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Initial Guidelines for Synthetic Moorings Used With Small Buoys in Shallow Waters

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Canadian Coast Guard

Guideline

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GUIDELINES FOR SYNTHETIC MOORINGS FOR SHALLOW WATERS

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Foreword

1. Purpose

This document is a guideline to address the design, acquisition, manufacturing, deployment, retrieval, and disposal of synthetic rope moorings for small buoys in shallow waters.

2. Scope

This document shall be limited to information specific to synthetic anchoring systems for small plastic buoys in shallow waters. The synthetic anchoring systems covered comprise marine grade synthetic rope and other fixed components. This guideline does not specifically address specialized mooring systems such as those including elastic tethers.

Small plastic buoys are defined as buoys with a diameter of less than 0.5 metres. The most common examples of this size of buoy are the 0.3m Tideland Signals SB-30 Spar buoy also known as the Ottawa River Type (ORT) and the 0.4m Tideland Signals SB-40 Can/Conical buoy.

Shallow waters shall be defined as water depths no deeper than 15 fathoms (90 feet, 27.4 m).

This document is based on the information available as of March 2, 2005.

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Summary

This guideline provides a means for Canadian Coast Guard (CCG) personnel to manage the life cycle of synthetic moorings for small plastic buoys in shallow waters. As titled, it is an initial guideline. It is based on the best information and practices known at the time of issue. This document provides personnel working with synthetic moorings, information and best practices to safely deploy, retrieve, store and retire synthetic moorings.

This guideline is currently applicable to synthetic moorings for buoys with a diameter of less than 0.5 metres anchored with 5/8" polyester rope that has a minimum breaking strength of 12000 lbs. It is currently intended for use with a maximum anchor weight of 600 lbs.

This guideline is a work in progress and as more is learned about synthetic moorings performance and best practices, this document will evolve to include such information.

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Chapter 1 SYSTEM DESIGN

1.1 SYSTEM DESCRIPTION

A floating Aid to Navigation (AtoN) requires an anchoring system to keep it in place so that it can perform its function. The plastic buoys used as AtoN's have ballast integrated within the body of the buoy and/or a weight attached to the bottom of the buoy. The mooring system consists of an anchor and cable connecting the anchor to the buoy. Chafing protection protects the cable from the sea bottom, the anchor itself and other hazards local to the anchor position. Shackles are used to connect the different components of the entire system together. Figure 1 shows a block diagram of the basic components.

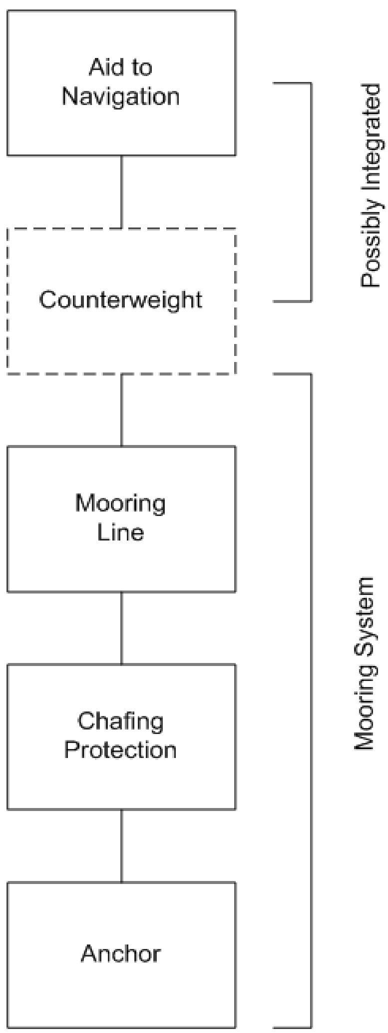

Figure 1 Typical Synthetic Mooring

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Chapter 2 RECOMMENDED MATERIALS

2.1 ROPE TYPE

A marine grade double braided polyester rope shall be used. For small plastic buoys, 5/8" diameter rope has been selected based on performance and ease of handling. Using appropriate safety factors (See Appendix A.1.2) the 5/8" rope shall be suitable for anchor sizes up to a maximum of 600 lbs (272 kg). The ropes must meet or exceed Canadian General Standards Board CAN/CGSB 40.16-95 and US Mil Spec #MIL-R-24677. To support the maximum anchor weight, the minimum tensile strength for 5/8" rope is 12,000 lbs see Appendix A.1.4. Two examples of rope types that fit these requirements are Novatec Braids Ltd. NovaBlue and Samson Rope Technologies 2 in 1 Stable Braid.

2.2 THIMBLES

Hot dip galvanized or steel (blue) tube thimbles are to be used at all splices. An example would be a Seamar G-219 for 5/8" rope. This thimble is available painted or galvanized.

Figure 2 Tube Thimbles

This thimble can be heavily galvanized to protect from corrosion and the fully enclosed sides provides further protection to the rope from external chafing at the anchor end of the mooring. The use of this thimble must be further reviewed as it is not currently traceable to a specification such as "Specifications for Moorings for Aids to Navigation" - MA2080[1)].

2.3 FLOATS

Eight inch Trawl Floats with a minimum buoyancy of 5 lbs (2268 grams) are to be used. Examples of suitable trawl floats are ICEPLAST 1085 or Utzon 1205.

2.4 CHAFING SOCK

To further prevent chafing at the anchor end of the mooring rope, a protective sleeve shall be installed. A nylon protective sleeve such as those used to protect abrasion of hydraulic lines is used as a covering for the rope. An example of this material is made by Gates Corporation. Gates Nylon Sleeve HG14 can be used for 5/8" rope.

2.5 SWIVEL, SHACKLES AND ANCHORS

Either stainless steel swivels or swivels specified by MA2080-F [1)] are to be used. Shackles and anchors as specified in MA2080-F are to be used. Refer to Figure 8 for the appropriate size. The selected swivels and shackles all have working loads (> 5000 lbs) that exceed the working load of the rope and the anchor sizes covered by this guideline. MA2080 uses a safety factor of 5X to determine safe working loads. The use of stainless steel as a material for swivels must be further reviewed as it is not currently traceable to a specification such as MA2080.

