MP-1™

REFERENCE PERFORMANCE RESULTS

MP-1 is similar in handling/use to 100% polyester tails, with important benefits. *MP-1's* construction leads to decreased water retention, resulting in lower in-use weight for deck hands. Overall, strength and cost-per-moor beat 100% polyester in lab and field testing:

MP-1 FIELD TRIALS

BACKGROUND

- Common issue with pulled yarns and snags with
- 100% polyester line
- Used ropes take on a "wet dog" appearance
- Average historical 100% polyester line residual strength at 18 months retirement is 58% of minimum break strength

TRIAL ROPES

- Four 100% polyester tails per vessel
- Four *MP-1* tails per vessel

TESTING PLAN STARTED SEPT./OCT. 2015

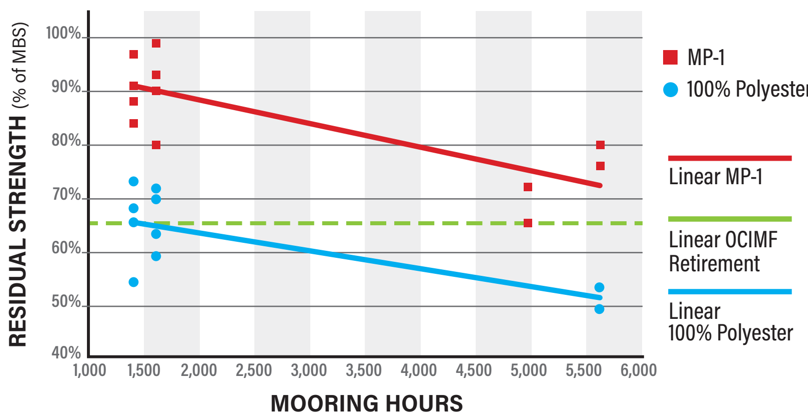
- Remove two 100% polyester tails and two *MP-1* tails at 6 months AND 18+ months use
- Inspect and test for residual strength

LAB EVALUATION

- Dock-side abrasion testing showed, after 42 miles of wear (simulated), *MP-1* had 89% residual strength, vs 73% held by 100% polyester line

FIELD TRIALS

- 6-month on-vessel testing showed *MP-1* with 90–91% of residual strength, while 100% polyester had 65% residual strength
- 18+ month on-vessel testing showed *MP-1* with 68-78% of residual strength, while 100% polyester had only 51–54%



MP-1 exceeds OCIMF recommended residual strength at retirement. 100% polyester lines fall below OCIMF recommended residual strength at only 8 months.

THE STRONGEST NAME IN ROPE

Coefficient of Friction (CoF)

Overview Why is rope CoF relevant? If you want your rope to behave in a predictable way, then rope coefficient of friction (CoF) must be considered. One of Samson's goals is to ensure that the appropriate rope product is used for the job. There are many properties to consider when selecting the right product. One consideration is how the rope interacts with contact surfaces while in use. A quantifiable way to describe these interactions is CoF. Without considering the appropriate CoF for the system, the rope life and performance may be compromised. See Table 1.

What is Rope CoF?

CoF is the ratio of shear force to normal force at the moment of impending slip (static CoF) or during sliding (dynamic CoF). In the case of rope systems, this is manifested as the ratio of the rope tensions on either side of a contact surface. In general, rope with a high CoF should be used to reliably maintain its grip on equipment and function effectively. CoF is expressed in the capstan equation, (Fig. 1). Ropes may come in contact with various surfaces such as a polished sheave, rusty drum, painted bollard, or concrete floor. Depending on the substrate, CoF, as well as rope wear, will be compromised.

There are two types of CoF values: static and sliding (kinetic). For most rope applications, static CoF is the value of interest to ensure appropriate rope selection. Because static CoF is directly related to the force at which slippage occurs, it can be used to determine functional criteria such as minimum safety wraps required, sheave count, etc. On the other hand, sliding friction causes heat generation, and is generally avoided for most applications.

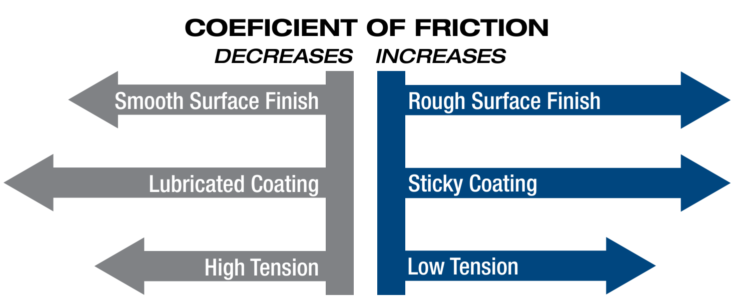


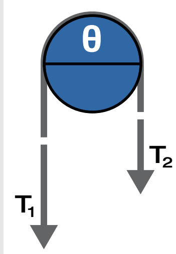
FIGURE 2 Factors affecting CoF

In Fig. 2, the magnitude of each arrow indicates the effect on rope CoF.

The most significant factors affecting the rope CoF are the surface finish of the substrate, material type (not shown), the fiber coating type, and the amount of tension in the system. Material types significantly impact the rope

TABLE 1 CoF requirements for specific applications. Other factors also play important roles in determining the right rope for the application. CoF values are not intended to be the sole property used for rope selection and guidance.

CoF REQUIREMENTS FOR SPECIFIC APPLICATIONS	
High CoF: Prevent slippage and reduce load	**Low CoF:** Minimize friction and heat generation
• Arborist/Climbing: Knotting • Arborist/Climbing: Descending • Mooring: Wraps on Split Drum • Traction Winch Systems • Tug: Bollard Tie-Off	• Rope Rescue: Hoisting • Tug: Contact with Bullnose



The relationship of coefficient of friction with its contact surface can be expressed as:

$$T_1 / T_2 = e^{(\mu\theta)}$$

μ = coefficient of friction

WHERE:

T_1 = *tension applied on one side of the surface*

T_2 = *tension resulting on the opposite side of the surface*

e = *2.718*

θ = *wrap angle, in radians*

μ = *coefficient of friction*

*The rope is wrapped around a capstan and tension is applied to one side of the drum. The tension is increased slowing until the rope begins to slip on the drum. When the rope slips, the tension being applied (T1) and the resulting tension on the opposite side of the drum (T2) are recorded to calculate CoF denoted as **μ**.*

FIGURE 1 CoF measurement and calculation

CoF, on a similar magnitude as the surface finish of the substrate. Slick materials such as HMPE result in a rope with lower CoF, whereas stickier materials such as polyester, LCP, or aramids, result in a rope with higher CoF. See Fig. 1.

Factors Affecting CoF

Rope CoF is dependent on usage conditions, such as contaminants, lubricants, line tension, substrate geometry, substrate surface finish (material and polish), wet vs. dry applications, temperature, etc. Rope characteristics such as fiber, coating, and rope construction heavily influence CoF which inherently affects rope wear, slippage, and wrap requirements. If a specific CoF value is required, it is important to work with Samson to achieve optimum rope performance. See Fig. 3.

CoF in Operation

The CoF between the rope and its substrate has a direct effect on how the rope will interact in a system. Fig. 4 makes a comparison between how the load is transferred throughout a series of capstan wraps for ropes with varying CoF values. Load transfer is an important phenomenon in the following applications where the rope is used to apply specific tension(s) throughout the system:

- **SPOOLING PERFORMANCE:** CoF dictates the tendency for rope to slip against itself and against the drum.
- **TYING OFF ON A BIT OR BOLLARD:** CoF determines the number of necessary dead wraps on bits and bollards to prevent slippage.
- **HEAT GENERATION DUE TO CONTACT:** Heat generation against chocks or bullnoses as the rope moves relative to the hardware increases with higher CoF values.
- **TRACTION WINCHES:** CoF is used in traction winch design to determine the required back tension in the system and the rope routing through the traction sheaves.
- **SAFETY WRAPS:** The required number of safety wraps on rope drum to ensure safe load transfer to the storage drum or inboard termination is calculated using the CoF.
- **SPLICING:** CoF influences the minimum splice length required, routing method, and tapering pattern for a particular splice.
- **FRICTION MANAGEMENT DEVICES:** CoF influences the required back tension and number of wraps to safely lower loads when rope is routed through hardware in arborist, climbing or rope rescue applications.

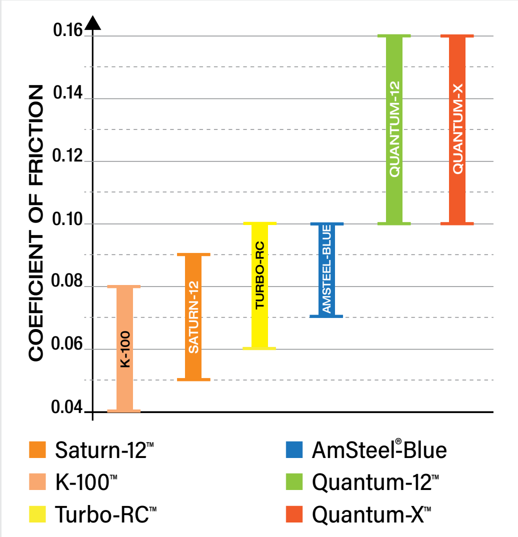


FIGURE 3 Samson product CoF values relative to one other based on contact with a steel drum with a surface roughness of approximately 100 to 300 RMS. CoF values are expressed as a range instead of a single distinct value due to the vast array of possible rope operating conditions. This graph is only to be used as a general guideline and presents a small sample of Samson rope products.

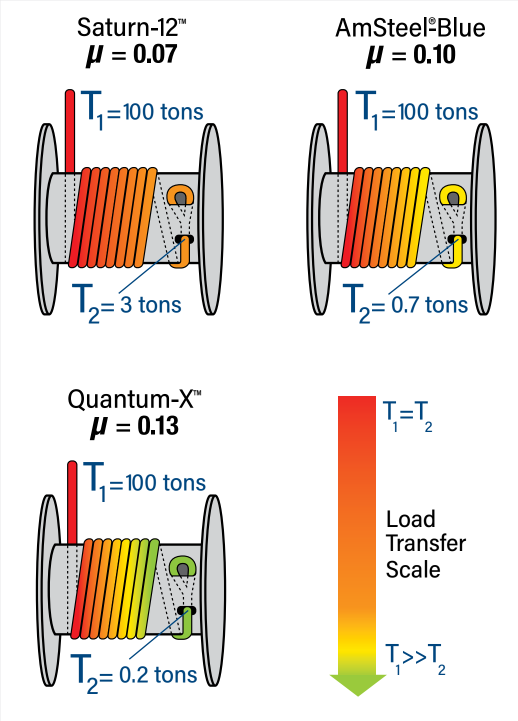


FIGURE 4 Rope with higher CoF will see greater load reduction over identical wrap counts. On the 8th wrap, Quantum-X (bottom left) reduces incoming load T_1 by 15x more than Saturn-12 (top left).

