The Use of

Synthetic Tension Members

per Appendix A of the UNOLS
Research Vessel Safety Standard

January 17, 2024

UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

NSF

Topics to be presented

- Definitions
- How does UNOLS wire rope experience shape the use of synthetics?
- How do others use synthetics?
- What does Appendix A say about synthetics?
  - How can we safely get the most from the synthetics?
  - What are the testing requirements?
  - What to look for during visual inspection.

UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

NSF

Definition

$$\text{Factor of Safety} = \frac{\text{Maximum stress a material can withstand}}{\text{Maximum stress planned during use}}$$

Tension members such as wire rope, cable or synthetic

$$= \frac{\text{Breaking Strength}}{\text{Estimated Load on the tension member during use}}$$

For Example: 9/16” Wire Rope

Coring operation w/ anticipated total pullout load of 20,000 lbs.

$$\text{Factor of Safety} = \frac{32{,}500}{20{,}000} = 1.6$$

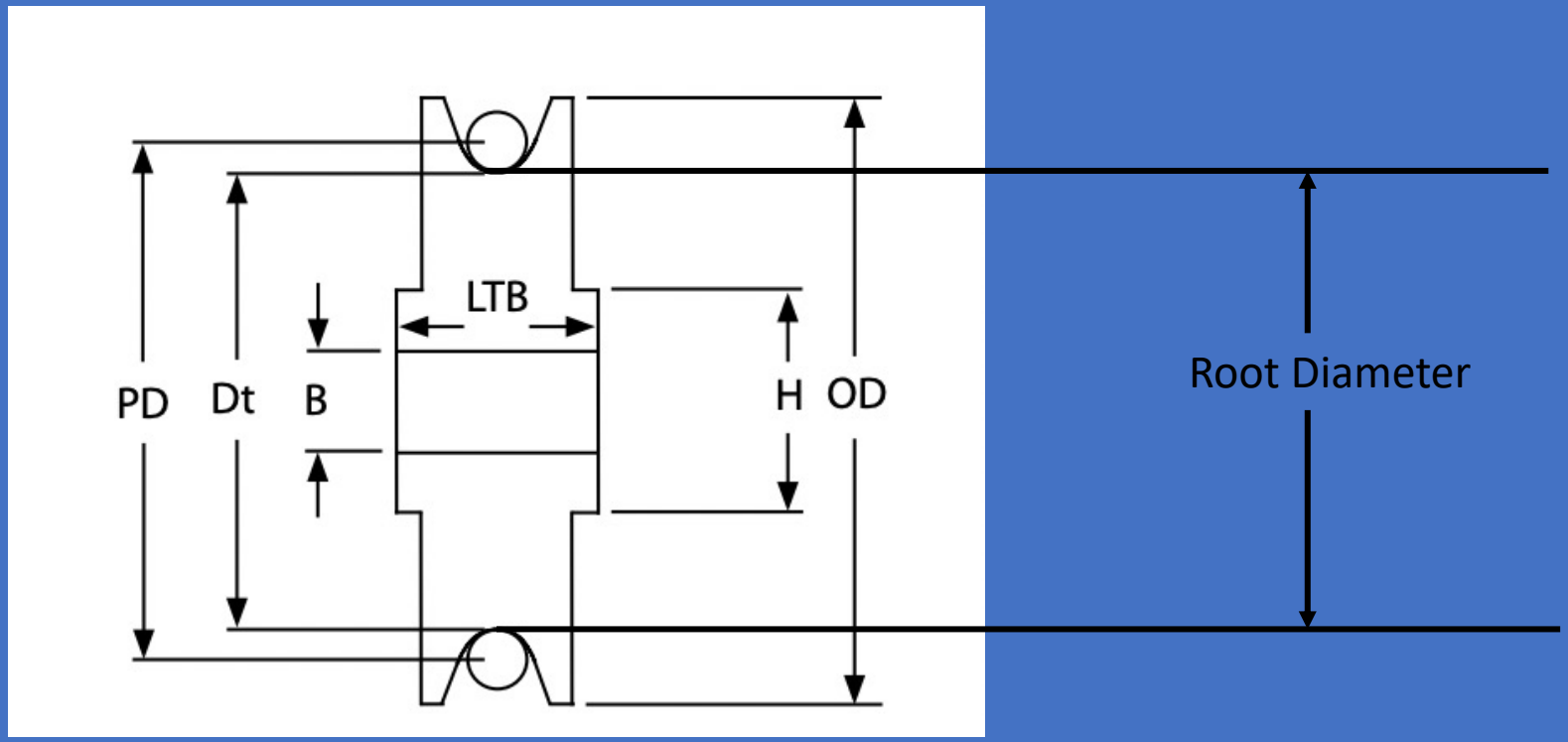
UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

