Introduction

The importance of routine maintenance is critical, and a well-run yacht is defined by the amount of time and effort spent on the care and monitoring of its systems. One system frequently overlooked in this maintenance schedule is the mast and its associated rigging components. Performance, reliability and safety depend on routine mast and rigging inspection schedules, whether you are a coastal cruiser or an America's Cup contender.

The following information and guidelines should help define rod, wire and fiber rigging life expectancy, help to outline and create a service schedule and answer some general questions regarding rod, wire and fiber cable maintenance.

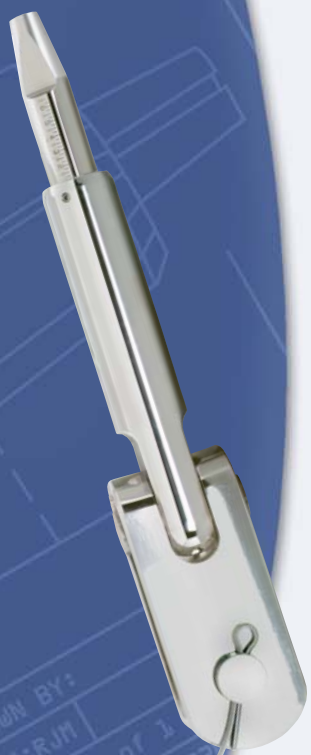
Rod Rigging Life Expectancy

There are many variables to consider when it comes to the longevity of the rod rigging being used with today's modern mast systems. The most prominent factors are:

1. The amount of time and/or miles the yacht has been in service

As a general rule, **Navtec recommends** complete Level C inspection for Category I & II boats (see Mast System Inspection Categories Section), of mast and rigging systems after a maximum of 40,000 to 60,000 sailing miles or 6 years, whichever comes first. This comprehensive maintenance schedule would include inspection of all the rod heads and end fittings. If any of the heads are cracked or worn, the rod must be re-headed.

This doesn't mean that the complete rod section must be replaced; that would depend on whether the turnbuckles had enough stroke to compensate for a shorter section of rod. In a good installation, the rod will typically last significantly longer than the cold heads on the end.



At the same time the rod is re-headed, **Navtec recommends** replacing the turnbuckle screws. The screws could last for many additional years, but it is less expensive to replace a few rigging screws than to replace the mast and all of the rigging.

One other rigging fatigue scenario to be aware of is winter storage with the mast system in place. This storage option causes cycling loads (the wind "whistling in the rigging"), which is frequently overlooked because the yacht isn't in service.

2. What loads are put on the rod in comparison to its breaking strength

Racing yachts generally use minimum rod sizes to keep rigging weight and windage as low as possible. As a result of cost constraints, this sizing issue can also be encountered with the rigging of production built cruising boats. Using a smaller rod size tends to shorten its working life, as maximum sailing loads may approach or exceed 50% of the breaking strength of the rod. Larger custom cruising yachts tend to have a higher safety factor because the chosen rod sizes are typically more conservative, so the rigging loads would only be 15-25% of breaking strength during maximum sailing conditions.

Smaller rod sizes for a given application tend to yield shorter rod life, as the overall safety factors for that application are reduced.

3. The yacht's predominant sailing conditions

If the yacht is predominantly sailed in heavy air conditions, the life of the rod will be shorter than if the boat was sailed infrequently or in lighter wind conditions. The higher the rigging is stressed on a regular basis, the shorter its life span will be.

4. The amount of care and maintenance given to the rigging

If the rigging has been periodically checked, the end fittings rinsed with fresh water, and general care and maintenance have been employed, it will last longer.

For example, a turnbuckle could build up corrosion so that it won't turn. Or a spreader bend left covered in leather or tape can eventually corrode the spreader or spreader bend. Basic maintenance and general inspection go a long way in extending the rigging's life.

Remember, a prudent yachtsman will have a more aggressive maintenance schedule with the knowledge that it will ultimately create less downtime or potential loss of earnings for the yacht.

5. How environmental conditions can affect the rigging

A major consideration in the longevity of the rigging system is the environmental conditions the yacht is subjected to. If the yacht spends most of its time in an environment with substantial air pollution, contaminants in the air will generally shorten the mast system's life span, and a frequent cleansing and inspection routine (Level A) should be a part of your regular schedule.