Chapter 3 RECOMMENDED MANUFACTURING

The mooring length is site specific. It is based on depth, criticality of the buoy to remain on station, tides and currents in the area. A basic rule of thumb for a sheltered harbour is depth plus 2 meters. A more general rule is 1.5 times the depth, however, the actual mooring length is based on years of experience and anecdotal information collected for that location. Each synthetic mooring is custom made for that location. It is recommended that standard lengths based on 1 fathom intervals be used. A properly trained rigger should perform all splices and float attachment.

3.1 EYE SPLICES

Each end of the mooring rope requires a tube thimble as part of the eye splice to prevent chafing. All splices must be made using the rope manufacturer's recommendations. Literature is available from the rope manufacturers on the proper method for splicing the rope. [8)]

Should an integral swivel be required for the mooring system being manufactured, perform the step described in the following paragraph, otherwise splice one end of the mooring and proceed to the chafing sock section.

The style of thimble in Figure 3 is not joined at the bottom which provides an opportunity for a swivel to be integrated with the thimble prior to splicing. The thimble is placed in a vise and the end opened up enough to allow the insertion of the swivel loop. Once the swivel is inserted, the thimble is returned to its original closed position.

Figure 3 Integrated Thimble and Swivel

Once the thimble is configured, if required, splice one end of the mooring cable.

Figure 4 Splicing: abridged process

3.2 CHAFING SOCK

Once the first splice is made, the other end of the cable can be configured by first inserting the rope through approximately 1 meter of chafing sock prior to splicing the remaining thimble and eye splice.

Figure 5 Chafing sock

After the splice is completed, the sock is slid in place next to the splice and both ends of the sock are folded inward by at least 1” to prevent fraying of the material.

Figure 6 Chafing sock stitching

Stitching is applied at both ends of the sock to hold it and the fold in place. The stitching at the splice end also acts as the lock stitch for the splice.

3.3 FLOAT LOCATION AND ATTACHMENT METHOD

The float position is located 1/3 of the total length of the mooring from the anchor. For 5/8" rope in shallow waters, a single float is all that is required. The process to attach the float follows. A suitable length of 5/8" rope is threaded through the float and knotted on either side to prevent the float from moving. The ends of this rope are sealed with electrical tape to prevent fraying and the float and rope are laid out next to the mooring rope. Enough slack is put in the line so that when the mooring rope is tight, the rope that holds the float is not stretched tight. The two ropes are then attached to each other using lock stitches and half hitches and the loose end is again secured to the mooring rope with electrical tape.

