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| IALA Guideline |

1006

On plastic buoys

Edition 4

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# INTRODUCTION

A plastic buoy may be defined as a floating aid with at least the hull being constructed of a plastic material.

Plastic buoys have been in production since the 1980s.

Initially they were produced in small sizes (small harbour or river markers, diameter 0.25 m) but nowadays there are several manufacturers producing plastic buoys in sizes up to and in excess of 4m diameter (large offshore buoys).

They are produced mainly from polyethylene materials in different designs.

# Scope

This guideline has been developed to assist aids to navigation manufacturers and authorities when developing and selecting plastic buoys for different purposes. Furthermore it gives information about plastic buoy related quality control- and test procedures.

# Background

## Points to be considered when evaluating plastic buoys

Because of the different material densities (steel: 7,85–7,87 g/cm3, plastic: 0,8-2,2 g/cm3) the weight of plastic buoys is less compared to steel buoys. Light weight buoys need a careful design to avoid having a rapid rolling or pitching motion detracting from their navigational effectiveness in waves, wind and current.

A well-manufactured buoy using high-quality pigments within IALA chromaticity standards and virgin material should retain an acceptable surface colour for the design life of the buoy, which can be in excess of 20 years. However, high ultra violet and/or high temperature exposure will significantly accelerate the ageing process.

Some plastic materials may have better resistance to dense marine fouling than other buoy types. Plastic buoys must be sufficiently robust to withstand fouling being scraped off, or high pressure water jetting, regularly during the working life of the buoy.

Some plastic buoys are particularly adaptable to certain ice conditions.

The purchase cost of plastic buoys is dependent on the construction technology. Whole life costs may be less than steel types; however users should carefully assess their requirements with costs factors, see also IALA Guideline No. 1047 On Cost Comparison Methodology of Buoy Technologies.

Plastic buoy technologies offer flexibility to incorporate new design developments.Compared with steel buoys plastic buoys may require new techniques in deploying, maintenance and handling. Therefore special considerations should be given the safe working load on plastic buoys.

Sea-based maintenance can be achieved on most plastic buoys, including jet washing and other normal service tasks. Various maintenance procedures are suitable for different plastic materials. More guidance is available in “IALA Guideline No. 1077 On Maintenance of Aids to Navigation”.

Depending from the design the metal components can require a more intensive maintenance regime, therefore the grade of steel must be considered, depending on environmental conditions. Major service intervals may be governed by the life expectancy of the metals used in the buoy assembly.

It may be necessary to incorporate an earthing strap on plastic buoys to prevent the build-up of static electricity, which may cause shock or damage electronic equipment.

When a radar reflector is integrated into the plastic buoy, the plastic material is allowed to have only low radar attenuating characteristics to avoid decreasing the performance of the radar reflector.

## BUOY CONSTRUCTION MATERIALS

For plastic buoys the following plastic materials are used primarily:

* polyethylene
* glass reinforced plastic (GRP)
* polyurethane / elastomer coated foam
* polystyrene foam coated
* ionomer foam

Polyethylene is the most common plastic for plastic buoys, the other materials are less in use. Therefore, the present guideline mainly deals with polyethylene plastic buoys (chapter 4).

# Polyethylene plastic buoys

## Polyethylene material - general

Since its discovery in the 1930s, polyethylene has been one of the most commonly produced bulk plastics due to the low price, chemical resistance, good electrical properties (isolator) and good processability. Concerning the use for plastic buoys also the high ductility and the high cold break resistance are advantageous.

Polyethylene is a thermoplastic. From a temperature of about 100 °C it behaves plastically. After cooling, the material solidifies again. Thus, it can be easily formed and welded under the influence of heat.

Based on the different density four main types are distinguished:

* High density polyethylene (HDPE)
* Medium density polyethylene (MDPE)
* Low-density polyethylene (LDPE)
* Linear low-density polyethylene (LLDPE)

Other important types are:

* Polyethylene with ultra-high molecular weight (UHMWPE)
* Very low-density polyethylene (VLDPE)
* Cross Link Polyethylene

Nearly all polyethylene types are used in plastic buoy manufacturing (except Cross Link Polyethylene, it cannot be welded or recycled.)

Some types offer the advantage that the buoys, which are made of them, can be repaired by hot fusion welding.

The polyethylene material must have a certain quality and special material specifications. The use of recycled polyethylene is not recommended.

## Mechanical properties and standards for polyethylene

The following table information about the minimum required properties of each polyethylene type and standards for testing them.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Property (Minimum Value Required) | Low Density & Linear Low Density | Medium Density | High Density | Standard Recommended | Comments |
| Density (g/cm3) | 0.910 – 0.920 | 0.926 - 0.940 | 0.941 - 0.965 | ISO 1183/ASTM D-4883/ASTM D-1505 |  |
| Hardness | 60 Shore D |  |  | DIN 53505 |  |
| Yield Strength | 17 N/mm2 |  |  | UNI EN ISO 527-1 |  |
| UNI EN ISO 527-2 |
| Fracture Strength | 10 N/ mm2 |  |  | UNI EN ISO 527-1 |  |
| UNI EN ISO 527-2 |
| Elongation | 100% |  |  | UNI EN ISO 527-1 |  |
| UNI EN ISO 527-2 |
| Abrasion Resistance | < 130 mm3 |  |  | DIN 53516 |  |
| Impact Resistance | 21 J/mm |  |  | ISO 6603/02 | Test done with samples at -20 degrees Celsius |
| Sun Radiation | UV-15 Stabilized Minimum or ∆E < 2.5 |  |  | DIN EN ISO 4892-3 and Xenon Lamp (500h) |  |

## Manufacturing the buoy body of Polyethylene buoys

### MANUFACTURING OF PLASTIC PARTS

Depending on the polyethylene material the plastic parts of polyethylene plastic buoys can be made

* by rotational moulding,
* in an extrusion process or
* by welding plastic parts (plates, pipes, etc.).

