ROPE A NEW PERSPECTIVE ON RISK MANAGEMENT THROUGH LINE MAINTENANCE AND SELECTION

TANKER OPERATOR CONFERENCE MAY 10TH ATHENS

140 YEARS STRONG

AGENDA

Samson Ropes

Mooring Experience

Mooring Line Life Cycle

- Effective Fibre and Line Selection
- Line Management Plan – Installation to Retirement

MEG 4 Overview

For info

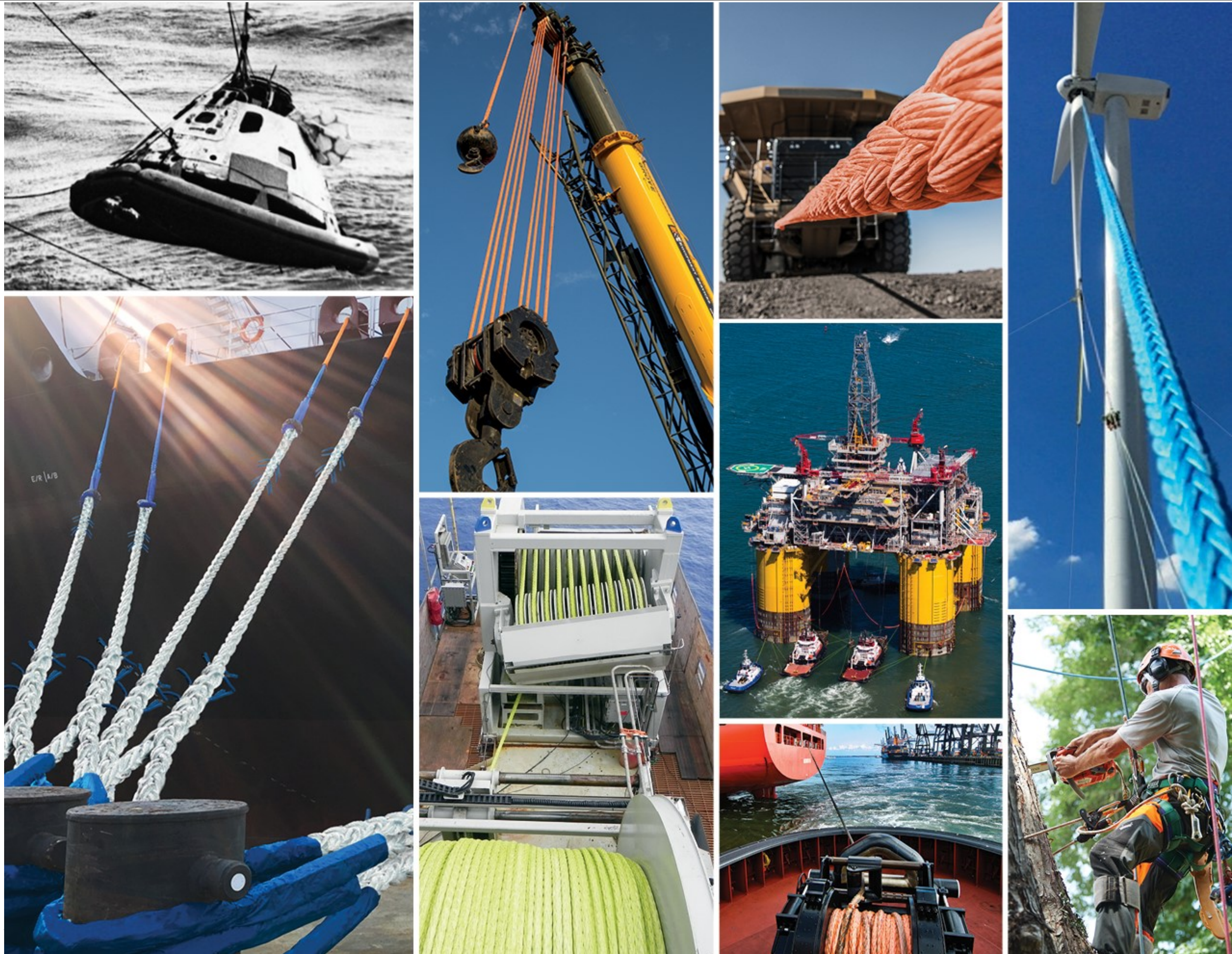
- **FSRU** Eversteel X
- **Vulcan ETOPS**
- **BW Tankers case study retrofit**

Summary

ABOUT SAMSON

samson
THE STRONGEST NAME IN ROPE

- Founded in 1878 in Boston
- History based in innovation
- Largest high-performance rope producer in the world
- Headquartered in Ferndale, Washington USA
- Manufacturing locations in Ferndale and Lafayette, Louisiana USA
- 320 employees world-wide
- Global distribution
- Products sold in 50+ countries



MOORING LINE LIFE CYCLE

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Line Selection

Equipment Compatibility

Maintenance & Inspections

Service Life & Retirement

Understanding wear mechanisms is important at each stage of the mooring line life cycle.

SAMSON'S PARTNERSHIP WITH DSM

DSM High Performance Fibres is the supplier of Dyneema® HMPE fiber

- High Modulus Polyethylene

Technical Partnership

- Mutual testing programs
- Construction/application trials

FIBER COMPARISON CHART

Fiber	Specific Gravity	Melting Temperature (°C)	Tenacity (gpd)	Elongation at Break (%)
Nylon	1.14	218° – 279°	7.5 – 10.5	15 – 28%
Polyester	1.38	254° – 260°	7.0 – 10.0	12 – 18%
Olefin	0.91 – 0.99	140° - 196°	6.0 – 7.5	12 – 24%
HMPE	0.97	144° – 155°	32 – 44*	2.8 – 3.9%
Aramid	1.39 – 1.47	Does not melt; Decomposes @ 500°C	18 – 29	1.5 – 4.6%
LCP	1.40	330°	23 – 29	3.3 – 3.6%
PBO	1.54 – 1.56	Does not melt; Decomposes @ 650°C	42	2.5 – 3.5%

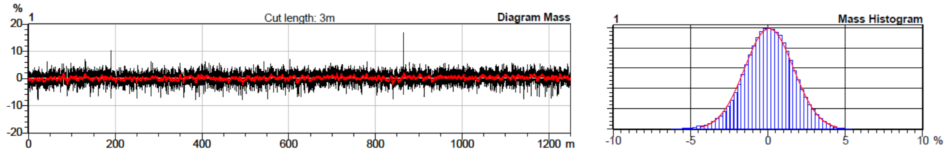
**Specialty grades of this fiber also exist with higher tenacities*

- Specific Gravity: Ratio of yarn density to that of water
- Tenacity: Ratio of yarn strength per weight; tested per ASTM D885
- Elongation at Break: Percent of length change; tested per ASTM D885

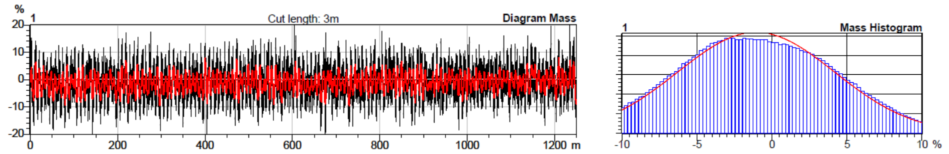
**CI 2003-05 Fibers for Cable, Cordage, Rope and Twine*