6. Routine inspections with no rod problems

After a thorough inspection (Level C: 40,000 to 60,000m or 6 yrs) with no evidence of damage, it may be reasonable to expect the rod to last an additional 20,000 to 30,000 miles. However, **Navtec Recommends** rod re-heading, and this is when a maintenance and inspection schedule becomes of paramount importance.

7. Monitor those T-hooks

One popular fitting that requires more diligent survey and potential replacement is the T-hook. Due to its design, it is typically one of the few fittings with a life expectancy dramatically less than the rod or wire. When inspecting the T-hook, look for cracks on the inside of the sharp bend, as this is a typical spot for fatigue cracking. T-hooks must be diligently monitored and depending on the application (i.e. Kevlar runner vs production shroud) should be replaced approximately once per year depending on usage, mileage and sailing conditions (Kevlar runner).

What to look for when inspecting rod rigging

Cracks in rigging components, especially cracks that are orientated transverse to the load, are a sign of impending failure. Cracks can be found using visual inspection, a magnifier, or by dye penetrate testing. **Navtec recommends** these techniques, but other professional testing techniques available are X-ray testing, eddy current testing and ultrasonic testing, which allows you to inspect rod heads for transverse cracks in closed fittings.

Traverse crack in Rod Head

For More Navtec Information, Please see; American Rigging Supply, Inc.

EXPOSED CRACK USING DIE PENETRATE TEST

For visual inspection, the rod or fittings must be cleaned or polished to expose the cracks. Rusty areas frequently indicate cracks underneath. In addition to cracks, you should look for corrosion, pitting, black streaks, rust and visible wear. Any areas showing discoloration or potential corrosion should be thoroughly cleaned and inspected. If any evidence of pitting, corrosion or wear remains after this cleaning, please consult an authorized Navtec service agent. Pitting, corrosion or visible wear could require re-heading, replacement of the rod or replacement of associated fittings.

Proper alignment to the load is also very important to generate a good working life for any rigging. Misalignment of fittings, caused by interference or bends, should be checked. Kinks or bends in rod rigging result in increased local stress and can dramatically reduce its life. If a fitting or rod has operated in a bent, kinked or misaligned condition, **Navtec recommends** it be replaced, as the damage due to cycling cannot be easily evaluated. If a rod is bent and then straightened before further service, depending on the severity of the bend, it could be used again to provide a normal working life. This is a judgment call, and your local Navtec service agent should be consulted.

Wire Rigging Life Expectancy

Stainless steel wire is a flexible and robust form of rigging with many different applications and termination solutions. Whether your yacht uses 1x19 stainless or Dyform wire with either swage or swageless fittings, inspection procedures at regular intervals are still critical, and typical life expectancy factors apply.

Inspection Considerations

When inspecting wire cables and their associated fittings, it is important to look for signs of corrosion, rust or pitting. Due to the natural flow of water down the wire, the lower terminals tend to exhibit these signs before the wire itself. Water and debris can collect in these fittings and generate corrosion from the inside, thus compromising the wire captured within the fitting or the fitting itself.

Swage Fittings

Both rotary and roll swaging are strong and efficient forms of termination utilizing a machine that compresses the fitting sleeve on the wire. Roll swaging, when done properly, leaves two "flash" lines on opposite sides of the fitting sleeve. These lines appear as raised ridges with rounded edges and are typical of this technique.

Occasionally terminals will be rolled several times in order to reduce the "flash" lines. This situation hardens the terminal and creates the possibility of cracking because of over-hardening. It can also be the source of crevice corrosion because of the creation of microscopic folds in the steel and can be a source of staining on the wire or terminal.

When monitoring swage fittings, pay careful attention to the inside edge where the wire exits. If there is any evidence of cracking, it is an indication of interior crevice corrosion. Depending on the method in which the wire was prepared prior to the swage being done and what predominant environmental conditions the boat has seen, these cracks could appear in as little as 1 to 2 years.

Navtec recommends careful inspection visually or with a die penetrate test to insure the safe and prolonged use of swage terminations.