The following table gives an overview about the polyethylene types and the manufacturing processes for each.

|  |  |  |  |
| --- | --- | --- | --- |
| **Polyethylene Resin Type** | **Density g/cm³** | **Rotational Moulding** | **Extrusion process** |
| Low Density & Linear Low Density | 0.910 - 0.925 | X |  |
| Medium Density | 0.926 - 0.940 | X |  |
| High Density | 0.941 - 0.965 |  | X |

#### Rotational moulding process

Rotational moulding can be used for the production of large, hollow, seamless plastic parts (enclosed modules). During the rotational moulding process the base resin is transformed with heat only.

A thin-walled hollow mould gives the outer shape of the plastic part. The mould gets filled with plastic, slowly rotated bi-axially and *heated. The plastic melts*, the temperature depends on the used plastic material.



(picture of rotomoulding machine? )

By cooling of the mould, the molten plastic slowly settles on the inner mould surface and thus forms the desired plastic part. The wall thickness depends on the amount of plastic and can be up to 35 mm.



Figure 3

Rotational moulding is particularly suitable for small to medium series production. The advantages are the relatively low mould costs and the almost unlimited possibilities of shaping. It is also possible to integrate metal parts into the plastic parts. The relatively long production cycles are disadvantageous compared with an extrusion process.



Figure 4

The enclosed modules, manufactured as described above, can either be used directly as a buoy, be welded to buoys or mounted as floats on a core structure.

Figure 1 shows a big enclosed module (YxCxV m), Figure 2 shows a small enclosed module.

#### Extrusion-process

Plastic extrusion is a high-volume manufacturing process, in which plastic is melted and formed into a continuous profile. The base resin is transformed with heat under significant pressure. Tubes/pipes, hoses, films, coatings, plates etc. can be produced. The significantly higher molecular weight of high density resin and the extrusion process create a material with significantly greater strength, abrasion and impact resistance than the polyethylene formed in rotational moulding.

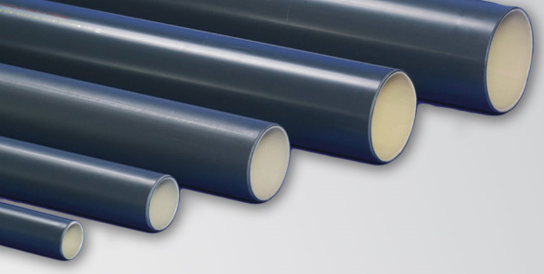


Figure 5

The process starts with feeding plastic from a funnel into the extruder. In the extruder, the plastic is compacted by a rotating screw, melted and pressed through a nozzle. The nozzle gives the end product its profile. This is followed by the cooling process, which is usually achieved by a water bath.

Pipes used for polyethylene buoys are mostly parts of water lines. The most common material is HD 100 polyethylene. The wall thickness and the pressure class vary depending on the SDR (side to diameter ratio). Typical for buoy applications are SDR 26 and pressure class 6.

Figure 5 shows pipes made by an extrusion process.

Figures:

Exturios process

Raw material

Finished pipes

Mirror welding

#### Welding of polyethylene Plates

Polyethylene plates can also be welded to parts of buoys or complete buoys.

Figure 4 shows as welded module made by PE-plates

Figures:

Plates

### Assembly of polyethylene buoy parts

Depending on the type, diameter and area of application, there are different designs of polyethylene plastic buoys. The buoy body can be made as:

* one enclosed module (for example rotational moulded)
* two or more enclosed modules/pipes/plates, welded
* modular plastic design: enclosed modules as floats, mounted on a plastic core structure
* hybrid metal/plastic design: enclosed module as floats, mounted on a metal core structure

Generally, small buoys are made as one or more parts, while larger types may be modular plastic or hybrid metal/plastic.

The composition of a buoy of several buoyancy modules offers the advantage that a reserve of buoyancy remains in case of damage to one or more segments.

Regarding large plastic buoys in modular design handling and transport can be simplified.

## Common types and sizes of polyethylene plastic buoys

### General

Available on the market is a great variety of different types and sizes of polyethylene plastic buoys. The following chapters give an overview about the most common buoys.

### small harbour or river markers

Those buoys mostly consist of 1 enclosed module.



Figure 7

|  |  |
| --- | --- |
| TABLE similar to go deep table |  |
| Application area | Harbour, rivers, marinas |
|  |  |
|  |  |
| Biggest diameter in the water line (m) | ≈ 1,5 |
| Height over all (m) | 5,4 |
| Total weight (kg) | 1000 |
| Buoyancy (kg/cm) |  |
| Äquivalent radar reflection area (m²) | ≈ 30 |
| Average wall thickness (mm) | ~ 25 |

part. Figure 5 shows some examples.

Figures:

### typical spar- and conical-buoys up to 1.5m diameter

Those buoys consist of some plastic parts, which are welded together.

The wall thickness of the lower elements is sometimes bigger than from the upper elements because of stability and ballast reasons.

* The buoy can be divided into a few waterproof sections.
* Radar reflector and other devices are usually placed inside the buoy body.
* Some of them can be equipped with a light-unit.
* The buoys can be filled with polystyrene or polyurethane foam.