Figure 7 Float attachment

3.4 RECOMMENDED COMMON SYNTHETIC MOORING TEMPLATE

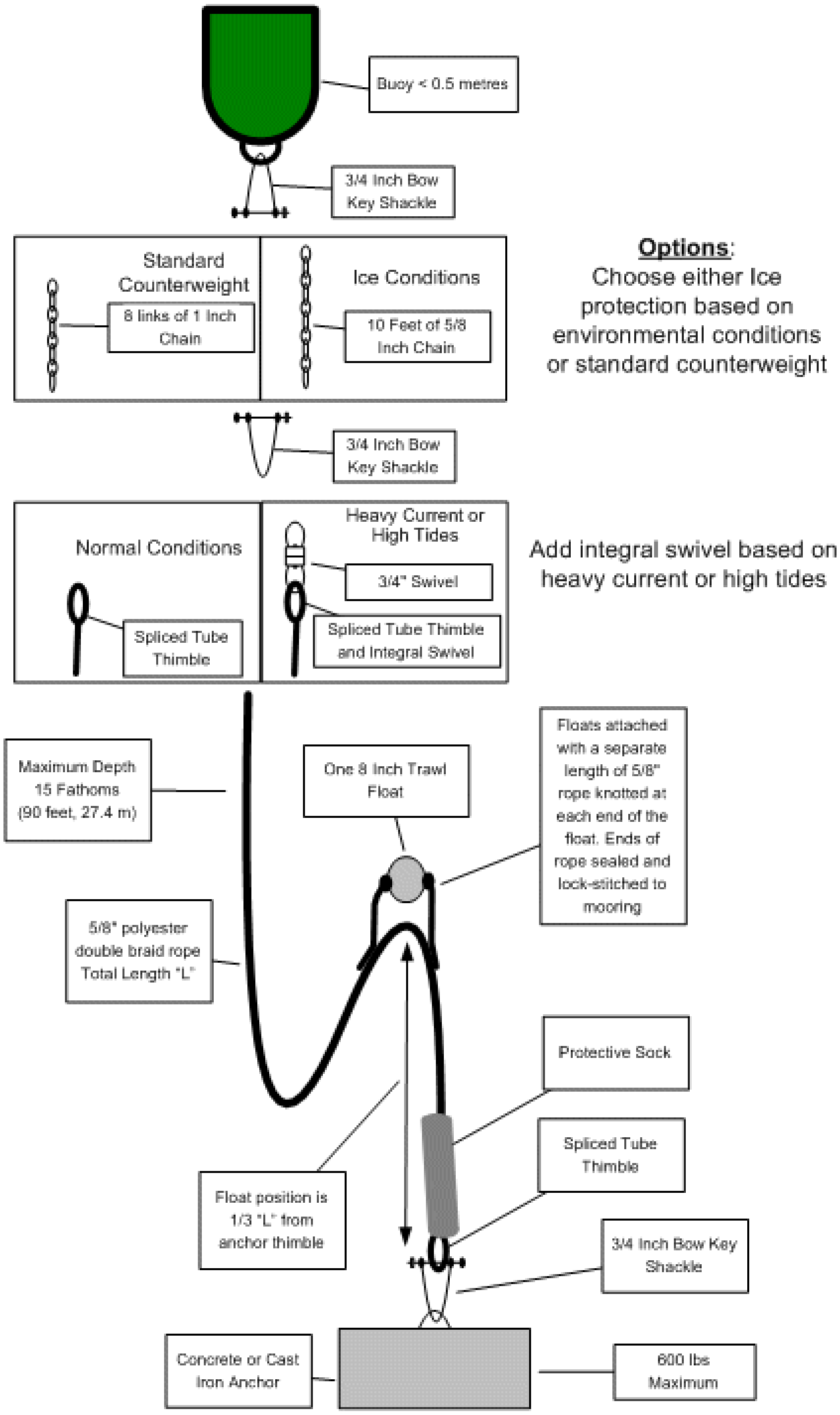

Figure 8 Recommended Common Synthetic Mooring Template

Hammerlock shackles can be added between the buoy and the synthetic mooring as appropriate.

Chapter 4 MOORING HANDLING

4.1 SAFETY

4.1.1 Rope Working Load

Marine rope manufacturers typically specify the working load to be 20% (5X safety factor) of the published strength but will include a caveat, such as the following:

"Working loads are for rope in good condition with appropriate splices, in non-critical applications and under normal service conditions. Working loads are based on a percentage of the approximate breaking strength of new and unused rope of current manufacture. For the three-strand, eight-strand, twelve-strand and double braid rope products depicted in this catalog, when used under normal conditions, the working load percentage is 20% of published strengths. Normal working loads do not cover dynamic conditions such as shock loads or sustained loads, nor do they cover where life, limb or valuable property are involved. In these cases a lower working load must be used." [9)]

Tackle Regulations specify a safety factor of 7X for fibre rope. Using Tackle Regulations as a reference, a safety factor of 7X has been adopted for the synthetic rope used by the CCG in synthetic moorings. This safety factor is used to determine the safe working load of the rope.

4.1.2 Wire Grip Use

A wire grip has been used by the CCG to retrieve synthetic moorings. A wire grip is designed for use with wire, not synthetic ropes. The wire grip can crush or damage the rope if significant loads are experienced during the lift of the mooring. It can also slip due to marine growth and wet conditions. Tests conducted at British Maritime Technology (BMT) Fleet Technology[10)] noted that during a horizontal pull, the fixed jaw of the grip should be oriented down to obtain the strongest pull. Pending further study of wire grip application with synthetic moorings, the use of a wire grip will be limited to 2 retrievals of a synthetic mooring. The mooring will be retired after it has been retrieved a second time.

Alternative methods for retrieval of synthetic moorings are under investigation. (See section 4.3.) Caution should be exercised when using this device with synthetic moorings.

4.1.3 Anchor Weights

5/8" rope can be used with a maximum anchor weight of 600 lbs (272 kg).

4.2 DEPLOYMENT

Synthetic moorings shall be deployed similar to other types of moorings for AtoN. To ensure that the anchor is sitting upright, the rope is not fouled, and that the chafing sock is correctly positioned, it is imperative that the anchor be lifted off the bottom slightly and placed back down to complete the deployment process.

4.3 RETRIEVAL

Mooring retrieval shall be performed in a safe and responsible manner by skilled and experienced personnel.

Some plastic buoys have a lug near the top of the buoy for lifting. This lug should only be used to lift the buoy and any slack in the rope required to secure the buoy. The buoy shall not be used to lift the anchor. Care shall be exercised to avoid dynamic loading of this lug. In cases where the buoy cannot be lifted using this lug (or there is no lug) without lifting the anchor at the same time, the top of the mooring shall be lassoed and disconnected from the buoy so that the buoy and mooring can be retrieved separately.

Safe practices such as the "Guideline for Safe Retrieval of Marine Floating Aids to Navigation" is available from the Newfoundland & Labrador Region. Equipment and methods for retrieving synthetic mooring should be assessed to determine and mitigate any risk associated. The worst case load occurs during the initial lift of an anchor that has settled in a sandy or muddy bottom. Extra care shall be exercised for 600 lbs. anchors in such locations.

The following four methods for mooring retrieval are offered as alternatives to the use of a wire grip:

1) Rope hauling winch.

2) Spooling winch or capstan.

3) Loops spliced into rope at fixed intervals.

4) Ropes of fixed length joined together with shackles.

The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) recommends methods 1 and 2 as possible methods for mooring retrieval. The following information related to these 2 methods has been taken directly from the IALA document[11)]. The winch or capstan must be designed for handling rope and must not allow the rope to slip on the winch drum when under load.

Conventional capstans as used for tensioning mooring warps, etc., may be capable of recovering a rope mooring, however, their tendency to allow the rope to slip on the capstan drum will result in considerable heat being generated at the rope/drum interface which will result in serious damage to the rope. Successful techniques have been developed using large spooling winches where the rope is wound onto a large rotating drum. This technique is limited by the length of rope and, hence, the number of moorings that can be carried on the drum at any one time.

The preferred method, where a large number of rope moorings are to be handled, is to use a specialized rope hauling winch. These can be installed at the vessel's deck edge so that the rope can lead directly to the winch without a fairlead being required. The winch consists of an arrangement of large rubber wheels, which grip the rope without causing damage to the surface fibres. The rope usually only passes over a segment of hauling wheel rather than being wrapped around a drum and can thus be placed in, or removed from, the hauling winch as may be necessary. This type of winch placed on the deck edge also has the advantage that there is no rope under load passing across the vessel's deck, which may present a serious hazard, should the rope break.

Another method is to splice loops into the rope at fixed intervals and use these loops to retrieve the mooring. This method has been used in the past with hurricane moorings[12)] and may be applicable here as an alternative method. Further investigation is required.

Finally, spliced ropes of fixed lengths can be connected together with shackles to form a complete mooring. These connection points can be used to retrieve the mooring using standard winches and associated equipment. This method needs further investigation to determine such things as the appropriate length of the spliced segments and impact of the configuration on the performance of the mooring.