Swageless Fittings

Norseman Swageless terminals are manufactured with 316 Stainless Steel and generally have a life span greater than the wire they are terminating. This lifespan can last through a wire re-rig, but **Navtec recommends** the replacement of the internal cone with each inspection. It is also important to carefully inspect the socket internally for signs of wear, and any sign of cracks would require replacement of the whole assembly.

Navtec recommends careful visual inspection to insure the safe and prolonged use of swageless terminations.

Wire

Wire inspection can be done visually and should include a close inspection for corrosion, pitting, discolored strands and cracks at fitting exit points. Rust on the wire generally comes from the fittings and bleeds down the individual strands of the wire. This phenomenon is called "rougeing". Pay close attention to wire exit points from all terminals as broken strands or "meat hooks" are a sure sign of fatigue failure. **Navtec recommends** replacement of the wire if **any** broken strands are found.

Wire Life Expectancy

There are many variables to consider when it comes to the longevity of the wire rigging being used with today's modern mast systems. The most prominent factors are:

1. The amount of time and/or miles the yacht has been in service

As a general rule, **Navtec recommends** complete Level C inspection (see Mast System Inspection Categories) of mast and rigging systems after a maximum of 40,000 sailing miles or 6 years, whichever comes first. This comprehensive maintenance schedule would include inspection of the mast, wire, turnbuckles and their screws and all associated fittings.

Navtec recommends replacing the turnbuckle screws after a maximum of 40,000 sailing miles or 6 years (whichever comes first). The screws may last for many additional years, but it is much less expensive to replace a few rigging screws than to replace the mast and all of the rigging.

2. What loads are put on the wire in comparison to its breaking strength

Production and custom cruising yachts tend to have high safety factors in their rigging because chosen wire sizes are typically very conservative, so rigging loads are generally 15-25% of the

breaking strength during normal sailing conditions. However, some boat builders have been known to use smaller sized rigging with less of a safety factor to reduce production costs.

3. The yacht's predominant sailing conditions

If the yacht is predominantly sailed in heavy air conditions, the life of the wire will be shorter than if the boat was sailed infrequently or in lighter wind conditions. The higher the rigging is stressed on a regular basis, the shorter its life span will be.

4. The amount of care and maintenance given to the rigging

If the rigging has been periodically checked, the end fittings rinsed with fresh water, and general care and maintenance have been employed, it will last longer.

For example, a turnbuckle could build up corrosion so that it won't turn. Or a spreader bend left covered in leather or tape can eventually corrode the spreader or spreader bend. Basic maintenance and general inspection go a long way in extending the rigging's life.

Remember, a prudent yachtsman will have a more aggressive maintenance schedule with the knowledge that it will ultimately create less downtime or potential loss of earnings for the yacht.

5. How environmental conditions can affect the rigging

A major consideration in the longevity of the rigging system is the environmental conditions the yacht is subjected to. If the yacht spends most of its time in an environment with substantial air pollution, contaminants in the air will generally shorten the mast system's life span, and a frequent cleansing and inspection schedule (Level A) should be a part of your regular schedule.

6. Monitor those T-hooks

One popular fitting that requires more diligent survey and potential replacement is the T-hook. Due to its design, it is typically one of the few fittings with a life expectancy dramatically less than the rod or wire. When inspecting the T-hook, look for cracks on the inside of the sharp bend, as this is a typical spot for fatigue cracking. T-hooks must be diligently monitored and depending on the application (i.e. Kevlar runner vs production shroud) should be replaced approximately once per year depending on usage, mileage and sailing conditions (Kevlar runner).

Wire life expectancy guidelines are based on many variables, including heat, geographic location, salinity content of the water, how aggressively the boat is cleaned, contaminants in the air and water, etc.

Navtec estimates a life expectancy schedule based on climate variables and water salinity:

Heat and water salinity at maximum (Florida, Caribbean Islands) - 5 to 10 years
Heat and water salinity at medium levels (East/West coast of US) - 10 to 15 years
Fresh water climate - 15 to 20 years

Fiber Rigging Life Expectancy

One of the main differences between rod, wire and fiber rigging (Kevlar, PBO), is the fiber

cable's susceptibility to damage from environmental conditions. Throughout its life, a section of rod may encounter a wide variety of conditions that really have no effect on its integrity, yet these same conditions could prove detrimental to the life expectancy of fiber cable.