Figure 6 and Figure 7 are showing examples, the following sizes are common:



Figure 8



Figure 9

|  |  |  |  |
| --- | --- | --- | --- |
|  | big spar/conical buoy | middle spar/conical buoy | small spar/conical buoy |
| Application area | see, coast, estuary | coast, estuary | estuary, shallow water |
| Biggest diameter in the water line (m) | ≈ 1.0 - 1,6 | ≈ 0.8 - 1,0 | ≈ 0.4 - 0.8 |
| Height above water line/focal plane (m) | ≈ 3 | ≈ 2.6 | ≈ 2 |
| Height over all (m) | ≈ 6 | ≈ 5-6 | ≈ 2-5 |

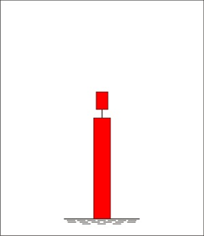
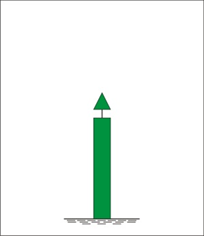
### Spars

The most spars consist mainly of one or more plastic pipe sections manufactured by an extruding-process. The top and the bottom parts are also made of plastic and become mainly mirror-welded on the pipe(s).

* The buoy can be divided into a few waterproof sections.
* Radar reflector and other devices are usually placed inside the buoy body.
* Buoys can be easily customized according to specifications.
* Some of them can be equipped with a light-unit and a battery compartment (primary battery).
* The buoys are usually filled with polystyrene or polyurethane foam.

Spars with the following characteristics are common:

|  |  |  |  |
| --- | --- | --- | --- |
|  | Big spar | Medium spar | Small spar |
| Application area | Offshore, Coastal | Coastal, Ports, Inland waters | Marinas, Inland waters |
| Diameter (m) | 0,8 – 1,0 | 0,4 – 0,5 | 0,16 – 0,225 |
| Height above water line/focal plane (m) | 3,0- 4,0 | 2,5 – 3,5 | 2,0 – 3,0 |
| Height over all (m) | 8,0 – 11,0 | 6,0 – 9,0 | 2,5 – 6,0 |



### Modular buoys with enclosed modules as floats

For bigger buoys (diameter more than 1.5m up to 4m) enclosed modules are used as floats. The floats are mounted on a core structure, which consists of plastic pipes or a metal construction.

#### Modular buoys with complete plastic design

Modular buoys with a plastic core structure (complete plastic design) are consisting of the following elements:

* enclosed modules as floats
* polyethylene tail tube
* polyethylene top structure
* mooring and lifting eyes made of steel
* cast iron ballast weight

add sample picture

The main advantage of those buoys is that no maintenance is required, except the mooring and lifting eyes.

#### Modular buoys with hybrid metal/plastic design

Modular buoys with hybrid metal/plastic design are consisting of the following elements:

* enclosed modules as floats
* steel tail tube or skirt
* aluminium or plastic top structure
* mooring and lifting eye made of steel
* cast iron ballast weight

add sample picture

The following sizes of modular buoys with polyethylene floats are typical:

|  |  |  |  |
| --- | --- | --- | --- |
|  | big modular spar/conical buoy | middle modular spar/conical buoy | small modular spar/conical buoy |
| Application area | open sea  estuary | Open sea, coastal, estuary | coastal, shelter, rivers, ports |
| Biggest diameter in the water line (m) | 3-4 | 2.2 -2.6 | 1.5/1.8/2 |
| Height above water line/focal plane (m) | 5-8 | 3.8- 6.5 | 1.7- 4.2 |
| Height over all (m) | 12-15 | ≈ 8.6 | 2.7-7.9 |

## Construction details of polyethylene plastic buoys

### general

The wall thickness of the plastic parts must be optimized to the size, the shape and the environmental conditions of the buoy to be sufficiently robust. The range is from 5 – 40 mm.

Polyethylene material will expand and contract about 3 to 5 %, depending on the colour and ambient temperature. Care should be taken in the design to ensure compatibility between different materials (e.g. elongated or oversized clearance holes).

Rotational moulded parts: In order to ensure the correct distances between threaded bushings or threaded rods, calibers may have to be used during the cooling process.

Plastic buoys can be filled with polystyrene or polyurethane foam, see chapter 4.5.7.

The polyethylene provides poor adhesion for conventional paints, but specialized hot plastic spraying processes are available and have been used successfully, see chapter 4.5.8.

### Construction requirements for use of plastic buoys in ice built up areas

A year-round use of plastic buoys can save money, because special winter work is obsolete than. Some plastic buoys, especially spar/conical buoys and spars, are able to resist ice conditions. For this some construction requirements have to be fulfilled:

#### Outer construction

When ice floes occur, the buoy will be stressed by impact, abrasion, cutting or compression. The buoy must be strong enough to go under the ice and come up after the ice field has moved away.

Buoy shape, strength, lifting- and mooring-eyes etc. must be constructed accordingly.

For the width of the lifting eyes a compromise between minimum size for a good handling and reducing the points for ice accreation is necessary.

#### Material

In some applications/areas the ice conditions require the use of extruded HDPE.XXXXXX

#### Top marks

When possible, top marks should be avoided in ice built up areas. If installed, a disposible solution is possible, but environment protection has to be considered.

#### Dimensioning and realising of wall thickness

The main reason for by ice destroyed plastic buoys are too thin or not homogeneously realized wall thicknesses. The wall thickness must be choosen accordingly and realized homogeneously while the production process. This should be measured and documented in order to the quality control requirements, see chapter 4.8.