4.4 RECOMMENDED STORAGE

A compilation of information from industry and best practices [3)] outlines the following:

1) All moorings should be stored clean, dry, out of direct sunlight and away from extreme heat (preferably at normal room temperature).

2) Never store rope on concrete or dirty floors or drag it over rough ground.

3) Keep rope away from contact with rusty surfaces.

4) It should be stored on racks to provide ventilation underneath and through the rope.

5) It should be kept away from chemicals of all types.

4.5 PRECAUTIONS IN HANDLING

As outlined in Appendix C item 3:

1) Double braided ropes shall not be coiled but laid down in figure eights.

2) Use extreme caution when wet ropes are used in proximity of live electric circuits.

3) Avoid all abrasive conditions and avoid all exposure to all types of chemicals.

4) After a rope has been in use, minimize handling of the rope when it has dried. If it must be handled extensively, it shall be thoroughly rinsed and preferably handled in wet condition.

5) Any fairlead that the rope runs over must be of sufficient diameter for the rope used, be of the roller type and present no sharp edges.

4.6 CRITERIA FOR ACCEPTANCE OR REJECTION

Appendix B outlines a set of criteria from the Cordage Institute to be used to determine whether a used rope can be re-used or whether it should be retired.

4.7 DISPOSAL

All rope used for synthetic mooring shall be returned to the Canadian Coast Guard for inspection, assessment and disposal. The CCG shall dispose of rope directly through a garbage disposal contractor. All rope splices shall be cut prior to disposal. Thimbles and floats shall be removed and reused as appropriate.

Until further data can be gathered and analysed related to the degradation of synthetic rope over time, standard seasonal and year-round synthetic moorings shall be replaced according to the following table. (See Appendix A.1.2 for more information). Note that the life of the mooring will be further limited, if the wire grip is used as a retrieval method (See section 4.1.2).

Table 1 Mooring Lifespan

Anchor Weight (lbs)	Lifespan (years)
200	6
300	5
600	3

Appendix A ENGINEERING

A.1 ROPE ANALYSIS

A.1.1 Anchor Weights in Salt Water

Due to specific gravity, the force on the rope exerted by an anchor will be less in water than in air. Steel anchors lose less weight than concrete as shown in Table 2.

Table 2 Anchor Weights in Salt Water

Anchor Weight (lbs)	Weight in Salt Water	
	Concrete	Steel
200	111	171
300	167	257
500	279	428
600	333	514

A.1.2 Minimum Rope Tensile Strength Required for Various Loads

A safety factor of 7X is used for the mooring rope. A maximum anchor weight of 600 lbs with 5/8" rope covers the majority of currently deployed CCG systems. By working back from the anchor weight, Table 3 outlines the minimum tensile strength required for a 600 lb anchor in air, salt water and factoring in the effect of bottom suction on the anchor. Based on BMT Fleet Technology measured break strengths[10)] for 3-4 year old rope from Newfoundland & Labrador Region, an additional de-rating factor of 1.666X (40%) has been introduced.

Table 3 Minimum Tensile Rope Strength Required for a 600 lbs Anchor

	Weight (lbs)		
	In Air	In Salt Water	Bottom Suction[1]
Steel Anchor	600	514	1028
Safety Factor (7X)	4200	3598	7196
Derating factor (1.666X)	6997	5996	11988

[1] Weight due to bottom suction is defined as 2X weight of anchor in salt water

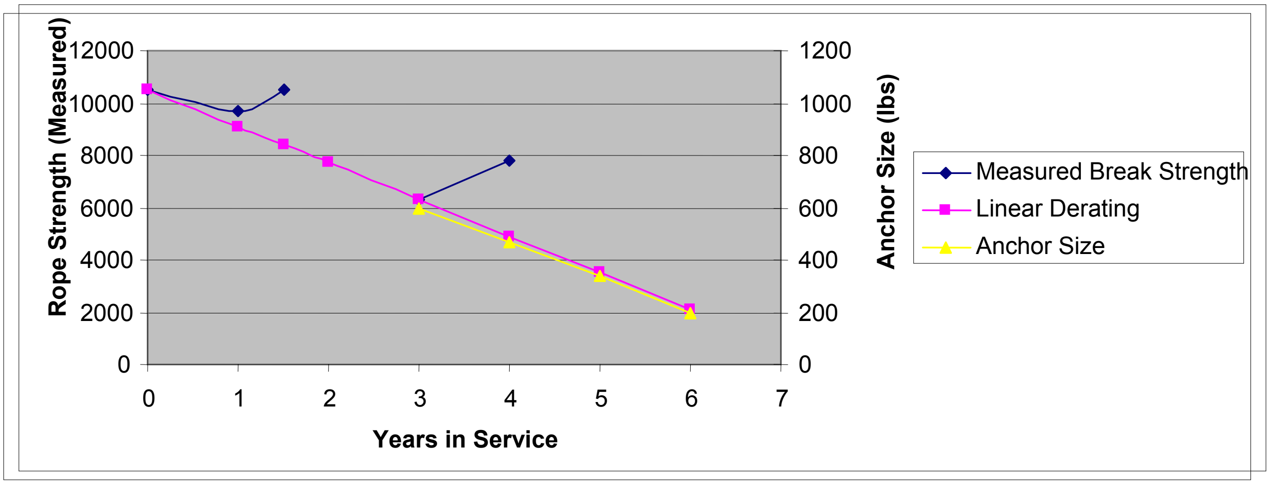

Figure 9 Anchor Size vs. Derated Rope Strength

Figure 9 plots the break test measurements conducted by BMT Fleet Technology[10)] for the new and aged rope samples from the Newfoundland & Labrador Region. Included on this plot is a linear extrapolation using the average measured wet strengths at the new and 3-year mark. It shows a 40% degradation of strength at the 3-year mark over the new rope, based on 2 samples. This residual strength supports a maximum of a 600 lbs steel anchor after 3-years based on the assumptions of 2X bottom suction and 7X safety factor.

