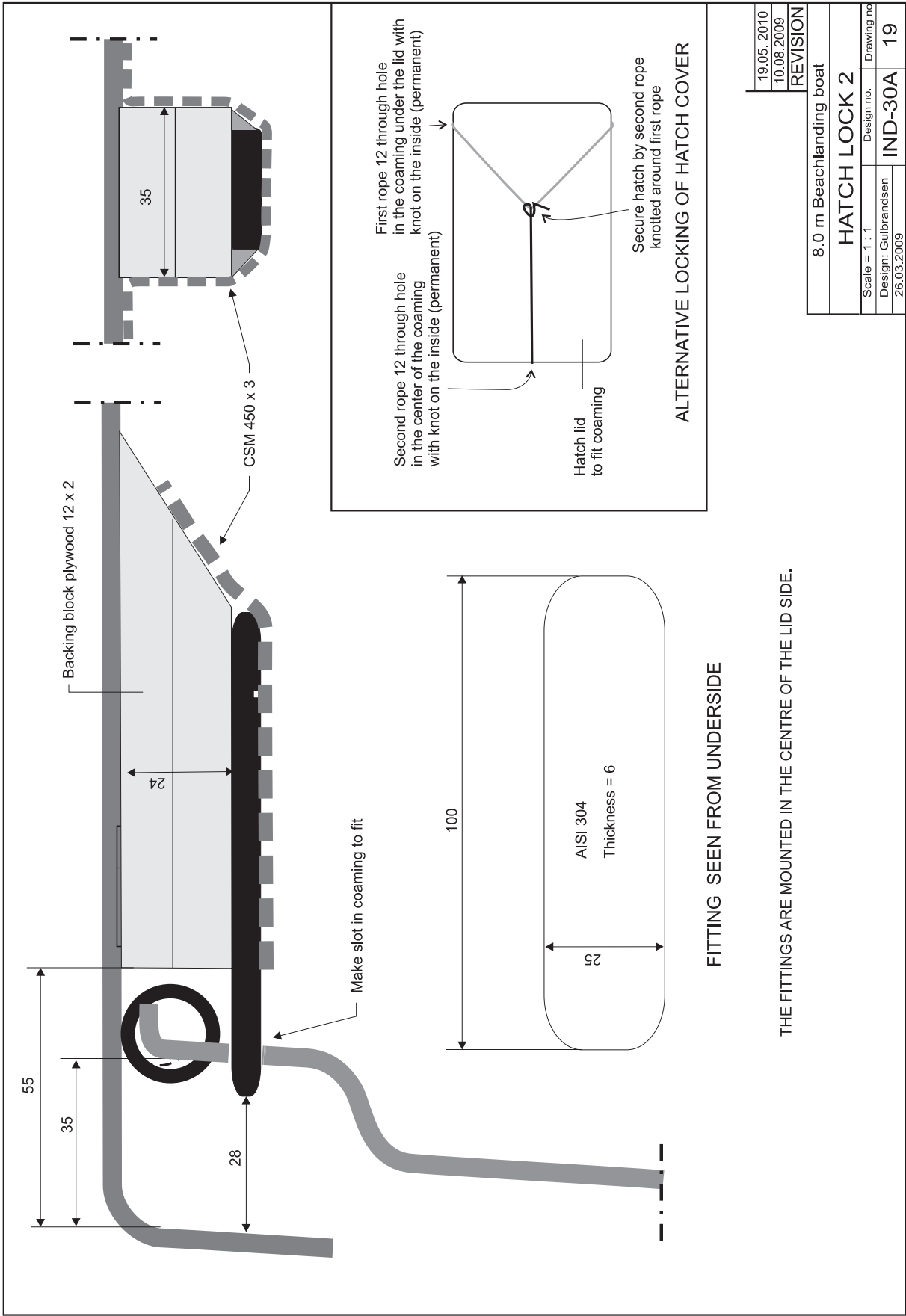


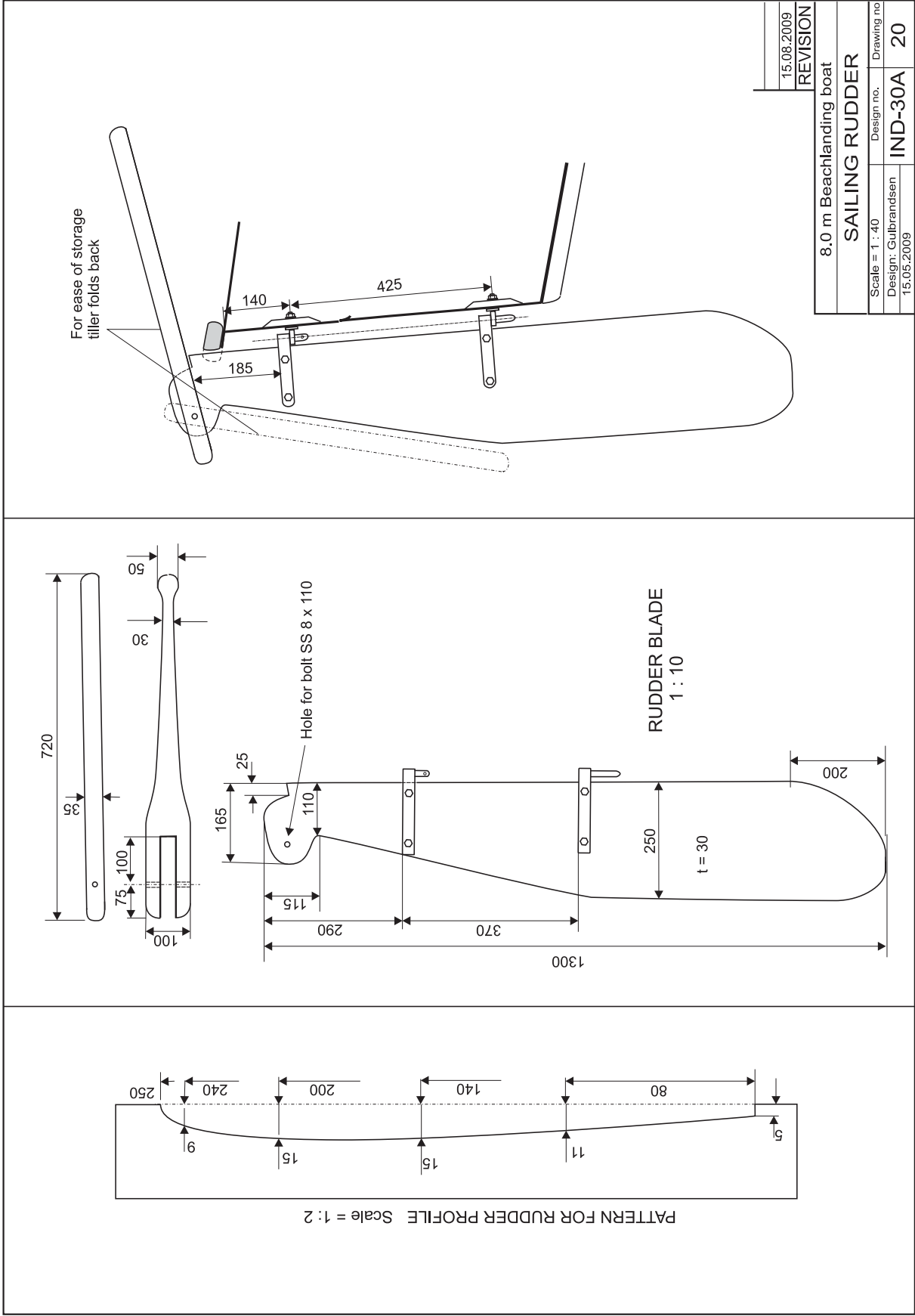


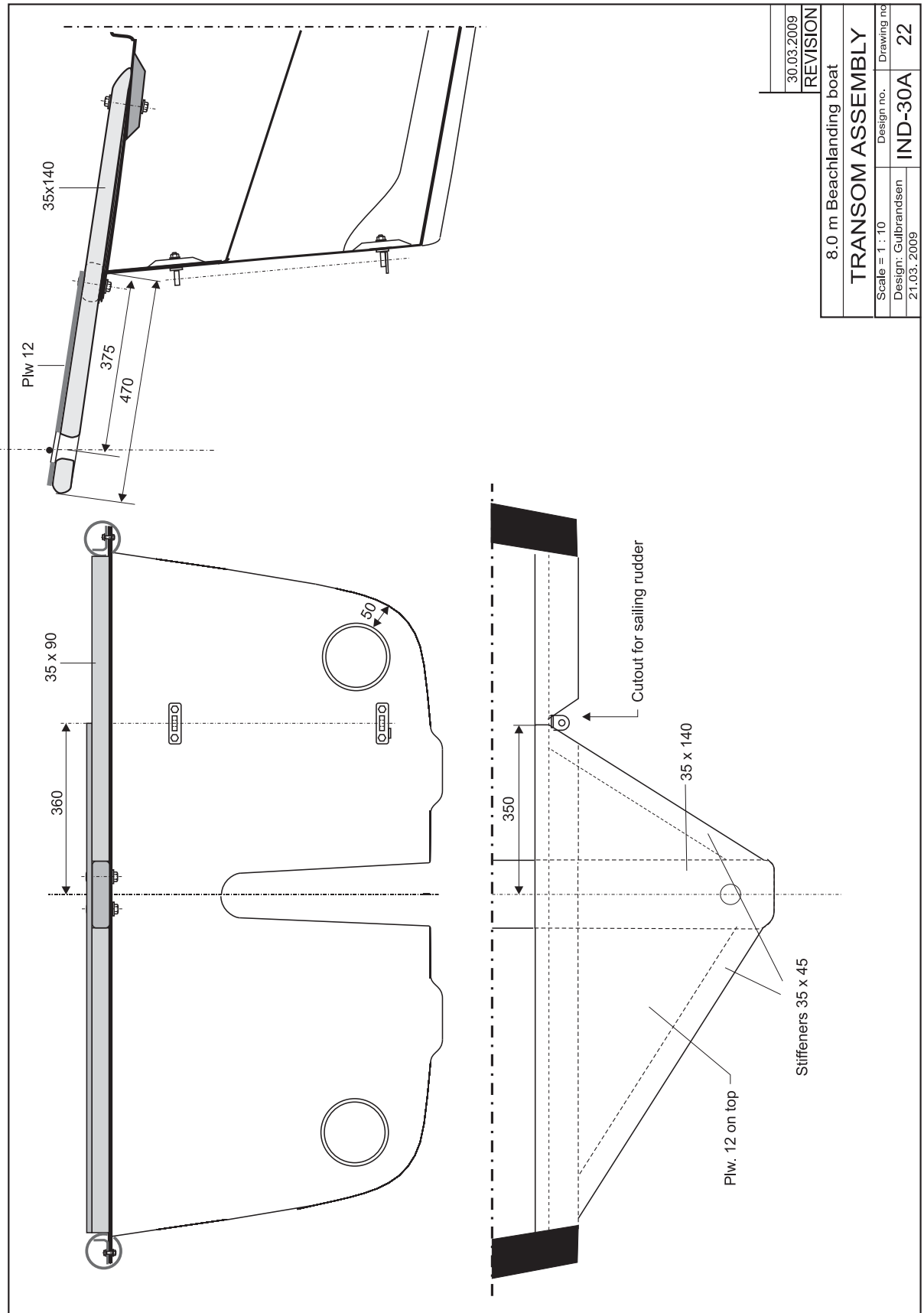


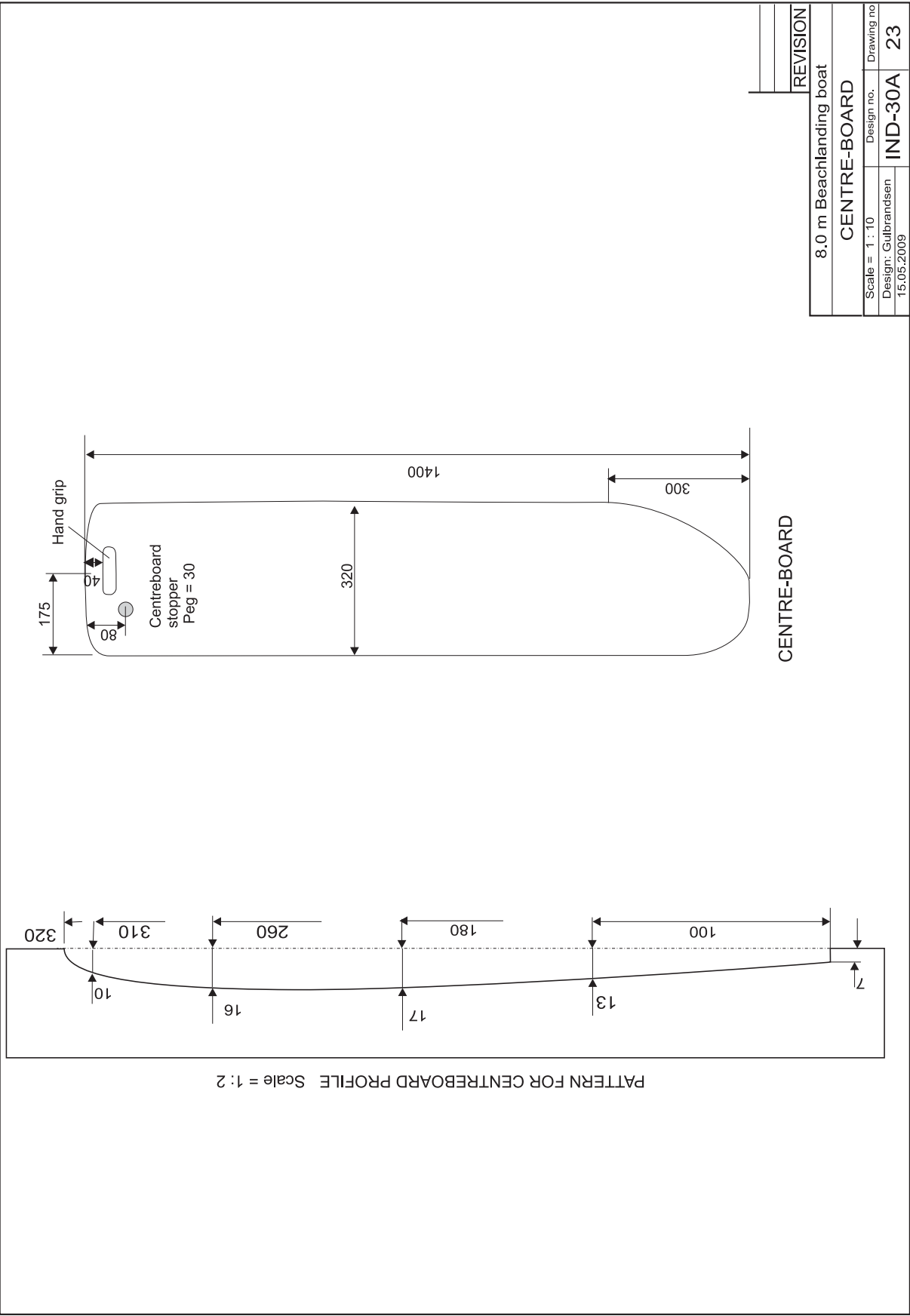


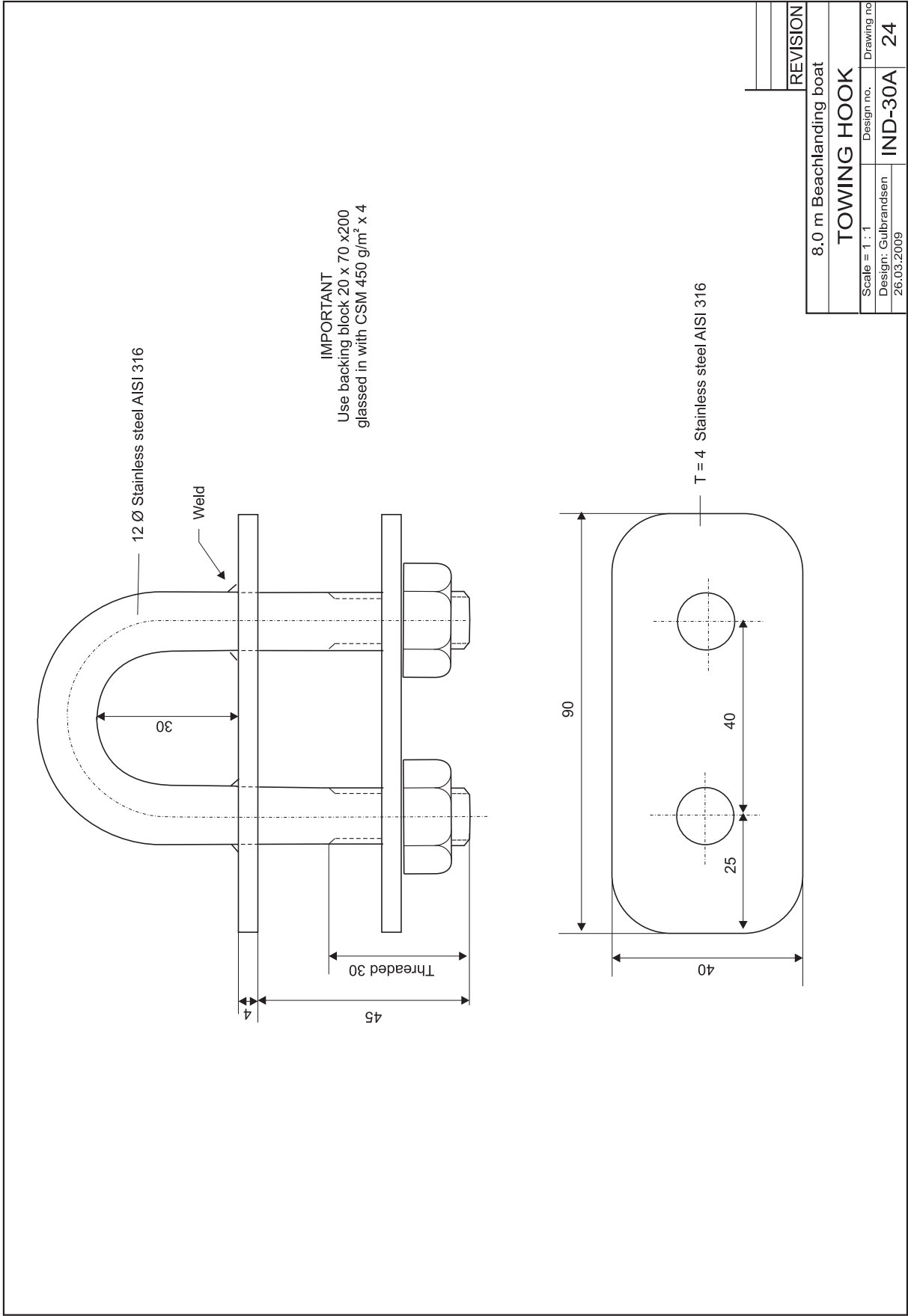


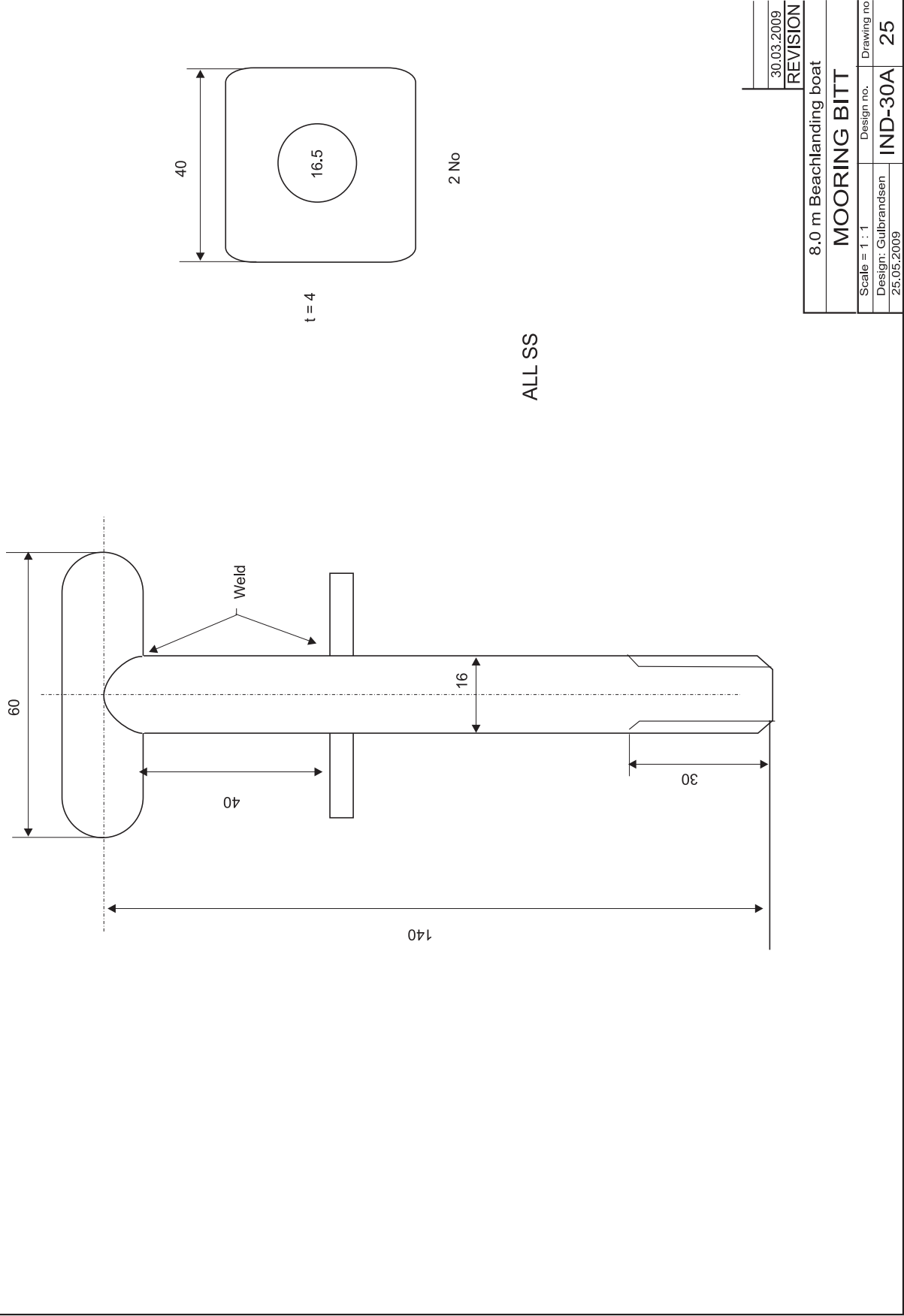


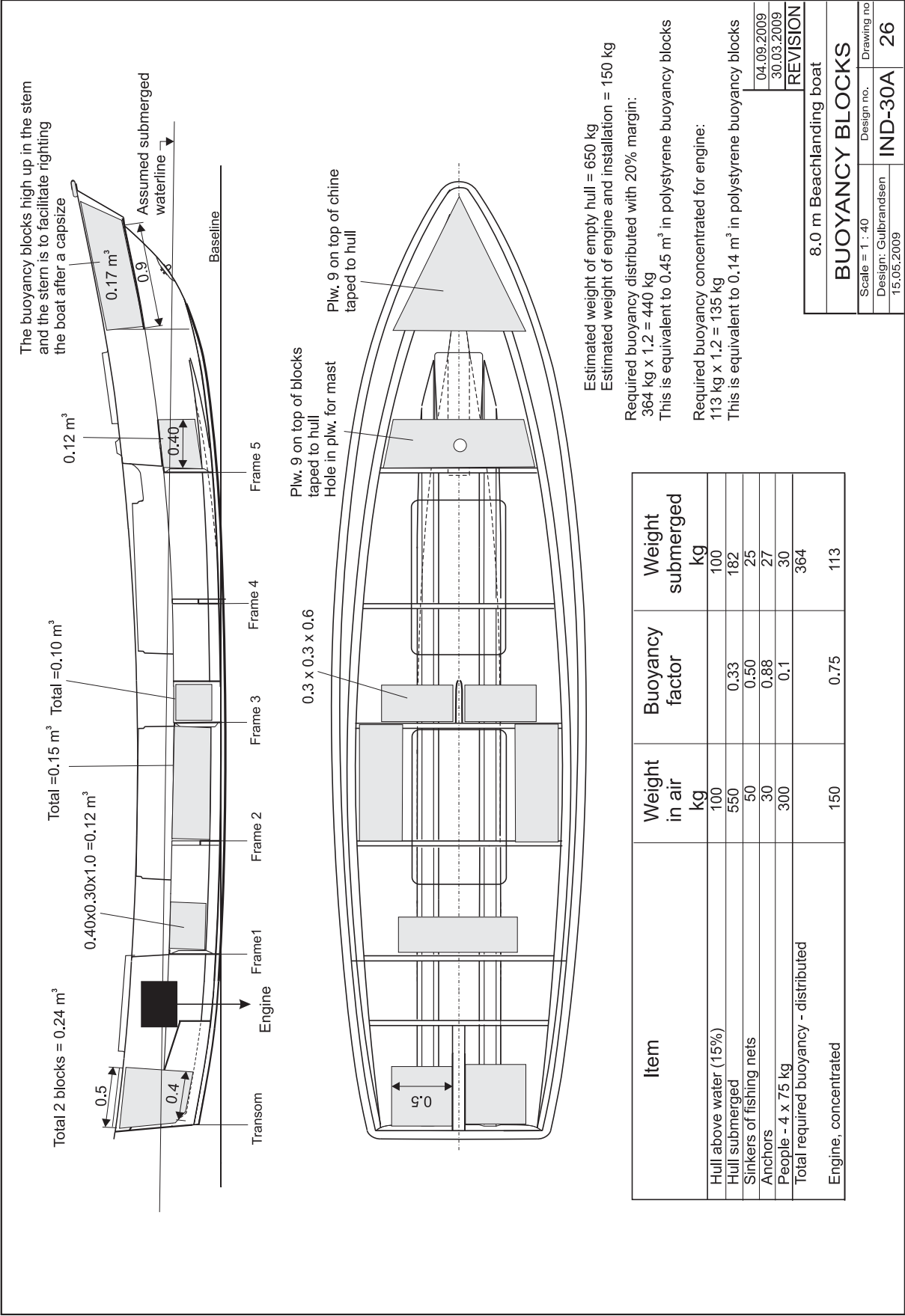


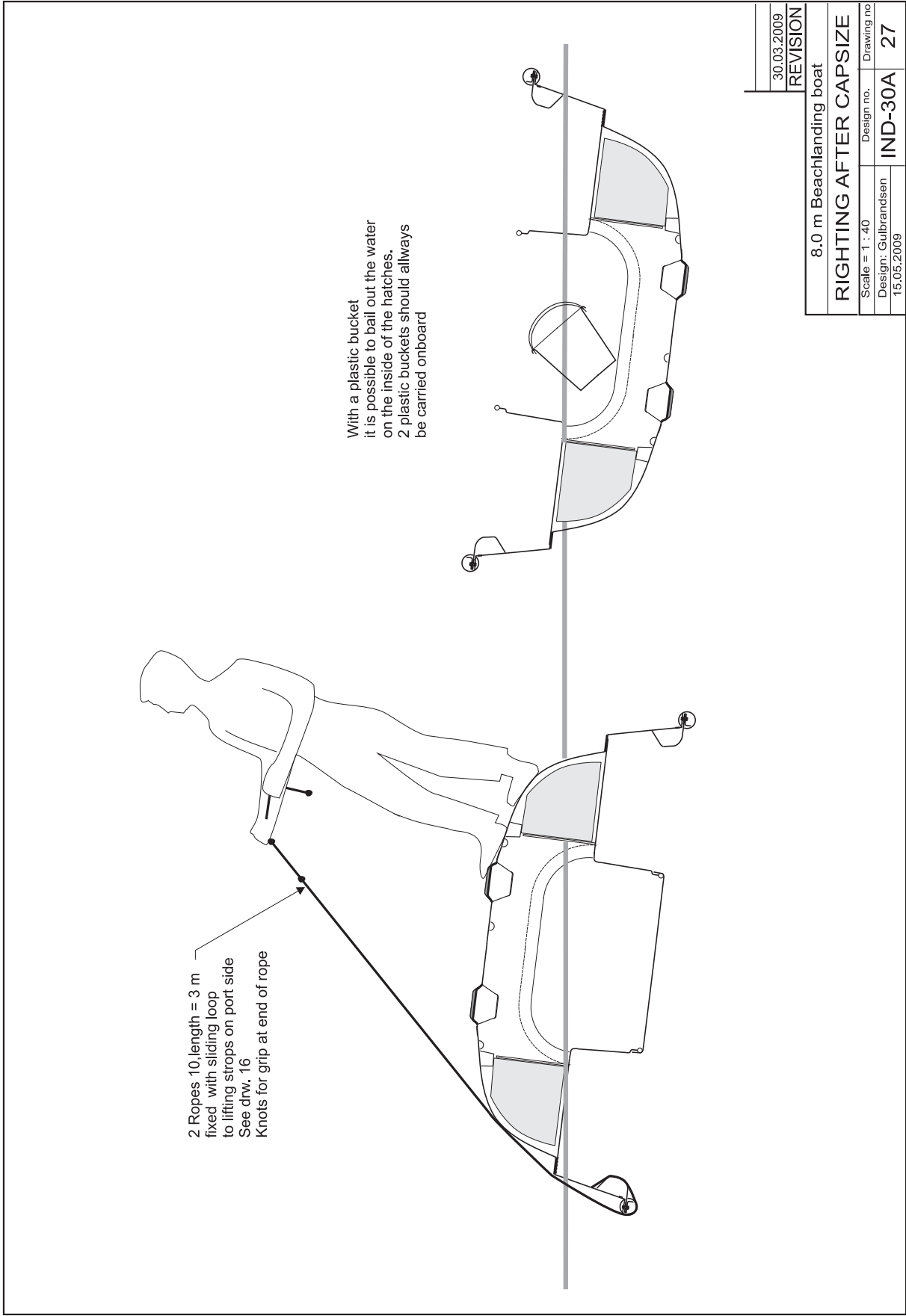


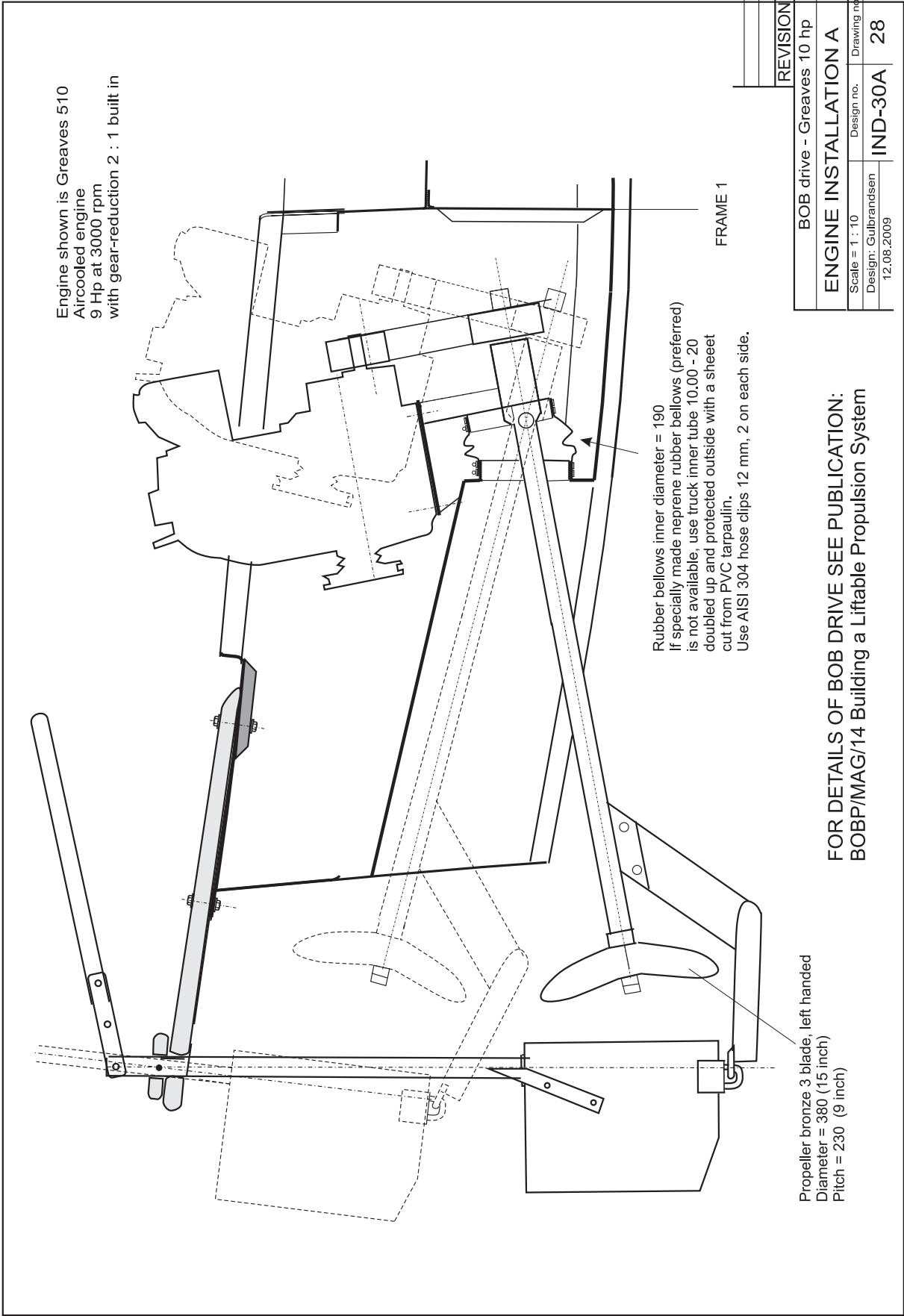


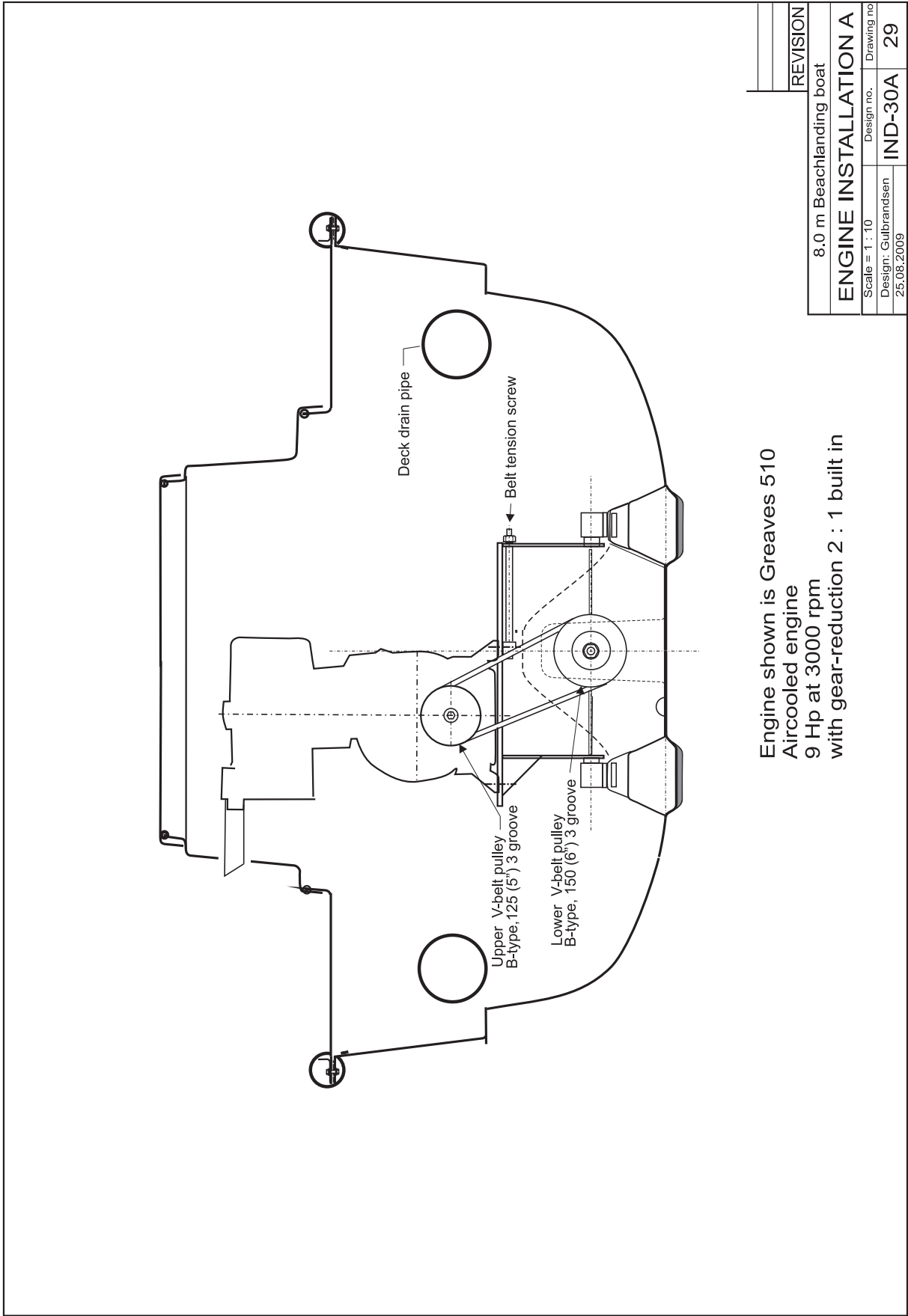


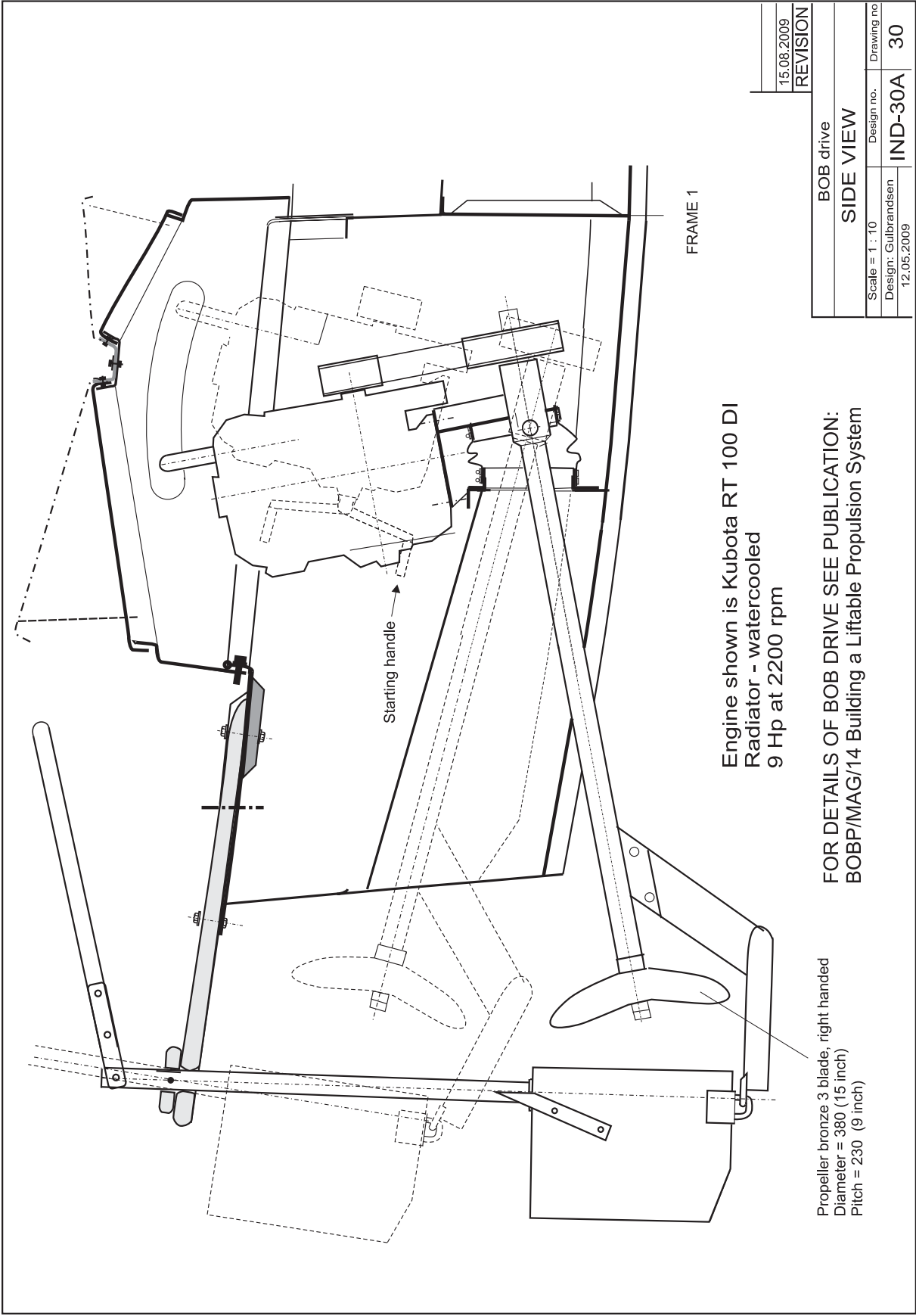


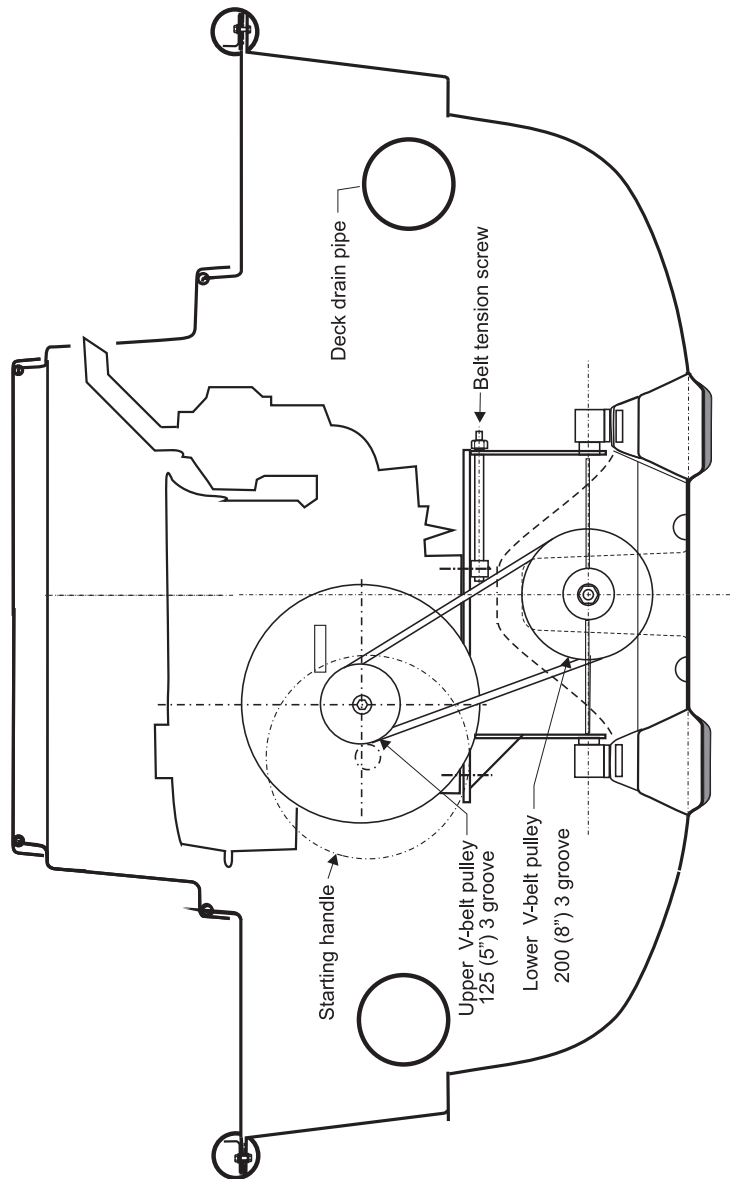








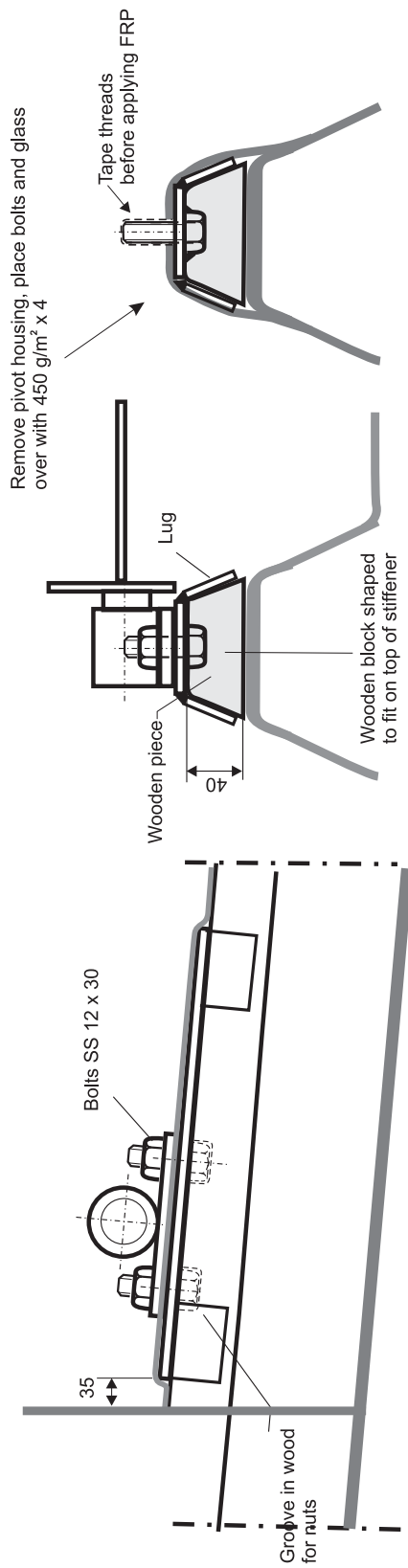




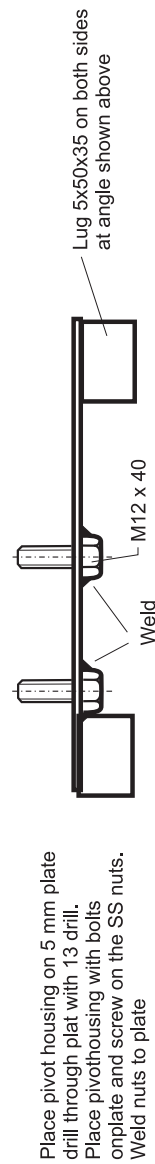
Engine shown is Kubota RT 100 DI
 Radiator - watercooled engine
 9 Hp at 2200 rpm

8.0 m Beachlanding boat	
REVISION	
ENGINE INSTALLATION B	
Scale = 1 : 10	Design no.
Design: Gulbrandsen	IND-30A
25.08.2009	31
Drawing no.	

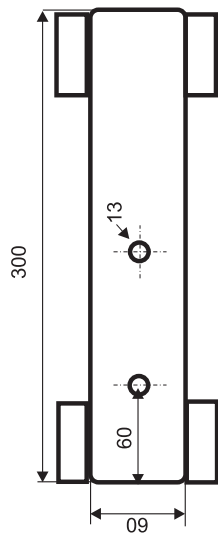
1. Make hardwood engine bed 40 high and shape to fit on top of longitudinal stiffener.
2. Place steel bedplate on top of wooden piece with end 35 from tunnel bulkhead.
3. Mark for nuts on the wooden piece and carve out for the nuts.