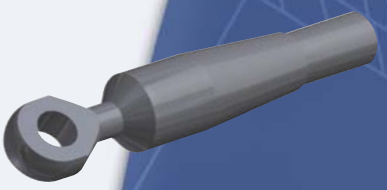
UV and the Elements

One example of a damaging situation is a jib sheet or halyard running over a fiber cable. The chafe from this sheet would have no detrimental effect on a section of rod, but could easily wear through the external jacket or internal core fibers. In this case, the fiber is now exposed directly to the elements and can begin to degrade due to exposure to UV light and moisture. Any exposure to either visible or ultraviolet light can cause property degradation, loss in strength and potential failure of the fibers. Also, high relative humidity at elevated temperatures can cause a loss in fiber strength over time. These conditions are common, therefore it is very important to inspect fiber rigging on a regular basis for any damage to the protective jacket, which may expose core fibers.

Cable Inspection

Inspection of fiber cables is critical for the safe and prolonged use of the cable rigging system. Routine visual inspection of the jacket and its termination points should be frequently carried out in order to maximize the working life of the cable. On passages or during regattas this state-of-the-art rigging technology should be inspected daily.

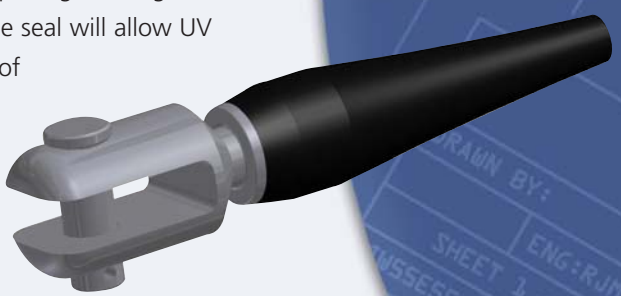
Carefully monitoring for signs of damage, abrasion points or breaks in the cover is critical to keep potential damage from UV light or water retention to a minimum. The other inspection point of fiber rigging is at the heat shrink on either end of the cable. Over time there may be a tendency for the heat shrink to pull away from the end fitting or cable slightly. This is normal, and shouldn't pose any immediate problem because it has an inner glue layer that creates a seal between the cable and the heat shrink. Yet regardless of this glue seal, it should be checked as part of the routine visual inspection.



If your cable system utilizes bi-conic termination technology (socket and cone), it is important to note there is no need to open the socket for internal visual inspection. Unlike rod, there is no head within the socket, and the cone holding the fiber system together is permanently set. Therefore, opening this cable termination will break the factory installed seal designed to protect the internal fibers from the environment.

However, there are metal fittings attached to these sockets as working termination points similar to those used with rod rigging. These fittings should also be routinely inspected as per your normal routine. Things to look for are severe wear, bent pins, corrosion and cracks.

If your cable system uses continuously wound technology (Z System), it is important to monitor the carbon termination covers for any cracking across the cover or opening at the glue seam. These covers are sealed against the elements, so any breach of the seal will allow UV light and moisture into the termination thus compromising the lifespan of the cable. Also, make sure the cable midspan is checked often for chafe and degradation of the cover.



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or wire. When inspecting the T-hook, look for cracks on the inside of the sharp bend, as this is a typical spot for fatigue cracking. T-hooks must be diligently monitored and depending on the application (i.e. Kevlar runner) should be replaced approximately once per year depending on usage, mileage and sailing conditions.

PBO Cable Life Expectancy

Based on Navtec's experience, a PBO cable that has been inspected regularly with no signs of damage can expect the following life expectancy depending on the application in which it was used:

If the maximum working load is less than 25% of the cable's rated strength (lateral or side rigging – stretch application), **Navtec recommends** changing the cable following 26,000 to 30,000 miles or 3 years of use, whichever comes first.

If the maximum working load is more than 25% (but less than 35%) of the cable's rated strength (headstay or running backstay – strength application), **Navtec recommends** changing the cable following 17,000 to 20,000 miles or 2 years of use, whichever comes first.