Refer to workshop Report of the “IALA Workshop on Challenges of Providing AtoN Services in Polar Regions” and “IALA Guideline No. 1108 On The Challenges of Providing AtoN Services in Polar Regions”.

### Construction requirements for use of plastic buoys in very hot climates

Summary of hot climate workshop...

Careful design considerations have to be given when proposing plastic buoys in very hot climates as some effects could severely impair the performance of the equipment in place.

The following are examples of problems that could result from high temperature exposure that may relate to the material being tested. Consider the following typical problems to help determine if the design is appropriate for the application. This list is not intended to be all inclusive.

* Parts bind from differential expansion of dissimilar materials.
* Materials change in dimension, either totally or selectively.
* Packing, gaskets, seals, etc. become distorted, bind, and fail causing mechanical or integrity failures.
* Gaskets display permanent set.
* Closure and sealing strips deteriorate.
* Shortened operating lifetime.
* Discoloration, cracking or crazing of plastic materials.
* Outgassing of composite materials.

Due to the usual high solar radiation in those regions, surface temperatures can add 15 to 30°C to the ambient temperatures, making the surfaces close to the 80°C mark.

It is important to consider studies made by manufacturers to compare specific materials’ degradation, reaction and resilience when in these extreme conditions.

Lifting eyes, fouling -> weight and weakness of plastic material: steel structure inside for force transmission.

Extreme weather events (fog, sand storm, humidity, heat, tropical seasonal winds )

Sample pictures from sahin

Guideline “Providing AtoN Services in extremely hot and humid climates” and IALA wiki

### Construction requirements for use of plastic buoys in extreme sea conditions

Plastic buoys can be used in most sea conditions. Extreme sea conditions (breaking waves, hurricane, debris) cause high mechanical stress to buoys. General it should be considered that the design fits to the environmental conditions.

### Force transmission

In general, it is important that all high forces are distributed evenly in the structure of the buoy and do not concentrate on small areas of the outer skin. High forces occur particularly in the areas of the mooring and lifting eyes, as well as in the areas between them. Solutions to avoid punctual forces and to safely initiate forces are:

* Sufficient wall thicknesses in the areas of the mounting points of the mooring and lifting eyes
* Installation of the mooring and lifting eyes on the plastic body via several screw connections
* Internal connection of the mooring and lifting eyes via internal metal parts. Avoiding of force transmission over the plastic buoy body.

Furthermore the wall thickness at those areas should be designed according to the forces.

### Colours of polyethylene buoys

#### Colours of new polyethylene buoys

Colour pigments must be of the highest quality suitable for marine use and UV exposure. The colours of polyethylene buoys should fit to the IALA Recommendation “E-108 On The Surface Colours used as Visual Signals on Aids to Navigation”.

#### CHROMATICITY STABILITY

Special focus should lie on chapter 4 of E-108 “degradation of pigments”. The speed of the colour degrading depends on the colour itself, the quality of the pigments and the UV stabilizing additives and the environmental conditions in the area, where the plastic buoys are used.

The user of the buoy should ask the manufacturer for information about the expected material behaviour during the lifetime...

The manufacturer can give information about artificial weathering methods (standards) and expected time of the material being inside the allowed area of E 108.

A correlation between the expected times and the real lifetime should be possible (factor 10-20 between expected times and real liftetime), depending of the area of use( North Europe, South Europe, Asia, Africa, North America, South America, etc.)

#### Multi-colour possibilities

The possibilities to produce multi-colour plastic buoys according to the IALA maritime buoyage system (MBS) depend from the buoy type and the design.

Welded spar- and conical-buoys according to chapter 4.4.2 and spars according to chapter 4.4.4:

* Enclosed modules can be made of different colours. They can be welded together according to the needed colour combination.
* Extruded pipes can be manufactured in multi colour combinations (for example red-white). The different plastic pipes can be welded accordingly.
* Other possibilities are the welding of coloured plastic plates on the buoy body or the mounting of a cap with the needed colour combination.

Modular buoys with a plastic core structure (complete plastic design) according to chapter 4.4.5.1:

* The floats can be made of different colours and combined according to the needed colour combination.
* On the polyethylene top structure coloured polyethylene plates can be mounted.

Modular buoys with hybrid metal/plastic design according to chapter 4.4.5.2 :

* The floats can be made of different colours and combined according to the needed colour combination.
* An aluminium top structure can be painted with different colours.
* On a polyethylene top structure coloured polyethylene plates can be mounted.

Another possibility is the mounting of a cap with the needed colour combination on the buoy body.

### Filling

If applicable, filling a buoy with polystyrene or polyurethane foam can have the following advantages:

* Filling can increase the impact stability/shock resistance of a floats.
* In case of leakage the filling can secure the buoy from sinking.

If filling is used, it must be of the highest quality closed-cell specification to prevent water absorption. Filling material should be of sufficient quality to survive the expected lifetime of the buoy.

Some disadvantages may exist in the use of foam filling:

* Some polyurethane foam types may not be recyclable. Furthermore the combination of polyethylene and foam is not easy to separate.
* For filling in foam into the floats additional holes are necessary. These are weak spots and must be closed carefully after the filling.

Information about the density and the water absorption behaviour of the foam should be taken in to consideration.