NOT ALL HMPE IS THE SAME

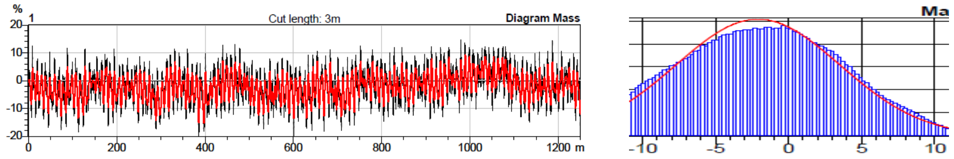
Dyneema®



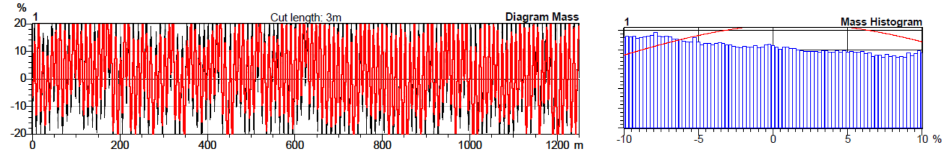
Generic HMPE 1



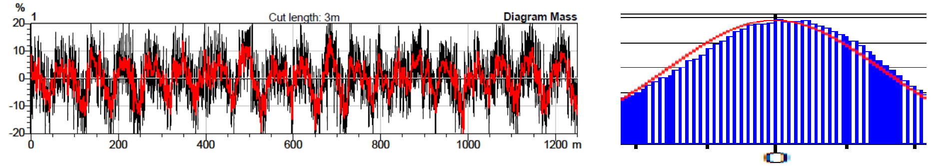
Generic HMPE 2



Generic HMPE 3



Generic HMPE 4



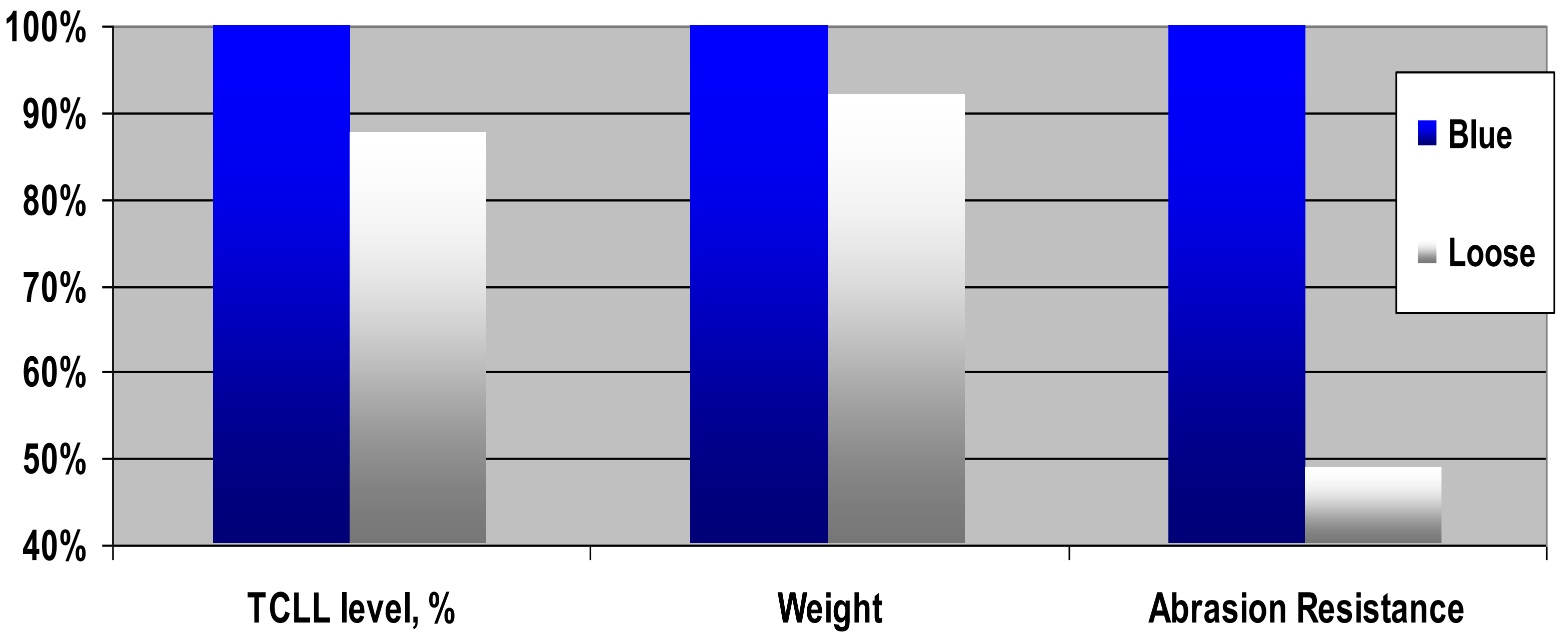
Rope Construction

	ADVANTAGES	DISADVANTAGES
12-STRAND ROPES	• Higher long-term residual strength because of 100% Dyneema fiber • Chafe protection can be easily installed and replaced • No jacket ruptures • Easy inspection, repair, and splicing	• Higher content of Dyneema fiber increases cost
JACKETED ROPES	• High strength, low weight • Core completely protected by outer jacket • Firm, round profile • Potential for higher heat resistance on the cover • Typically less expensive	• Impossible to inspect core (strength member) • The cover will wear faster than core • Doesn't float • Jacket can rupture • Difficult to repair

TANKER MOORING LINE SAMSON AMSTEEL BLUE

- **Features and benefits:**
  - *Using Dyneema HMPE fibresSK78*
  - *Abrasion resistant*
  - *Easy to inspect and splice*
  - *Enhanced creep properties*
  - *Excellent wear characteristics*
  - *Extremely low stretch*
  - *Floats*
  - *Torque-free construction*
  - *UV stabilized*