4. Place engine chassis with bearings on top of engine bed, align and adjust wooden piece if required.
5. Tape wooden piece to fix to stiffener, remove chassis with pivot bearings and fibreglass steel bedplate and wooden piece to stiffener and frames. Protect threads on engine bolts with tape.



ASSEMBLY
Scale = 1 : 4

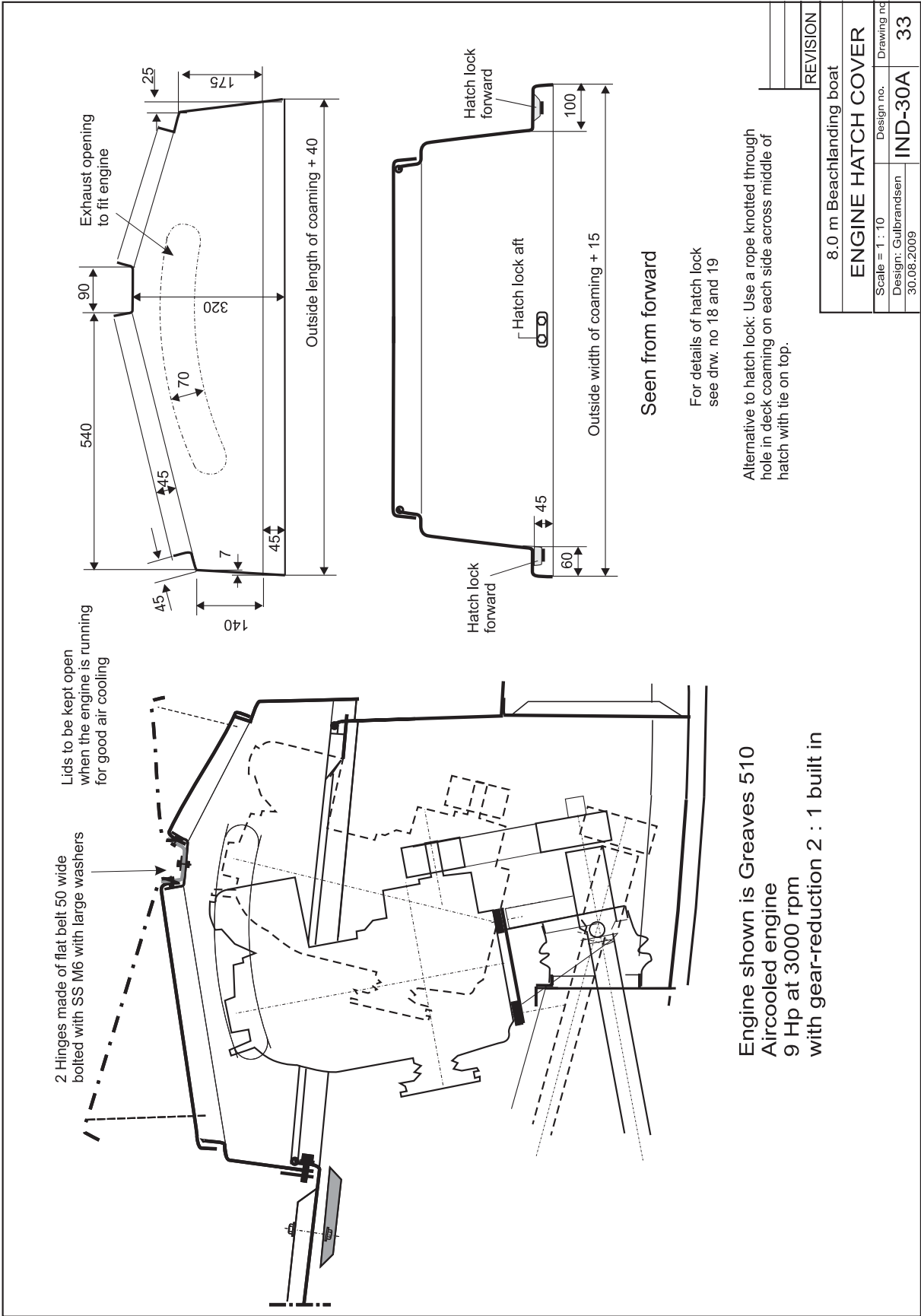


ENGINE BED-PLATE



ENGINE BED-PLATE

REVISION	
8.0 m Beachlanding boat	
ENGINE BED	
Scale = 1 : 4	Design no.
Design: Gulbrandsen	IND-30A
25.08.2009	Drawing no
	32



Annex 4: FRP CONSTRUCTION STANDARDS*

1.1 Definitions

For the purpose of these recommendations, unless expressly provided otherwise, the following definitions apply:

1.1.1 *Breadth (B)*** is the maximum breadth of the vessel, measured at maximum beam to the moulded line of the frame in a vessel with a metal shell and to the outer surface of the hull in a vessel with a shell of any other material.