NSF

Definition

D/d

Root Diameter of a sheave
Outside diameter of the tension member



UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

NSF

Definition

Sheave Groove Diameter

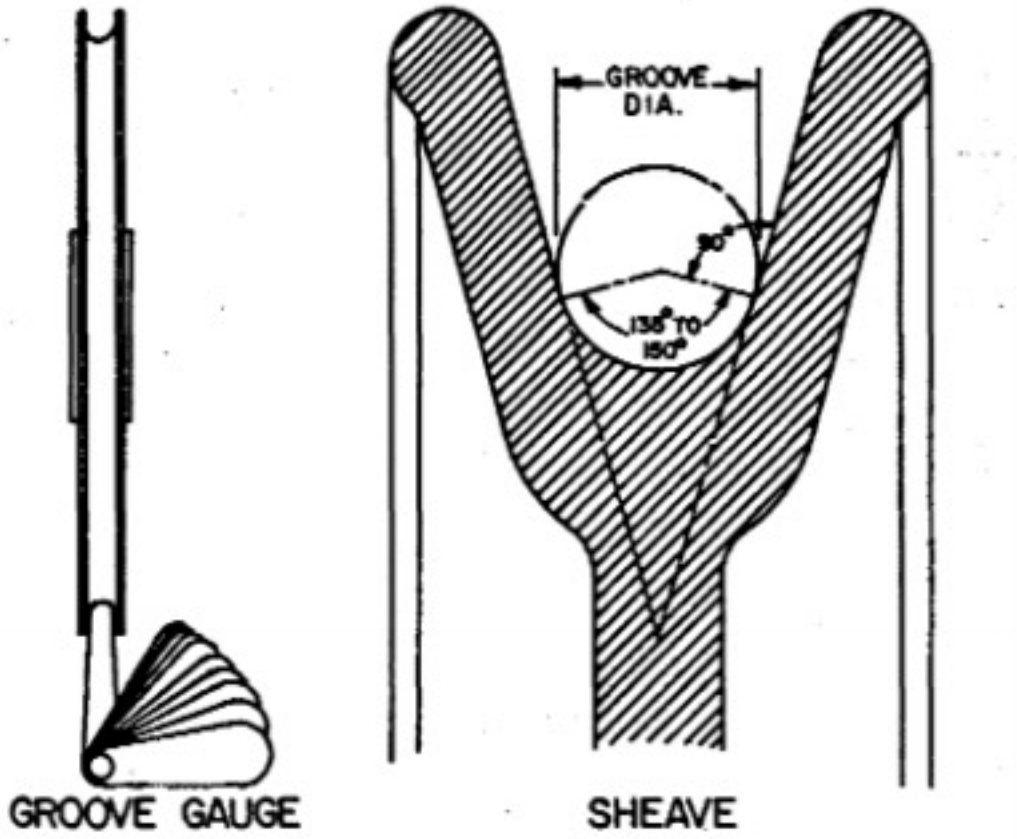


FIGURE 1-16

SHEAVE GROOVE DIMENSIONS

UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

NSF

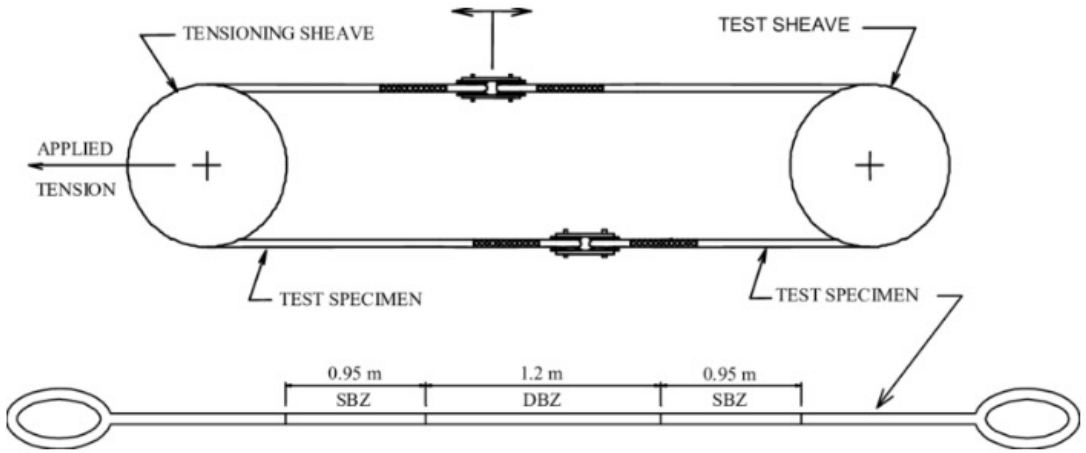
Cyclic Bend over Sheave Tests of Wire Rope