THE STRONGEST NAME IN ROPE

SAMSON TECHNICAL BULLETIN

The Effect of Twist on Braided Ropes

Overview Twist reduces the strength of a braided rope and can lead to unexpected failures. In order to avoid this, it is important to be able to identify twist in a rope, take appropriate actions to remove it from the line, and prevent further twisting.

Mooring lines with twist induced.

Braided vs Laid Ropes

BRAIDED ROPE CONSTRUCTION All braided ropes, including 8-strand, 12-strand single braids, double braids, and core-dependent double braids, are constructed from an equal number of "S-strands," or strands that twist to the left, and "Z-strands," or strands that twist to the right. This creates a balanced, or torque-neutral construction that will not naturally twist while under load. In order for a rope to maximize its full-strength potential, all strands of the rope must share the load equally. This load sharing (and thus the strength of the rope) is reduced when a rope is twisted.

LAID ROPE CONSTRUCTION Laid ropes, such as 3-strand, 6-strand, and wire rope constructions, are not torque neutral at all loads. Laid ropes can be "torque balanced" at a specific load range, however this will not eliminate all untwisting while the rope is loaded. As a load is applied to a laid rope, the rope will naturally untwist until it reaches a torque-balanced state.

Why does Twist Reduce the Strength of a Braided Rope?

As a braided rope, that has been twisted, is loaded, the strands become loaded unequally. Depending on the direction of twist either the S- or Z-strands will take more of the load.

Figure 1 illustrates this phenomenon, where all of the Z-strands are tight and all of the S-strands are loose. The loose S-strands will not bear the same load as the tight Z-strands. The tight strands will carry more load than the loose strands leading to a loss in rope efficiency.

FIGURE 1 The loose strands at the top of the rope do not contribute to the strength of the rope. The tight strands at the bottom of the picture bear most of the load.

Effect of Twist on Rope Strength

Rope strength is decreased with the amount of twist induced into the rope. The effect of twist varies with the fiber type, diameter, and construction of the rope.

Figure 2 shows 24 mm (1" diameter) *AmSteel®-Blue* a 12-strand single braid construction, to illustrate how little twist it takes to affect the strength of the rope.

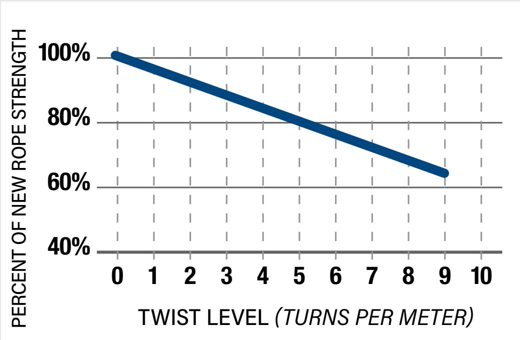


FIGURE 2 Rope strength vs twist.

SAMSON TECHNICAL BULLETIN

The Effect of Twist on Braided Ropes

Identifying Twist

Identifying twist in a braided rope is relatively easy. Simply follow a single line of picks (or crowns) down the length of the rope (see Fig. 3). If the picks form a straight line parallel to the length of the rope, there is no twist. If the line of picks spirals around the circumference of the rope, that section of rope is twisted.

Causes of Twist in a Braided Rope

Although a braided rope will not twist on its own under load like a laid rope, there are various ways a braided rope can become twisted; for example when it is attached to a laid synthetic or wire rope. As a laid rope is loaded, it unwinds, transferring twist to the braided rope component.

> To prevent twist, do not connect a braided rope to a laid rope or wire rope

It is also important to handle the rope correctly and not introduce twist into the line.

Improper reeling or unreeling of a rope can cause twist. Rope should never be taken from a reel lying on its end. It is best to support the reel horizontally so it may spin freely and then pull the rope off the top (see Fig. 4).

> The spinning of a load while lifting or pulling will cause twist in the rope.

Removing Twist

If a twisted line has been identified, take the following steps to remove the twist:

1. Pay out as much of the twisted section of rope as possible onto a flat surface.
2. Manually untwist the line by flipping the eye repeatedly in the opposite direction of the twist until the twist is removed.
3. It may be necessary to milk the twist to the end of the line for the best results.
4. Wind the line back onto the winch or spool under reasonable tension taking care to prevent re-twisting of the line.
5. If the strands appear damaged or the twist is impossible to remove, contact a Samson representative for advice.

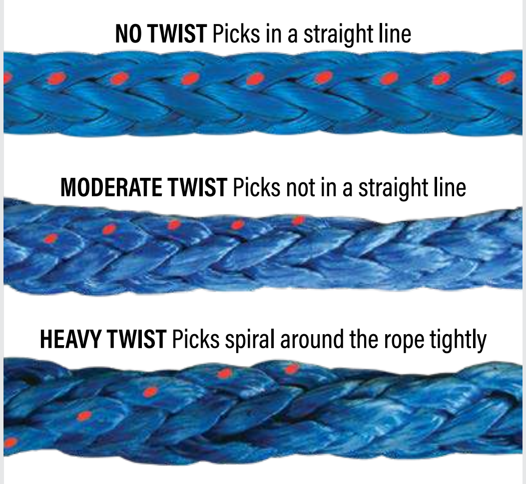


FIGURE 3 Twist in a rope is identified by the alignment of the picks.

Using a braided pendant with a braided mainline will reduce the likelihood of twisting the mainline.

Using a swivel to connect the messenger line to the mainline or pendant can reduce twist in the pendant and mainline.

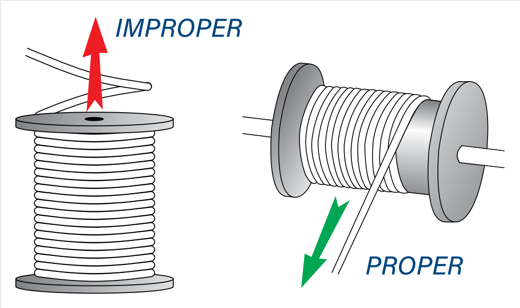


FIGURE 4 Improper reeling or unreeling of a rope can cause twist.

samson
THE STRONGEST NAME IN ROPE

SAMSON TECHNICAL BULLETIN

Proper Handling Techniques for Samson 8-Strand High-Performance Ropes on H-Bitts

Overview To overcome slippage, a common issue with high-performance ropes, Samson created unique 8-strand ropes engineered with surfaces that allow them to grip when needed. Samson recommends the following handling techniques to maximize the service life of these lines when used on H-bitts.

Although *Proton®-8* and *Quantum-8™* have many desirable advantages, these types of 8-strand ropes have a longer "lay length" than traditional 8-strand ropes and are more susceptible to twist damage. Care should be taken during use to avoid excessive twisting that can occur when wrapping H-bitts. Over-twisting can cause permanent damage to the lines, evidenced by hockles, or bulges in strands where core yarns have protruded through the surface yarns, as shown in Figs. 1 and 2.

Hockles are created by excess twisting in one direction. As the rope is twisted, strands are twisted in the same direction as the rope twist. At the same time, twist is removed from the strands that are twisted in the opposite direction. This creates uneven fiber lengths in the strands and will cause the strands that have been untwisted to become overloaded, which can cause a premature failure. Although the hockles themselves are not damaging to the rope, they are good indicators that the rope has been over-twisted.

How to Minimize Twist

It is impossible to eliminate all twist when working on an H-bitt, but twist can be minimized by alternating wrap directions each time the line is used. As the H-bitt is wrapped, twist is introduced into the line. Repeatedly wrapping in one direction will add twist in that direction. If the H-bitt is wrapped in the opposite direction each time it is used, any twist that was created during the previous job will be removed. It is important to make sure that the actual twisting of the line is reversed and not just the wrap pattern or direction. A common mistake is to assume that starting the wrap pattern in a different direction will automatically cause the rope to twist in the opposite direction. This is not always the case. A right-handed person, regardless of the starting point, will typically induce a "left" twist into the rope. Caution should be taken to avoid this.

The easiest way to induce an opposite twist is to switch sides of the H-bitt when starting a new job. As shown in Fig. 3 and 4, using the opposite side of the H-bitt will force an opposite twist in the rope.

Another way to help prevent twist is to preset the line. Once these ropes have been loaded, they do not return to their original dimensions. A rope that has been preset is less likely to accept permanent twist. Presetting should be performed only on new and unused rope, and with extreme caution. In order to preset the line, couple it with a force gauge to monitor

FIGURE 1 Proton-8 with a hockle.

FIGURE 2 Proton-8 with severe strand hockles.

FIGURE 3 Proton-8 with "left" twist.

FIGURE 4 Proton-8 with "right" twist.

the load, then firmly attach the line to a fixed location strong enough to withstand the load. The rope should then be stretched to a load of 30–50% of the minimum breaking strength (as specified on the Certificate of Compliance). Holding this load for approximately five minutes is adequate to preset the line. Once the line is preset, use of the alternating wrap pattern during application is still recommended.

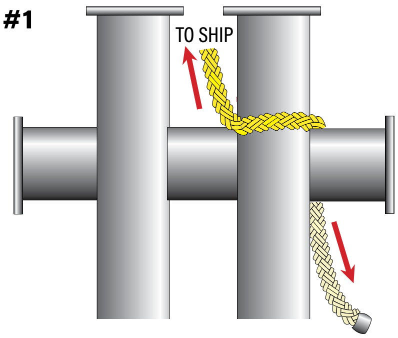
Samson products are built for a long service life, and proper care and use of ropes will ensure maximum value. *Proton-8* has been successfully used with H-bitts, and many users have continued to work these ropes without any issues—even after strand hockles have appeared. However, minimizing twist will extend service life and provide greater long-term cost savings. Please see the diagrams at right for detailed illustrations on the proper wrap pattern of 8-strand ropes on an H-bitt.

Proper H-Bitt Wrapping Techniques

Minimizing slippage is vital to prolonging the life of the rope. The following diagrams illustrate how to properly wrap an H-bitt to minimize slippage. Testing has shown that using this wrap pattern can reduce slippage as much as 50% over other wrap patterns. Care should also be taken to ensure each wrap is "snug" over the preceding wrap. It is also important to avoid surging the line, especially during initial loading. Easing into the load, allowing the rope to grip, will reduce the amount of slippage at full load.