A.1.3 Rope Characteristics

There are many ropes to choose from when trying to pick the correct rope for a specific application. BMT Fleet Technology has compiled available literature into a report.[3)]

Manufacturer's recommendations, information gathered by BMT Fleet Technology and regional preferences all point to double braided polyester rope as the rope of choice for this application. It provides the strength required, is resistant to Ultra-Violet degradation, it absorbs little water and provides low elongation under load. 5/8" rope is a good compromise based on physical size for handling and tensile strength.

Novatec Braids Ltd. and Samson Rope Technology products are referenced to determine safe working loads. The lower of the two minimum tensile strengths are found in Table 4.

Table 4 Safe Working Loads (lbs) for Double Braid Polyester

Double Braid Polyester	5/8"
Minimum Strength - lbs	13900
Safety (Design) Factors	
Manufacturer's Specifications (5X) [4) 9)] (lbs)	2780
Safety Factor (7X) (lbs)	1986
Derating Factor (1.666X)	1191

A.1.4 Statement of anchor weights per rope type

A comparison of Table 2, Table 3, and Table 4, is shown in Table 5.

Table 5 5/8" Rope Lift Capability vs. Worst Case Lift in lbs

Cast Iron Anchor	Weight (lbs)	Margin (%)
Weight in Air	600	50
Weight in Salt Water	514	57
Worst Case Lift with Bottom Suction	1028	14

Limiting the anchor used with 5/8" double braided polyester rope to 600 lbs is a reasonable solution based on current knowledge and assumptions. More investigation is required to optimize and engineer the synthetic mooring solutions.

A.2 COUNTERWEIGHTS

Synthetic moorings are much lighter than the chain moorings, as such, attention to the counterweight requirements for a particular buoy is important. Once the weight of all the components that contribute to the downward force on the buoy is determined, a specific counterweight is added to meet the manufacturers recommended counterweight specification. Table 6 details some manufacturer's recommended anchor weight, counterweight and submergence specification.

Table 6 Sample of recommended counterweights for specific plastic buoys

Buoy Type	Manufacturer Part	Recommended Anchor Weight (lbs)	Recommended External Ballast (lbs)	Submergence (lbs/inch)
0.3 m	Tideland SB-30	250 - 500	36	6
0.4 m	Tideland SB-40	150 - 300	20 (Conical) 26 (Can)	7.25
	Tideland WB-390	250 - 500	36	33
0.3 m	GDI 2.00M		65	3

A.2.1 Chain and Shackle Weights

Table 7 Bow Key Shackle Weights – Measured

Size	Weight
3/4"	5 lbs

Table 8 Chain Weights per link from MA2080F

Chain Size	Weight (lbs)
5/8"	0.76
1"	2.89

Table 9 Sample of Rope Weight per 100 ft in Salt Water

Rope Size & Type	Weight (lbs / 100 ft)	
	In Air	In Salt Water
5/8" NovaBlue Polyester	12.5	3.21
5/8" 2-in-1 Stable Braid	14.2	3.65

By using the information provided in Table 6, Table 7, Table 8 and Table 9, a recommended configuration to provide the correct counterweight in a particular situation is possible.

The Tideland SB-30, SB-40 and WB-390 need between 20 and 36 lbs of counterweight. Two ¾" shackles and 8 links of 1" chain provide ~33lbs in addition to the weight of the synthetic mooring. This weight provides an adequate counterweight for these buoys.

A.3 TRAWL FLOATS

A trawl float is intended to keep the slack of the rope mooring from tangling with the anchor and up off the sea bed. This helps to reduce chafing and keep the rope from becoming tangled. Floats from various manufacturers have different buoyancy. It is important to ensure that the float is capable of lifting the load applied.

Table 10 Length of 5/8" 2-in-1 Stable Braid rope that 1 Trawl Float can lift

Float Type	Buoyancy (lbs)	Length (ft)
ICEPLAST 1084 - Green	7.50	164.46
ICEPLAST 1085 - Orange	6.06	133.02
ICEPLAST 1086 - Yellow	5.62	123.34
ICEPLAST 1087 - Ivory	5.29	116.09
ICEPLAST 2000 - White	5.07	111.25
Utzon 1205 - Orange	7.61	166.87

Table 10 includes 20% reserve buoyancy. For the 5/8" rope, the thimble will be held vertically.

If the length of the rope is 1.5 times the depth and the float is located 1/3 of the length up from the anchor, then the float must lift a weight of rope equivalent to approximately ½ the depth. It is important that the floats sourced have a minimum buoyancy of 5 lbs or 2268 grams.

Table 11 Maximum Length of 5/8" Rope Lifted by 5 lbs of Buoyancy

	Length (ft)
1 Trawl Float	110
2 Trawl Floats	219

Table 11 outlines the maximum length in feet that a trawl float with a buoyancy of 5 lbs can lift. This is based on the Samson 2-in-1 Stable Braid, which is the heavier of the two ropes. 20% reserve buoyancy is used to ensure an adequate lift.

The recommended location for the floats is up from the anchor 1/3 of the total length of the rope.

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Appendix B ROPE REJECTION CRITERIA

The following tables have been provided by the Cordage Institute as reference for damage associated with rope. All rope identified as being damaged shall be returned to the CCG for evaluation and assessment.