ROPE DESIGN


100%
90%
80%
70%
60%
50%
40%
Blue
Loose
TCLL level, %
Weight
Abrasion Resistance

CONTEXT

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MOORING CHALLENGES

Uncertainty about when to retire lines

Safety risks associated with mooring lines

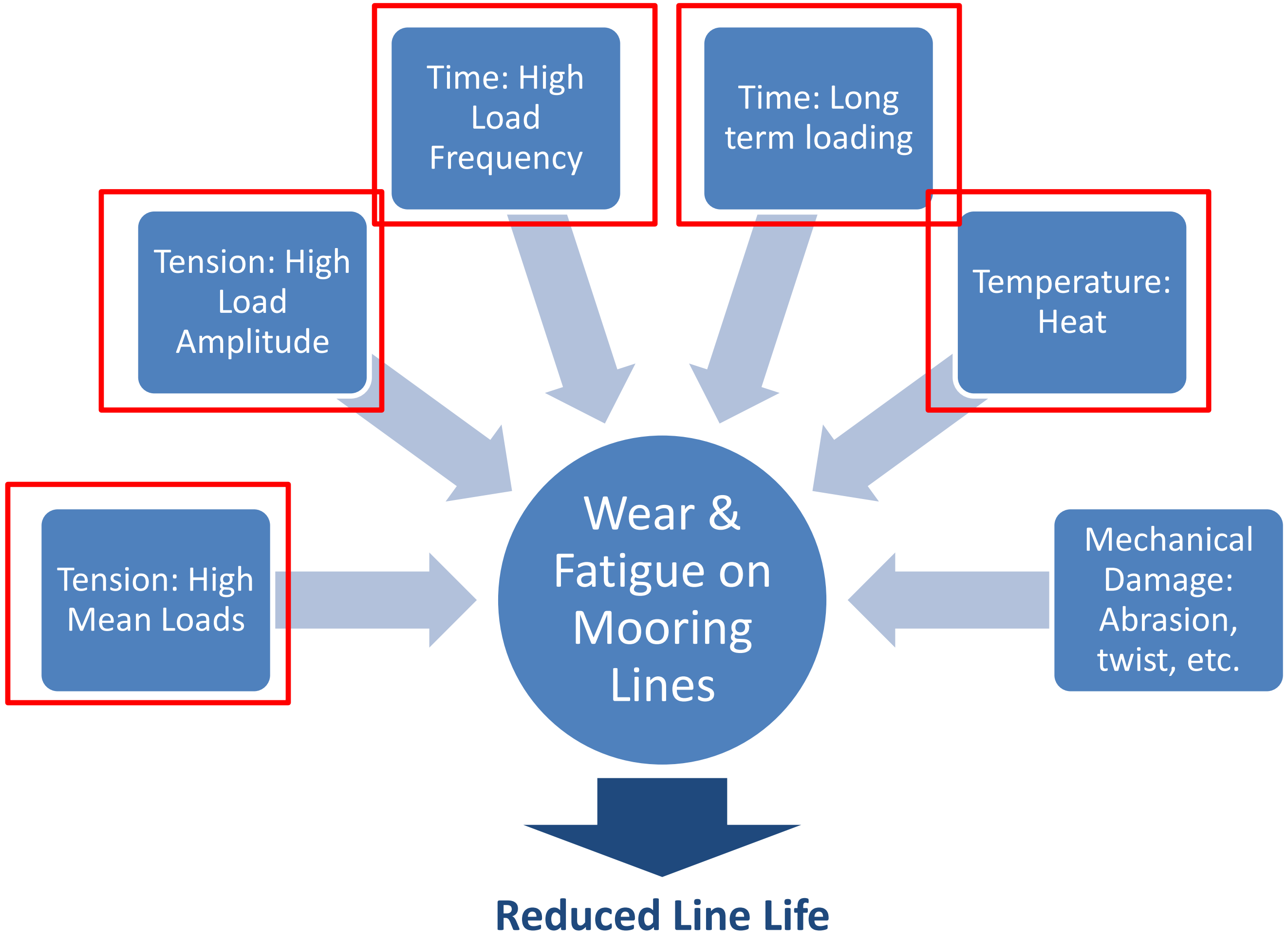
Evolving industry standards

Crew members without HMPE experience

Lack of infrastructure for best practice implementation

Lack of consistent comprehensive visibility to hardware and line condition

MOORING LINE WEAR MECHANISMS

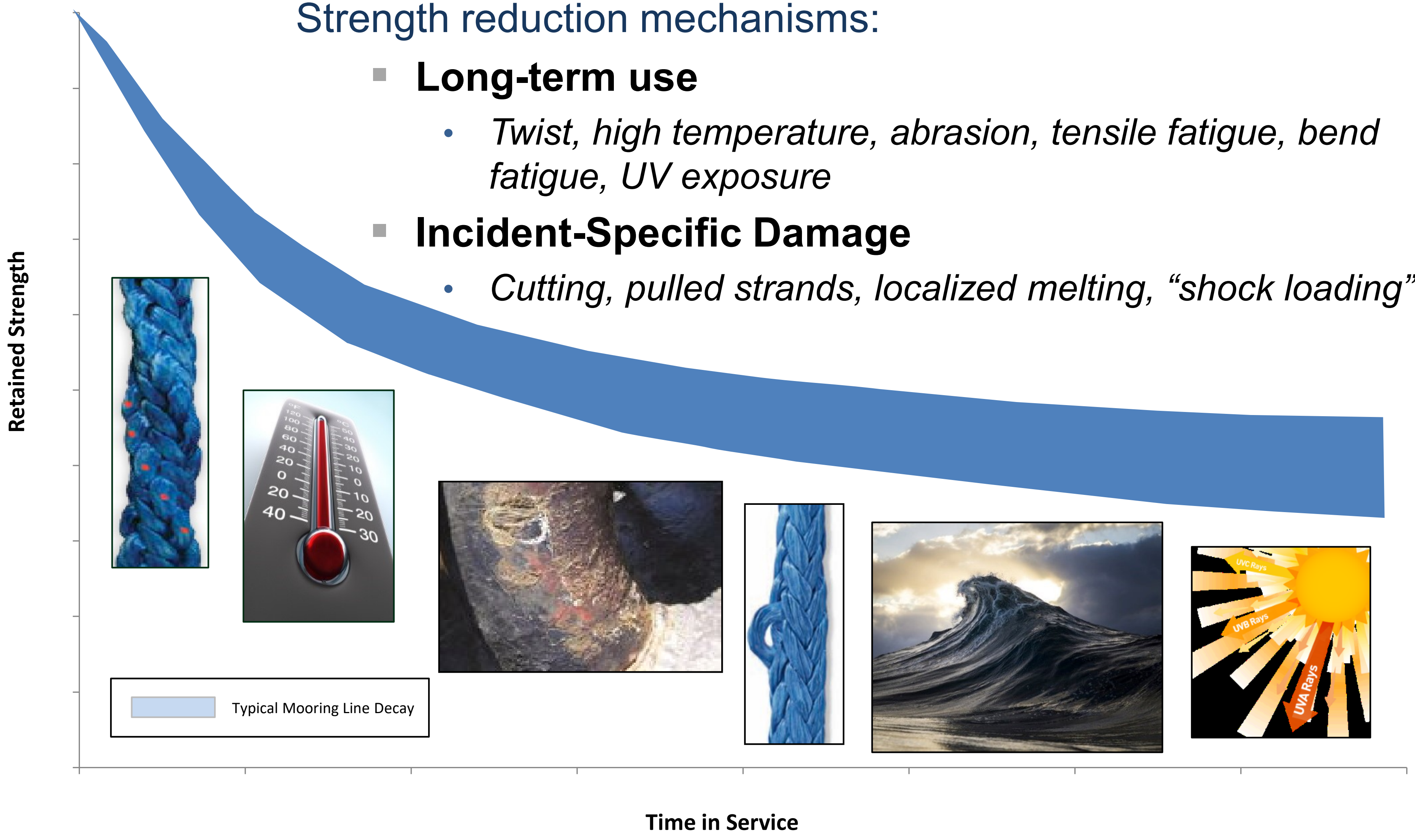


Mooring line damage is accelerated with high loads, high load frequency and high ambient temperatures.

LIFECYCLE

Strength reduction mechanisms:

- **Long-term use**
  - *Twist, high temperature, abrasion, tensile fatigue, bend fatigue, UV exposure*
- **Incident-Specific Damage**
  - *Cutting, pulled strands, localized melting, “shock loading”*



SHORT TERM WEAR MECHANISMS

Mechanical damage due to short term wear stems from:

Twisting

- Mishandling

Cutting

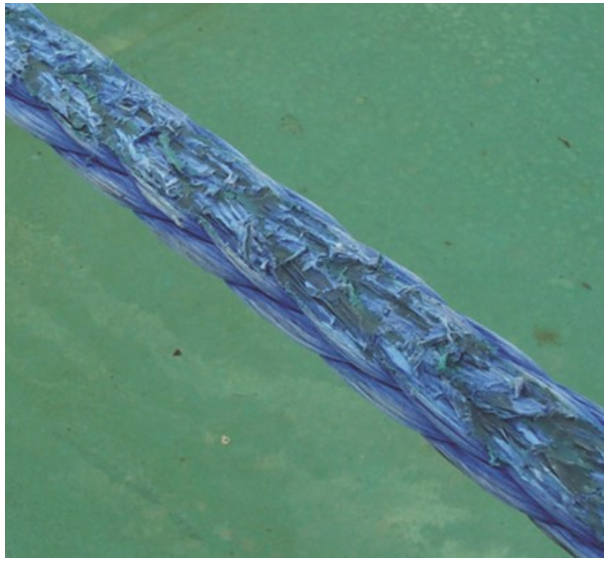
- Sharp hull contacts

Localized melting

- Slippage on tension drum

External Abrasion

- Rough deck hardware conditions



IMPROPER INSTALLATION

It is extremely important to install Samson's synthetic mooring lines with the recommended 45-90kgs of back tension.

If lines are not tensioned while being installed the risk of damaging the lines when high loads are experienced increases.

A minimum of 8 turns preferably 10 on working section of the winch

INSUFFICIENT WRAPS HAZZARD

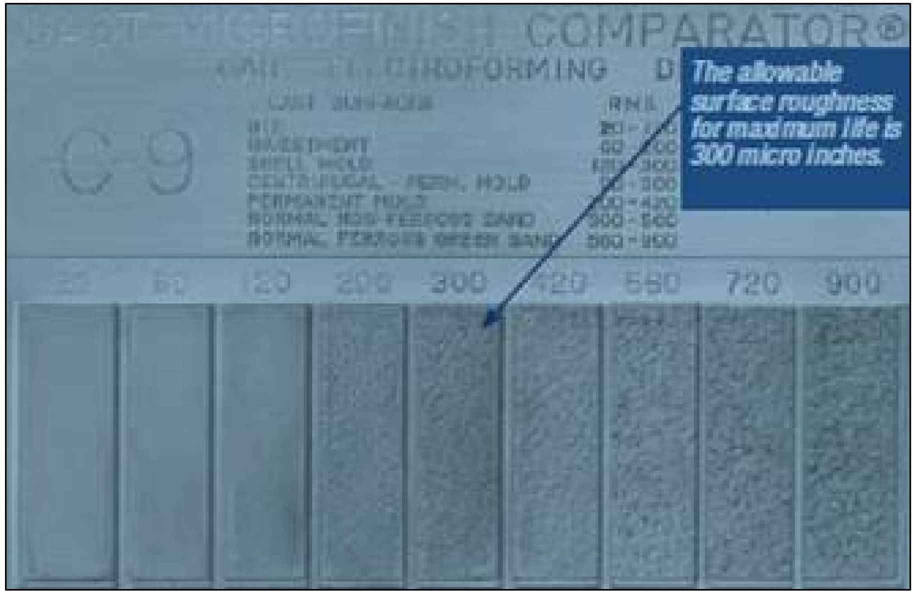
Insufficient wraps will lead to the ropes slipping on the drum.

- This will generate heat and damage the rope fibres.
- In severe cases, this damage will appear as a dark coloured, hard glazed area on the rope

INSTALL OR RE INSTALL WITH TENSION

INSTALLATION CONSIDERATIONS

- **Inspect all surfaces prior to installing new rope**
  - ***Rough cast surfaces / sharp machined edges***



- **Synthetic rope life decreases when contacting sharp edges / rough surfaces**
  - ***Maintain contact surface roughness less than 300 micro inch RMS***
  - ***Radius sharp edges to 2mm or greater***
  - ***Key Locations are:***
    - *Panama/Roller leads*
    - *Capstans*
    - *Inside of Winch flanges*
    - *Dividing plate*

DIVIDING PLATE

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When circumstances allow it, the retrofitting of the leading edge of the dividing plate profile should be 40-50 mm in diameter.

CHAFE PROTECTION

Sliding chafe gear (DC Moor-Gard)

- Coating designed for abrasion resistance and reduced friction
- Easily moved for inspection

Fixed chafe gear

- Tightly braided HMPE cover (DC Gard)
  - *Maximum protection, flexible*
  - *Must remove for inspection*

- Open-weave HMPE cover (Dynalene)
  - *Excellent durability, lightweight*
  - *Easy inspection*

100% HMPE solutions offer the highest protection against external abrasion

CHAFE GEAR

Samson DC Moorgard Chafe gear should be utilized during the installation to avoid heat or abrasion in the leads.