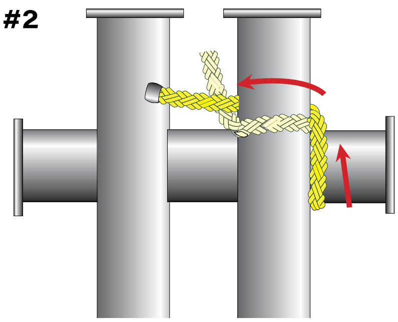
THE STRONGEST NAME IN ROPE

STEP #1



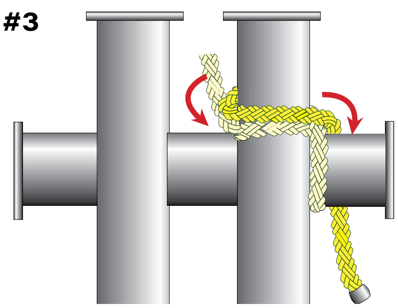
Make the first wrap by going around the vertical pin 180 degrees, then going over the horizontal pin.

STEP #2



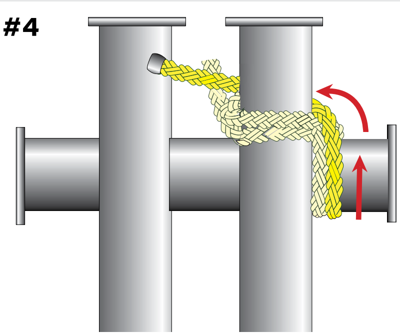
Wrap the horizontal pin 360 degrees, then cross back over the rope, forming a "X", and behind the vertical pin.

STEP #3



Bring the rope around the vertical pin 360 degrees, crossing over the rope again to form the "X", then behind the horizontal pin.

STEP #4



Repeat steps #2 and #3 at least five wraps.

SAMSON
TECHNICAL
BULLETIN

HMPE Rope and Chocks — Closed vs. Roller

Overview Closed chocks or roller chocks—which type is better suited for use with rope constructed of HMPE fiber? This is a question asked by many users of Samson mooring lines. Most users will assume that a roller chock is best simply because the chock can “move” with the line, therefore mitigating abrasion. In theory, this is true. However, due to the low coefficient of friction in many HMPE lines, not enough friction is created to actually “roll” most chocks. The line will simply slide over the roller.

Additionally, most roller fairlead designs utilize a smaller diameter and therefor result in lower D/d ratios (the relationship of the bend the rope makes around the hardware to the rope diameter). Even if the roller is well maintained and free to turn with the rope, the lower D/d results in higher stresses in the line resulting in accumulated local damage in those areas. It is important to note that regardless of the type of chock used, a poorly maintained chock can be a rope’s worst enemy. Both closed and roller chocks must be kept as smooth as possible and free from any grooves and/or “pits.”

Based on substantial trials with both types of chocks, it was concluded that properly maintained closed chocks will provide a longer service life and offer significant advantages over roller chocks. Some of these advantages are as follows:

Cost

The installation of roller chocks can be a very expensive addition to any vessel, running in excess of 100,000. Roller chocks also require more maintenance, which results in higher up-keep costs. Standard steel closed chocks are relatively inexpensive, and maintenance costs are low. Another option is stainless steel closed chocks, which, although more expensive up front than standard steel, are still much less expensive than roller chocks and have low maintenance costs. This cost savings can be a big advantage when converting a vessel from wire to HMPE rope. Conversion is a costly expenditure and installing new closed chocks, instead of new roller chocks, can provide significant savings.

Maintenance

Closed and roller chocks both require basic maintenance, which includes keeping the contact surfaces free from rust and damage. Roller chocks require additional bearing maintenance to keep the rollers moving smoothly.

Closed chocks.

Roller chocks.

All chocks must be kept free or grooves, pits and/or rust to minimize rope damage potential.

HMPE Ropes and Chocks — Closed vs. Roller

Usage

Usage is typically not a concern, but roller chocks actually can create "pinch points" leading to rope damage. Special attention is needed when the rope exits the chock at a sharp angle. This is common on spring lines. Depending on the varying heights between the ship and berth, the mooring line can become "jammed" between the horizontal and vertical rollers.

Abrasion

Even the smoothest chock will cause some damage to the surface of the rope. Typically a chock's wear pattern will be consistent—with a closed chock this can be an advantage. The constant movement between the rope and the chock will actually keep the chock smooth. This also occurs with roller chocks, because most of the time, the rollers don't move as they should. The disadvantage to a roller chock is the fact that the roller will move from one mooring to the next, exposing a "new" surface to the rope, which is often rusted and can lead to additional damage.

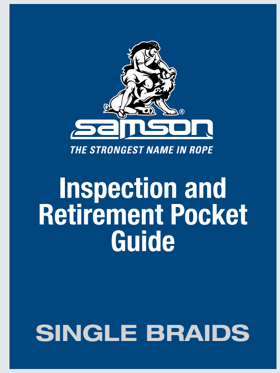
For additional information on this subject, please contact the Samson engineering department.

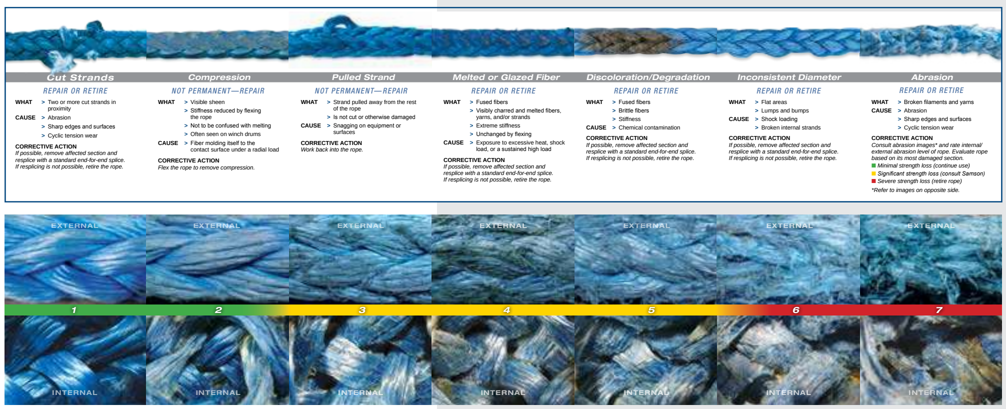
Samson recommends the use of chafe protection for mooring rope contact points.

SAMSON TECHNICAL BULLETIN

Inspection & Retirement Pocket Guide

Overview The visual inspection of synthetic ropes before use is critical in most industrial applications. The residual strength of a rope, the prime indicator of its useful and safe remaining working life, must be assessed before committing the rope to continued use. With high-performance synthetics like HMPE replacing steel-wire ropes in many applications, the need for a method to determine the state of a rope is more critical than ever before. The problem is that there is no common, standardized language or reference scale to describe the state of a rope. To date, judgment on the state of the rope has required a synthetic rope expert to complete an inspection on-site. The alternative is removing the rope from service and testing the rope to destruction in order to evaluate residual strength.





The Pocket Guide includes information on proper rope inspection techniques and corrective action steps.

The Samson Inspection and Retirement Pocket Guide is designed to alleviate this problem by establishing a common language and a reference scale to describe the current state of a rope. The Pocket Guide is based on a statistical analysis of several years of lab testing reports of ropes used in a variety of different applications and tested to destruction in the Samson R&D labs. All testing in the Samson labs is well documented with photos of the samples tested and pre-test assessments of the general state of the rope. The type of damage, its extent, and any mitigating conditions (like chafe gear) are all properly noted. The rope is then tested to destruction to determine the actual residual strength of the sample.

The resulting guide provides a means of estimating the state of the rope and whether it should be repaired or retired from use. The Inspection and Retirement Checklist section of the Guide describes the seven common forms of damage: cut strands, compression, pulled strands, melted or glazed fiber, discoloration/degradation, inconsistent diameter, and abrasion. It provides a visual reference for each and a determination of the cause and possible corrective action that can be taken.

The comparator is an easy reference that can be used in the field to help assess the state of a rope. Small and easily held in the hand while performing an inspection, it helps establish a guideline and a common language when discussing the state of a rope.

Abrasion

Of all the forms of damage that a rope is subjected to, the most commonly observed are abrasion and cutting. Both result in broken filaments in the rope and in a potential reduction in strength. Cutting is characterized as a highly concentrated density of broken filaments localized in one or several strands at one particular position on the rope. Cutting is generally easier to assess than abrasion in terms of the volume of broken filaments in relation to the size of the rope. See *Localized Damage Assessment: 12-Strand Class II Ropes* technical bulletin for additional information.

Abrasion is characterized as a low density of broken filaments distributed across a larger volume of rope, both along the length of the rope as well as among the various strands at any position along the rope. Abrasion can be both external—along the surface of the rope, and internal, within the structure of the rope itself.

It is easy to visualize how external abrasion occurs—ropes dragged across rough surfaces can easily break surface fiber filaments. Internal abrasion is caused by fiber filaments rubbing against one another, or by the ingress of grit or gravel into the braid of the rope. In ropes that are dragged against rough surfaces without proper chafe protection, or experience repeated bending over sheaves and across fairleads, the surface fibers are slowed in relation to the internal fibers, causing fiber-on-fiber abrasion.

The effect of abrasion on the residual strength of the rope is more difficult to assess than cutting or other forms of physical damage. To help assessment in the field, the second side of the Pocket Guide is devoted to a visual comparator of the various states of both internal and external abrasion.

The Abrasion Comparator

The Abrasion Comparator shows a 12-strand HMPE rope—*AmSteel®-Blue*—in a range of abrasion states from new rope to rope ready for retirement. The images represent a scale numbered from 1 through 7 that ranges from minimal strength loss (steps 1 and 2), significant strength loss (steps 3 through 5), to severe strength loss (steps 6 and 7). Each is further tagged with an action—for ropes with significant strength loss, consult Samson; for severe strength loss, retire the rope. Images are provided for both external abrasion and internal abrasion. When consulting your Samson dealer or representative you now have a ready reference to accurately describe the state of the rope in question.

The comparator is an easy reference that can be used in the field to help assess the state of a rope. Small and easily held in the hand while performing an inspection, it helps establish a guideline and a common language when discussing the state of a rope. It is printed on extremely durable synthetic paper that is resistant to tearing and comes packaged in a vinyl sleeve to make it 'pocket friendly.'

Abrasion occurs both externally, along the surface of the rope and internally, inside the structure of the rope. It is important to evaluate both forms to accurately assess the condition of the rope.

SHOWN AT ACTUAL SIZE: The detailed photos make comparison quick and accurate.

THE STRONGEST NAME IN ROPE

Mixed Moorings

Overview Due to the increasing popularity of high-modulus synthetic fibers (HMSF) in mooring, there have been increasing instances where shipowners or operators are attempting to introduce these synthetic lines into their mooring systems, in conjunction with existing wire lines. Samson studied the effects of using HMSF mooring lines with wire rope mooring lines, and developed recommendations for these "mixed mooring" scenarios.