1.1.2 *Competent authority* is the Government of the State whose flag the vessel is entitled to fly. The competent authority may delegate certain of its duties to entities authorized by it and that it deems suitably qualified to undertake those duties.

1.1.3 *Cubic Numeral (CuNo)*** is the result of multiplying LOA x B x D.

1.1.4 *Decked vessel* is a vessel having a fixed watertight deck covering the entire hull above the deepest operating waterline. Where open wells or cockpits are fitted in this deck the vessel is considered a decked vessel if flooding of the well or cockpit will not endanger the vessel.

1.1.5 The *depth (D)*** is the moulded depth amidships.

1.1.6 *Design categories*

The categories here indicate sea and wind conditions for which a vessel is assessed by this standard to be suitable, provided the vessel is correctly operated and at a speed appropriate to the prevailing sea state.

1 Design category A

Category of vessels considered suitable to operate in seas with significant wave heights above 4 m and wind speeds in excess of Beaufort Force 8 (19 m/s), but excluding abnormal conditions, e.g. hurricanes.

2 Design category B

Category of vessels considered suitable to operate in seas with significant wave heights up to 4 m and winds of Beaufort Force 8 (19 m/s), or less.

3 Design category C

Category of vessels considered suitable to operate in seas with significant wave heights up to 2 m and a typical steady wind force of Beaufort Force 6 (12 m/s), or less.

4 Design category D

Category of vessels considered suitable to operate in waters with significant wave heights up to and including 0.30 m with occasional waves of 0.5 m height, for example from passing vessels, and a typical steady wind force of Beaufort 4 (7 m/s), or less.

1.1.7 *Length overall (LOA)*** should be taken as the distance in a straight line parallel to the design waterline, between the foremost point of the bow to the aftermost point of the stern.

1.1.8 *Undecked vessel* is a vessel which is not a decked vessel.

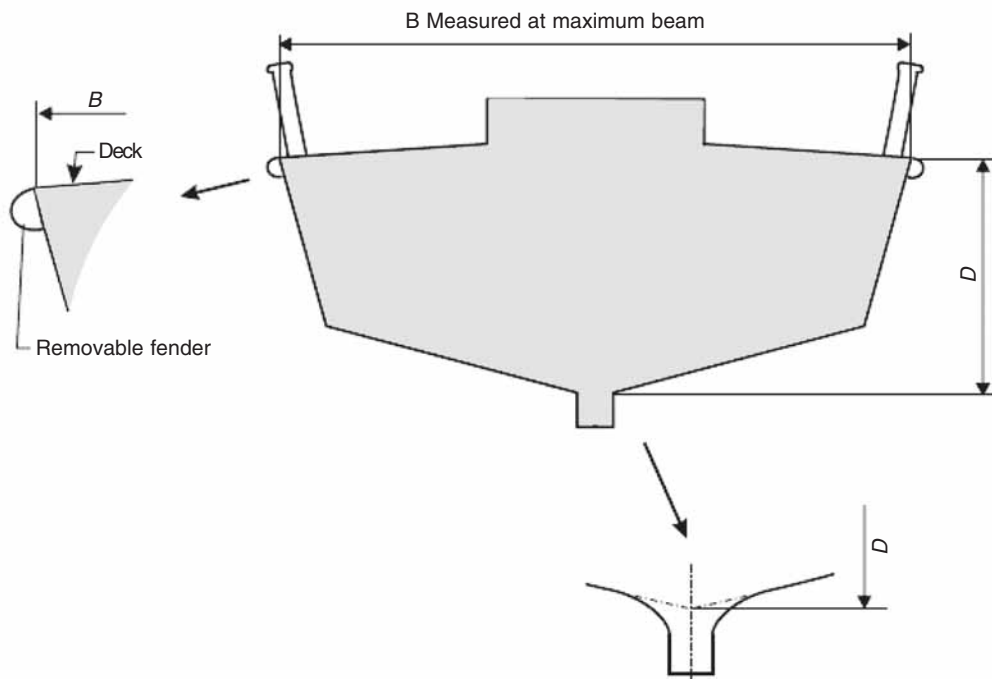
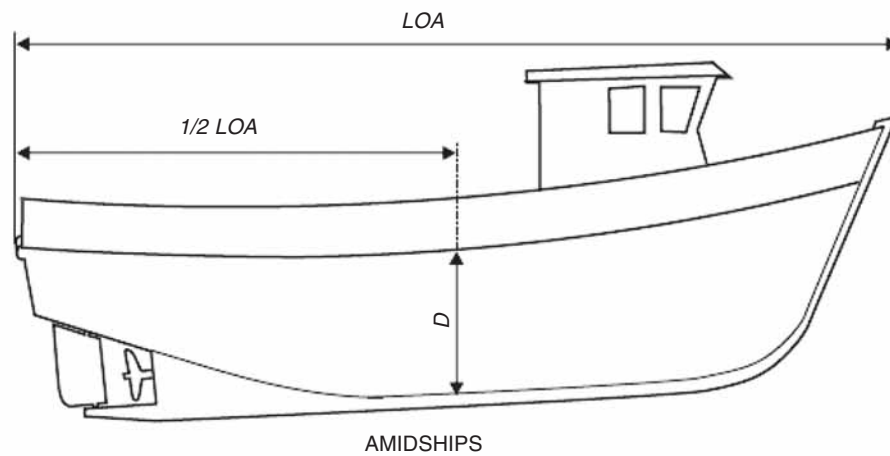
* Drawn from the draft FAO/ILO/IMO Safety recommendations for decked fishing vessels of less than 12 metres in length and undecked fishing vessels.