Kevlar Cable Life Expectancy

Based on Navtec's experience, a Kevlar cable that has been inspected regularly with no signs of damage can expect the following life expectancy:

If the maximum working load is less than 40% of the cable's rated strength, **Navtec recommends** changing the cable following 26,000 to 30,000 miles or 4 to 6 years of use, whichever comes first.

Yacht Displacement Classifications

Germanisher Lloyd, a marine technical monitoring group, with input from Navtec and other mast and rigging suppliers, has put together the following chart outlining yacht classifications. These different displacement categories will tend to experience different usage, mileage and sailing conditions. Full inspection intervals will vary depending on which category your yacht falls into.

Category	Displacement Characteristics	Typical Purpose Characteristics	Typical Handling Characteristics
I	Motor Sailor/Heavy Cruiser	Ocean Going	Handled by Crew
II	Mid Displacement	Offshore	Handled by Crew, Owner or Shorthanded
III	Light Displacement	Coastal Pleasure Cruising/ Club Racing	Handled by Crew, Owner or Shorthanded
IV	Ultra Light Displacement	Racing	Handled by Professional Crew

For More Navtec Information, Please see; American Rigging Supply, Inc.

Category I & II

Heavy displacement sailing vessels, (i.e. large cruising yachts or super yachts), have a different criteria for general rig inspections because they tend to accumulate many more miles than typical racing yachts. The same is true, but to a lesser degree, for mid displacement yachts. Also, the useful lives of heavy displacement sailing vessels tend to be much longer than the normal useful (competitive) life of racing yachts. For this reason, rigging design generally shifts toward longevity rather than ultimate performance concerns.

These concerns stem from the fact that these yachts generally do not bend their masts significantly to control sail shape. Many use simple marine eye and toggle terminations, which are heavier than typical high-performance fittings but have much better alignment capabilities under load. In these cases, bending stresses are minimal, and the controlling failure mode frequently shifts to simple tensile fatigue.

If failure occurs, tensile fatigue failures generally occur after a much larger number of loading cycles than bending fatigue failures. Large cruising yachts and super yachts frequently sail 15,000 to 30,000 miles per year and can reach large mileages quickly, leading to the possibility of tensile fatigue failure.

As a result, maintenance and inspection issues shift into a slightly different schedule and mindset as Safe Working Load (SWL) issues are not the primary concern.

Category III & IV

Light and ultra light displacement yachts generally have different sailing characteristics (e.g. mast bend and rake), and use higher loading scenarios with smaller rod in their rig plans than heavier displacement yachts. These working issues will potentially generate higher loads on the rod and fittings than published Safe Working Load. It is not unheard of for racing yachts to operate at 40-50% of the breaking strength of the rod.

This creates a shorter working life in the rod and fittings and should reflect in the frequency and intensity of the maintenance and inspection schedule for your yacht. Frequent inspection is necessary and will guarantee that any problems are caught before they become catastrophic.

Recommended Maintenance Inspections

Mast system inspections should be conducted regularly and schedules should be based on the size and general classification of your yacht. Controlling variables are displacement and type of usage.

Heavy displacement yachts falling into Category I & II will have different inspection criteria based on tensile fatigue issues rather than those of category III & IV, which will base inspection intervals on usage and potential Safe Working Load issues.

The following inspection scenarios should be implemented based on general usage and predominant sailing conditions. At a minimum, **Navtec recommends** a **Level A** mast system inspection at least once a year, regardless of yacht classification category.

Mast System Inspection Categories

Level A: Visual Inspection w/Mast In

- Comprehensive general mast system visual inspection
- Check all fittings/terminations, rod/fiber/wire, spreaders, sheaves, halyards, headstay, backstay, mast base, partners, halyard blocks and chainplates
- Check for cracks, corrosion, pitting, rust
- Service log/update schedule for next service

Level B: Visual Inspection w/Mast In - Jack Down

- Pre-check rig to assess service (Level A Inspection)
- Un-jack mast
- General visual inspection
- Check for bends/kinks in fittings and rod
- Check/lubricate all accessible fittings
- Properly re-tune to align and seat all cold heads and hardware, and generate proper tension/tuning
- Service log/update schedule for next service