Wire Rope manufactured by WireCo

Load = Factor of Safety of 2.5

D/d of test sheaves = 30

Wire Rope Size	Bend Cycles to Failure
¼”	4460
3/8”	5008
½”	3964
9/16”	5242



Cyclic Bend-over-Sheave (CBOS) Fatigue Test Schematic

Source: Performance Tests of 3x19 Wire Ropes, Report No. FR-2967 by S. Kelley, F. Lee, P.T. Gibson (TMT Laboratories)

UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

NSF

Impact of Sheave Size on Rope Service Life

D/d = 30 to D/d = 40 66% increase in the bend service life of the rope

3/8” wire rope: 11.25” to 15” diameter

Appendix A: Sheave diameter (D) for any specific steel tension member is either 40d or 400 d1 which ever is greater

Wire rope used by the ARF uses 400d1 for Sheave Diameters

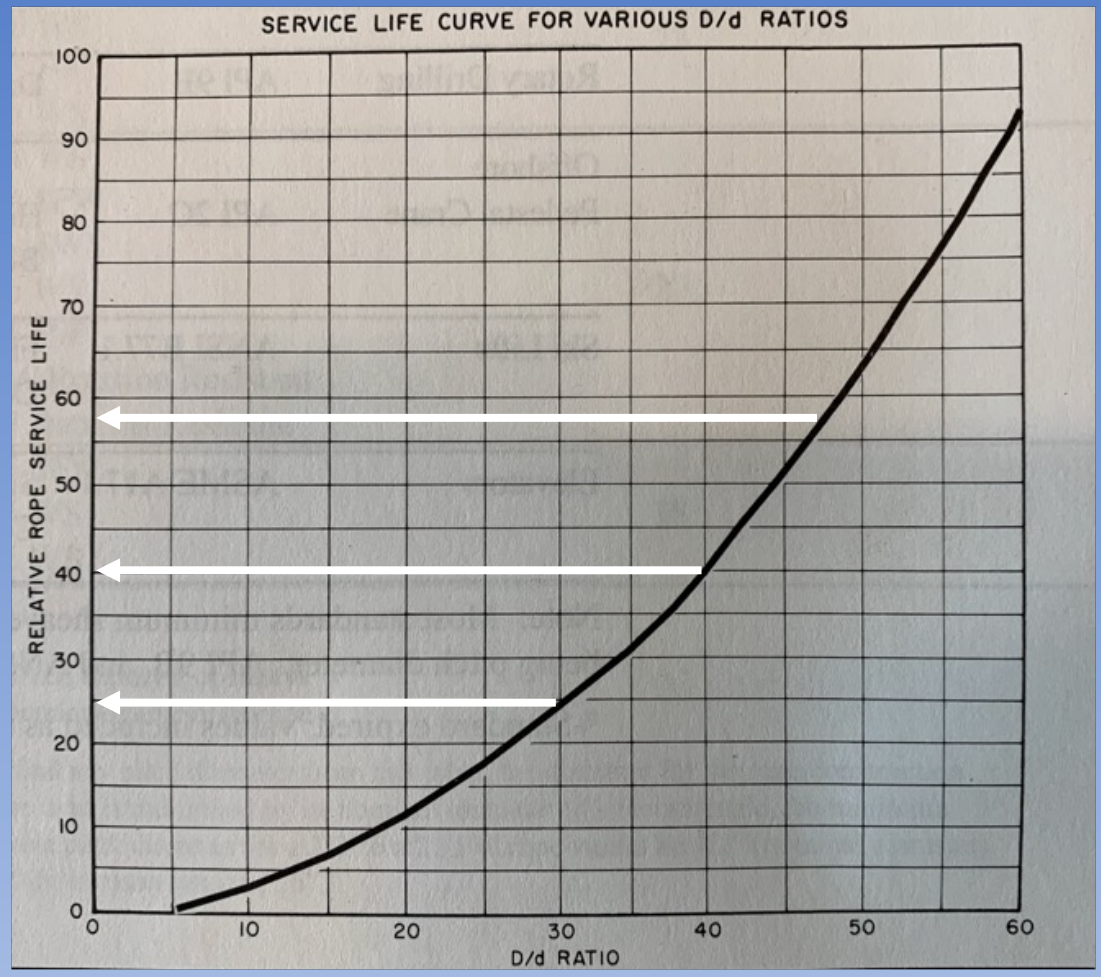