** The dimensions are illustrated in Appendix 1.

Appendix 1: ILLUSTRATION OF TERMS USED IN THE DEFINITIONS

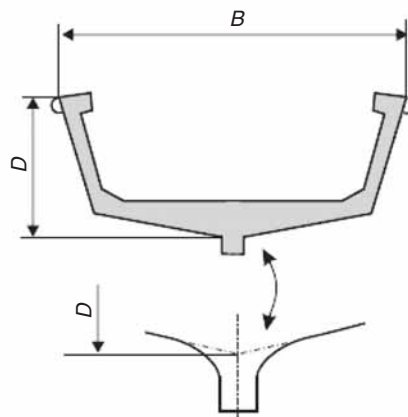
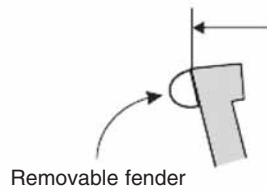
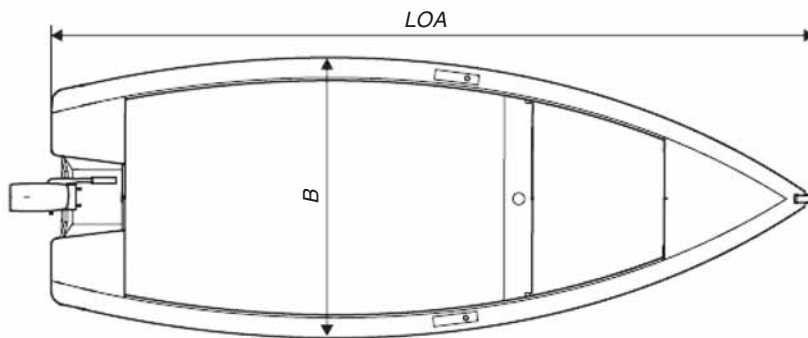
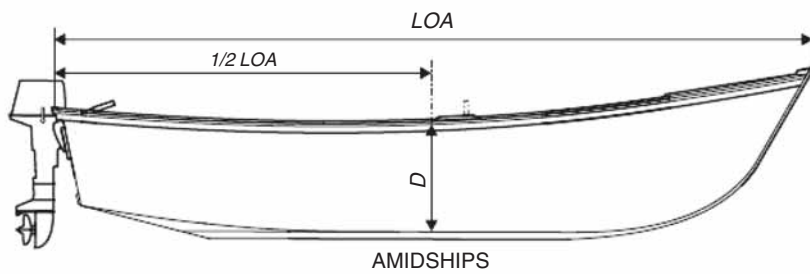
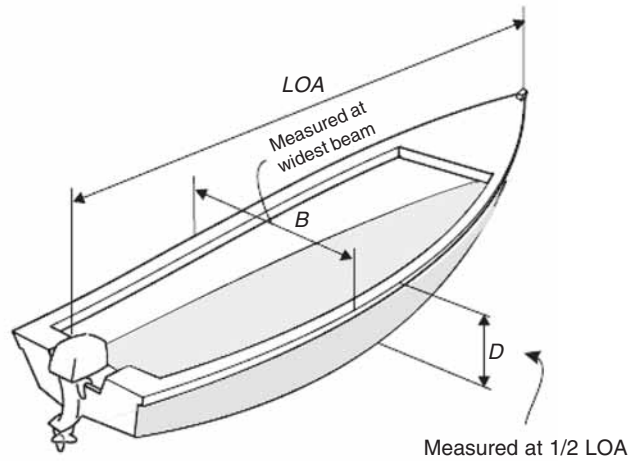
DECKED BOATS - MEASUREMENTS

LENGTH OVER ALL (LOA)
BREADTH (B)
DEPTH (D)

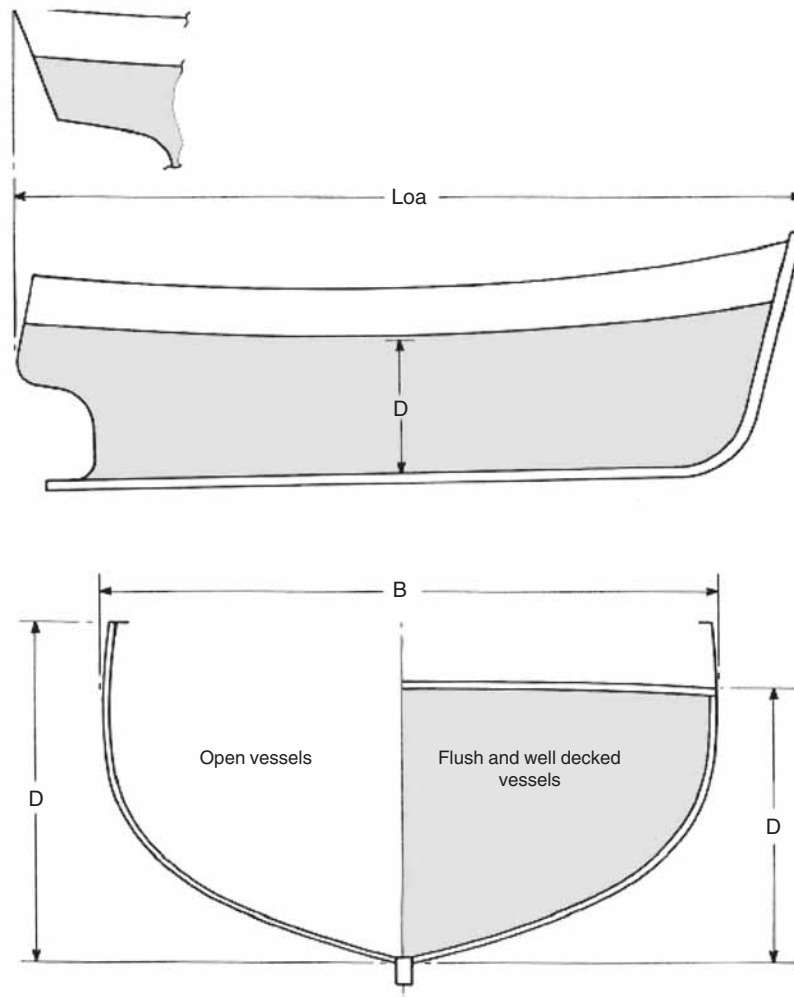


OPEN BOATS - MEASUREMENTS

LENGTH OVER ALL (LOA)
BREADTH (B)
DEPTH (D)



$LOA \times B \times D = \text{Cubic numeral (CuNo)}$



Appendix 2: RECOMMENDED CONSTRUCTION STANDARDS FOR GRP FISHING VESSELS

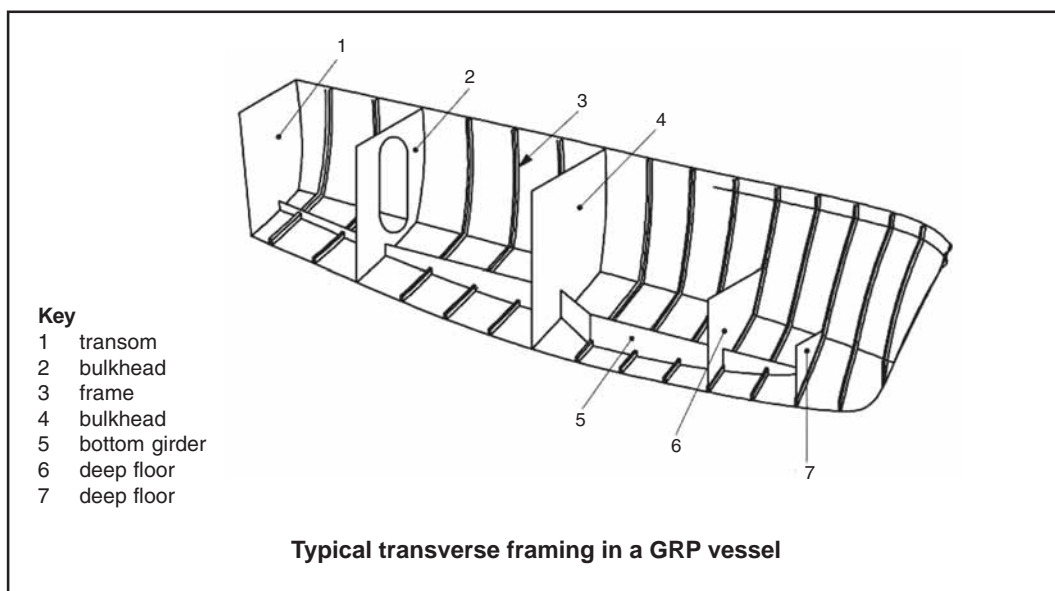
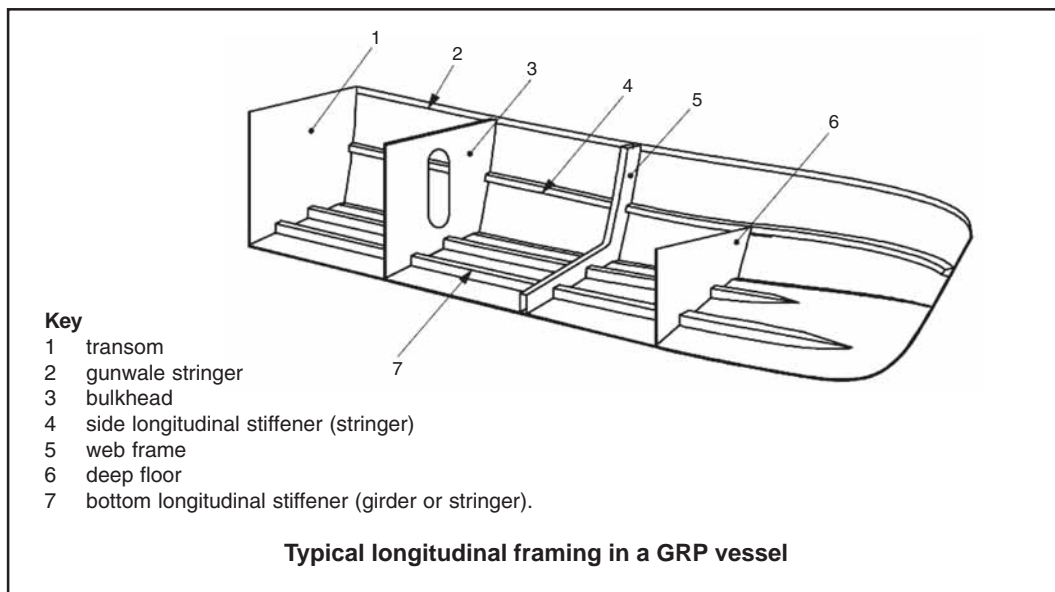
PART I - GENERAL

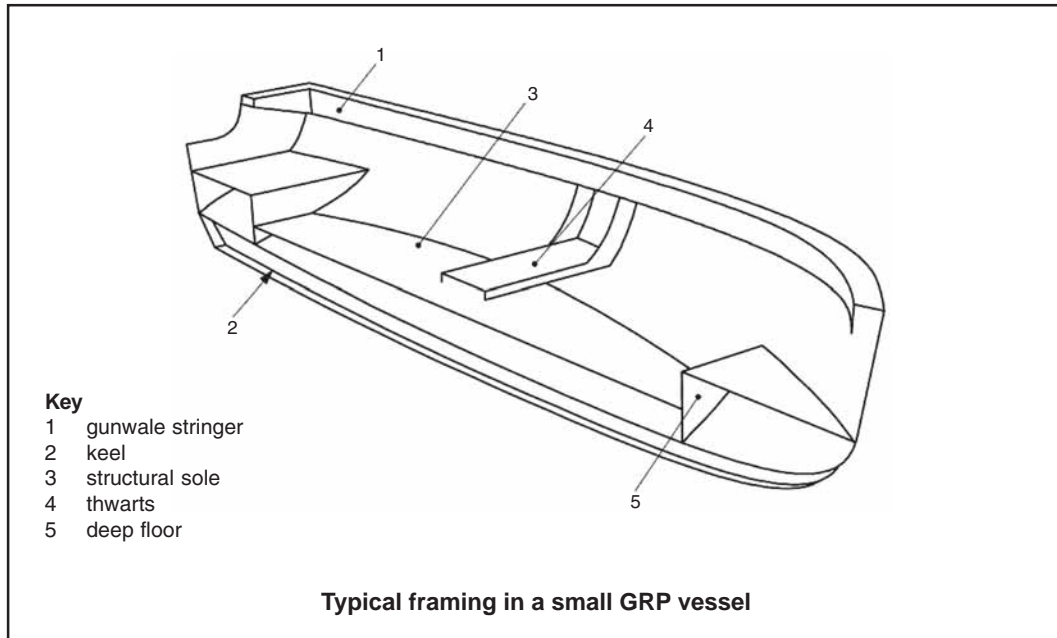
1. Scope

1.1 These construction standards apply to decked vessels of less than 12 m in length and undecked vessels of any size.

1.2 In general the standards apply to vessels of conventional form and of glass reinforced plastic construction (GRP), i.e. single hull vessels of glass rovings and mat and polyester resin construction that in general should consist of:

- moulded hull of single-skin construction;
- deck of GRP sheathed plywood, GRP or traditional timber construction;
- transverse framing;
- longitudinal structure including gunwale, stringers and engine beds;
- in small vessels internal furniture and hull form may provide adequate stiffening.





1.3 Standards are given for vessels operating at speeds of up to 16 knots as shown in Table 1 in Part III. Vessels operating at higher speeds require special consideration by the competent authority.

1.4 A number of vessel types are not covered by the requirements of these construction standards, including the following.

- Vessels constructed of other materials such as Kevlar reinforcements and epoxy resins.
- Vessels of sandwich construction.
- Vessels judged by the competent authority to be outside the scope of this standard.