Table 12 Initial Evaluation – General

Damage Description	Fig. Ref.
Rope displays moderate wear. No history of use, no records or no specifications. Time in service unknown. No severe damage. Potential personal injury or material damage exists if rope should break.	None

Table 13 Excessive Tension / Shock Loading

Damage Description	Fig. Ref.
Visible damage; i.e. broken strands, splice slippage, measurable creep or internal fusion. History of excessive tension or shock loading.	None
Back of eye flattened and hard; cannot be softened	Figure 10

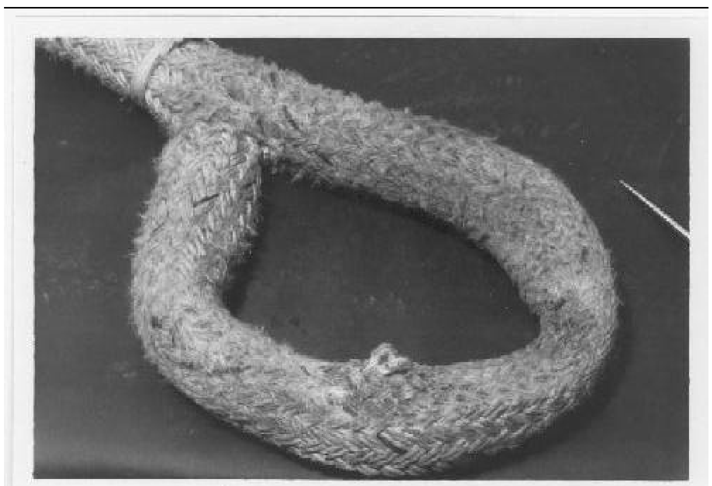

Figure 10 Wear in Double Braid Eye Splice

Table 14 Cyclic Tension Wear

Damage Description	Fig. Ref.
Broken or seemingly cut outer filaments that are packed into the surface or protrude, uniformly over working length. Fuzzy appearance uniform over length. Broken internal filaments over length. Packing of broken filaments that hardens rope giving less than normal flexibility; rope cannot be pried open for internal inspection.	Figure 11 Figure 12 Figure 13

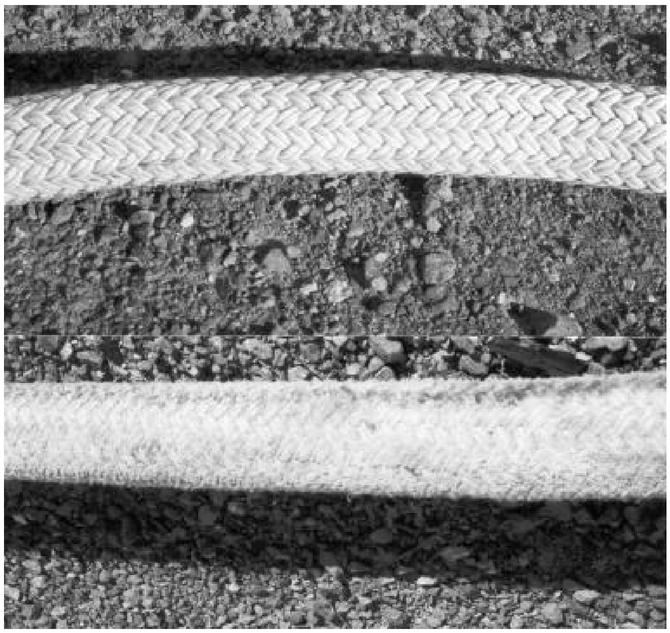

Figure 11 Fibre Abrasion – Cyclic Tension Undamaged – Upper Photo

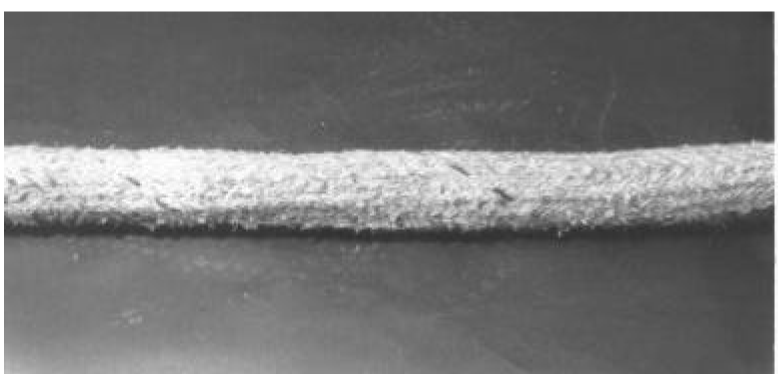

Figure 12 Fibre Abrasion – Cyclic Tension (extreme Wear)

Figure 13 Inter-Strand Abrasion (Exposed internal core reveals wear)

Table 15 External Abrasion

Damage Description	Fig. Ref.
Outer braid worn away by less than 10% of the circumference or 10% over one fourth of strands along the length; core not exposed significantly.	Figure 14 Figure 15 Figure 16
Outer braid worn away by more than 10% of the circumference or over one fourth of the strands along the length; core exposed.	Figure 14 Figure 15 Figure 16
Localized hard or burn areas, area less than 15% of rope circumference in width; penetration less than 5% of rope diameter.	Figure 17
Localized hard or burn areas, area more than 15% of rope circumference in width; or length in excess of one half number of strands; and penetration more than 5% of rope diameter.	Figure 17