Conversion Process

The use of synthetic auxiliary lines (typically polyester fiber) in conjunction with wire rope primary mooring lines has been widely accepted, provided they are arranged and used symmetrically about the midship. When properly planned and managed, there are times when synthetic fiber mooring lines can be added in combination with existing wire. In some cases, it even provides additional security. However, the combined use of synthetic and wire rope primary mooring lines, a "mixed mooring," has historically been discouraged due to the potential for large differences in elastic elongations, especially with vessels using fixed brake winches. [1]

With the increased popularity of HMSF synthetic fiber mooring lines that have elastic elongation in the same order of magnitude of traditional wire rope, the issue of mixed moorings has resurfaced. Many vessel operators want to take advantage of the new synthetic technology due to its ergonomics and overall economic value, but do not want to retrofit an entire vessel prior to extensive field trials. The most common solution is to request a single line for trial and to use it in parallel with the existing mooring lines. This practice can still create a dangerous situation if the elongations and breaking strengths are not carefully matched.

SCENARIO 1 Even though high-modulus fiber rope has published elastic elongations similar to the elastic elongation of wire rope, the differences can still be very significant. For example, if a core-dependent HMSF jacketed mooring line is used in a trial with a wire rope as a breast line as shown in the graphic scenario in Fig. 1, the wire rope would see an increased tension (see Table 1 for actual results). This difference would effectively limit the holding power of the mooring system, but would not likely produce catastrophic results immediately. In this instance, the wire rope would fatigue at a much higher rate than the core-dependent HMSF jacketed mooring line which over time would create premature failure of the wire rope mooring lines (see Fig. 2). [2]

SCENARIO 2 Changing the position of the high-modulus synthetic fiber lines can minimize the line tension differential. In an actual mooring scheme, the majority of the lines sent ashore are used to restrain a combination of lateral and longitudinal forces as well as yaw moments;

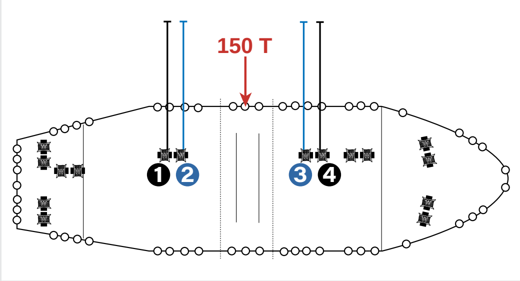


FIGURE 1 MOORING SCHEMATIC [1].
Blue lines represent core-dependent jacketed HMSF mooring line and the black lines represent wire rope.

TABLE 1 Line tension comparison for Figure 1.
(Where total applied load = 150 metric tons)

MOORING LINE	LOAD	% OF NEW ROPE BREAKING STRENGTH
#1 – Wire Rope	44 metric tons	**37%**
#2 – Turbo-DPX™	31 metric tons	**25%**
#3 – Turbo-DPX™	13 metric tons	**25%**
#4 – Wire Rope	44 metric tons	**37%**

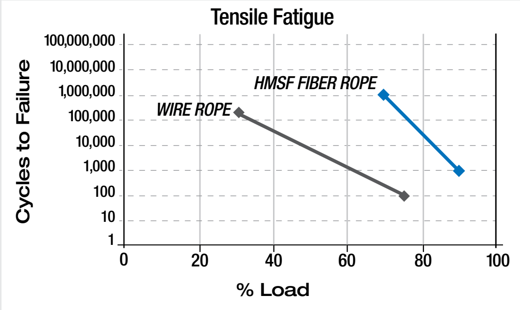


FIGURE 2 Tensile Fatigue Comparison.

therefore this situation will still produce tension differentials between dissimilar material mooring lines. For simplicity, we assume a vessel uses the mooring arrangement in Fig. 3. By placing the synthetic lines side-by-side, the situation is no longer dependent on the overall elastic elongation differences between the wire rope and the synthetic fiber mooring lines. However, this mooring arrangement creates an unbalanced system, where the vessel's stern can be displaced more than the bow (see Table 2).

This is further complicated by combining a new synthetic rope with the existing wire rope. Wire rope, like synthetic fiber rope, will degrade over its lifetime, which will likely affect its strength and the elongation characteristics. The degraded strength and elongation could result in the wire rope taking even more load and fatiguing at an increased rate. Without proper testing of the wire rope mooring lines, the addition of synthetic fiber rope is further discouraged.

SCENARIO 3 Changing out a complete set of lines can effectively minimize the load and elongation differentials that the two previous scenarios described. If the complete set of spring lines is changed to synthetic, the lateral restraining forces will be equally distributed and the resultant elongations will be equal in both directions.

Conclusion

Mixed moorings, not including the use of auxiliary or secondary lines, even with high-modulus synthetic fiber ropes, can have negative effects on mooring systems and should only be used if testing is performed and the load/elongation characteristics are carefully matched. To successfully implement a change from wire rope mooring lines to HMPE synthetic mooring lines, we recommend contacting our Commercial Marine Sales Division or Application Engineering. Samson has also produced detailed information on how to successfully retrofit a vessel and achieve safe and long service life from HMPE mooring lines. See *Retrofitting Ships from Wire to High-Performance Synthetic Mooring Lines* technical bulletin for additional information.

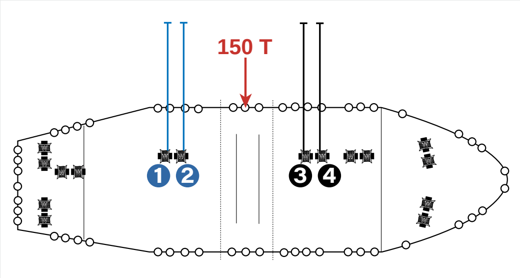


FIGURE 3 MOORING SCHEMATIC [2].
Blue lines represent core-dependent jacketed HMSF mooring line and the black lines represent wire rope.

TABLE 2 Line tension comparison for Figure 3.
(Total applied load = 150 metric tons and 60m leads)

MOORING LINE	DISPLACEMENT
#1 – Turbo-DPX™	0.60 meters
#2 – Turbo-DPX™	0.60 meters
#3 – Wire Rope	0.32 meters
#4 – Wire Rope	0.32 meters

REFERENCES

[1] OCIMF, *Mooring Equipment Guidelines, Fourth Edition,* Section 1.5.

[2] DSM supplied data.

samson®
THE STRONGEST NAME IN ROPE

Retrofitting Ships from Wire to High-Performance Synthetic Mooring Lines

Overview Samson has been successfully supplying torque-free, braided HMPE (high modulus polyethylene) synthetic fiber mooring lines to ocean-going vessels for more than 20 years. Samson mooring lines made with HMPE fiber have been proven to save operators money due to:

- **Faster and safer mooring operations with less personnel required**
- **Less mooring injuries due to line flexibility and light weight**
- **Significantly longer service life than wire rope**

The proven savings that have been achieved on new-builds and modern vessels can also be reached on older vessels still using wire rope.

Preparing a vessel with chock, roller, and winch damage due to extended use of wire rope is as simple as grinding and re-surfacing. This procedure is best accomplished in a normal shipyard or repair visit.

A metal surface that is as smooth as possible is optimal for extending the service life of a line. Many tug and marine customers now employ stainless-steel chock surfaces for their ropes. However, attention to elimination of rusted, uneven surfaces on chocks, rollers, and other metal objects that may come in contact with the lines, is the key to successful retrofitting of the ship from wire to synthetic mooring lines.

The following guide to correct preparation of all rope contact surfaces is extremely important when switching from wire rope to Samson's high-performance mooring lines. When employed correctly, surface-repair instructions and care will ensure a long and successful service life for Samson fiber mooring lines such as *AmSteel®-Blue*, *Force-8™*, *Proton®-8*, *Turbo-DPX™*, and *Turbo-75™*.

Recommendations to Maximize Service Life

Avoid chafing and cutting damage by first inspecting all contact surfaces for the following:

All metal surfaces in contact with the rope should be smooth. The surface roughness should be no greater than 300 micro inches AA (arithmetic average), so its surface is free of snags, burrs, rust, and wire rope scoring.

All fairleads and rollers should be re-ground to remove all existing rust and wire rope induced defects (i.e. burrs and scoring).

All rough surfaces should be welded and ground smooth to eliminate inconsistencies in the contact surfaces.

The grinding needs to eliminate all barbs, sharp edges, or other significant irregularities.

Roller fairleads should be well maintained and able to roll.

UNACCEPTABLE CONTACT SURFACE EXAMPLES

Contact with rusted, uneven surfaces will shorten the service life of synthetic lines due to abrasion and cutting damage.

Once all surfaces have been refurbished, periodic examination and maintenance should be performed to keep surfaces free of rust, and fresh paint should be reapplied.

Use the following International Marine Coatings primer or equivalent:

- Interbond 501 Primer Finish

Use the following International Marine Coatings paints or equivalent:

- Intercare 755 Cosmetic Finish
- Interthane 990 Cosmetic Finish
- Interguard 740 Cosmetic Finish

Paint should be dry on contact surfaces before the rope is deployed as to avoid taking paint off surfaces, bunching paint, or creating sharp paint shards.

The continued use of steel-wire mooring ropes on contact surfaces, such as fairleads and rollers that are intended for HMPE fiber ropes, may cause chafe damage and is not recommended.

Mooring Winches

> Samson ropes are commonly used on wire rope mooring winches. It is important to clean and prepare the contact surfaces on the winches to the same standard as the other contact surfaces.

> Ropes made with HMPE fiber have a lower coefficient of friction than steel-wire ropes. Consequently, more turns may be necessary on the tension drum to compensate for this loss of grip. The lower coefficient of friction will result in the lines burying on other wraps.

> To avoid or relieve the severity of this, the line should be installed under some tension (100 to 200 lb) on the storage drum and no more than one layer of wraps should be on the working drum.

Samson Chafe Sleeve Protectors

To further protect your Samson mooring lines and achieve the optimal service life, the use of chock chafe-protective sleeves is always recommended. Friction heat created in ship chocks and cut, uneven, or rusted areas in the chock can damage synthetic ropes. Therefore, these ropes must be protected.