AVOID POOR MAINTAINED CHAFE SLEEVE

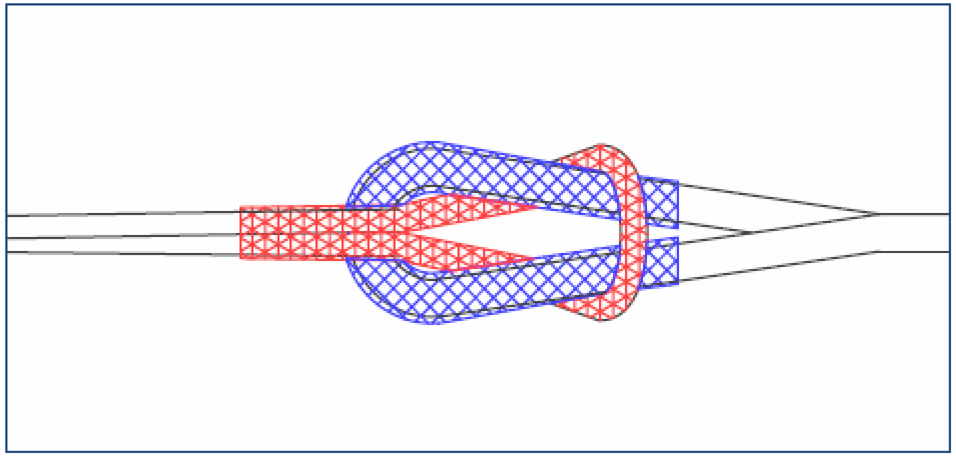
TWIST

If a 3-strand messenger line is used during the installation, there is a high probability that the twist from the 3-strand will transfer into the torque neutral 12-stand Samson line.

Samson's 12-strand lines are torque neutral, twist that is induced into the constructions will actually temporarily decrease the strength. At 3 twist per meter, the strength is decreased by 10%. If twist is induced during installation, **remove** before berthing.

DECK EQUIPMENT MAINTENANCE

CONNECTION MECHANISM



A Cow-Hitch should be utilized when connecting the mooring mainline to the mooring tail.

It is recommended to use smaller diameter synthetic lines in-between the eyes of the mainline and tail. This will dramatically help when it comes time to separate the two.

ROPE MANAGEMENT

ROPE MANAGEMENT PLAN

Line installation

Defined maintenance inspection schedule

Wear Zone Management mitigation of risks associated with localized damage;

- Hardware maintenance
- Line rotation, outboard cropping, swap used end with un-used end, line end-for-end, remove damaged mainline sections

Expected service life & retirement define discard/repair criteria

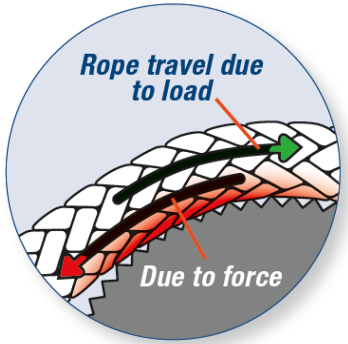
- Data-driven decisions adjust based on data

ROPE WEAR MECHANISMS

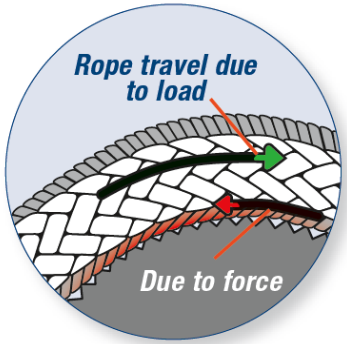
Internal abrasion is a degradation of the internal yarns of the rope caused by fiber-to-fiber interactions.

Two main causes:

- **Cyclic tensile loading**
  - *Induced by wave interactions*
- **Cyclic bending**
  - *Induced by non-linear requirements and deck hardware*



Without Chafe Gear



Without Chafe Gear

ROPE MAINTENANCE PLAN

User-defined service life expectations

End-of-life retained strength / FoS (target)

- Supported by residual strength test data

Planned maintenance schedule

- Routine inspections (crew)
- Detailed inspections (expert)

Mitigation of risks associated with localized damage;

- Swap used end with un-used end (End-for-end)
- Remove damaged mainline sections (Cropping)
- Line rotation with detailed line tracking
- Define discard/repair criteria

CYCLIC BEND FATIGUE

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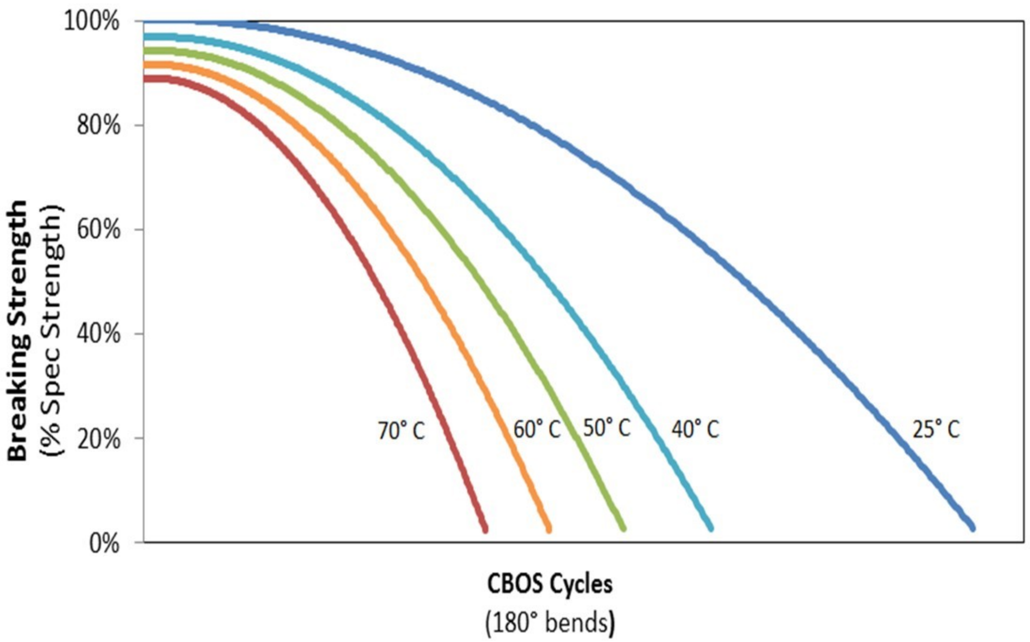
Cyclic bend fatigue combines external and internal abrasion, and can also generate temperatures capable of damaging fibers

- **Best practices to mitigate impact:**
  - ***Maximize D/d ratios***
  - ***Select appropriate fibers, coatings, rope constructions, and safety factors***

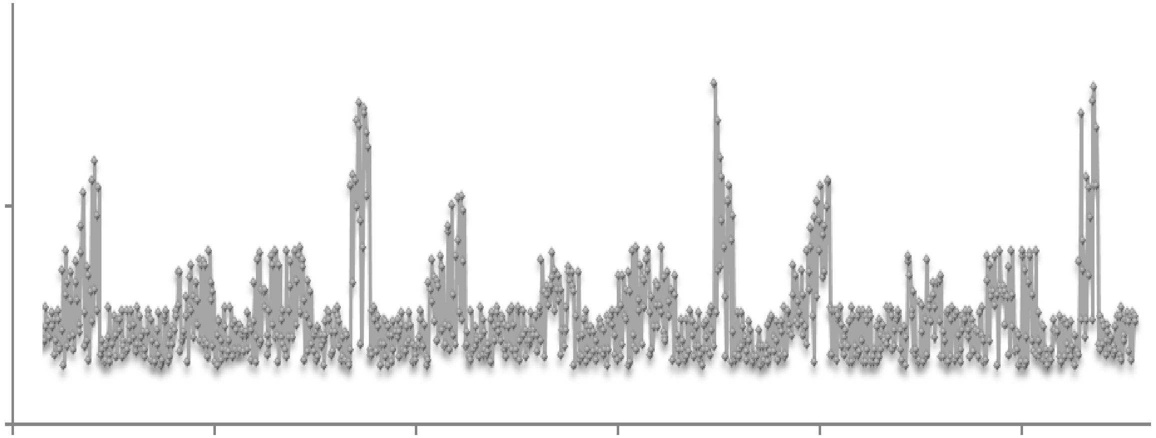


LONG TERM WEAR MECHANISMS

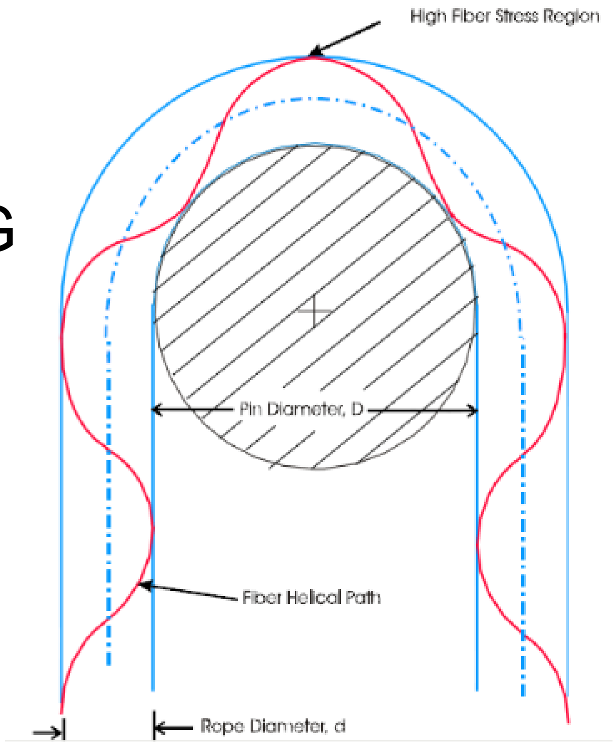
Long term wear characterized as rope fatigue.