¼” 12” diameter sheave, D/d=48

3/8”, 18” diameter sheave, D/d = 48

½”, 23” diameter sheave, D/d = 46

9/16”, 26” diameter sheave, D/d=46

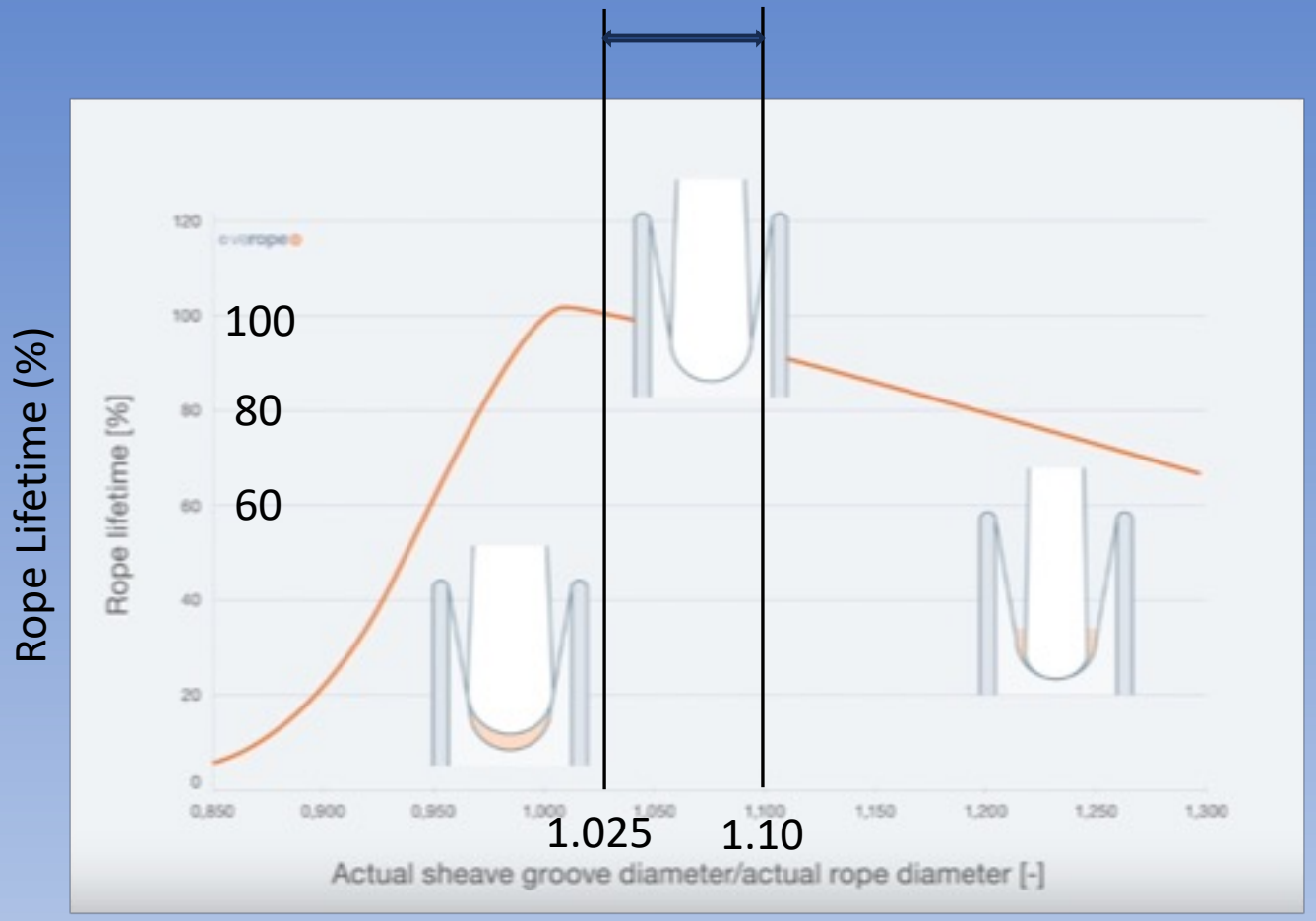
Doubles the service life compared to D/d=30



Source: Wire Rope Users Manual, 4th Edition, Wire Rope Technical Board

d1 for wire rope is the largest diameter of the outer wires

Impact of Groove Diameter On Rope Life



Sheave groove diameter
Rope diameter

UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

NSF

Wire Rope

Attention to the Factor of Safety and the Loading

Little to no consideration given to previous operations*. The log is updated but we don't worry to any great extent about its history. Maybe we should but decades of experience has been our guide.