### Lettering methods

Most administrations apply the position name/number on the buoy body. Appropriate methods have to be found to achieve a long term stability of the lettering. Solutions could be:

* Painting
* Adhesive foils
* Mounted plates (welded or fixed by screws)
* Scaring/engraving
* Plastic spray method
* Mould-In-method (only for long term use of the buoy on the same position)

### Metal parts

#### General

A common plastic buoy includes at least the following metal parts:

* lifting eye(s)
* mooring eye(s)
* standard parts
* inserts
* ballast (in case of cast iron or steel)

The metal parts of a buoy must be selected in such way, that no galvanic element is produced. Sometimes it is necessary to insulate metal parts (paint, insulating hull, bitumen coat).

It is desirable to use non corrosive standard parts, for example from hot-dipped galvanized steel, marine-grade aluminium, marine grade stainless steel or bronze.

#### Lifting eye and mooring eye

Depending on the buoy type according to chapter XXXXXXX0 the lifting eye and the mooring eye can be made as follows:

* part of the plastic body
* inserts of plastic
* additionally mounted galvanized-steel-part
* additionally mounted stainless-steel-part
* part of the metallic structure (buoy core)

The safe working load should be optimized regarding the handling, deploying and recovering of the buoy in order to insure safe operation.

Because of the mooring eye wear an appropriate reserve is needed, which depends on the maintenance intervals. With measurements during the maintenance process the wear can be determined. The mooring eye should be changeable in case of wear.

Information about the safe working load of the lifting eye should be given by the manufacturer........XXXXXX

The lifting eye is not designed for lifting the buoy and the sinker.....only for lifting the buoy.....

Information about changing the practice of buoy handling.....

#### Standard parts

Standard parts (screws, nuts, washers, etc.) should be made of stainless steel, hot dip galvanized in accordance with 4.4.9.1

Standard.....

#### Inserts

Inserts are used for fastening the lantern, colour plates, lettering, etc. They can be made from brass or stainless steel.

In the manufacturing process, care should be taken to ensure that threaded inserts are fixed and aligned correctly in the material, otherwise they should be avoided.

Care must be taken when using threaded inserts to avoid detachment of the insert within the polyethylene.

#### ballast

According to chapter 4.5.10 ballast could be needed to achieve good buoy stability. For using a buoy type in different conditions the ballast may be adjustable.

A permanent part can be mounted inside, depending of the buoy type it can be mounted outside for adjustment reasons

Material: Steel, cast iron, concrete, pig iron, as part of the chain

Internal ballast: It must be secured, no movement is allowed.

Fastening methods (outside part): retaining system, bolts

### Swimming Stability

For a good hydrostatic design information regarding current, tidal range, wave height, wave interval, wind speed and water depth at the deployment location is needed. The IALA guideline “1099 on the hydrostatic design of buoys” gives detail information.

## Handling

The buoy handling on the buoy tender or in the buoy yard includes work safety danger for the personnel. The risk of work safety danger can be minimized by appropriate work safety precautions and.

The handling of a plastic buoy generally does not differ from steel buoy handling.

The weight of plastic buoys is lower than from steel buoys. Therefore they are easier to manoeuvre. The devices for manoeuvring could be from less capacity.

Long term storage:

* The storage should be done according to the manufacturer instructions (for example to avoid deforming of spar buoys).
* When plastic buoys are stored outside for a long time (for example on a buoy yard) they should be protected against UV to prevent them from premature aging.

## Repair & Maintenance

* Linear polyethylene can be easily repaired by trained technicians using hot fusion welding equipment in required colours.
* Maintenance procedures are outlined in IALA Guideline “No.1077 on Maintenance of Aids to Navigation”, chapter 2 synthetic buoys.
* PPE??????XXXXXX

## Quality control and testing

### General

A well-designed plastic buoy manufactured in equal and lasting quality can ensure safety requirements. Also the buoy lifetime can be longer, for example concerning the degradation of colours.

Compared to steel buoys on plastic buoys the wear and tear of the buoy body, for example the plastic material condition (aging, overload) can not be seen at the first sight.

During the manufacturing process of the buoy body and the metal parts some important quality control mechanisms should be applied.

* The manufacturer should have an internal quality control principle, for example ISO 9001 or comparable.
* If required, each buoy can be delivered with an according quality control report. The content of the report has to be determined according to the customer requirements.
* The customer should establish an internal system to monitor the history of the buoy.

### Quality of the buoy body

To accomplish a long lifecycle quality of the buoy body the following tests can be applied.

#### Tests before series production: prototype testing

After manufacturing the first samples of plastic parts these could be checked according to the requirements:

* Measurement of the overall dimensions of each part
* Measurement of the weight of each part
* Measurement of the wall thickness on different points (rotational moulded parts)
* Check the water tightness of the enclosed modules by pressure tests
* Check the surface
* Chromaticity measurements
* Mechanical tests
* Sawing of the compartments to get detail information (rotational moulded parts)

Tests on completed sample buoys: In addition to the measurements described above, the following quality controls should be carried out.

* Ultrasonic measurements of welded joints?????
* Tension tests up to the break load (welded buoys)
* Swimming stability

#### Tests during the manufacturing process of the buoy body

Depending from the customer requirements the tests can be done on each buoy body or batch tested.

* Measurement the overall dimensions
* Measurement of the weight
* Measurement of the wall thickness on different points
* Check the water tightness
* Tension tests up to a specified work load
* Check the surface
* Chromaticity measurements

#### Special tests during the lifecycle of buoys

According to 1077, xXXXXXX: On some sample buoys from different waterway areas the following tests can be done periodically:

* Chromaticity measurement
* Tension tests up to a specified work load
* POSITION IN THE DOCUMENT

## Recycling / Disposal

Guideline 1036, chapter 6.9

Polyethylene buoys can be recycled, however it must be possible to separate any metal components and impurities (marine growth / paint etc) from the plastic and remove any internal filling.