Level C: Full-service w/Mast Out

- Pre-check rig to assess servicing schedule (Level A Inspection)
- Un-step mast
- Complete disassembly of mast/fittings
- Visual Inspection
  - Clean/polish rod, cold heads and fittings to facilitate inspection process
  - Visual inspection for cracks, corrosion, pitting, rust, general discoloration: remember - Rust Indicates Cracks
- Non-Destructive Testing (NDT) of Rod
  - **Navtec Recommends:** Dye penetrate testing (liquid penetration testing) by authorized professional
  - Alternative methods: X-ray, ultrasound testing, eddy current testing
- Visually inspect and Safe Working Load (SWL) pull test all fiber rigging
- Make repairs as needed: re-head rod, replace any fittings or rigging screws
- Reassemble mast system
- Update service log/update schedule for next service
- Re-step/re-tune mast

Recommended Maintenance Intervals

For Category I & II yachts, Navtec Recommends:

- **Level A:** a comprehensive visual inspection, several times per year
- **Level B:** a jack-down visual and fitting inspection/lubrication, once per year with a maximum of four years between inspection intervals
- **Level C:** a comprehensive full-service mast inspection/refurbishment, once every four years with a maximum of ten years between inspection intervals

For Category III & IV yachts, Navtec Recommends:

- **Level A:** a comprehensive visual inspection, several times per year
- **Level B:** a jack-down visual and fitting inspection/lubrication, at least once per year with a maximum of two years between inspection intervals
- **Level C:** a comprehensive full-service mast inspection/refurbishment, once every two years with a maximum of four years between inspection intervals

For More Navtec Information, Please see; American Rigging Supply, Inc.

Maintenance Authentication

The survey and inspection of the spar and rigging system should be carried out at regularly scheduled intervals. This improves the chance that any potential service issues will be caught before they become a problem. An important part of the inspection and maintenance schedule is the creation of a photographic, data and service log.

Photographic Log

A photographic log of all fittings and terminations creates a point of reference to start each inspection and builds a visual library for future use. This photographic reference library will allow for easier pre-planning of future service intervals because you will have a visual log of the parts in question. It can also be accessed if there are any questions or insurance issues arising from your rigging service or its scheduling.

Data/Service Log

A data log, in conjunction with a photographic library, will facilitate a good maintenance schedule because it will force you to keep track of what is going on with your spar system. When you inspect rod heads, stem balls, tip cups, tangs, turnbuckles, etc., reference what their condition is or how they are serviced. This data log will help to plan future inspections and will allow for shared knowledge between future service technicians. This data log should also extend to dimensions and part numbers. The more information you have regarding your mast system, the better you will be able to maintain it.

General Information

Lubricant/Grease

Navtec recommends the use of a thin layer of lanolin-based waterproof grease on rod heads, stem balls, tip cups, tangs and turnbuckles with dissimilar metals. Lanocote is an excellent example that maintains its hold where applied and helps to prevent corrosion. Tef-Gel is also an excellent anti-seize and anti-galling agent for use with dissimilar metals in the marine environment.

For turnbuckles or tip cups with stainless bodies and screws, **Navtec recommends** a dry lubricant containing Molybdenum Disulfide. A coating of this dry lubricant on the threads allows for good lubrication in a stainless to stainless application. Be advised to apply carefully; this aerosol spray or liquid is black and can cause staining on sails and anything else it comes into contact with.

Loctite

Navtec uses Loctite Retaining Compound RC 680 (Green). It is important to make sure surfaces are cleaned and free of dirt and oil before use. It is also recommended to use Loctite primer to prepare surface for bonding. It should be noted that this compound is only removable at high temperatures, so it is inappropriate for use with Navtec insulators or other areas that are sensitive to heat. A low temperature compound should be used in this application, and Loctite 242 (Blue) is advised. When using Loctite to retain rigging fittings or set screws, it is important to test the part for locking after the Loctite has set. Be advised the use of Loctite is inappropriate for any fittings which may be tensioned/adjusted after installation, (e.g. turnbuckles).

Rigging Tape

Navtec recommends using a non-adhesive tape in rigging applications. Navtec Rig Wrap is a white self-amalgamating tape which will leave no residue and forms better chafe protection than traditional forms of taping protection, (e.g. electrical tape).