2 Design categories

2.1 These construction standards are based on the division of vessels into appropriate design categories. The categories indicate sea and wind conditions for which a vessel is considered to be suitable, provided that the vessel is correctly operated and at a speed appropriate to the prevailing sea state. Design categories are defined in 1.1.6 (see page 127).

3 Construction standards

3.1 The appropriate standards of construction for GRP vessels should be determined as set out in Parts I-III.

Design category	Part I	Part II	Part III
A	✓	✓	
B	✓	✓	
C	✓		✓
D	✓		

3.2 Vessels fitted with sails should be considered to operate in categories C and D only unless given special consideration by the competent authority.

3.3 Consideration should be given by the competent authority to increasing the scantlings given in the standards in parts of a vessel where special conditions may arise, including:

- operation of fishing gear likely to damage structure by impact or abrasion;
- landing and hauling out of vessels on beaches and river banks.

Information on appropriate factors is given in Table 5.

4 Construction standards for GRP vessels of all design categories

4.1 Materials

4.1.1 Resins should be approved for marine use and be mixed and used in accordance with the manufacturers' recommendations.

4.1.2 Glass reinforcements should be approved for marine use and may be in the form of chopped strand mat, woven rovings, fabric, powder bound mat or other approved materials.

4.1.3 Colour pigment may be used in the gelcoat sufficient to give a satisfactory colour; the amount used should be in accordance with the manufacturers' recommendations. No pigment should be used in the lay-up resin of the hull laminates.

4.1.4 Formers for stiffeners should be of rigid foam, timber, metal or other approved materials. Where timber is used it should have a moisture content of not more than 15 percent. A common type of former for top-hat stiffeners is made of one layer of mat in a mould of the required stiffener dimensions.

4.1.5 Careful attention should be paid to the manufacturers' recommendations concerning the storage and use dates of the materials to be used.

4.2 Workshop practice

4.2.1 All building activities should be carried out under a fixed roof and preferably in an enclosed workshop.

4.2.2 The cleanliness of the workshop is important for the health of workers and to prevent contamination of the resin and reinforcements.

4.2.3 Waste material, dust, sand and other contaminants should be removed immediately from the workshop.

4.2.4 The moulding area should be kept clear of dust and accumulation of waste material that could contaminate the mould surfaces.

4.2.5 The recommended humidity and temperature ranges under which laminating may take place are: temperature 15 to 25 degrees C, humidity 70 percent. The moulding process should cease if the following limits are reached: temperature <13 or >32 degrees C, humidity >80 percent.

4.2.6 The workshop should be as free as practical from dust and fumes to allow comfortable and safe working conditions. Styrene fumes are heavier than air and should be removed from moulds by the use of mechanical ventilation systems.

4.2.7 Completed mouldings should not be taken outside the workshop environment within seven days of the start of the moulding process. Where mouldings are moved outside after this period they should be protected from rain.

4.2.8 The addition of catalyst to polyester products should be strictly controlled within the limits set by the manufacturers. Tables giving amounts of catalyst/resin should be available in the workshop.

4.2.9 The catalyst must be properly dispersed through the resin by very thorough mixing.

4.2.10 Where a primary bond is to be achieved, little preparation of the surface is required prior to further laminating or bonding. A primary bond is generally achieved if the surface has cured for about 24 to 48 hours and is still chemically active, allowing a chemical bond.

4.2.11 Where a secondary bond is to be achieved, additional surface preparation is required in the form of abrasion and cleaning. A secondary bond is achieved when the surface has cured for over 48 hours and is no longer chemically active; in this case, the bond relies on the adhesive properties of the resin.

4.3 Laminate lay-up

4.3.1 The outside surface of all laminates should have a layer of gelcoat or be treated with equivalent surface protection after completion of moulding. This layer should be 0.4 to 0.6 mm thick.

4.3.2 The gelcoat should only be left exposed in accordance with the manufacturers' recommendations; generally a maximum of 24 hours.

4.3.3 Heavy reinforcements should not be applied directly to the gelcoat; the first two layers should consist of a light chopped strand mat of maximum weight 300 g/m², unless the competent authority is satisfied that manufacturing experience justifies variation from this figure.

4.3.4 Where woven rovings are incorporated, these should be alternated with layers of chopped strand mat.

4.3.5 A suitable topcoat should be applied in bilge and keel areas where water could accumulate, unless the competent authority is satisfied that manufacturing experience justifies variation.

4.3.6 Laminates should be locally increased in thickness in way of fittings and equipment. The increase should be gradually reduced to the normal thickness by stepped layers.

4.3.7 Any holes or openings cut in laminates should be sealed with resin or other suitable material.

4.3.8 The overlap of mats or woven rovings should be at least 50 mm and the shift of subsequent reinforcement overlaps at least 100 mm.

4.3.9 Laminate should be laid up in accordance with a documented sequence.

4.3.10 Laminates should be worked in such a way that they are fully consolidated, *i.e.* thoroughly wetted out, free from blisters, air gaps, delamination, resin-starved areas or excess resin.

4.3.11 The interval between layers should be carefully timed to enable proper completion of each laminate.

4.3.12 The time elapsed between the completion of hull or deck laminate and the bonding of structural members should be kept within the limits of the manufacturers' recommendations.

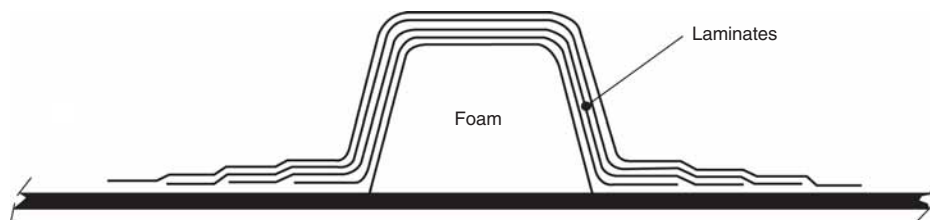
4.4 Hull construction

4.4.1 The hull bottom should be a solid laminate of glass reinforcements in resin, laid up to a satisfactory weight. The keel and sheer strake areas of the hull should have additional reinforcements. See Table 6.

4.4.2 Hulls should be adequately stiffened; this may be in the form of longitudinal or transverse stiffeners or a combination of both. Small vessels may make use of internal structures and features for stiffening.

4.4.3 Stiffeners may be constructed by moulding over foam or hollow formers, which should be bonded to the inside hull laminate; see sections 4.2.10 and 4.2.11 for a description of primary and secondary bonding. Frame formers may be of top-hat or rectangular section. Where frames have gunwales or stringers through bolted, the core of the frames is to be of timber.

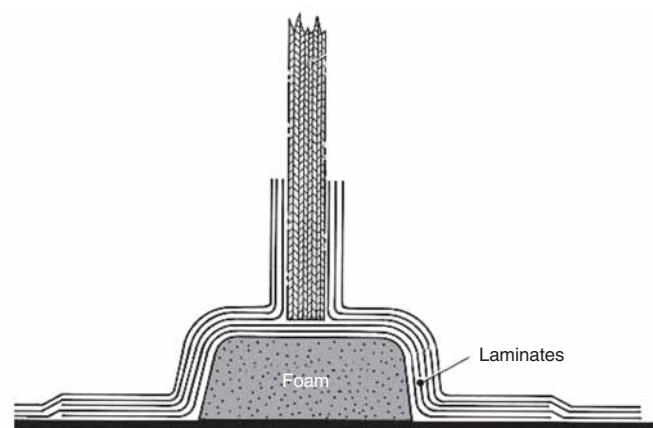
4.4.4 Floors moulded over formers should be fitted to the top of the frames at the centreline and bonded to the frames.



Typical framing construction

4.4.5 Stringers, where fitted, may use foam or hollow formers and should be bonded to the hull shell; see sections 4.2.10 and 4.2.11 for a description of primary and secondary bonding. Alternatively, these may be formed in combination with other longitudinal structural members such as soles, decks and lockers.

- 4.4.6 In vessels below 7 m LOA where a combination of bonding of internal furniture and hull form provides adequate stiffening, the framing may be omitted subject to the approval of the competent authority.
- 4.4.7 In undecked boats, the required bottom stiffening may be provided wholly or partly formed by the bonded-in flooring arrangement.
- 4.4.8 Where through-bolting connections are required, e.g. for gunwales or beam stringers, fastenings should be hot-dip galvanized or stainless steel. The edges of the laminate and the fastening holes should be sealed with resin or other suitable material.
- 4.4.9 The hull surface gelcoat should be adequately protected in the way of all fishing gear hauling positions by glass-reinforced plastic (GRP) sheathing, metal, hard rubber or plastic to prevent damage.
- 4.4.10 Discontinuities and hard points in the structure should be avoided. Where the strength of a stiffener may be reduced by attachment of fittings, openings, etc., additional laminates should be included.
- 4.4.11 Transoms not subjected to loads from outboard engines or steering arrangements should have scantlings as required for the shell laminate.
- 4.4.12 The glass weight at the corner of the transom and hull shell should be increased to provide additional reinforcement. See Table 6.
- 4.4.13 Transoms that are to be used for the mounting of outboard engines should be constructed to include a marine-grade plywood panel of sufficient dimension and of adequate strength for the proposed installation.
- 4.4.14 The stem should be moulded to include a gradual reduction from the keel weight to that required for the sheer.
- 4.4.15 The centre of the hull aft of the keel to the transom should be stiffened by lay-ups as required for the keel.
- 4.4.16 Where fitted, rubbing strakes may be of hardwood, rubber or plastic; securing bolts should be hot-dip galvanized and sealed to prevent leakage.
- 4.4.17 Engine seatings should generally be continuous structures and where space permits, the seatings should extend at least twice the length of the engine, unless the competent authority is satisfied that manufacturing experience justifies variation.
- 4.4.18 The seatings should be bonded to the hull and stiffened transversely with floor sections and side support brackets. A continuous flat steel plate of adequate thickness and width should be fitted to the top of the seating in way of the engine and gearbox and bonded to the seating.
- 4.4.19 Where included, it is recommended that bulkheads are fitted to a rigid foam core seating or frame section. When not practical to fit on a frame position, the bulkhead should be bonded to the shell with double angles of a satisfactory weight.



Typical bulkhead installation

4.4.20 Bolt connections should be well sealed and glassed over to prevent leakage.

4.4.21 Consideration should be given to including easily replaceable sacrificial structures in locations where impact or abrasion may occur. These include areas subject to wear such as gunwales and keels and areas subject to impact or abrasion by fishing gear.

4.5 Deck construction

4.5.1 Decks may be of GRP sheathed plywood, GRP or traditional timber construction.

4.5.2 A beam shelf or stringer should be bonded to the hull shell to support the deck beams. A system combining through bolting and bonding is recommended.

4.5.3 Deck beams should be fitted at each frame position; with longitudinal stiffening provided by hatches and carlings as required.

4.5.4 Decks in way of gallows, warp leads, deck machinery and heavy work positions should have additional stiffening and pillars to the approval of the competent authority.

4.5.5 Main beams should be fitted in way of all deck openings, machinery and deckhouse casings and in way of masts and heavy deck machinery.

4.5.6 Where deck beams of timber are fitted, reference should be made to appropriate construction standards for wooden vessels.

4.5.7 Where decks and deck beams are of GRP construction, openings in the deck may be stiffened by forming continuously moulded flanges, the weight of which should be 25 percent greater than the laid-up deck laminate weight. Deck openings over 500 mm in length should be fitted with longitudinal stiffening.

4.5.8 Plywood decks should be bolted and bonded to the beam shelf and bonded to the hull. The complete deck area should be sheathed with a GRP laminate. Special attention should be paid to the sheathing in way of working areas that may require extra protection.

4.5.9 Where laid timber planked decking is used for decks, reference should be made to appropriate construction standards for wooden vessels.

PART II – RECOMMENDED CONSTRUCTION STANDARDS FOR GRP VESSELS OF DESIGN CATEGORIES A AND B

1 Introduction

1.1 The construction standards described here should be applied to all decked vessels in design categories A and B.

2 Construction

2.1 In general, the requirements of Part I should be complied with in addition to the requirements below.

2.2 The strength and construction of the hull, deck and other structures should be built to withstand all foreseeable conditions of the intended service.

2.3 All vessels should meet requirements that are compatible with a recognized GRP vessel construction standard* or an equivalent standard and be built to the satisfaction of the competent authority.

* The standards include:

1. the Nordic Boat Standard;
2. the construction rules of the United Kingdom Sea Fish Industry Authority (Seafish); and
3. the construction rules of recognized organizations.

PART III – RECOMMENDED CONSTRUCTION STANDARDS FOR GRP VESSELS OF DESIGN CATEGORY C

1 Introduction

1.1 The construction standards described here should be applied to all decked and undecked vessels in design category C.

1.2 The tables and figures given in this part are based on the ISO standards 12215-5&6 – Small Craft Hull Construction and Scantlings.

1.3 The construction standards described here should always be read in conjunction with Part I of this Appendix.

1.4 The hull construction standard is based on maximum operating speeds according to vessel length. The operating speeds are shown in Table 1.

1.5 The hull construction standard is based on the loaded displacement of the vessel including vessel, crew, fishing gear, fuel, fish and ice, stores and equipment. Where this is not known, an approximation can be made from the Cubic numeral (CuNo) of the vessel; approximate values are shown in Table 2.

2. Construction

2.1 Hull and deck

2.1.1 Hull laminate should be of a thickness suitable for the size of vessel and the spacing of framing. Table 3 shows the minimum required laminate weight (w) and equivalent thickness (t).

2.1.2 Deck laminate should be of a thickness suitable for the loaded displacement of the vessel and the spacing of frames (or panel size). Table 4 shows the minimum required laminate weight (w) and equivalent thickness (t).

2.1.3 Additional factors should be applied to the minimum laminate weight according to the intended use of the vessel; appropriate factors are shown in Table 5. The factors account for the design and use of the vessel and should be applied as considered necessary by the competent authority.

2.1.4 The following areas should be reinforced by additional laminates: keel, stem, chine and deck edge. Table 6 gives the total laminate weight required and the width of the reinforcement.

2.2 Stiffeners

2.2.1 Hull and deck stiffeners should be of a size suitable for the size of vessel, the spacing of stiffeners (or panel size). Tables 7 and 8 show the required section modulus.

2.2.2 The section modulus can be modified by the application of factors to the table values. Table 9 shows the factors for stiffener curvature and glass mat/roving content. If in doubt the table and figures without factors should be used.