Primarily due to swell/wave/wind induced motions and interaction with deck fittings:

CYCLIC TENSILE LOADING



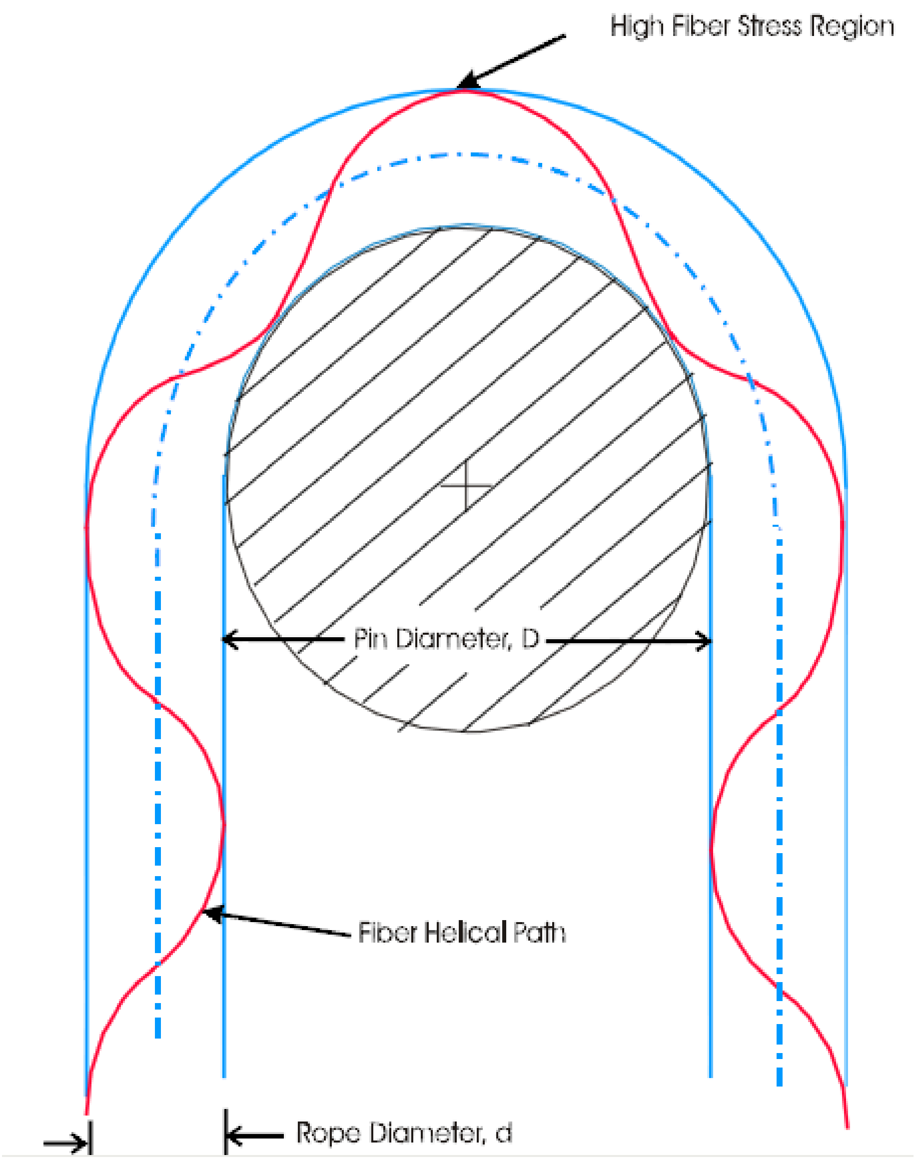
CYCLIC BENDING



LONG TERM WEAR MECHANISMS

Cyclic bending

- Damage caused by
  - *Abrasion between hardware and rope*
  - *Higher load on outer strands*
- Hardware diameter
  - *Minimum D/d ratios (hardware/rope)*
  - *Increasing diameter not always feasible*
- Rope construction impacts
  - *Instantaneous strength*
  - *Wear characteristics*

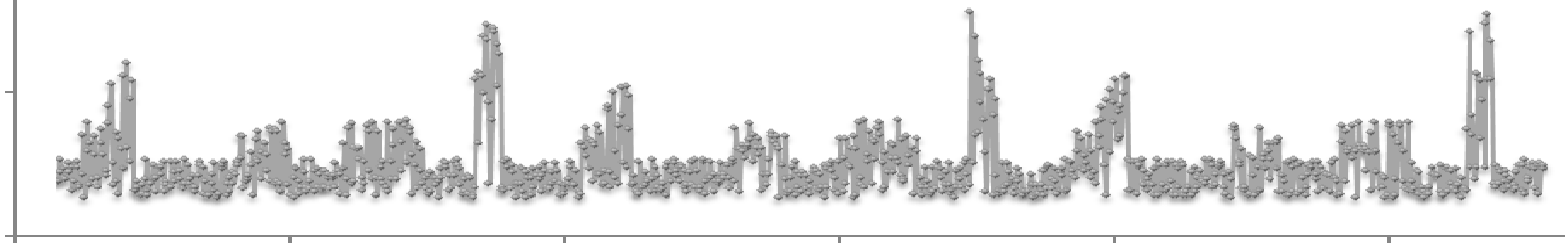


LONG TERM WEAR MECHANISMS

Cyclic Tensile Loading

- Damage caused by
  - *Motion between yarns and strands*
  - *Heating resulting from load / unload cycles*
- Tension fatigue - Cycled at 50% of rope MBL:
  - *Dyneema has 1500 times longer cycle life versus wire*
  - *Dyneema has 10 times longer cycle life versus aramid*

LINE LOAD OVER TIME



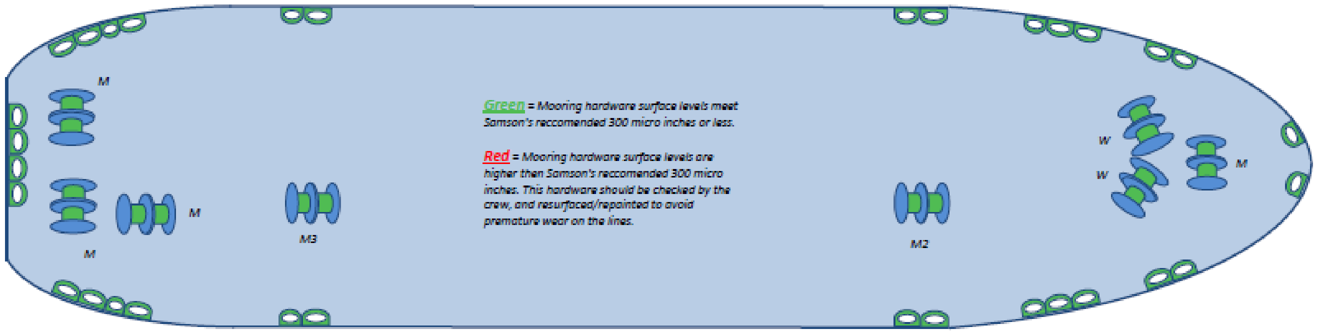
INSPECTION TOOLS

THE STRONGEST NAME IN ROPE

Mooring Line Installation Report
October 24th, 2016

THE STRONGEST NAME IN ROPE

Winch Drum Capacity	9 Wraps	Connection Method	U-Bolt	Winch Drum Setting	67.2MT	Winch Break Setting	50.4MT	Chock Type	Closed/Panama

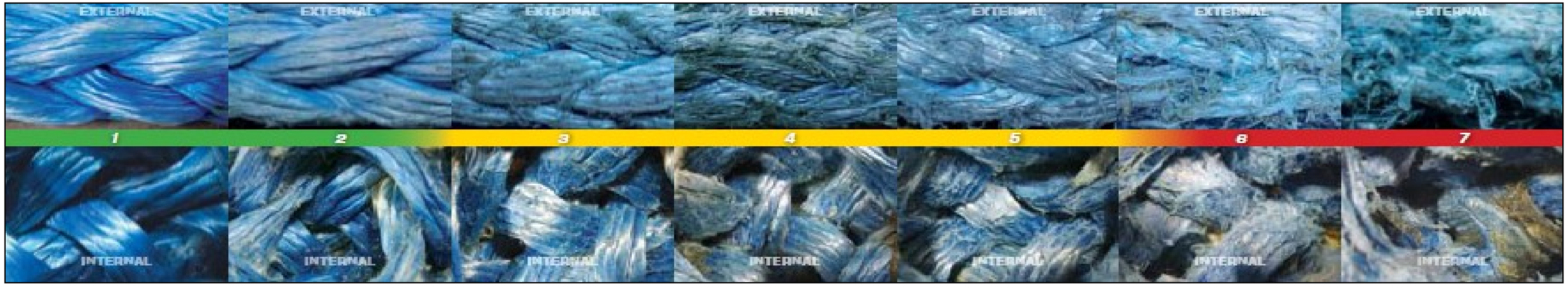


Certificate Number	X35251	Mainline Specfacation	1-5/16" AS-78 722'	Pendant Specfacation	Non Samson	Chafe Gear Specfaction	10' DC Moor-Gard