One effective chafe protection option is Samson's Pro-Moor chafe sleeve, which can be sewn on to the mooring line. Samson also offers a replacement sleeve that is attached to the mooring line with a

ACCEPTABLE CONTACT SURFACE EXAMPLES

Once contact surfaces have been prepared for HMPE lines continued use of steel-wire ropes is not recommended.

hook-and-clasp securing system. These, and other chafe protection options offered by Samson, are designed to provide the lightest weight, most durable, and cut-resistant protection to your valuable mooring lines. Pro-Moor chafe sleeves are made from HMPE fiber and consist of two different wear surfaces:

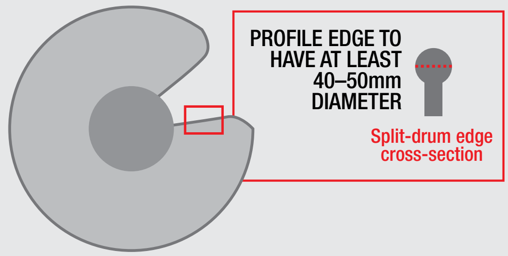
- The outer woven fabric is thicker and has a coating with a high coefficient of friction (CoF), which grips the painted metal chock surface and prevents the gear from moving in the chock during mooring.
- The inner woven material has a slick, or low, CoF; allowing the mooring line to move inside the chafe gear during mooring without dislodging the gear from the chock.

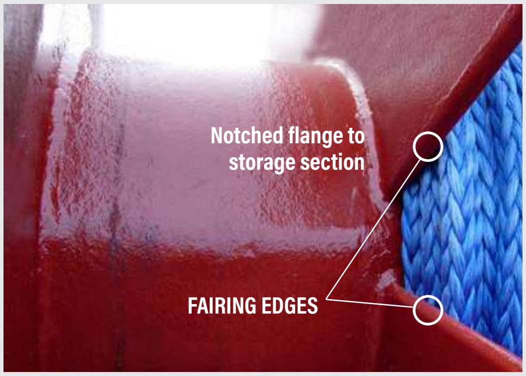
To avoid chafing in the transfer section between the storage drum and the split drum, it is important to pay attention to the fairing edge—see diagram at right.

Using one leg of the spliced eye, or the bitter end of the rope, (which ever is applicable), pass through the hole in the flange. The U-bolt that is used to secure the line to the flange should be secured at the base of this splice.

Both Pro-Moor chafe sleeves (the sewn sleeve and the hook-and-clasp securing system) have grommet eyes on each end of their 2-meter length to allow the attachment of tag lines, which the crewmember can use to place the gear in chocks during mooring.

Samson's Pro-Moor chafe sleeve sewn on to AmSteel®Blue





Working side of a winch drum

Rope Measurement

Overview Samson recognizes the importance of accurate rope measurement. ISO and the Cordage Institute (CI) offer guidelines to achieve accuracy and consistency in measurements, and this bulletin provides additional guidance to maintaining quality standards and best practices in rope handling.

Rope Measurement Recommendations

These recommendations should be used when a cut length of rope is needed:

> If a reliable rope length counter is available, it should be used as indicated by the manufacturer's instructions, while adding back-tension of approximately 10 lbs.

> In the absence of a length counter, the recommended methods are identified in ISO standards 2307:2005 and CI 1500:2006. These recommendations state that the rope sample should be laid out straight on a flat surface with slight hand force or lightly tensioned by hand to measure the length. The rope should not be curved or twisted at any point along its length.

Length Tolerance at Samson

In order to meet Samson quality standards and practices, all high-performance products made in whole or in part from high-modulus fibers such as HMPE, aramid, liquid crystal polymer (LCP), etc., are measured with a length tolerance of +5%/−0%. Other ropes made with olefin, nylon, or polyester fibers are measured with a length tolerance of +/−5%. These are determined during the reeling process, as described at right.

Length Measurement Accuracy

The length counters are checked for accuracy weekly using a reference standard. The standard used is a predetermined rope sample with a firm shape and very low stretch that is run through the counters to verify the length readout.

How Long is a Piece of Rope?

Several standards are available as references for measured lengths of testing samples, but do not include a method for determining a length for storing or shipping:

> CI 1500-02, International Standard: Test Methods for Fiber Rope

> ISO 2307:2005, Fiber Ropes: Determination of Certain Physical and Mechanical Properties

> ASTM 4268, Standard Test Methods for Testing Fiber Ropes

Do not allow the length of rope being measured to be curved or twisted.

A rope is run over an elevated roller, or through two horizontal breaker bars that add back-tension to control the rope as it is pulled through the reeling system. The rope is then looped around a number of capstans that are controlled to a tension of 10 lb. The rope finally passes through a length counter as it is wound on to the final reel and cut at the required length. The back-tension on the rope as it moves through the counter assists in providing a consistent length measurement and a solidly wound reel.

SAMSON TECHNICAL BULLETIN

Rope Measurement

These standards refer to measuring length under a low load or reference tension when measuring rope length for test calculations. However, CI-1500 states that "Because of the soft, flexible nature of fiber rope, reproducible measurements of diameter, circumference, and length cannot be made on the untensioned rope."

The following is a list of the common difficulties of rope length determination in the field:

- Availability of a flat surface to lay the rope straight for measuring
- The ability to tension the rope
- The material is flexible and soft, which may cause variation
- No standardized method for measuring rope length
- Using an inadequate and/or inconsistent type of measuring device
- The availability of a measuring device
- The position of the measuring device at the starting and ending points of the rope
- The method by which the measuring device is used
- The rope's length may change as it is used

The Difference in Measuring Length on Tensioned and Untensioned Rope

The greatest difference can be seen in the length of the measured rope when comparing it at a tensioned and untensioned state. Tests have shown an approximate 2% difference in length is found with 12-strand *AmSteel®-Blue* when tension is used during measurement compared to an untensioned rope. Greater variability was seen with untensioned measurements, with as much as 2% of the same rope's length but when tensioned that difference dropped to 0.5%. The amount of variation seen between tensioned and untensioned ropes will also be affected by the material and construction of each rope.

Necessary Rope Measuring Procedures:

- Supply constant, even tension (no more than 10 lb is needed) to all diameter ropes.
- Tension can be added simply by winding the rope in an S shape around two horizontal or vertical bars that will create the needed tension.
- A controlled tensioning system can also be used as described on page one of this technical bulletin.
- When no tensioning device is available, laying the rope to the complete required length on a flat surface, and tensioning it with hand force while measuring the full length will reduce the variability and difference in length.

THE STRONGEST NAME IN ROPE

Controlled tensioning system.

Tension rope with hand force and measure to reduce the variability in length.

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SAMSON TECHNICAL BULLETIN

Surface Preparation for Synthetic Ropes

Overview The following recommendations can be applied at the shipyard or during vessel operations. Lab testing has shown that many coatings work quite well and adequate surface preparation before the coating is applied has a large impact on the rope service. The surface should have a roughness of 300 micro inches or less. If this roughness cannot be achieved, other means to smooth the surface must be employed. Once that is accomplished, the following steps apply.

Check Ambient Conditions

Verify that hardware idle time and weather conditions will allow adequate curing prior to beginning installation work. Details of time required for curing should be available from the coating manufacturer. If conditions are favorable, follow these steps:

STEP 1 SURFACE PREPARATION Proper surface preparation is the most critical step in this process. Many standards and publications exist that specify both the smoothness and cleanliness of steel surfaces. These should be referenced if the person doing this work is not an expert in common surface preparation practices. Prepare hardware for application of treatment by removing rough edges, rust and debris by sandblasting, and/or use of a pneumatically operated wire bristle brush or needle-scaler (shown bottom right). Rust will prevent proper adhesion of the coating and result in premature wear of the repaired area, so removal is imperative.

STEP 2 COATING PREPARATION Prepare coating per manufacturer instructions (see label and instructions that came with product). Use appropriate personal protective equipment — typically at least safety glasses and rubber gloves.

2 part coating mixture (Intershield 300V shown)

STEP 3 COATING APPLICATION Apply the coating liberally to the hardware (brush or spray on). Where possible, extend the coating 2–4 inches beyond the area of probable contact to ensure complete coverage of the affected area.

STEP 4 CURING After complete curing (24+ hours depending on thickness and product), hardware can be used.

Rust damaged chock typical of crude tankers.

Rough finish as coating wears away.

Coating removal using a needle scaler

SURFACE PREPARATION—APPENDIX

Introduction

Proper surface preparation is essential for the success of any protective coating scheme. The importance of removing oil, grease, old coatings and surface contaminants (such as mill-scale and rust on steel) cannot be over emphasized.

The performance of any paint coating is directly dependent upon the correct and thorough preparation of the surface prior to coating. The most expensive and technologically advanced coating system will fail if the surface preparation is incorrect or incomplete.


The adhesion and longevity of any paint coating is dependent upon the surface preparation prior to coating.

Steel Preparation Standards

Some of the various methods of surface preparation of steel are briefly described below. For more explicit details and recommendations please refer to full specifications, such as:

1. International Standard ISO 8504:1992(E).
   Preparation of steel substrates before application of paints and related products – Surface preparation methods.
2. Steel Structures Painting Council (SSPC)
   Pittsburg, PA, USA. Full range of surface preparation standards.
3. International Standards ISO 8501-1:2007(E) and ISO 8501-2:1994.
   Preparation of steel substrate before application of paints and related products – Visual assessment of surface cleanliness.
4. Swedish Standard SIS 05 59 00 (1967)
   Pictorial Surface Preparation Standards for Painting Steel Surfaces.
5. Shipbuilding Research Association of Japan
   Standard for the preparation of steel surface prior to painting ("JSRA" Standard).
6. International Protective Coatings Hydro-blasting Standards.
7. International Protective Coatings Slurry Blasting Standards.
8. International Protective Coatings Abrasive Sweep Blasting Standards.

Removal of Contaminants

The performance of protective coatings applied to steel is significantly affected by the condition of the steel substrate immediately prior to painting. The principal factors affecting performance are:

a) surface contamination including salts, oils, grease, drilling and cutting compounds,
b) rust and mill-scale,
c) surface profile.

The main objective of surface preparation is to ensure that all such contamination is removed to reduce the possibility of initiating corrosion so that a surface profile is created that allows satisfactory adhesion of the coating to be applied.

Removing contamination improves the surface profile for subsequent coating adhesion.

Recommended procedures are outlined in International Standard ISO 8504:1992(E) and SSPC SP Specifications.

Degreasing

It is essential to remove all soluble salts, oil, grease, drilling and cutting compounds and other surface contaminants prior to further surface preparation or painting of the steel. Perhaps the most common method is by solvent washing, followed by wiping the surface dry with clean rags. Cleaning the surface is critical; if cleaning is not carried out thoroughly, the result of solvent washing will simply spread the contamination over a wider area. Proprietary emulsions, degreasing compounds and steam cleaning are also commonly used. Recommended procedures are described in International Standard ISO 8504:1992(E) and SSPC-SP1.

It is essential to remove all soluble salts, oil, grease, and other surface contaminants prior to further surface preparation or paint application.