Synthetic Rope

Very limited experience

Every time the rope passes over a sheave under load there is a small increment of damage. The damage is accumulative, from deployment to deployment, cruise to cruise.

How much damage has accumulated and how much is too much?

Accurate use logs and visual inspection are critical elements for assessing current rope condition and determining suitability for the next proposed operation.

* Unless there was obvious damage

UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

NSF

Disregarding environmental influences and handling:

ROPE LIFE

1. Sheave Diameter
2. Number of sheaves needed to overboard
3. Loading (Factor of safety)

UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

NSF

Institution	Vessel	Synthetic Material	Dia. (in)	Dia. (mm)	Factor of safety
Royal Netherlands Institute for Sea Research (NIOZ)	RV Anna Weber-van Bosse (under const.)	Dyneema	1.10	28	5
Univ. of Hamburg	R/V Meteor R/V Maria Merian	Aramid Technora	.315 .315	8 8	3.6- 4 4
Institute of Marine Research and Univ. Bergen Norway	R/V G.O Sars	DynaLight Dyneema	.945 .866	24 22	4.4 4
NOC Southampton, England	RRS Discovery RRS James Cook	Plasma	.875	22	2.0* (Lloyd's Registry Dispensation) Cable/Line monitoring sys.
Foss Maritime	Tug Rachael Allen	Plasma	3.	76	4-5

UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

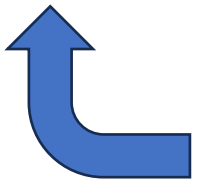
NSF

Synthetic Tension Members

Determining appropriate factors of safety (Appendix A, Section A.8.3.1)

A factor of safety of 5.0 or greater and D/d ratio = 40 is required along with the provisions detailed in Table A.8.5.

With adequate tension member history, details of the proposed operation and over-boarding configuration and anticipated loading the manufacturer can be consulted to determine if a lower factor of safety can be safely used during the proposed operation.



PLAN ACCORDINGLY!

THIS TAKES A LOT OF TIME

UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

NSF

Actual Request for Synthetic Rope

- R/V Neil Armstrong Coring Cruise
- Puerto Rico Trench, 8000 m + water depth
- Core head, barrels and couplers, trigger core and arm = 7500 lbs.
- Pullout for cores 7500 to 10,000 lbs. or greater
- Total anticipated loads 15,000 to 17,500 lbs.
- 9/16” diameter Plasma HiCo line, 37,900 lbs. minimum tensile strength

Working with a Factor of Safety of 5 would limit the Safe Working Load to 7580 lbs.

UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

NSF

Life Factor

Manufacturer uses an expression called Life Factor to quantify rope life under certain conditions.

Life Factor = D/d * Factor of Safety

(Sheave Size) (Anticipated Load)

The manufacturer has a CBOS database containing the number of cycles to failure for a range of sheave sizes and loads.

UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

NSF

Life Factor = D/d * Factor of Safety

Real Life Example:

R/V Neil Armstrong coring cruise using 9/16” diameter Plasma HiCo line

The predicted piston core pullout loads was 15000 lbs.

Load expressed as a Factor of Safety is: $\frac{\text{Breaking Strength of 9/16” Plasma Hico}}{\text{Anticipated Load}}$ or $\frac{37{,}900}{15{,}000}$ =2.53

$\frac{D}{d} = \frac{\text{Diameter of sheave}}{\text{diameter of the rope}}$ $\frac{48 \text{ inches}}{.5625 \text{ inches}} = 85$