Line Information				Zone 1 - Chock/Fairlead Hardware Contact Points						Zone 2 - Working Side Winch Drum						Misc.	
Certificate Number	Total Mooring Hours	Line Position	Winch #	External Abrasion Rating (1)	Internal Abrasion Rating (1)	Length of Abrasion (1)	Distance from Outboard Eye (1)	Cut Yarn Severity (1)	Length of Glazing (1)	External Abrasion Rating (2)	Internal Abrasion Rating (2)	Length Of Abrasion (2)	Distance from Outboard Eye (2)	Cut Yarn Severity (2)	Length of Glazing (2)	Twist Severity	Chafe Gear Hole Count
D35251-1-14	0	Spare	AFT Spare	1	1	N/A	N/A	N/A	N/A	1	1	N/A	N/A	N/A	N/A	N/A	N/A
D35251-1-15	0	Spare	AFT Spare	1	1	N/A	N/A	N/A	N/A	1	1	N/A	N/A	N/A	N/A	N/A	N/A
D35251-1-7	0	Spare	FWD Spare	1	1	N/A	N/A	N/A	N/A	1	1	N/A	N/A	N/A	N/A	N/A	N/A
D35251-1-8	0	Spare	FWD Spare	1	1	N/A	N/A	N/A	N/A	1	1	N/A	N/A	N/A	N/A	N/A	N/A
D35251-1-12	0	Head	M1P	1	1	N/A	N/A	N/A	N/A	1	1	N/A	N/A	N/A	N/A	N/A	N/A
D35251-1-16	0	Head	M1S	1	1	N/A	N/A	N/A	N/A	1	1	N/A	N/A	N/A	N/A	N/A	N/A
D35251-1-18	0	FWD Spring	M2A	1	1	N/A	N/A	N/A	N/A	1	1	N/A	N/A	N/A	N/A	N/A	N/A
D35251-1-19	0	FWD Spring	M2F	1	1	N/A	N/A	N/A	N/A	1	1	N/A	N/A	N/A	N/A	N/A	N/A
D35251-1-9	0	AFT Spring	M3?	1	1	N/A	N/A	N/A	N/A	1	1	N/A	N/A	N/A	N/A	N/A	N/A
D35251-1-10	0	AFT Spring	M3?	1	1	N/A	N/A	N/A	N/A	1	1	N/A	N/A	N/A	N/A	N/A	N/A
D35251-1-5	0	AFT Spring	M4A	1	1	N/A	N/A	N/A	N/A	1	1	N/A	N/A	N/A	N/A	N/A	N/A
D35251-1-20	0	AFT Spring	M4F	1	1	N/A	N/A	N/A	N/A	1	1	N/A	N/A	N/A	N/A	N/A	N/A
D35251-1-2	0	AFT Breast	M6P	1	1	N/A	N/A	N/A	N/A	1	1	N/A	N/A	N/A	N/A	N/A	N/A
D35251-1-3	0	AFT Breast	M6S	1	1	N/A	N/A	N/A	N/A	1	1	N/A	N/A	N/A	N/A	N/A	N/A
D35251-1-6	0	AFT Breast	M7P	1	1	N/A	N/A	N/A	N/A	1	1	N/A	N/A	N/A	N/A	N/A	N/A
D35251-1-17	0	AFT Breast	M7S	1	1	N/A	N/A	N/A	N/A	1	1	N/A	N/A	N/A	N/A	N/A	N/A
D35251-1-11	0	FWD Breast	W1P	1	1	N/A	N/A	N/A	N/A	1	1	N/A	N/A	N/A	N/A	N/A	N/A
D35251-1-13	0	FWD Breast	W1S	1	1	N/A	N/A	N/A	N/A	1	1	N/A	N/A	N/A	N/A	N/A	N/A
D35251-1-4	0	FWD Breast	W2P	1	1	N/A	N/A	N/A	N/A	1	1	N/A	N/A	N/A	N/A	N/A	N/A
D35251-1-1	0	FWD Breast	W2S	1	1	N/A	N/A	N/A	N/A	1	1	N/A	N/A	N/A	N/A	N/A	N/A

2090 Thornton Street | Ferndale, WA 98248 USA
Tel +1.360.384.4669 | Fax +1.360.384.0572 | www.samsonrope.com

ABRASION MEASUREMENT



- **Visual comparison guide**
  - ***1 million+ individual filaments per rope***
  - ***Operator can effectively rate level of rope wear***
- **Retirement or required action to be determined by qualified person based on the following:**
  - ***Internal/External abrasion level (higher than 3)***
  - ***Excessive twist in braided rope (greater than 2 turns/meter)***
  - ***Gross damage or deterioration of the end connections***

The Pocket Guide includes information on proper rope inspection techniques and a visual guide to internal and external abrasion

INSPECTION & RETIREMENT

EYE TAGS

Eye tags are found secured on both the inboard and outboard eyes of the line.

Certificate number found here should be documented along with winch number.

Product Type

Specifications

Break Strength

Manufacture date

Details

The certificate number should be documented with corresponding winch numbers during the installation for tracking purposes.

REMOTE INSPECTIONS

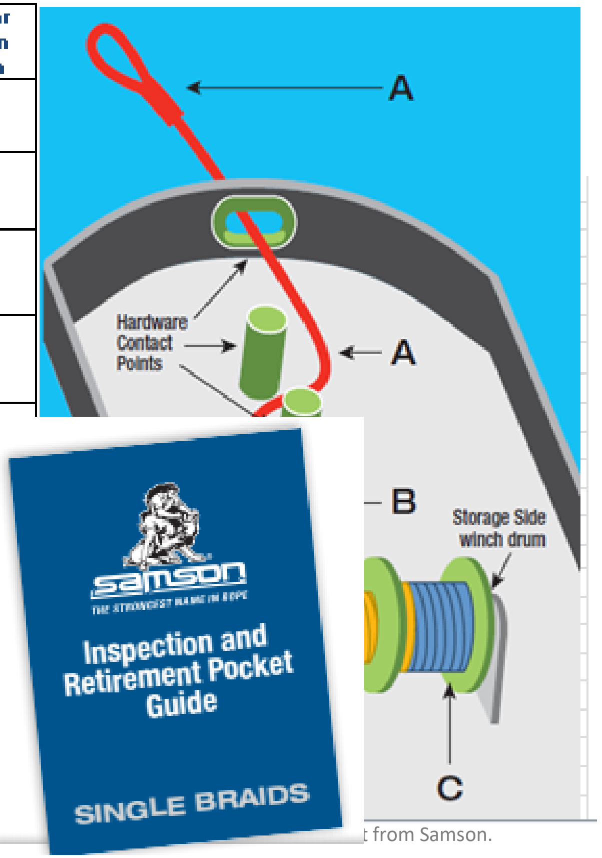
- *Crew-performed inspections with data managed by Samson and reports accessed through Partner Portal*