Hand and Power Tool Cleaning

Loosely adhering millscale, rust and old paint coatings may be removed from steel by hand wire brushing, sanding, scraping and chipping. However, these methods are incomplete, and always leave a layer of tightly adhering rust on the steel surface. Methods for hand tool cleaning are described in SSPC-SP2 and should be to ISO 8501-1:1988 grade St2-B, C or D. Power cleaning is generally more effective and less laborious than hand tool cleaning for the removal of loosely adhering millscale, paint and rust. However, power tool cleaning will not remove tightly adhering rust and millscale. Power wire brushes and impact tools such as needle guns, grinders and sanders are all commonly used. Care should be taken, particularly with power wire brushes, not to polish the metal surface as this will reduce the key for the subsequent paint coating. Methods are described in SSPC-SP3 and SSPC-SP11 and should be to ISO 8501-1:1988 grade St3-B, C or D. SSPC-SP11 describes a degree of surface profile which can be achieved by power tool cleaning.

Care should be taken when using power tools to remove rust and debris from steel surfaces to not polish the surface—this can cause bonding issues for the subsequent coating product.

Blast Cleaning

By far, the most effective method for removal of millscale, rust, and old coatings, is the use of abrasives such as sand, grit, or shot under high pressure.

The grade of blasting suitable for a particular coating specification depends on a number of factors, the most important of which is the type of coating system selected.

The primary standard used in the product data sheets in this manual is ISO 8501-1:1988(E), preparation of steel substrate before application of paints and related products—visual assessment of surface cleanliness. This standard represents a slight extension of the Swedish Standard (SIS 05 59 00), which was developed by the Swedish Corrosion Institute, in co-operation with the American Society for Testing &Materials (ASTM), and the Steel Structures Painting Council (SSPC), USA, and is already used on a world-wide scale.

Where appropriate, the nearest equivalent SSPC specification has been quoted on individual product data sheets. It is recognized that the SSPC and ISO standards are not identical, and as a consequence certain product data sheets may show grade Sa2½ (ISO 8501-1:1988) as equivalent to SSPC-SP6, (commercial blast cleaning), whilst others will be equivalent to SSPC-SP10 (near white metal). The selection of these blast cleaning grades has been assessed using a number of factors including coating type, performance expectation, and in-service conditions.

By far, the most effective method for removal of millscale, rust, and old coatings, is the use of abrasives such as sand, grit, or shot under high pressure.

As a general principle, where products are recommended for immersion or aggressive atmospheric conditions, the blasting standard required will be to Sa2½ (ISO 8501-1:1988) or SSPC-SP10; however, when products are recommended for general atmospheric exposure, the blasting standard required will be Sa2½ (ISO 8501-1:1988) or SSPC-SP6.

Prior to blasting, steelwork should be degreased and removed of all weld spatter. If salts, grease or oil are present on the surface they will appear to be removed by the blasting process, but this is not the case. Although not visible, the contamination will still be present as a thin layer, and will affect the adhesion of subsequent coatings. Weld seams, metal slivers and sharp edges revealed by the blasting process should be ground down, as paint coatings tend to run away from sharp edges, resulting in thin coatings and reduced protection. Weld spatter is almost impossible to coat evenly, in addition to often being loosely adherent, it is a common cause of premature coating failure.

The surface profile obtained during blasting is important, and will depend on the abrasive used, the air pressure and the technique of blasting. Too low a profile may not provide a sufficient key for coating, while too high a profile may result in uneven coverage of high, sharp peaks possibly leading to premature coating failure, particularly for thin film coatings such as blast primers. The table (right) gives a brief guide to typical roughness profiles obtained using various types of abrasive.

Abrasive	Mesh Size	Max. Height of Profile
Very fine sand	**80**	37 μ *(1.5 mils)*
Coarse sand	**12**	70 μ *(2.8 mils)*
Iron shot	**14**	90 μ *(3.6 mils)*
Typical non-metallic "copper slag" 1.5 – 2.0 mm grain size	**–**	75 – 100 μ *(3 – 4 mils)*
Abrasive	**Mesh Size**	**Max. Height of Profile**
Iron grit No. G16	**12**	200 μ *(8.0 mils)*

Wet Abrasive Blasting/Slurry Blasting

Wet abrasive blasting uses a slurry of water and abrasive as opposed to dry abrasive alone. The advantage of this method is the virtual elimination of hazards and health problems that are associated with dust.

A further important advantage is that when wet blasting old, well rusted surfaces, many of the soluble corrosion products in the pits of the steel will be washed out, which will greatly improve the performance of the applied coating system. However, a disadvantage of this technique is that the cleaned steel begins to rust rapidly after blasting. It is therefore common practice to include proprietary inhibitors in the blast water which will prevent this rusting for a sufficient time to allow painting to be carried out. In general, the use of very low levels of such inhibitors does not affect the performance of subsequent paint coatings for non-immersed steelwork. The use of a moisture tolerant primer, which can be applied to wet blasted steel while it is still damp, can make the use of inhibitors unnecessary, but International Protective Coatings should be consulted for specific advice. If wet-blasted surfaces have been allowed to corrode, they should be mechanically cleaned or preferably sweep blasted, to remove the corrosion prior to painting.

The advantage of wet abrasive blasting methods is the virtual elimination of dust-related hazards.

Hydroblasting

Hydroblasting is a technique for cleaning surfaces, which relies entirely on the energy of water striking a surface to achieve its cleaning effect. Abrasives are NOT used in hydroblasting systems. Consequently the problems caused by dust pollution and by the disposal of spent abrasives are eliminated. Two different hydroblasting operating pressures are commonly encountered.

> *High pressure hydroblasting, operating at pressures between 680 bar (10,000 p.s.i.) and 1,700 bar (25,000 p.s.i.).*

> *Ultra-high pressure hydroblasting, operating at pressures above 1,700 bar (25,000 p.s.i.).*

The terms hydroblasting, hydrojetting and water jetting essentially mean the same thing, with all being used to describe the same process. There can be confusion however over the difference between simple water washing and hydroblasting. To clarify the situation, International Protective Coatings have adopted the following commonly accepted definitions.

Low Pressure Water Washing:
Operates at pressures less than 68 bar (1,000 p.s.i.).

High Pressure Water Washing:
Operates at pressures between 68-680 bar (1,000–10,000 p.s.i.).

High Pressure Hydroblasting:
Operates at pressures between 680–1,700 bar (10,000–25,000 p.s.i.).

Ultra High Pressure Hydroblasting:
Operates at pressures above 1,700 bar (25,000 p.s.i.) with most machines operating in the 2,000–2,500 bar range (30,000–36,000 p.s.i.).

The International Protective Coatings Hydroblasting Standards have been prepared using ultra high pressure hydroblasting equipment. This standard however is also applicable to surfaces produced by a whole range of hydroblasting pressures, providing the equipment used is capable of cleaning to the visual standard depicted.

The steel surfaces produced by hydroblasting do NOT look the same as those produced by dry abrasive blasting, or slurry blasting. This is because water on its own cannot cut, or deform steel in the same way as abrasives. Hydroblasted surfaces therefore tend to look dull, even before they "flash rust." In addition steel, with active corrosion pitting, shows a mottled appearance after hydroblasting. Mottling occurs when the corrosion products are washed out of the pits, leaving a bright patch, and the surrounding areas are left a dull grey, brown to black color. This pattern is the reverse of that left by abrasive blasting, where anodic pits are often dark, due to corrosion products not being entirely removed, and the surrounding areas are bright. "Flash rusting," i.e. light oxidation of the steel, which occurs as hydroblasted steel dries off, will quickly change this initial appearance.

When flash rusting is too heavy for a coating application, it may be removed or reduced by brushing with a hard bristle brush, or by washing down with high pressure fresh water. High pressure washing, at pressures above 68 bar (1,000 p.s.i.) using either the rotational nozzles, or fan jet lances of the hydroblasting equipment itself is the preferred method. It will cause the area to re-rust, but it is possible to reduce the degree of flash rusting from heavy to light using this method. Hand wire or bristle brushing to remove heavy flash rusting may be acceptable for small areas, but will generally produce an inadequate surface. Mechanical rotary wire brushing can however produce acceptable surfaces for large areas.

When large areas are hydroblasted, flash rusting, which obscures the original blast standard, may occur, before an inspection can be carried out. Establishing the required standard by blasting a small test area prior to the main blast may help, providing the rest of the job is blasted to the same standard. Methods for ensuring the rest of the job is blasted to the same standard will vary from project to project.

Flash rusting can be prevented by the use of water soluble chemical corrosion inhibitors. These inhibitors may leave a crystalline layer on the steel surface as the water evaporates, which can then lead to a loss of adhesion and osmotic blistering, if coatings are applied over this type of surface. International Protective Coatings do not recommend the use of corrosion inhibitors to hold wet blasted surfaces. If inhibitors are used, they must be thoroughly washed off with fresh water before International Protective Coatings products are applied.

Hydroblasting, hydrojetting, and water jetting are essentially the same process under different pressures.

International standards are applicable to surfaces produced by a range of hydroblasting equipment, providing it is capable of cleaning to the visual standard depicted.

The temperature of steel substrates can rise during the hydroblasting process.

There are two reasons for this:

a) Compression of the water to reach hydroblasting pressure will create a temperature rise in the water itself,

b) The velocity of the water striking the steel will impart energy to it as heat.

This temperature rise can be substantial and may help hydroblasted surfaces dry off more quickly, with a corresponding reduction in the severity of flash rusting.

An important property of the hydroblasting process is that it can emulsify and remove oil and grease from a surface as it is blasted. However, this does not preclude the need for proper degreasing procedures as specified in SSPC-SP1, prior to hydroblasting. Hydroblasting will not produce a surface profile, although the process can eventually erode steel and result in metal loss. The surface profile exposed after hydroblasting will have been produced by earlier surface preparation work, or by corrosion. For most coating schemes, International Protective Coatings will accept a profile in the 50 to 100 microns range.

SEVERAL EXAMPLES OF GOOD AND BAD SURFACE PREPARATION / COATING APPLICATION

BEFORE REPAIR

DURING REPAIR

AFTER REPAIR

STAINLESS ROLLER INSTALLATION

PROS

> *Smooth finish of material and durable material*

CONS

> *Inadequate support under material*

> *Roller not entirely covered and weld*

> *Not adequately smoothed following installation*

THE STRONGEST NAME IN ROPE

Mooring in High-Temperature Climates

SAMSON TECHNICAL BULLETIN

Overview Many areas of new oil and gas reserve development and production are occurring in the Middle East, the Northwest Shelf, Western Africa, or other regions that have extremely high climatic temperatures and utilize ocean-going vessels to transport this cargo to their ultimate destination. High modulus synthetic fiber-based mooring lines relatively low melting point and published critical temperature have raised concerns about the product viability in these climates. *We have determined that Samson HMPE lines will have negligible degradation due to high temperature ports.*

The climates of the Middle East, Northern Africa, and the Northwest Shelf can have high daily temperatures. Samson conducted three experiments to better understand the effects of heat:

1. **Effects of Ambient Heat**
2. **Effects of Conducted Heat**
3. **Effects of Temperature, Load and Time**

Effects of Ambient Heat

Ambient Temperature is the temperature measured for a given environment. This ambient temperature will cause all objects in the environment to be heated to the environment's temperature [1]. Fig. 1 shows the temperature profile of three Samson HMPE fiber ropes moved from room temperature to a 100°C environment: one 12-strand single braid, one 12-strand braid with a polyester jacket, and one 12-strand braid with a Samson HMPE/polyester fiber hybrid jacket. All the ropes in the experiment ultimately reached 100°C regardless of the insulating properties of their jackets.