2.2.3 The properties of various “top hat” type stiffeners are given in Tables 10 and 11.

Table 1: Maximum operating speeds

Length Overall LOA (m)	4	6	8	10	12
Maximum Speed (knots)	9	11	13	15	16

Table 2: Cubic numeral and loaded displacement

Cubic numeral (CuNo)	Undecked Vessel Approximate Loaded Displacement	Decked Vessel Approximate Loaded Displacement
m ³	kg	kg
4	600	-
6	900	-
8	1200	-
10	1500	-
12	1800	-
14	2100	-
16	2400	-
18	2700	-
20	3000	4800
25	3750	6000
30	4500	7200
35	-	8400
40	-	9600
45	-	10800
50	-	12000
60	-	14400
70	-	16800
80	-	19200
90	-	21600
100	-	24000

Note: The figures given are approximate and where possible it is better to obtain accurate displacement figures from calculations and measurements.

Table 3: Table of minimum hull laminate weight

Panel Width (mm)	500	500	600	600	800	800	1000	1000	1200	1200	1400	1400
Loaded Displ (kg)	t mm	w (min) g/m ²	t mm	w g/m ²	t mm	w g/m ²	t mm	w g/m ²	t mm	w g/m ²	t mm	w g/m ²
250	3.9	1670	4.4	1880	5.2	2250	6.6	2810	7.9	3370	9.2	3930
500	4.3	1860	4.9	2090	5.8	2490	6.9	2960	8.3	3550	9.7	4140
1000	4.8	2070	5.4	2330	6.5	2780	7.7	3280	9.2	3930	10.7	4580
2000	5.4	2330	6.1	2620	7.3	3130	8.6	3690	10.3	4400	12.0	5140
4000	6.2	2640	6.9	2960	8.3	3540	9.8	4180	11.5	4930	13.4	5760
6000	6.6	2840	7.5	3190	8.9	3820	10.5	4500	12.3	5280	14.4	6160
8000	7.0	3000	7.9	3370	9.4	4030	11.1	4750	12.9	5530	15.1	6450
10000	7.3	3130	8.2	3520	9.8	4200	11.6	4960	13.4	5740	15.6	6700
12000	7.6	3240	8.5	3650	10.2	4360	12.0	5140	13.8	5920	16.1	6900
15000	7.9	3390	8.9	3810	10.6	4550	12.5	5370	14.3	6140	16.7	7160
18000	8.2	3510	9.2	3950	11.0	4720	13.0	5570	14.8	6330	17.2	7380
20000	8.4	3590	9.4	4030	11.3	4820	13.3	5680	15.1	6470	17.5	7510
22000	8.5	3660	9.6	4110	11.5	4910	13.5	5790	15.4	6590	17.8	7630
25000	8.8	3750	9.8	4220	11.8	5040	13.9	5950	15.8	6770	18.2	7790

Note: The figures listed for a 500mm panel width are the minimum figures to be used and weights below this should not be used after the application of factors.

Table 4: Table of minimum deck laminate weight

Panel Width (mm)	500	500	600	600	700	700
Length Overall (m)	t mm	w g/m ²	t mm	w g/m ²	t mm	w g/m ²
4	3.3	1420	3.8	1650	4.5	1920
5	3.5	1510	3.8	1650	4.5	1920
6	3.8	1650	3.8	1650	4.5	1920
7	4.0	1700	4.0	1700	4.5	1920
8	4.2	1790	4.2	1790	4.5	1920
9	4.4	1880	4.4	1880	4.5	1920
10	4.6	1970	4.6	1970	4.6	1970
11	4.8	2060	4.8	2060	4.8	2060
12	5.0	2150	5.0	2150	5.0	2150
13	5.2	2240	5.2	2240	5.2	2240
14	5.5	2340	5.5	2340	5.5	2340
15	5.7	2430	5.7	2430	5.7	2430

- Notes:** 1. The figures given show w, the minimum required weight in g/m² of dry laminate to be used in construction.
2. The table shows weights of laminates where chopped strand mat is 90 to 100% of the total glass weight. Correction for other combinations of mat and roving are accounted for in Table 5.
3. The figures listed for a 500mm panel width are the minimum figures to be used and weights below this should not be used after the application of factors.

Table 5: Table of factors applied to minimum laminate

Panel Curvature Factor, Fc						
c/b	0.03 and below	0.06	0.09	0.12	0.15	0.18 and above
Fc	1	0.9	0.8	0.7	0.6	0.5

Glass Mat/Roving Factor, Fw							
R	0.3	0.4	0.5	0.6	0.7	0.8	0.9 - 1.0
Glassfibre content	0.41	0.39	0.37	0.35	0.33	0.32	0.30
Mat/Roving Factor Fw	0.89	0.91	0.93	0.95	0.97	0.98	1.0
Where $R = \frac{\text{Weight of Chopped Strand Mat (CSM) in g/m}^2}{\text{Total weight of Glassfibre in g/m}^2}$							

Usage Factor	Type	Conditions	Factor
Fv Vessel landing	River landing	Calm water	1.00
	Harbour landing	Impact on quays, walls etc	1.05
	Beach landing	Small surf	1.10
	Beach landing	Large surf	1.20
Fg Fishing gear	Light fishing gear (nets & lines)	Damage unlikely	1.00
	Heavy fishing gear (trawl)	Impact structure	1.10
Usage Factor = Fv x Fg			

- Notes:** 1. The minimum required weight in g/m² of dry laminate should be multiplied by the relevant factors from the tables above. Thus the required weight of dry laminate = minimum weight x Fc x Fw x Fv x Fg.
2. The total factor applied (Fc x Fw x Fv x Fg) need not be greater than 1.2.

Table 6: Table of hull additional reinforcement weight and width

Loaded Displacement (kg)	Width of Additional Reinforcement (mm)	Keel	Stem	Chine & Deck Edge
250	50	multiply	multiply	multiply
500	60	min fibre	min fibre	min fibre
1000	70	weight by	weight by	weight by
2000	90			
4000	110	2.2	2.0	1.7
6000	120			
8000	130			
10000	140			
12000	150			
15000	160			
18000	170			
20000	180			
22000	190			
25000	200			

Note: The width of additional reinforcement is distributed either side of the keel/stem/chine; see illustration below.

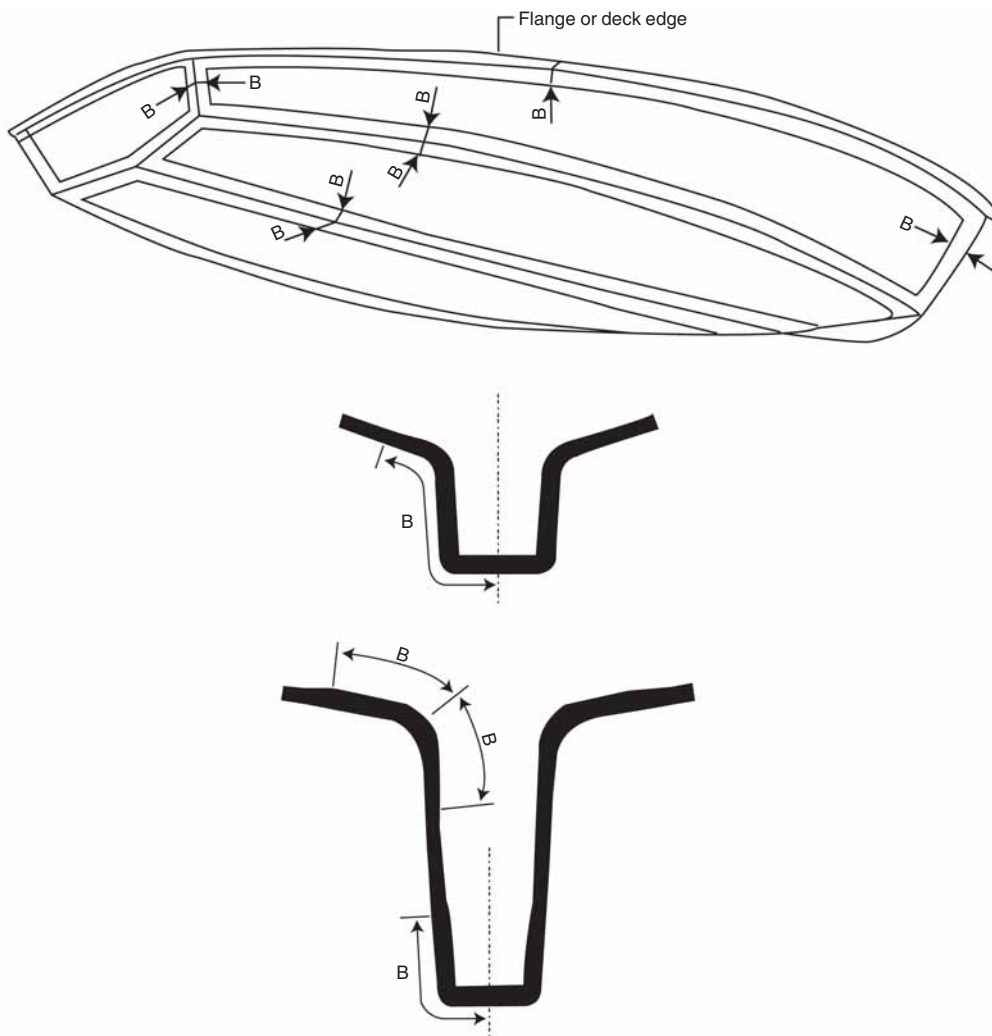


Table 7: Hull stiffeners section modulus – SM cm³

Loaded displacement m_{LDC} (kg)	Stiffener spacing s = 500 mm						
	Stiffener span / (mm)						
	500	750	1000	1250	1500	1750	2000
500	2.5	4.6	7.1	11	16	22	28
1000	3.1	5.9	9.0	13	19	26	34
5000	5.4	10	16	21	30	41	54
10000	7.0	13	20	28	38	52	68
15000	8.2	15	24	33	44	60	78
20000	9.2	17	27	36	48	65	86
25000	10	19	29	40	52	70	92

Loaded displacement m_{LDC} (kg)	Stiffener spacing s = 600 mm						
	Stiffener span / (mm)						
	500	750	1000	1250	1500	1750	2000
500	2.8	5.3	8.5	13	19	26	34
1000	3.5	6.6	10	16	23	32	41
5000	6.1	12	18	25	37	50	65
10000	8.0	15	23	32	46	63	82
15000	9.3	18	27	37	53	71	93
20000	10	20	30	41	58	79	103
25000	11	22	33	45	62	85	110

Loaded displacement m_{LDC} (kg)	Stiffener spacing s = 700 mm						
	Stiffener span / (mm)						
	500	750	1000	1250	1500	1750	2000
500	3.1	5.9	10	16	22	31	40
1000	3.9	7.3	12	19	27	37	48
5000	6.8	13	21	32	46	63	82
10000	9.0	17	26	37	54	73	95
15000	10	20	30	43	61	83	109
20000	12	22	34	47	67	92	120
25000	13	24	37	50	72	99	129

Loaded displacement m_{LDC} (kg)	Stiffener spacing s = 800 mm						
	Stiffener span / (mm)						
	500	750	1000	1250	1500	1750	2000
500	3.4	6.4	11	18	26	35	46
1000	4.3	8.0	14	22	31	42	55
5000	7.5	14	22	34	49	66	87
10000	9.7	18	28	43	61	83	109
15000	11	21	33	49	70	95	124
20000	13	24	37	53	77	105	137
25000	14	26	40	58	83	112	147

Table 8: Deck stiffeners section modulus – SM cm³

Stiffener spacing $s = 500$ mm						
Stiffener span l (mm)						
1000	1500	2000	2500	3000	3500	4000
7.0	16	28	44	64	87	113

Stiffener spacing $s = 600$ mm						
Stiffener span l (mm)						
1000	1500	2000	2500	3000	3500	4000
9	19	34	53	77	104	136

Stiffener spacing $s = 700$ mm						
Stiffener span l (mm)						
1000	1500	2000	2500	3000	3500	4000
9.8	20	36	56	81	110	143

Table 9: Stiffener - curvature factor f_{cs}

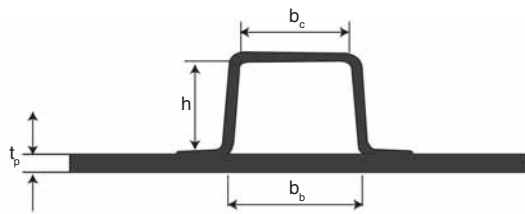
$\frac{c}{l}$	0.03 and below	0.06	0.09	0.12	0.15	0.18 and above
f_{cs}	1.0	0.90	0.80	0.70	0.60	0.50

Stiffener mat - roving factor f_{ws}

R	0.3	0.4	0.5	0.6	0.7	0.8	0.9 – 1.0
Glass fibre content	0.32	0.31	0.30	0.28	0.27	0.26	0.25
f_{ws}	0.72	0.75	0.78	0.87	0.91	0.96	1.00

Table 10: Top hat stiffeners

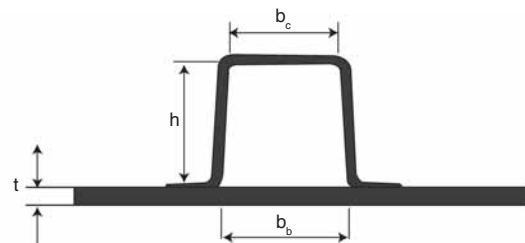
Low top hat stiffener



Glass content: $g = 0.30$
(Chopped strand mat CSM)

Dimensions of former			Plating thickness t mm	Stiffener glass weight w g/m ²	Section modulus SM_{min} cm ²
h mm	b_b mm	b_c mm			
25	36	30	5	600	1.8
			10	600	2.7
			15	600	5.1
40	60	50	5	600	4.5
			10	600	5.4
			15	600	7.5
50	75	65	5	900	10
			10	900	12
			15	900	14
60	90	75	5	1200	19
			10	1200	21
			15	1200	24
75	100	85	5	1200	27
			10	1200	30
			15	1200	33
100	150	125	5	1800	73
			10	1800	81
			15	1800	87
125	175	150	5	2100	125
			10	2100	140
			15	2100	149
150	220	190	5	2700	230
			10	2700	260
			15	2700	280