Mooring Line Inpsection Sheet

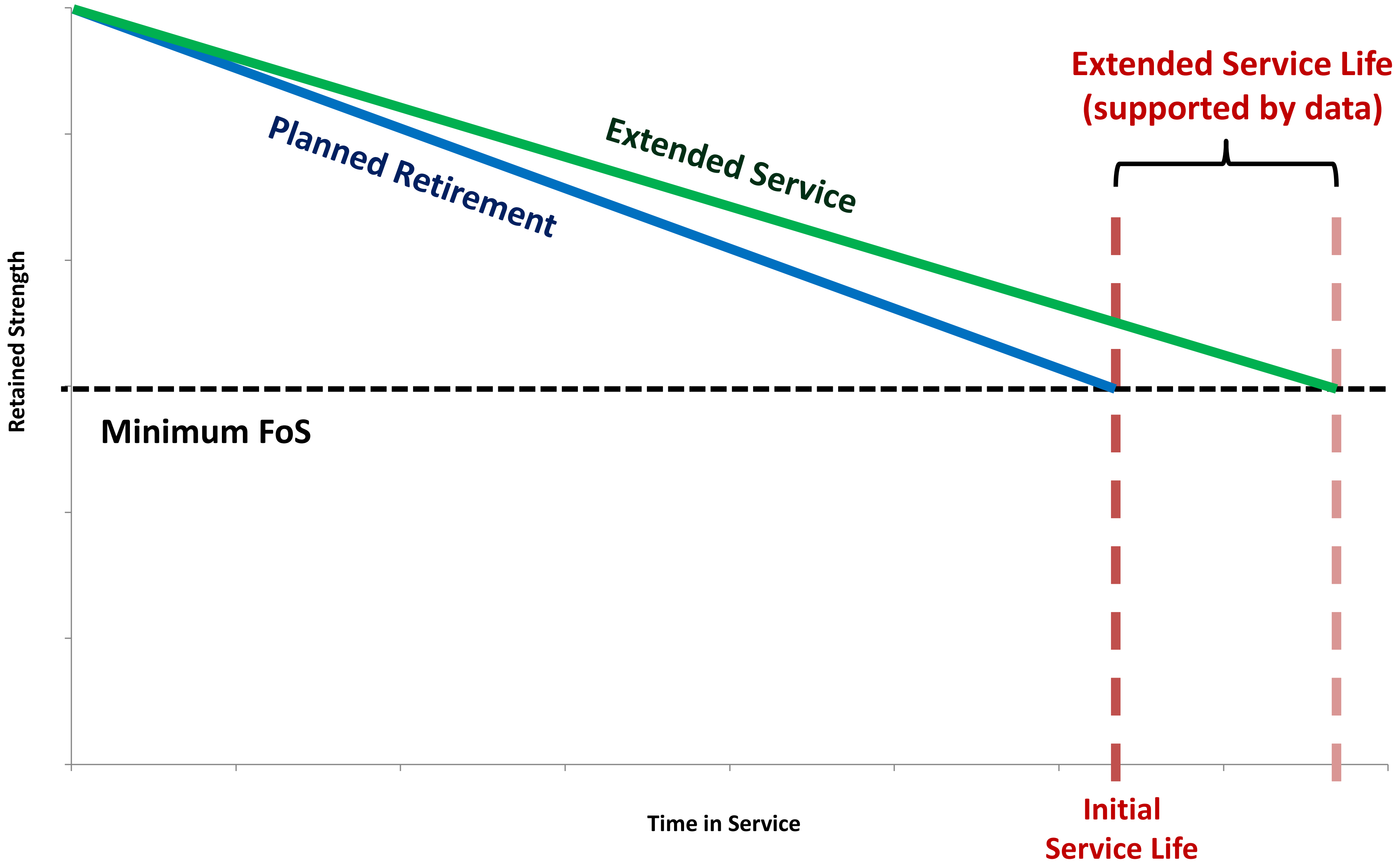
Date:	
Conducted By:	
Vessel Name:	

Contact Samson:	X/Red

Certificate Number	Winch Number	Section	External Abrasi	Internal Abrasion Rating	Cut Yarns? (Y/N)	How many cut yarns in	Melted/Glazed strands?	Twist	# Wraps on	Chafe Gear Protection Condition
	1	Section A								
		Section B								
		Section C								
	2	Section A								
		Section B								
		Section C								
	3	Section A								
		Section B								
		Section C								
	4	Section A								
		Section B								
		Section C								
	5	Section A								
		Section B								
		Section C								
	6	Section A								
		Section B								
		Section C								
	7	Section A								
		Section B								
		Section C								
	8	Section A								
		Section B								
		Section C								
	9	Section A								
		Section B								
		Section C								



LINE POLICY MANAGEMENT



MEG 4 PUBLISHED Q2 – WHAT DOES IT MEAN ?

MEG4 – KEY CHANGES

- ***Testing***
  - *MEG 4 - Standardised tests for key parameters that define the capability of mooring lines (not specified in MEG3)*
  - *Standardised Forms for presenting / sharing product performance (tests)*
  - *Tests proposed include;*
    - Break Force (standardized)
    - Angled Break Force and Angled Endurance (to account for D/d influence)
    - Linear Density & Load Bearing Linear Density (to account for material content / fatigue)
    - Tension-Tension Fatigue (separately for tails)
    - Yarn temperature performance
    - Axial Compressions Fatigue
- ***Line design terminology:***
  - Ship's Design MBL → LDBF → WLL
- ***Line Management Plan***
  - based on holistic Maintenance, Inspection & Retirement principles
- ***Improved guidance on lines, tails, connectors & related test parameters***

MOORING LINE LIFE CYCLE

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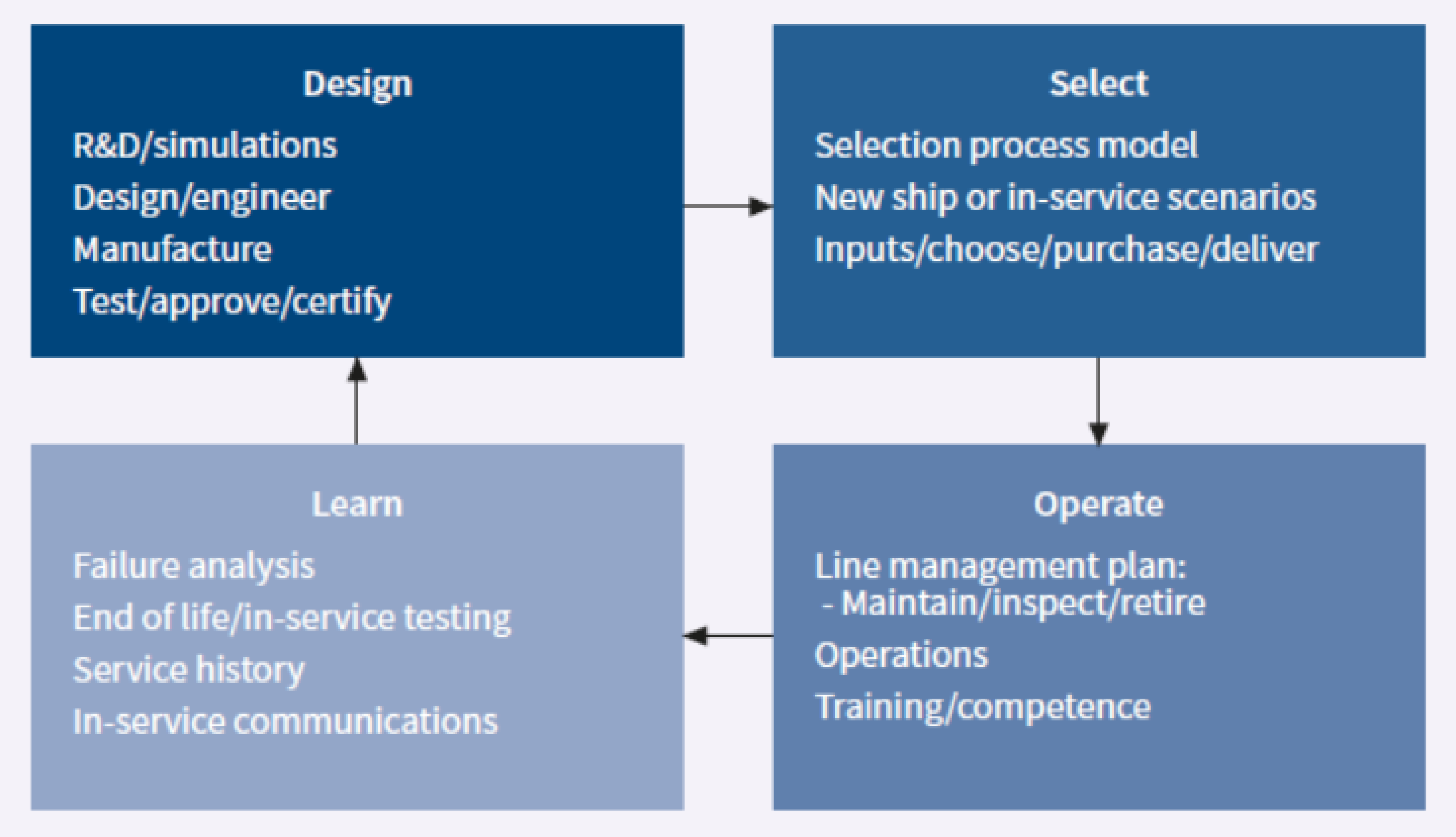


MOORING TAILS

Tail Strengths

- [125% MBLsd] ≤ TDBF ≤ [30% MBLsd]
- Benchmarking to MBLsd removes challenges of matching differing line strengths
- Nylon tails tested/specified as wet strength - all tail materials have single design value to simplify procurement

Cowhitch

- Removal of quantified strength loss from MEG3
- Loss is accounted for in system design / tail over-strength
- Language added for grommet tails to raise awareness

Service Life

- 18 month language removed
- Users encouraged to utilize data to drive or refine service life expectations (Line Management Plan framework)

MEG4 – KEY CHANGES

- **Systemic and holistic approach to Mooring**
- **Mooring Management Plan (MMP)**
  - ***Part A – General Vessel Particulars***
  - ***Part B – Mooring Equipment Design Philosophy***
  - ***Part C – Detailed List of Mooring Equipment:***
  - ***Part D – Inspection, Maintenance and Retirement Strategies***
  - ***Part E – Mooring Hazard Management, Safety of Personnel and Human Factors***
  - ***Part F – Records and Documentation***
  - ***Part G – Mooring Equipment Passport (MEP)***
- **Closer alignment with IACS and ISO on equip. design requirements**
- **Remove conflicts/ambiguity with definitions and terminology**
- **Long term horizon – beyond MEG 4:**
  - ***OCIMF.com/MEG4;***
  - ***Committee of International Rope Testing Standards (CIRTS) - EC and CI consistency and possible development of Mooring Rope Simulation Test;***
  - ***Condition Monitoring Technologies***

SUMMARY OF CHANGES

Mooring line life cycle

System Design Terminology

- Clarification of strength **requirements** vs equipment **specifications**

Mooring line specification & selection (Appendix B)

- Clear framework for **testing** & **reporting**

Deck equipment size & compatibility

- Improve awareness of impacts of bends (designers **and** operators)

Mooring line life cycle management:

- Line Management Plan
- Record Keeping & Certificates

FOR INFO. FSRU – ONLY SAMSON HAVE FIBRE EXPERIENCE IN MOORING

WHY *EVERSTEEL-X*?