Exposing the ropes to temperatures between 25°C and 75°C does not have a significant effect on the residual strength of *AmSteel®-Blue,* as shown in Fig. 2 [2]. Similarly thermal cycling, for example, cycles of 8 hours at 65°C followed by 16 hours at 20°C did not result any significant strength loss over a period of 60 days [2].

At elevated ambient temperatures, HMPE fibers will soften, which results in a reduction of strength. However for realistic environmental temperatures, between 20°C and 50°C, the fiber loses less than 8% of its breaking strength (Fig. 3).

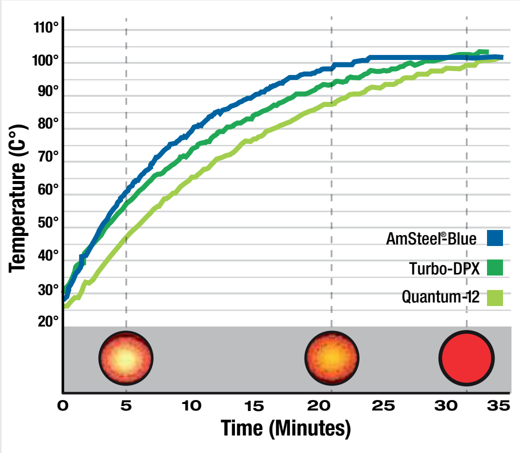

FIGURE 1 Internal Rope Temperature Profiles

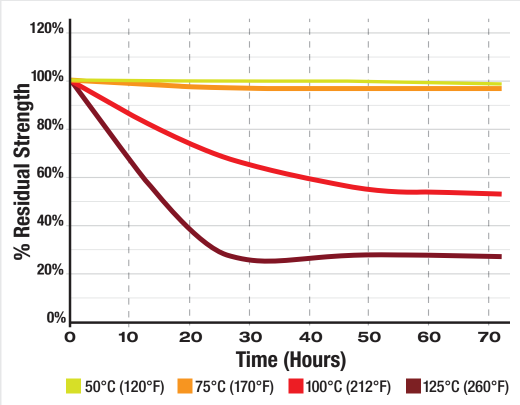

FIGURE 2 Temperature Affect on Strength of 1/2" diameter AmSteel®-Blue

Samson customers have been working in the Middle East, Northern Africa, and the Southeast Asia and Australia with HMSF mooring lines without incident.

Effects of Conducted Heat

When a rope comes in contact with a hot surface, the heat is conducted into the rope. However, unlike the effects of ambient heat, the conducted heat may not increase the entire rope's temperature to the same temperature as the contact surface [3]. Lab tests placing ropes on a 70°C constant heat source shows the temperature increase with time, as shown in Fig. 4. Interestingly, the rope's upper surface never reaches the heat source temperature, showing a steady-state heat equalization with the environment. Since not all the fibers are heated to the temperature of the hot surface, it is expected that most of the strength of the rope is still maintained.

Effects of Temperature, Load and Time

The combination of elevated temperature, load and time can accelerate a phenomenon known as creep. Creep studies have been performed on HMPE fiber ropes to identify how it influences other rope properties such as strength [4]. We can use this predictive model to determine the length of time before reaching rupture for a rope that is loaded under different conditions.

For an LNG tanker trading in Qatar to Europe, the effective creep life for an *AmSteel®-Blue* mooring line would exceed 40 years, which far exceeds the actual lifetime of a mooring line. At the effective creep life, the *AmSteel®-Blue's* residual strength would exceed 80% minimum breaking strength (MBS) assuming the following conditions [5]:

1. Load:
- a. *Initial Tie-up = 30% MBS*
- b. *Mooring Load = 18% MBS*

2. Time:
- a. *Initial Tie-up = 2 hours/mooring*
- b. *Mooring = 46 hours/mooring*
- c. *13 moorings in Qatar per year*
- d. *26 mooring total per year (13-Qatar) (13-Europe)*

3. Temperature:
- a. *Initial load always occurs at the maximum daily temperature*

Even under the extreme case, e.g., every time it moored in Qatar the temperature exceeded 50°C and the strain on the lines is 18% MBS, an *AmSteel®-Blue* LNG tanker mooring line still has a residual strength of 80% MBS after 10 years.

Conclusions

In summary, climatic temperature is not a factor affecting the lifetime of HMPE mooring lines.

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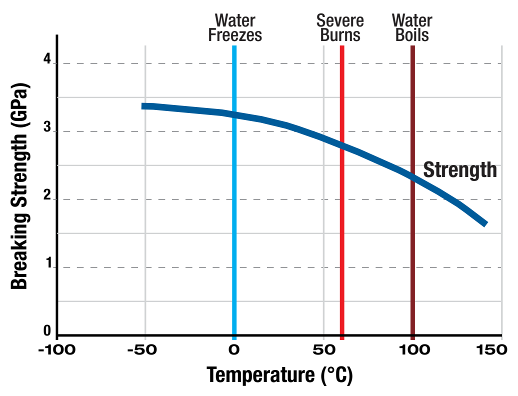

FIGURE 3 Strength of HMPE fibers Influence of Testing Temperature

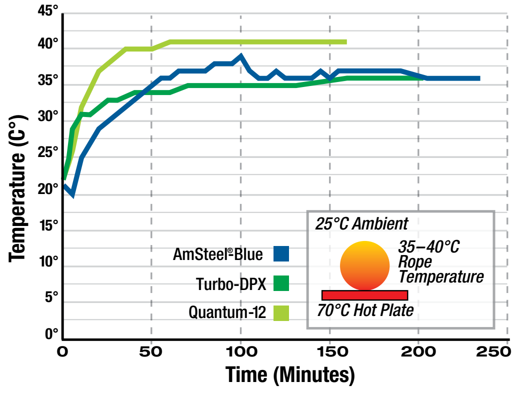

FIGURE 4 1-5/8" Rope on 70°C Hot Plate

REFERENCES

[1] TR-037-2004-FDL., Samson 2004

[2] TR-036-2004-FDL., Samson 2004

[3] TR-038-2004-FDL., Samson 2004

[4] Smeets, P., et. al, *Creep as a Design Tool for HMPE Ropes in Long Term Marine and Offshore Applications,* Samson 2004

[5] TR-040-2004-FDL., Samson 2004

SAMSON TECHNICAL BULLETIN

Tension Fatigue Testing

Overview Tension fatigue occurs in steel wire or synthetic ropes subjected to fluctuating loads over an extended period of repeated cycles during use. It results in degradation of the material and a reduction in the strength of the rope. The impact of repeated tension cycles on the rope's strength is typically a function of the stress level exerted on the rope (represented by the load as a percentage of the rope's average break strength) as well as the material and construction characteristics of the rope.

In real-world applications, tension fatigue is usually only one of many contributing degradation mechanisms to which the rope is subjected. It is often difficult to represent "fatigue life" based purely on laboratory test results. However, lab testing is one way to indicate the relative difference in expected operating life between different rope products.

The most commonly utilized testing standard for comparing tension fatigue performance is the Thousand Cycle Load Limit (TCLL) test established in the *"OCIMF Guidelines for SPM Mooring Hawsers."* Samson uses this procedure to compare product performance amongst internal products as well as with ropes made by competitors. TCLL values express the maximum percentage of the breaking strength at which a rope can be cycle loaded 1,000 times. The object of the test is to measure the rope's resistance to tension-tension fatigue. A higher TCLL Value indicates higher resistance to cyclical tensile loading.

TABLE 1 TCLL Value of Various Materials
(condensed from DSM Dyneema chart)

UNIT	STEEL WIRE	ARAMID	POLYAMIDE	DYNEEMA
TCLL Value	60	73	55	90

A higher TCLL Value indicates higher resistance to cyclical tensile loading.

Tension Fatigue Properties

Ropes made from high modulus polyethylene (HMPE) have superior tension fatigue properties compared to ropes made from steel wire or other synthetic fibers (i.e. nylon, polyester, aramids, etc.), as shown in Table 1.

The testing summarized in this document is focused on HMPE-based ropes. The test included two samples of each rope type from three different manufactures, referred to here as *AmSteel®-Blue* and *Saturn-12* (both Samson products), Product C, and Product D (from 2 different domestic manufacturers). All samples were 12-strand single braids, 3/8" (9 mm) nominal diameter, made from HMPE fiber (Samson *AmSteel®-Blue* and *Saturn-12* are 100% Dyneema® HMPE fiber, Product C and D are 100% Spectra® HMPE fiber). Product D uses heat setting in post processing while Product C uses construction design characteristics that optimize break strength and keep stretch low. Samson's two products use a balanced construction that strives to achieve high strength and low stretch while maximizing fatigue life and abrasion resistance.

The effects of heat setting on HMPE rope is well documented (see Samson Technical Bulletin: *HMPE Rope—Effects of Post Production Processes*). HMPE ropes characteristically show an initial increase in strength as

Tension Fatigue Testing

they are worked for the first 40% of their expected tension fatigue lifetime. Heat setting pushes the rope along the expected strength curve to the maximum strength the fiber will be expected to achieve before it is placed in service. The strength gain comes at the price of a significantly reduced fatigue lifetime.

The rope's construction design—twist levels and braid angles—also influences both strength, fatigue life and resistance to abrasion. (See Samson Technical Bulletin: *HMPE Rope: Design vs. Performance*). High strength can be achieved using a longer cycle length that results in a looser braid. Testing shows that it also results in lower tension fatigue resistance and lower abrasion resistance.

Test Procedure

For these tests, the procedure for TCLL testing documented in the OCIMF (Oil Companies International Marine Forum) Guidelines was followed except that the rope was tested dry versus the recommended wet test. Dry was chosen as an acceptable method as long as all samples were subjected to the same conditions. Testing was performed at Samson's Innovation and Training Center testing laboratory in Ferndale, Washington.