Professional company specialised on recycling

Difference between filling polystyrene (easy) and polyurethane (difficult)

Costs?

Identification (manufacturer/year/batch/ etc/RFID?)

# GLASS REINFORCED PLASTIC (GRP) (Appendix 3, Figure 4)

## General

GRP is the usual abbreviation for glass reinforced plastic which in its most common form consists of glass matt bonded by polyester resin.

## Construction

Complex shapes can be easily produced by laying-up resin and glass reinforcement into a mould by hand (or spray machine). The cylindrical buoy body is usually formed by joining two half body shapes. It is important to note that the join is often the weakest area of the body.

The strength of GRP is basically dependent of the ratio of glass fibre to resin and thus this is another area which requires definition and quality control. High strength (required in ice conditions) can be achieved by the use of carbon or Kevlar fibres, but their costs may be high. These fibres may be used in specific stress areas of the buoy.

The outer layer of resin, the gel coat, prevents water absorption into the glass reinforcement and must be protected from mechanical damage. This is usually provided by some form of fendering.

### Filling

In the event of a collision, a GRP buoy may well crack from an impact which would only dent a steel buoy. To prevent the buoy from sinking the buoy should be divided into separate watertight compartments or filled with polyurethane foam or polystyrene foam. If foam is used it must be of the highest quality closed-cell specification. If the foam is porous it may absorb water over a long period of time and increase the weight of the buoy to such an extent that it cannot be lifted by the servicing craft, or the buoy may sink.

### Fasteners / Mooring attachment

Care must be taken when bonding metal attachment points into GRP due to the considerable difference in thermal expansion rates between metals and plastics, and the inherent flexibility of the GRP. Another option is to use through bolted fixings with generous backing plates and resilient washers or coatings between the metal and the GRP.

It is desirable to use non corrosive fasteners including; hot-dipped galvanized steel, marine-grade aluminium, marine grade stainless steel or bronze.

Similar problems may exist with the fastening of lifting eyes and tower type superstructures. It is important that any high loads are distributed throughout the structure of the buoy and not concentrated in small areas of the skin. One solution to this problem is to incorporate a central (usually steel) spine to connect the mooring eyes, lifting eyes and superstructure.

### Quality Control

As many commonly available types of glass fibre and polyester resin have limited resistance to extended immersion in water, the manufacturing materials must be carefully specified and certification obtained from the manufacturer to ensure that correct quality materials have been used. Confirmation must also be obtained that laminating and curing has taken place in the correct environment.

## Repair and Maintenance

GRP buoys will require cleaning, repainting and any necessary repair to the gel coat.

Repair of GRP is usually straightforward but does require standards of cleanliness and specific working temperatures. Effective drying of damaged laminates or foam cores may also be difficult in cold climates. It may be necessary to use heaters to warm and dry damage areas and to ensure effective curing of the repair.

The final surface colour of GRP buoys can be incorporated into the gel coat. If this not the case or if a colour change is required, then buoys will require normal painting to achieve the required surface colours.

GRP buoys may be cleaned onsite using water jetting, however care should be taken to ensure paint flakes and surface materials avoid polluting the surrounding environment.

The area in which a foam filled buoys are used must be considered as oily water in around the Port environment could penetrate the damaged buoys, making the repair of it very difficult.

Maintenance procedures are outlined in IALA Guideline No. 1077.

## Handling

Care should be taken to avoid damage to the GRP through impact due to its rigidity.

## Recycling / Disposal

Crushed GRP may be used as a component for road construction. Therefore, it may be considered as a recyclable material.

## Health & Safety

The use of laminating resins and solvents is subject to increasing control by health and safety regulations.

# POLYURETHANE / ELASTOMER COATED FOAM (Appendix 4, Figure 5)

## General

These buoys typically consist of a thick, flexible marine grade polyurethane elastomer skin on a flexible closed cell foam core. They have the advantage of overall flexibility and resilience. The flexibility will also be an advantage when the buoy has to be lifted or serviced in rough weather.

## Construction

The buoys are usually manufactured by spraying the polyurethane skin material onto a shaped foam core and can thus be made to almost any required shape without the need for an expensive mould.

In the manufacturing process, particular attention must be made to the attachment or the interface between the flexible skin and steel mooring eyes. This requires very careful design to prevent water penetration into the foam or tearing of the skin.

The quality of the skin and foam materials is of the utmost importance. The consequences of failure of the skin are self evident but poor quality foam may absorb water through an apparently sound skin or may simply shrink, resulting in a wrinkled buoy with a considerable loss of buoyancy!

### Fasteners / Mooring attachment

The points noted regarding mooring eyes on GRP buoys apply equally to these buoys. The concept of a central structure steel spine between the mooring and lifting eyes is commonly employed.

## Repair &maintenance

Polyurethane may be repaired with two component pouring or trowelling compounds. Correct working conditions are critical (temperature and humidity) and detailed health and safety precautions must be observed.

## Maintenance procedures

These are outlined in IALA Guideline No. 1077.

## Handling

There are no specific requirements

## Recycling / Disposal

Polyurethane products are difficult to recycle.

## Health & Safety

The manufactured polyurethane products present no particular health and safety risks in normal use, but are hazardous if ignited.

# ALL FOAM (Appendix 5, Figure 6, Figure 7)

## General

The life and durability of the buoy is entirely dependent on the quality of the foam used. The flexibility of the foam can provide good impact resistance but resistance to aggressive abrasion is not good. This last factor is important for buoys which will dry out on a hard bottom at a tidal site or may be subject to moving ice conditions.