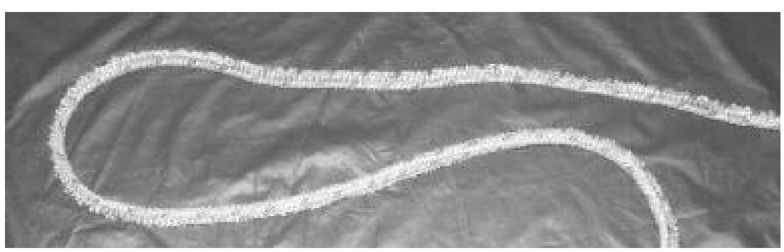

Figure 14 Uniform Surface Abrasion

Figure 15 Extensive External Abrasion

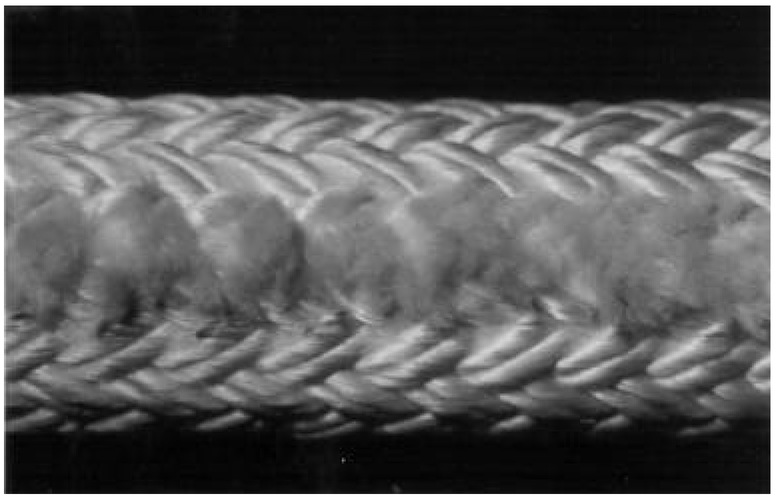

Figure 16 Localized External Abrasion

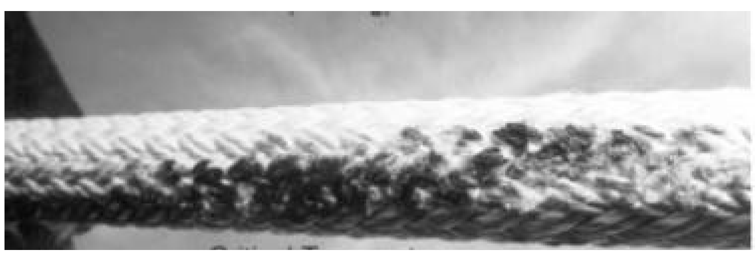

Figure 17 Burn and Melting from External Abrasion

Table 16 Cutting

Damage Description	Fig. Ref.
Outer braid cut by less than 5% of the circumference or 10% of diameter of one fourth of number of total strands along one cycle length; core not exposed.	None
Outer braid cut by more than 5% of the circumference or 10% of diameter of one fourth of number of total strands along one cycle length; core not exposed.	None

Table 17 Pulled Strands and Yarns

Damage Description	Fig. Ref.
Inner core protrudes through jacket. Rope can be massaged back into original structure without kinking.	Figure 18
Inner core protrudes through jacket. Rope cannot be massaged back into original structure without kinking. Displays moderate wear.	Figure 18

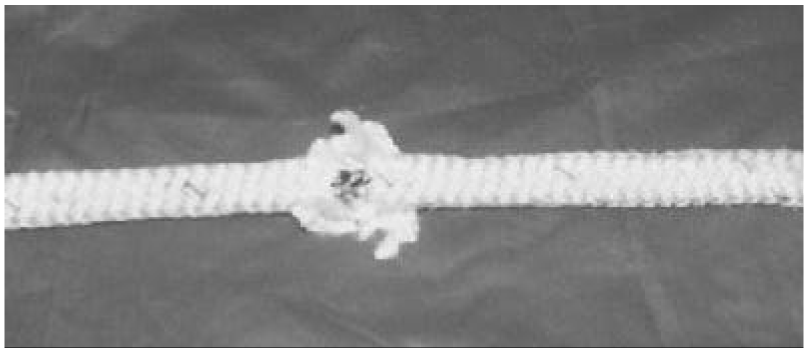

Figure 18 Cut in Jacket Exposing Core

Table 18 Flex Wear on Pulleys, Rollers, Chocks and Fairleads

Damage Description	Fig. Ref.
Broken outer filaments that are packed into the surface with fuzzy appearance uniform over flex length. Broken internal filaments over flex length. Packing of broken filaments that hardens rope giving less than normal flexibility; rope cannot be pried open for internal inspection. Non-recoverable flattening.	None

Table 19 Spliced Eye – Wear, Fabrication, Thimbles

Damage Description	Fig. Ref.
Improperly made splices. Check for correct fabrication. Refer to qualified person, manuals or published procedures. Old splice can be cut out and new one made.	None
Surface abrasion or cut damage in splice eye.	Figure 19
Splice has slipped. Strand tails have pulled back into rope. Old splice can be cut out and new one made.	None
Leg junction shows cut or ragged strands. Old splice can be cut away and new splice made.	Figure 20
Damaged or improper splice cannot be remade with confidence that strength is not compromised.	None
Thimbles have sharp edges or corrosion. Thimble loose in eye. Rope does not fit thimble. Thimble can be replaced. Assess rope damage if applicable.	None