The test procedure called for each sample to be subjected to 4 levels of cycling based on the rope's specified average break strength (ABS) — 50%, 60%, 70%, and 80% of ABS. The samples were subjected to 1,000 cycles to each of the first three loads (50%, 60%, 70%) and then, if they survived, 2,000 cycles at 80% of average break strength, totaling 5,000 cycles. The samples were then loaded to destruction, to measure the rope's residual strength.

For ropes that survived this cycling, a calculation was performed to determine a theoretical TCLL value. This value is intended to represent the load-level at which the rope would fail upon completing 1,000 cycles (see appendix A for relevant calculation and test method info).

Test Results

After completing 5,000 cycles, Samson's *AmSteel®-Blue* and *Saturn-12* samples all broke above specified average strength. This indicates that there was minimal to no strength loss in the Samson ropes due to tension fatigue. Products C and D did not complete the testing. Product C averaged less than 4,400 total cycles, while product D averaged only 3,140 cycles. Additional results summarized in Table 2 and Figure 1 show the total cycles for each product.

The two Samson ropes outperformed the competitor's ropes. This was attributed to their fiber and rope construction (designed to maximize longevity), as well as the fact that Samson ropes are not heat set. The effect of heat setting is illustrated in Figure 1.

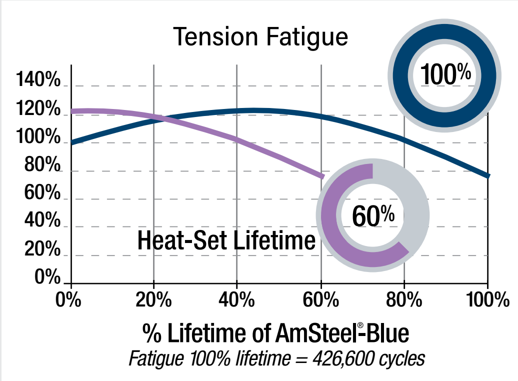

FIGURE 1 Fatigue lifetime comparison between AmSteel®-Blue and Post-Processed Rope
(refer to Samson Technical Bulletin: *HMPE Rope—Effects of Post Production Processes*)

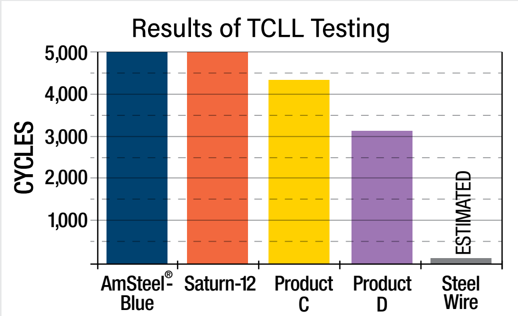

FIGURE 2 Results of TCLL Test
(refer to appendix for calculated cycles at 80% method)

TABLE 2 Results of TCLL Test (refer to appendix for calculated cycles at 80% method)

ROPE	AMSTEEL®-BLUE	SATURN-12	PRODUCT C	PRODUCT D
Construction	12-Strand Dyneema® HMPE	12-Strand Dyneema® HMPE	12-Strand Spectra® HMPE	12-Strand Spectra® Heat Set HMPE
Total Cycles	5,000	5,000	4,400	3,140
Calculated Cycles @ 80% Avg. Break Strength	2,113	2,113	1,468	253
Residual % Avg. Break Strength	116%	116%	80%	80%

Putting TCLL in Context

The prescribed TCLL test used is one way to indicate the relative difference in the expected operating life between different rope products. The results are based on the mean of the population for each rope type. The given number of cycles a rope will survive varies from sample to sample.

The calculated TCLL value does not differentiate between samples that may survive many more cycles beyond the 5,000 cycle test. Although it was chosen to test the samples dry, the impact of cyclic heat generation may have had a larger impact versus testing wet. The heat is generated by the cyclic loading in the test. Ropes in the field may rest relatively long periods of time, reducing the impact of heat generation. HMPE fiber strength is negatively affected by increasing temperature.

APPENDIX

Equivalent Cycles at Higher Loads (OCIMF TCLL Standard)

> 1,000 cycles at 50% = 251 cycles at 60%

> 1,000 cycles at 50% + 1,000 cycles at 60% = 215 cycles at 70%

> 1,000 cycles at 50% + 1,000 cycles at 60% + 1,000 cycles at 70% = 113 cycles at 80%

Determination of Thousand Cycle Load Level

> Calculation of load in which the sample would fail in a thousand cycles. The thousand cycle load level is expressed as a percentage of new (wet) rope break strength and calculated using the following equation:

WHERE:

TLL = *test load level, percentage of new (wet) rope break strength, the load level at which CTF was determined*

CTF = *cycles to failure at test load level*

6.91 = *natural logarithm of 1,000*

REGISTERED TRADEMARK NOTICES:

AmSteel® is a registered trademark and *Saturn-12*™ is a trademark of Samson Rope Technologies, Inc. All rights reserved.

Spectra® is a registered trademark of Honeywell International, Inc.

Dyneema® is a registered trademark of Royal DSM N.V. Dyneema® is DSM's high-performance polyethylene product.

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Type Approvals and Product Certifications

Overview Product certification can be obtained through a number of certifying bodies and can be carried out to varying levels of customer requirements. Samson holds many certifications covering product design, quality policies and procedures, manufacturing procedures, and product compliance to national, international, and industry standards. Samson may also obtain certifications for specific project requirements through third party certification.

CURRENT TYPE APPROVAL CERTIFICATIONS HELD BY SAMSON TO ISO 2307:

ABS, BV, DNV, Lloyd's Register, and Russian Maritime Register of Shipping (RMRS).

Product	MEG4	ABS	BV	DNV	Lloyd's	RMRS
AmSteel®-Blue	X	X	X	X	X	X
AmSteel®-X	X					X
EverSteel™-X	X	X	X*			
Force-8™		X				
Fusion-12™		X				
HTP-12™	X					
M-8™		X				X
MP-1™	X					
Neutron-8™		X				
Proton-8™		X				
Quantum-12™		X			X	X
Quantum-8™		X				X
Quantum-X™		X				
RP-12 Nylon™	X**					X
Saturn-12™		X				X
Turbo-DPX™		X				
Turbo-EPX™		X			X	X
Turbo-RC™	X	X				X

To qualify for MEG4 certification, the manufacturing, testing, and documentation steps are carried out as instructed in MEG4 Appendix B, with the results captured on a uniquely formatted Base Design Certificate. A certifying class society (ABS) reviews the product's documentation and alignment to the MEG4 requirements and, upon approval, provides their endorsement on the product's certificate. Having this certification enables the user to be in compliance with the latest industry guidance, adhere to terminal requirements, and easily compare the performance indicators of multiple products while ensuring they meet a performance baseline. For each product, the regime of tests and endorsement must be renewed every 5 years.

There are three certificates associated with Bureau Veritas type approval.

1 COMPANY RECOGNITION CERTIFICATE: Samson has obtained BV Mode I recognition, which is obtained through in-depth audits of the quality systems and policies in place to manufacture and self-certify ropes in accordance with BV rule NR 320 Section 3. The recognition certificate stands for the Ferndale, Washington manufacturing facility.

2 TYPE APPROVAL CERTIFICATE (TAC): The TAC recognizes the product design and manufacturing method meet BV requirements. TACs are granted to product families of the same design for a given size range, as specified within the certificate.

3 CERTIFICATE OF PRODUCT CONFORMITY (CPC): The CPC recognizes a specific product run for its conformance to product specifications. To issue a CPC, sample testing on the production run must be performed and witnessed.

**BV's POSA framework qualifies the rope for permanent mooring at a jetty, making EverSteel-X the first and only high-performance synthetic rope to achieve this designation. The testing requirements for this certification are extensive: break strength, fatigue characteristics, performance at elevated temperatures, and dynamic stiffness are all tested to verify the rope conforms to specifications and to provide confidence that the product is fit for the intended operational environment.*

***Pending.*

EVERSTEEL-X™ APPROVED FOR PERMANENT JETTY MOORING

FROM BUREAU VERITAS:

"Bureau Veritas appreciated the proactive behavior of Samson during the process of certification of Eversteel-X for permanent jetty mooring applications: at a time where no dedicated standards were yet published, Samson approached BV with its own methodology and testing program for the qualification of their model of rope.

This methodology was accepted by Bureau Veritas as it took into account an extensive testing program, especially regarding the tension fatigue behavior of Eversteel-X in straight pull or angled configurations. Through the completion of this complete testing program and the technical discussions that followed, Samson showed a real commitment in demonstrating not only compliance of their product to the considered standards, but also the high mechanical and physical properties of Eversteel-X rope.

Bureau Veritas was confident to provide Samson with the first ever BV Type Approval Certificate for fiber ropes intended for permanent jetty mooring applications. This certificate will enable ship designers to use Samson's Eversteel-X in the scope of BV notation for the classification of permanent jetty mooring systems (POSA JETTY)."

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Type Approvals and Product Certifications

Type Approval

Samson's most commonly requested type approvals include those through ABS, BV, DNV, Lloyd's Register, and RMRS.

To obtain type approval, manufacturers must first submit all information regarding a specific product to the class society; including quality procedures and processes, detailed construction information, manufacturing procedures, and product specifications, such as weights and strengths. After review of the specifications, a testing program is established to manufacture and test selected sizes for the product in accordance with the specified test procedures. All testing is witnessed by a representative from the class society to assure accuracy and compliance. For further details of the applicability of each type approval, please view the certificate through the respective society's type approval database.

Once approved, there is typically an annual or bi-annual plant inspection/audit performed by the class society. This is done to review the manufacturer's quality manual, such as an ISO 9001 manual, and to verify that there are no issues with the quality system or the manufacture of the product. Hence, the quality and consistency of the product is ensured.

A type approval certificate provides the most assurance as to both quality and consistency of a product supplied by the manufacturer, which are all backed by the rigorous testing, inspections, and audits that are required.

Tests are normally conducted at Samson facilities, but may also be performed offsite at a location approved by the certifying body.

Third Party Certification

Different from type approval, a third party certification is a one-time inspection of a specific product and/or production run.

In order to obtain a third party certification from Samson, we require:

> Exact product and diameter(s) to be certified
> The certifying body required
> The certification requirements needing attestation (i.e. the specification, standard and/or test method)

Samson will contact the certifying body to arrange the requested validation.

Once the certifying body completes the required validation, a certified report documenting all results will be provided.

General Samson Recognition and Certifications

In additional to product-specific type approvals, Samson has been recognized by Lloyd's Register, Bureau Veritas, and the America Bureau of Shipping for its quality systems. Samson maintains certifications for ISO 9001:2015 (LR), manufacturing assessment (ABS), and Mode I recognition (BV). These certifications ensure proper traceability and consistency of products in accordance with industry and international standards.

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Check out an excellent selection of marine lines & chains we offer on our website.