Creep can contribute to line failure in long term loading scenarios.

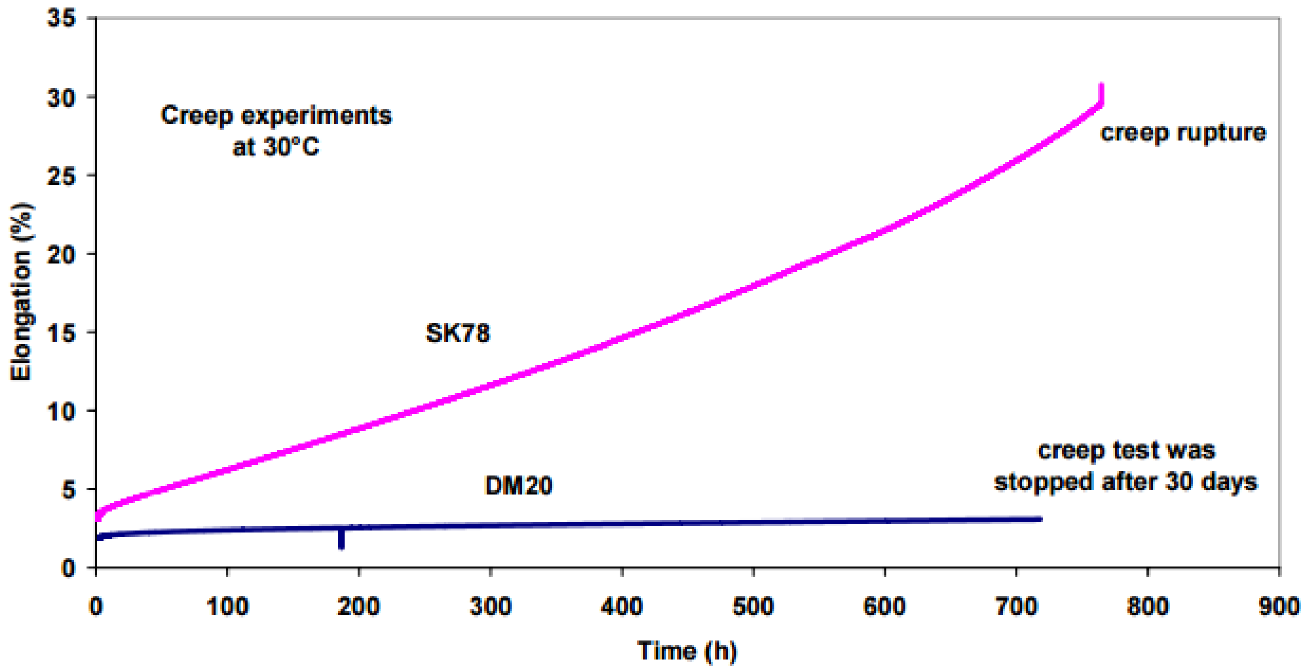


Figure 6 Creep elongation of 29 mm rope with DM20 and SK78 at 30°C

- Creep rupture occurs when a rope is under load for a long time (i.e. rope breaks).
- Creep elongation can be troublesome if precise length is needed in rope (i.e. rope grows in length)
- **EverSteel-X* contains DM20 fiber

EverSteel-X has superior creep performance making long term loading manageable and reduced likelihood of creep like failures.

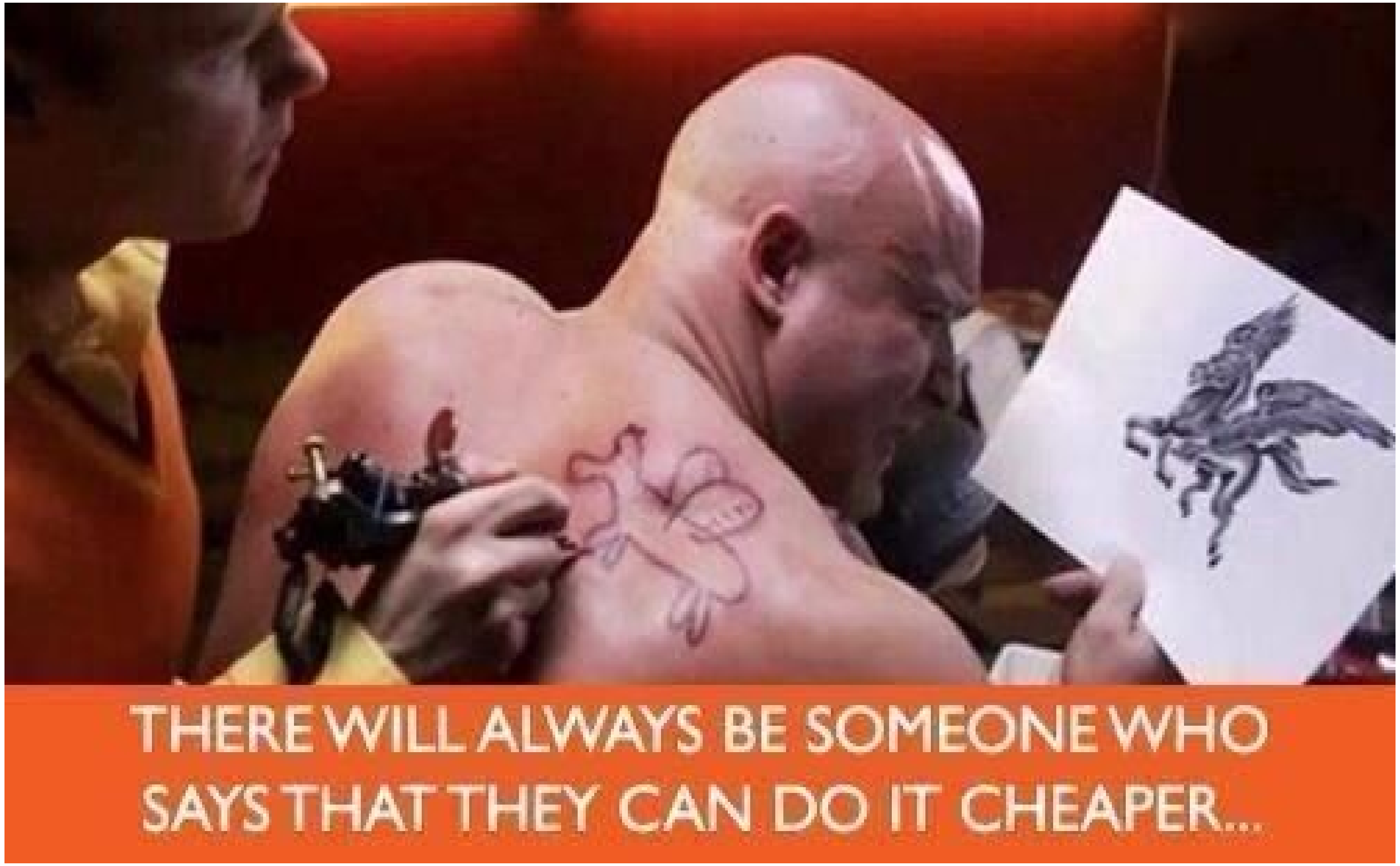
WITH Dyneema®

FOR INFO. VULCAN ETOPS

- Worlds only Fibre ETOP
- Patented design
- Nominated for Seatrade award 2015
- 60- 70% lighter than wire
- Easier to deploy and store
- Reduced injury risk
- Maintenance free

SUMMARY

1. Be aware of product selected for Mooring
2. Short term and long term wear mechanisms
3. Robust Rope Management plan
4. Consider adoption of Icaria
5. MEG 4 is coming


THERE WILL ALWAYS BE SOMEONE WHO
SAYS THAT THEY CAN DO IT CHEAPER...

THANK YOU FOR KEEPING AWAKE!

Contact details:

rcollett@samsonrope.com