A foam buoy hull can sustain considerable damage or loss of material without sinking. A damaged buoy can not be repaired by the user. The material is not recyclable. Other advantages of foam buoys include their lighter weight which may result in good performance in fast water.

## Construction

These buoys are usually constructed by wrapping closed-cell foam around a central structural core, the layers of foam being heat sealed together during the wrapping process. A major US manufacturer uses ionomer foam which is produced in sheet form. The outer layer of the rolled foam shapes can be "densified" through the application of pressure and heat to make a hard, smooth surface. Pigments are usually incorporated into the foam during the extrusion process, so the colour is continuous throughout the entire hull and daymark. The buoys include a structural steel framework, steel lifting and mooring eyes, and stainless steel connecting hardware. Internal radar reflectors can be mounted in the daymarks.

The manufacturing technique particularly lends itself to the production of one-off designs as a variety of body shapes can be made without the need for a mould. Buoys of this type are significantly lighter than steel buoys of the same size.

### Fasteners / Mooring attachment

Please refer to the section on polyurethane/elastomer coated foam (Section 3.3 refers).

## Repair and maintenance procedures

These are outlined in IALA Guideline No. 1077.

## Handling

There are no specific requirements.

## Recycling / Disposal

Ionomer foam is generally not recyclable but it can be returned to the manufacturer.

## Health and Safety

There are no specific issues.

# Buoy equipment

Similar to steel buoys additional equipment can be mounted in or on the plastic buoy. The following chapters give an overview about the components.

## Light units

Plastic buoys can be equipped with lanterns (powered by solar-, wind- or wave energy respectively by a primary battery or gas) or self-contained lanterns.

Compact self-contained lanterns become increasingly smaller. At the same time, the amount of their functions increases. Chapter 3.2.8 “Integrated Power Supply Lanterns” of the IALA Navguide and the IALA guideline 1064 “Integrated Power Systems Lanterns” give information in detail.

If the plastic buoy is used under ice conditions according to chapter 0, the self-contained lantern or the stand alone lantern must also be designed to be ice-resistant. At some plastic buoys (especially spars) a primary battery instead of a solar power supply is used then.

## Monitoring systems and sensors

Modern self-contained lanterns can be equipped with a remote monitoring and remote control system or sensors. Depending from the buoy location different communication ways for the data transfer can be used.

The status of the lantern, the power supply and other devices as well as buoy related data can be determined, transferred and displayed. This enables further optimization of the technical maintenance operation, especially with regard to the cost intensive buoy tender fleet.

The IALA Guideline 1008 “Remote monitoring and control of aids to navigation” gives information in detail.

## Radar reflector

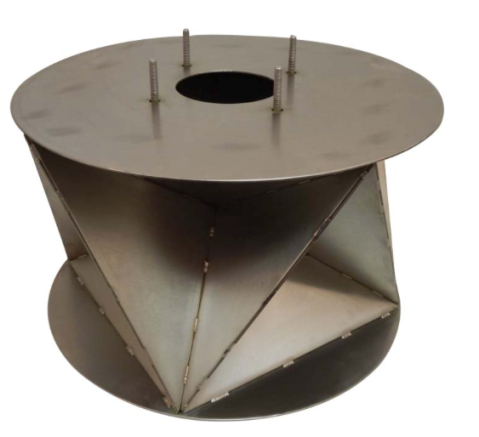
A radar reflector is a passive device designed to enhance the radar conspicuity of aids to navigation. Chapter 4.9.1 “Radar Reflectors” of the IALA Navguide provides more information. (more information: paper of Dr. Speckter and VV-WSV 2406).

Most plastic buoys are equipped with a radar reflector, mounted inside or outside of the buoy body.

The advantage of an integrated radar reflector is, that the radar reflector is protected from environment conditions. The disadvantageous effects are:

* The retrofitting of a radar reflector could be difficult.
* The surrounding polyethylene wall reduces the reflection performance of the radar reflector. The effects have to taken into considerations.

Pictures...



Echomax, firdell

## Racon

A Radar beacon (racon) enhances the radar detection and identification of the object on which it is mounted. For detail information look at chapter 4.9.3 “Radar Beacon” in the IALA-Navguide and the “IALA Guideline No. 1010 on Racon Range Performance”.

## AIS

Buoys can be equipped with AIS-transponders to transmit different messages. Also remote monitoring is possible. For detail information look at the IALA Recommendation “A-126 On The Use of the Automatic Identification System (AIS) in Marine Aids to Navigation Services” and the IALA guideline “1098 the application of AIS - AtoN on buoys”.

## Top marks

The shape and the dimensions of top marks are described in the IALA guideline 1094. Top marks can also be designed to enhance the radar response.

## Retroreflective sheeting

Plastic buoys can be equipped with retroreflective sheeting, so the mariner can detect the position and colour at night by use of a searchlight. For detail information look at the IALA Guideline 1094.