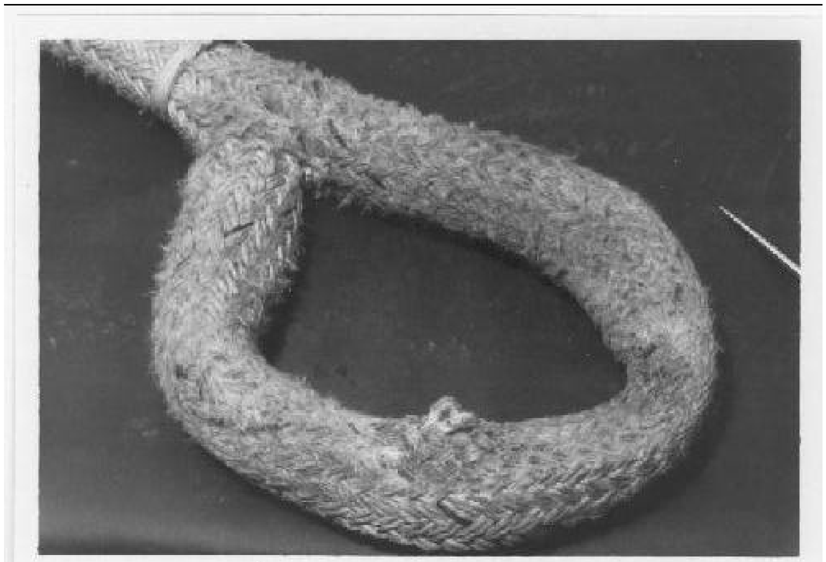

Figure 19 Wear in Double Braid Eye Splice

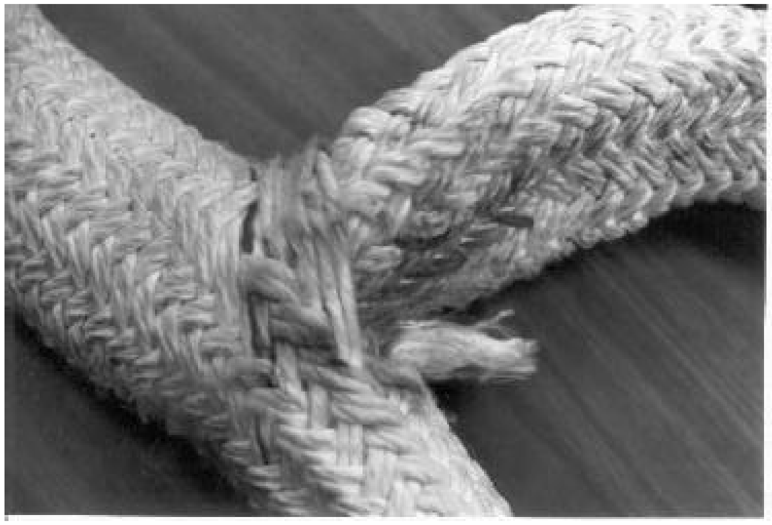

Figure 20 Tearing at Leg Junction of Eye Splice

Table 20 Creep (Cold Flow)

Damage Description	Fig. Ref.
Rope is very close to or exceeds the creep limit set by the user or rope maker. Creep is checked by procedures set by user or rope maker and found to be near limit.	None
Rope type is subject to creep and history of use shows that it may have experienced excessive creep. Rope has been used for extended time at high loads expected to cause creep.	None

Table 21 Hockle, Twist, Kink or Corkscrew

Damage Description	Fig. Ref.
Discernable twist when laid out straight, even under tension. Twist can be removed by twisting in opposite direction.	Figure 21
Kinking is present. Kink will not disappear completely when slight tension is applied or springs back when tension is removed. Rope is hard and flattened at kink.	None

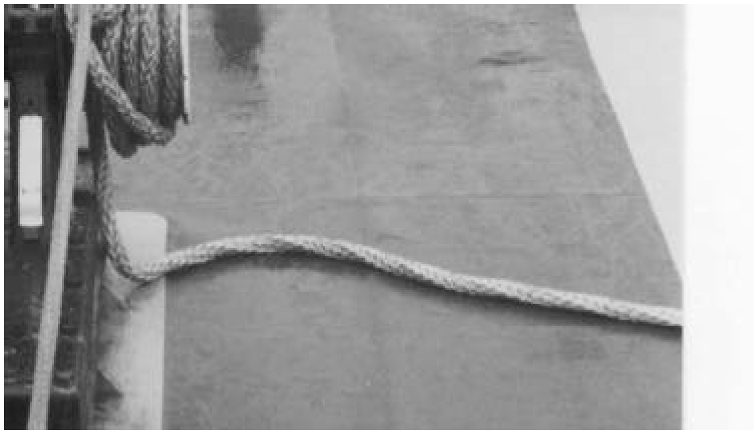

Figure 21 Twist in 12 Strand Braid

Table 22 Sunlight Degradation

Damage Description	Fig. Ref.
Ropes less than 1 inch diameter that are known to have had extensive exposure (year or more) to bright sunlight. Especially nylon, aramid and polypropylene.	None

Table 23 Chemical and Heat Degradation

Damage Description	Fig. Ref.
Known that there has been significant exposure to chemicals and/or high temperatures. No information from qualified persons or rope manufacturers.	None
Discoloration, brittle fibres, fusion, bonding of fibres together, hardness. Chemical exposure is suspected.	None
Nylon rope has been used or stored when wet in contact with iron or steel that is rusted. Rope is reddish or brown. The condition has existed for an extended period.	None

Table 24 Dirt and Grit

Damage Description	Fig. Ref.
Ropes exhibit grit or silt deposits on the inside. Broken or powdery fibre material may be present. The grit tends to fall out when the rope is dry and it is flexed.	None
Seawater has dried and left a salt deposit on the inside of the rope. The rope has been used extensively when dry with the salt present.	None
Rope has been significantly impregnated with oil or sticky substances. This material attracts and retains dirt and grit. It is not possible to clean the rope.	None

Appendix C REFERENCE

1) "Specification for Moorings for Aids to Navigation", Canadian Coast Guard Specification: 57-000-000-EU-TE-001 (Formerly MA2080).

2) The America Group – Marine and Industrial Ropes.

3) "Synthetic Mooring Ropes – Draft Final Report" Prepared by BMT Fleet Technology Ltd., December 2004.

4) Novatec Novabraid "Performance By Design" Catalog, 2004.

5) Canada Shipping Act "Tackle Regulations" CRC, Vol XVII, c.1494.

6) US Department of Labour, Occupational Safety and Health Administration, 1926.251 - Rigging equipment for material handling.

7) "Memorandum of Understanding between Director General Marine Programs and Director General Integrated Technical Support of the Canadian Coast Guard" (MECTS 2004-012-00422).

8) "Class 1 Double Braid Eye Splice", , Splicing Instructions, Samson Rope Technologies, http://www.samsonrope.com/home/pdf/ClassI_DblBrd_EyeSplice.pdf.

9) "Samson Commercial Marine 2004 Catalog", Samson Rope Technologies.

10) "Little Mule Wire Grip Safety Evaluation for use With Synthetic Rope", Draft final Report, Prepared by BMT Fleet Technology Ltd., February 2005.

11) "Guidelines on Synthetic Mooring Lines", IALA, December 2001.

12) "Hurricane Mooring Evaluation", Final Report, BMT Fleet Technology Ltd., March 2002.