Square top hat stiffener

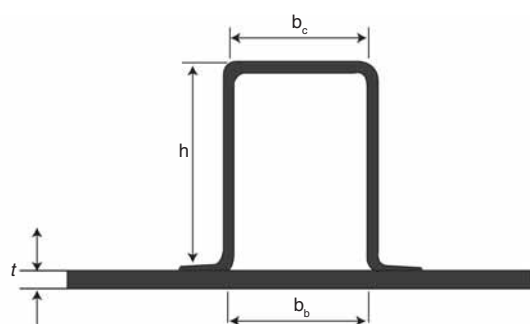


Glass content: $g = 0.30$
(Chopped strand mat CSM)

Dimensions of former			Plating thickness t mm	Stiffener glass weight w g/m ²	Section modulus SM_{min} cm ³
h mm	b_b mm	b_c mm			
25	25	20	5	600	1.5
			10	600	2.2
			15	600	4.6
40	40	35	5	600	3.6
			10	600	4.4
			15	600	6.3
50	50	45	5	900	8.2
			10	900	9.5
			15	900	12
60	60	50	2	1200	15
			10	1200	17
			15	1200	19
75	75	65	5	1200	23
			10	1200	26
			15	1200	28
100	100	85	5	1800	56
			10	1800	65
			15	1800	69
125	125	105	5	2100	98
			10	2100	112
			15	2100	112
150	150	125	5	2700	173
			10	2700	198
			15	2700	213

Table 11: Top hat stiffeners and laminate step stiffener

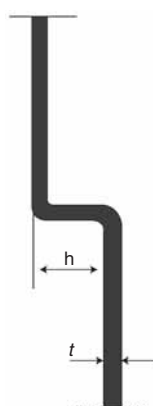
Tall top hat stiffener



Glass content: $g = 0.30$
(Chopped strand mat CSM)

Dimensions of former			Plating thickness	Stiffener glass weight	Section modulus
h	b_b	b_c	t	w	SM_{MIN}
100	50	50	5	1.800	41
			10	1.800	48
			15	1.800	53
125	50	50	5	2.100	65
			10	2.100	77
			15	2.100	84
150	50	50	5	2.700	104
			10	2.700	126
			15	2.700	139
150	75	75	5	2.700	126
			10	2.700	150
			15	2.700	163
175	75	75	5	3.000	161
			10	3.000	194
			15	3.000	213
200	75	75	5	3.600	240
			10	3.600	290
			15	3.600	322
200	100	100	5	3.600	277
			10	3.600	331
			15	3.600	364
250	100	100	5	4.200	433
			10	4.200	518
			15	4.200	576

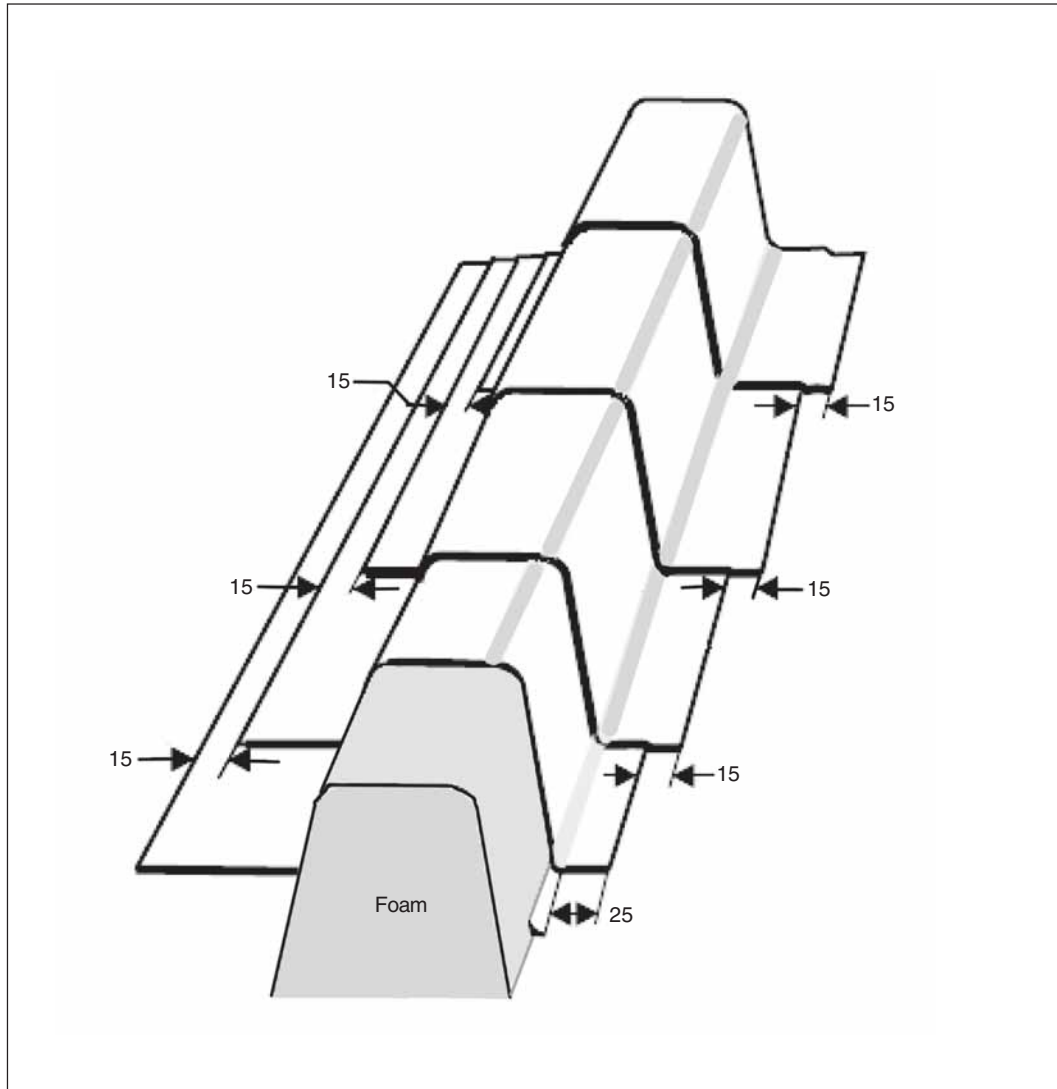
Laminate step stiffener



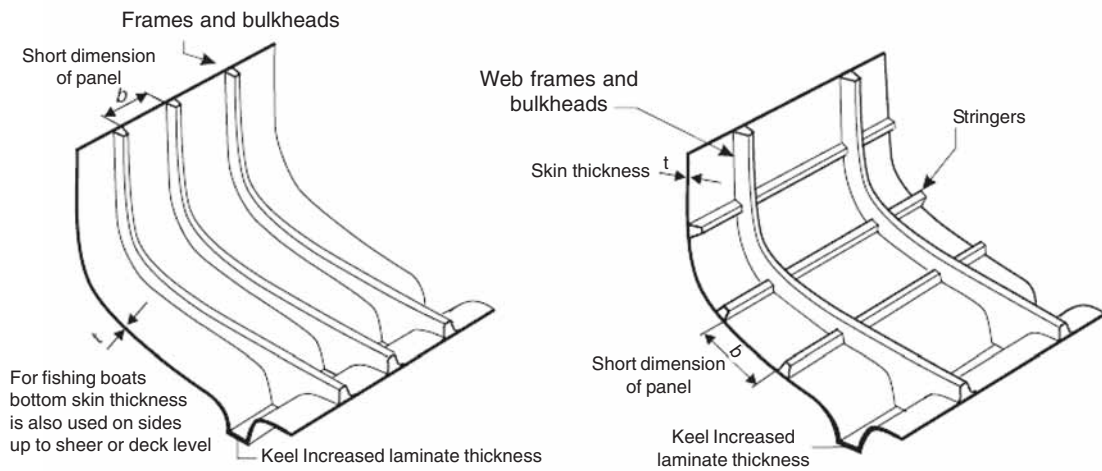
Glass content: $g = 0.30$
(Chopped strand mat CSM)

Height of step h mm	Laminate thickness t mm	Laminate glass weight w kg/m ²	Section modulus SM cm ³
15	5	2.100	1.0
	10	4.300	2.2
	15	6.400	3.6
20	5	2.100	2.9
	10	4.300	3.4
	15	6.400	5.2
30	5	2.100	4.4
	10	4.300	8.0
	15	6.400	11
40	5	2.100	8.2
	10	4.300	14
	15	6.400	20
50	5	2.100	14
	10	4.300	23
	15	6.400	32
60	5	2.100	20
	10	4.300	34
	15	6.400	46

Bonding stiffeners

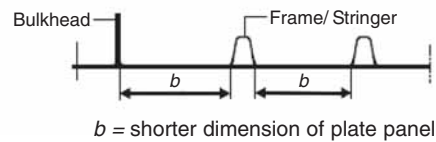


Design details: Single skin laminate



TRANSVERSE STIFFENERS

TRANSVERSE AND LONGITUDINAL STIFFENERS

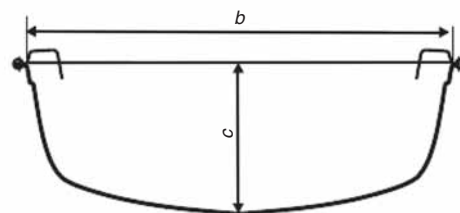


SMALL BOATS WITH HARD CHINES. TRANSVERSE FRAMES WITH GREATER SPACING THAN b

$$\text{Panel curvature} = \frac{c}{b}$$

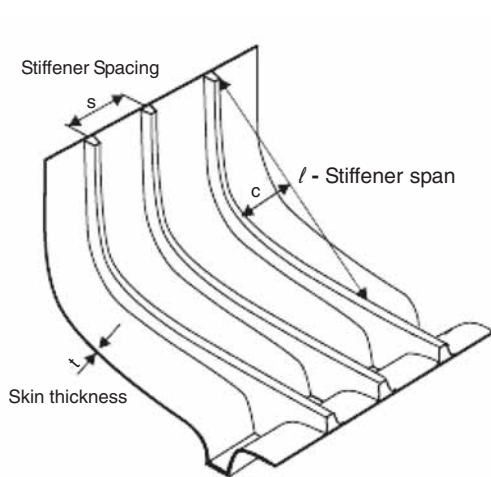


BOAT WITH CURVED BOTTOM AND KEEL + TRANSVERSE FRAMES SPACED MORE THAN b

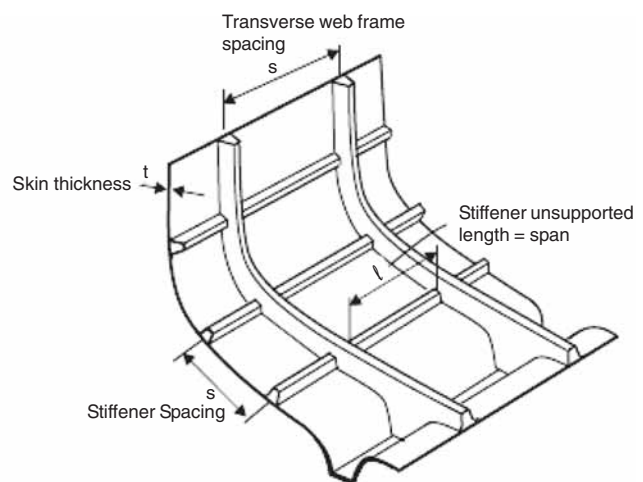


SMALL BOAT WITHOUT KEEL

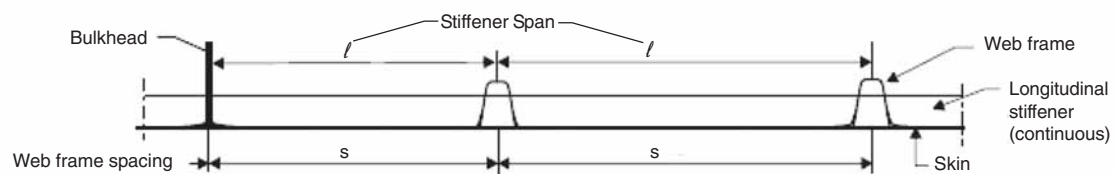
Stiffeners



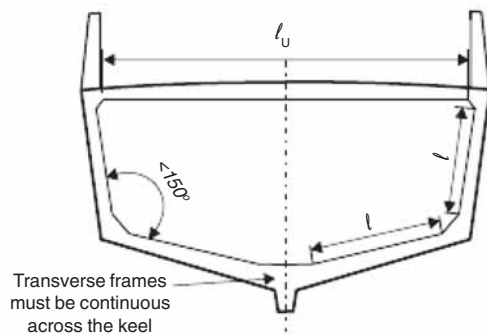
TRANSVERSE STIFFENERS: Frames and bulkheads



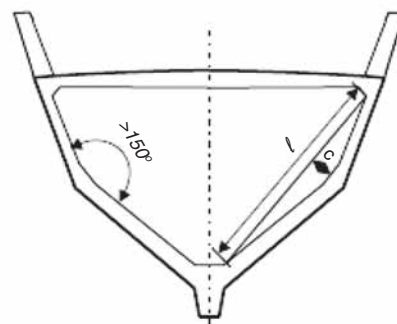
TRANSVERSE AND LONGITUDINAL STIFFENERS
PRIMARY STIFFENERS: Web frames and bulkheads
SECONDARY STIFFENERS: Longitudinal stiffeners



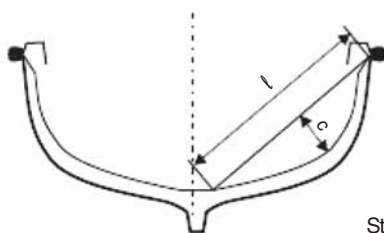
TRANSVERSE WEB FRAMES AND LONGITUDINAL STRINGERS



STIFFENER LENGTH l
CHINE ANGLE LESS THAN 150°

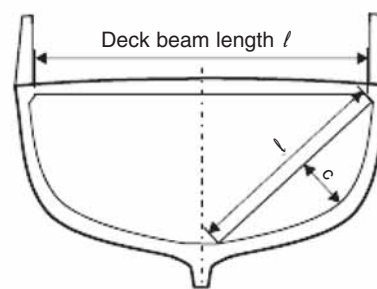


STIFFENER LENGTH l
CHINE ANGLE MORE THAN 150°



SMALL OPEN BOAT
TRANSVERSE FRAME
Keel and rail are main longitudinal stiffeners

$$\text{Stiffener curvature} = \frac{c}{l}$$



DECKED BOAT
TRANSVERSE FRAME

[illegible]

BOBP/REP/119

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