# ACRONYMS & Definitions

## Acronyms

IMO International Maritime Organization (Acronym style)

## Definitions

Abcde (Body text)

# REFERENCES

Body text

1. Abcd
2. Efgh
4. Advantages and Disadvantages of Plastic Buoys

**ADVANTAGES**

* Plastic does not corrode;
* It is easier to maintain; only removal of marine growth, no painting for plastic parts required;
* There is less maintenance on shore for the plastic components (no grit blasting, no painting with the exception of GRP) therefore less resources may be utilised;
* Plastic buoys are of lower weight (1/2 to 1/3 mass of the equivalent diameter steel buoys). Therefore, the service may be able to use smaller buoy tender;
* Whole life costs may be less than steel buoys; see also IALA Guideline No. 1047 On Cost Comparison Methodology of Buoy Technologies
* Since the 1980´s plastic buoys have been operated successfully;
* There are a number of commercial companies offering plastic buoys;
* Most plastic is recyclable;
* Where plastic buoys are of modular construction, it is possible to change individual parts or segments if they are damaged or need refurbishment;
* Large modular buoys are easier to transport and store, as parts can be disassembled for transit;
* The number of spare parts (whole buoys held) can be reduced;
* It is possible to encase a radar reflector within a plastic buoy’s superstructure.

**DISADVANTAGES**

* It is more difficult to change the colour of a plastic buoy, as conventional painting is not reliable for plastic surfaces;
* Generally plastic buoys have a shorter lifetime than steel buoys;
* Plastic buoy components will be specific to each manufacturer and may therefore not be interchangeable;

1. Examples of polyethylene buoys



Figure 10

Small Rotationally Moulded Buoy

**

*All Polyethylene Modular Buoy (except cast iron ballast and steel mooring and lifting eyes)*





*Modular Buoy*

1. Example of Glass Reinforced Plastic (GRP) buoys



*Large Glass Reinforced Plastic Buoy (Polyurethane Foam Filled)*

1. Example of polyurethane / elastomer coated foam buoys



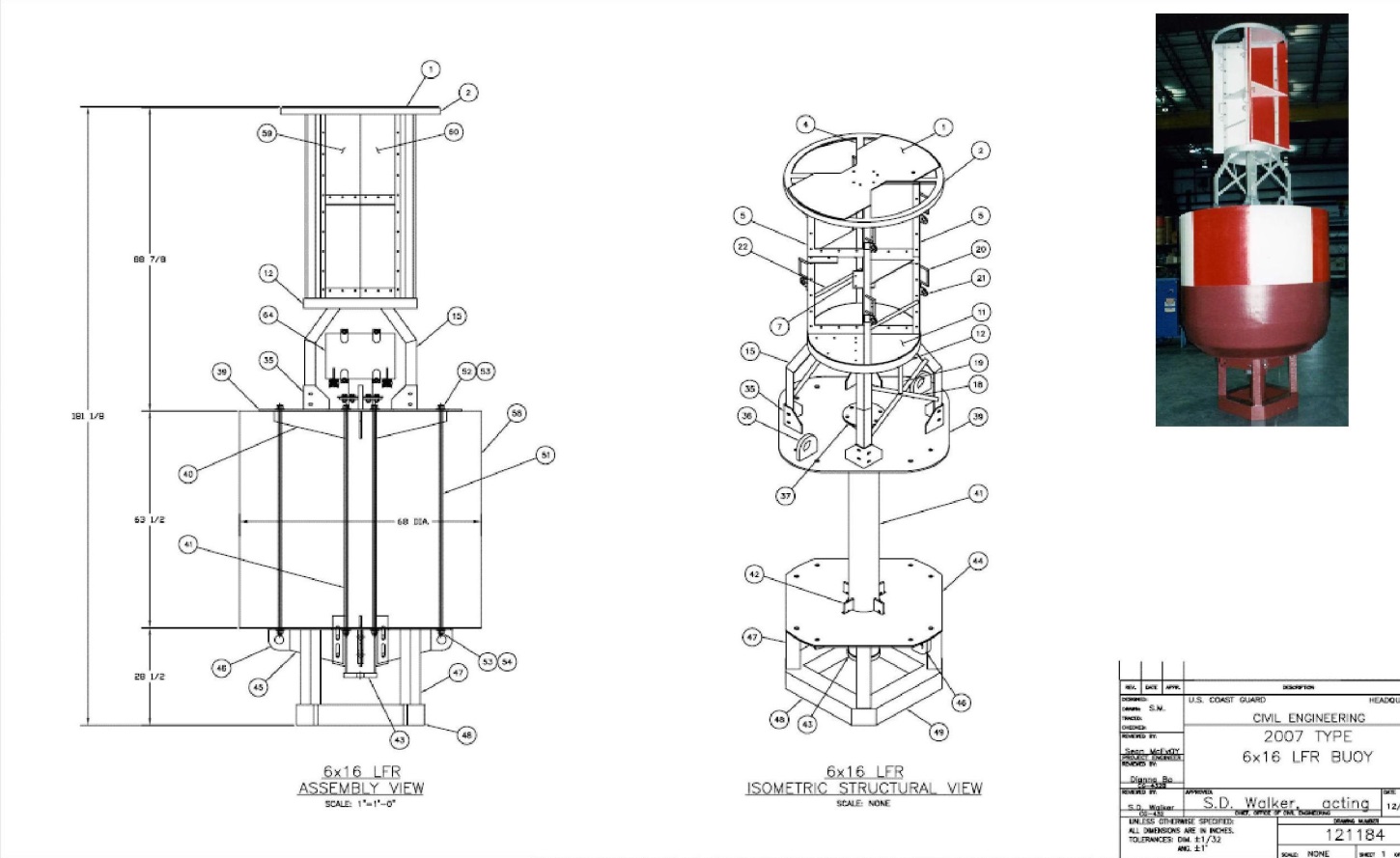
*Small polyurethane / elastomer coated foam buoy*

Note: Large polyurethane / elastomer coated foam buoys are also available

1. Example of foam buoys



*Foam Buoys from 0.75m to 1.6m diameter*



*Large Modular foam buoys*