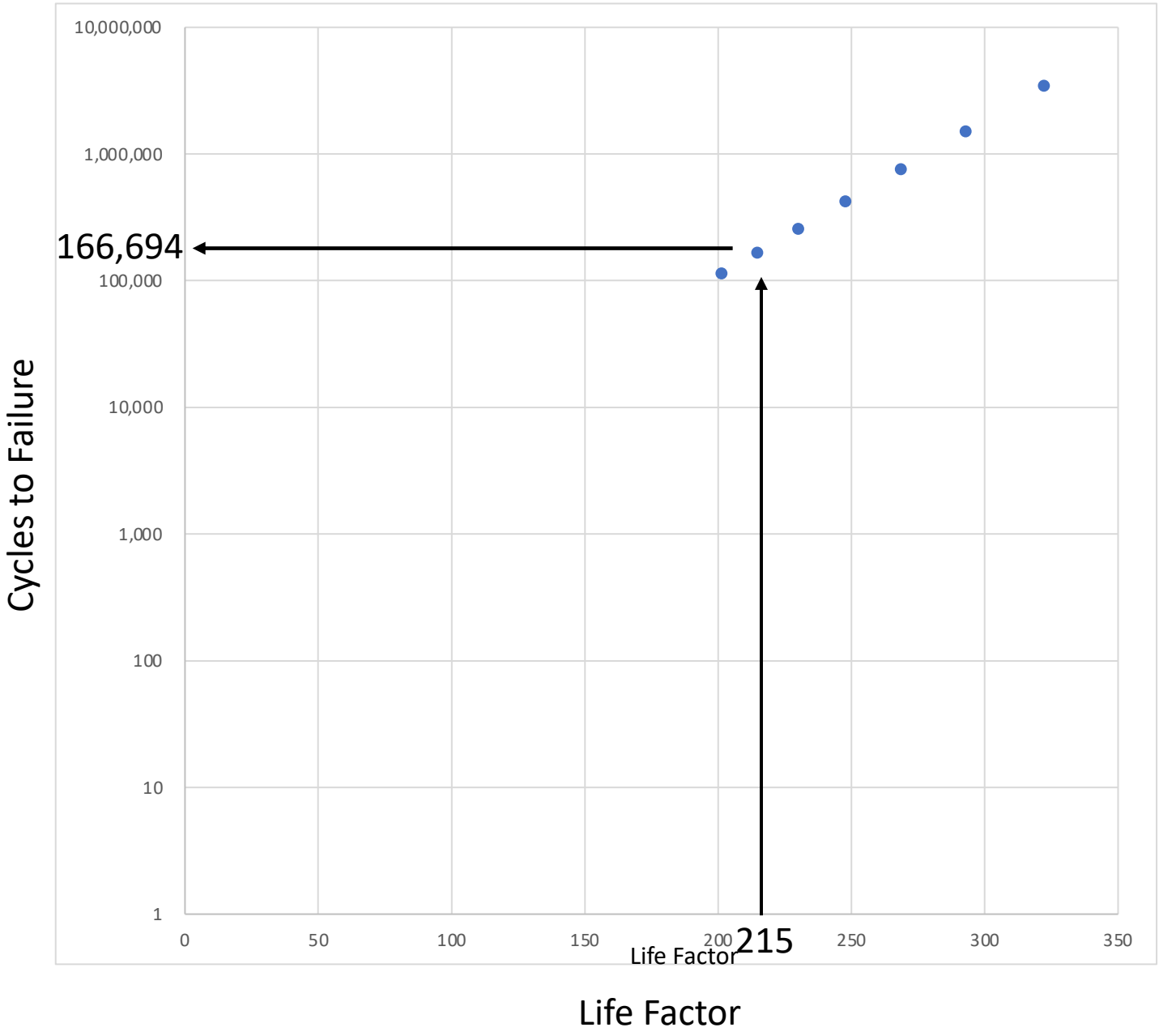
Life Factor = D/d* Factor of Safety = 85*2.53 = 215

Based on Manufacturers CBOS Test Result: The Plasma Rope with Life Factor of 215 had 165,000 cycles to failure.

UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

NSF

Manufacturer's CBOS Data

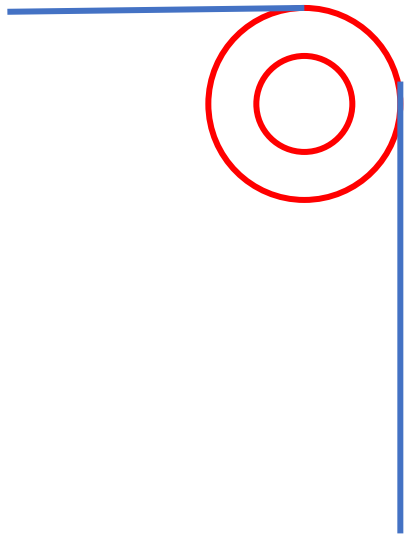


R/V Neil Armstrong Coring Cruise

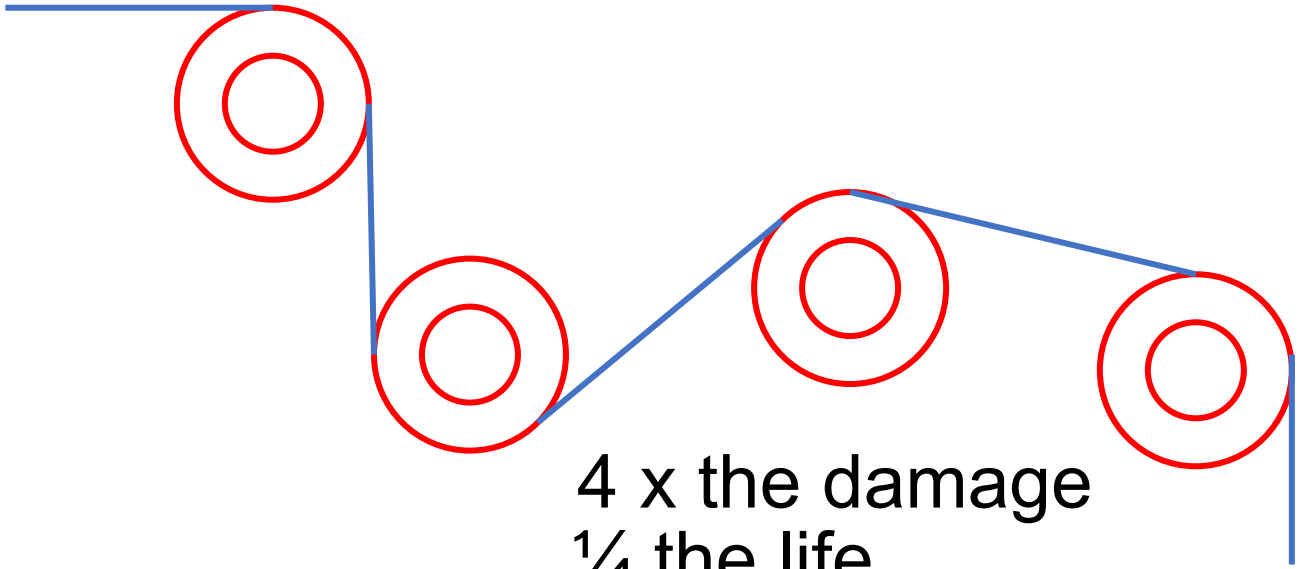
Rope Life ➡ Sheave diameter & Load

Sheave Diameter; D/d = 85

Anticipated Load; 15,000 lbs., Factor of Safety = 2.5



Predicted double bend cycles to failure = 166,974



4 x the damage

¼ the life

~40,000± operations to failure

UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

NSF

Pre-cruise determination:

Proposed coring operations could be safely carried out on the Armstrong using the 9/16” Plasma line with the 48” diameter sheaves and a factor of safety of 2.5.
An occasional dip to a factor of safety of 2.0 would not be a show-stopper.

Post-cruise

The rope use log was obtained to have a record of:

- No. of actual deployments
- Maximum Rope Deployed for each
- Maximum load for each operation

In addition, samples were sent to the manufacturer for evaluation and break tests were conducted.

Inspection found little to no levels of internal abrasion and light levels of external abrasion.
All (5) samples broke higher than the minimum breaking load.

UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

NSF

Information required for evaluating operations where a factor of safety <5 is needed.

- A comprehensive log with all previous deployments
- Number of sheaves encountered during the over-boarding operation (including traction head sheaves)
- Tread diameter of all sheaves encountered
- Groove diameter of sheaves encountered
- Science Requirements
  - Dry and wet weights of gear to be deployed
  - Weight of sample(s) to be collected
  - Anticipated total static load during the proposed operation (deployed gear plus samples plus any transient loads [e.g. core pull out loads]

UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

NSF

Synthetic Tension Member Evaluation

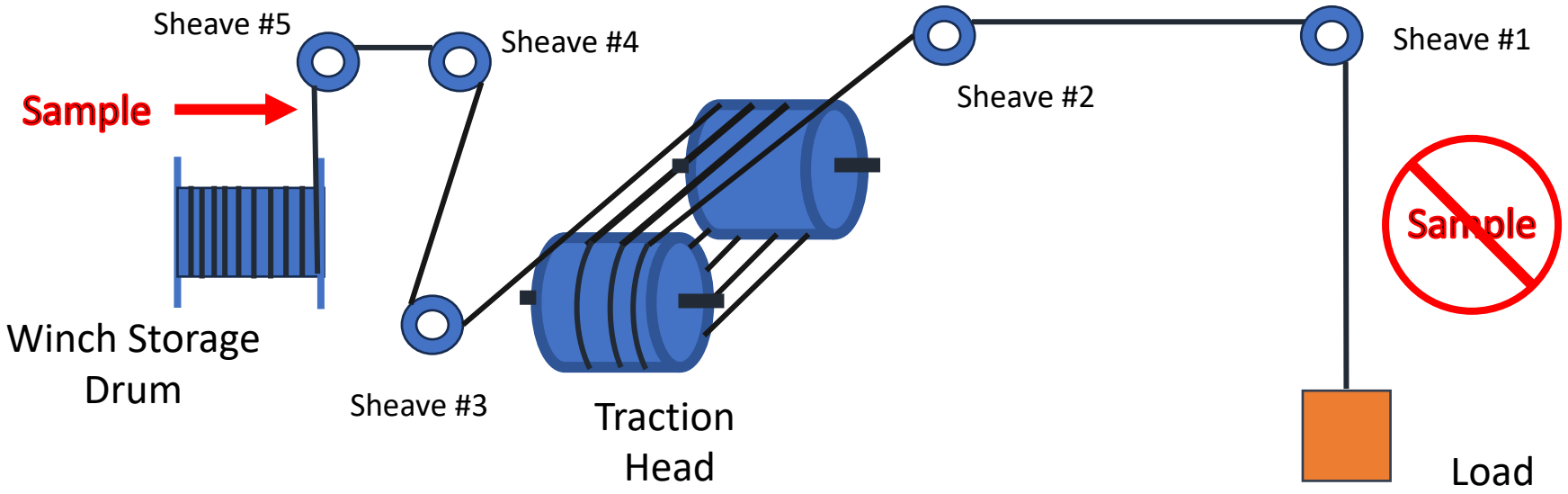
Testing Synthetic Ropes per Appendix A

- **Samples requested before and after each cruise when synthetic is utilized**
- **Sample prior to its next use can be taken from the working end.**
  - **Provides a reasonable pre-use condition, by considering any deterioration that may have occurred while in storage, e.g. environmental conditions, hot work, oils, grease contamination etc.**
- **At the conclusion of its use, a sample from the extreme working end is NOT representative of the rope's condition.**
  - **Sample from a section that has gone around all the sheaves while under load.**
  - **Sample location and length will vary from ship to ship.**
  - **Provides a post-use condition.**
  - **Contributes to determining to what degree the use has affected rope life.**

UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

NSF

Post Cruise Synthetic Sample Location



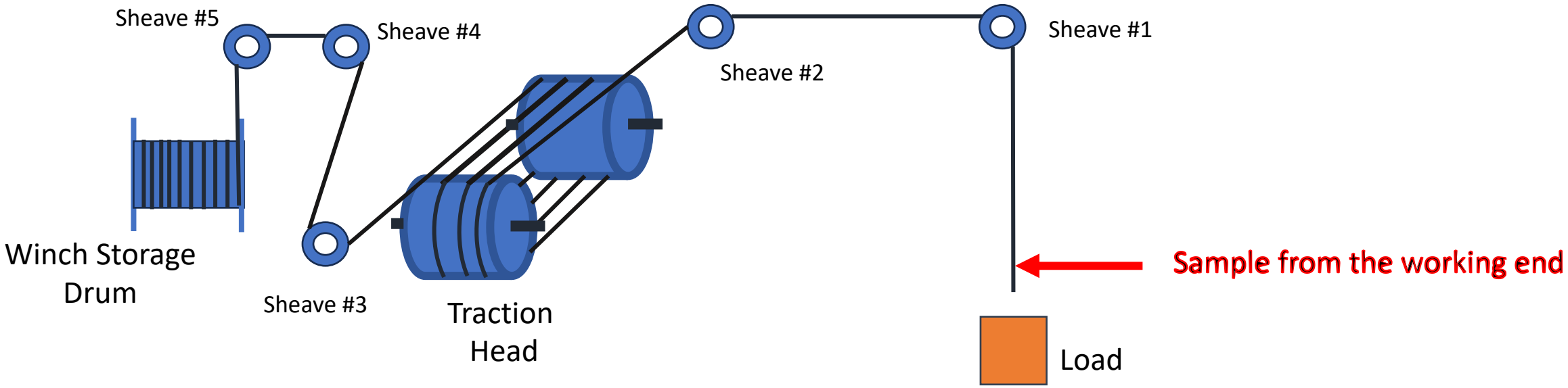
Sample taken between the load and sheave #1 has not encountered all the components that contribute to degradation.

Sample should be taken between Sheave #5 and winch storage drum

UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

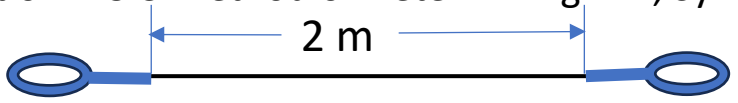
NSF

Pre-Cruise Synthetic Sample Location



Operator shall send a sample terminated on both ends with thimbles typical of those used in the field.

Rope sample should have at least 2 meters of rope that are not involved with the spliced or other applied terminations. Total length should not exceed what is needed for the end terminations plus 2 meter clear span. (Appendix A, Section A.5.3 Method of Determining TBL, Synthetic Tension Members)



UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

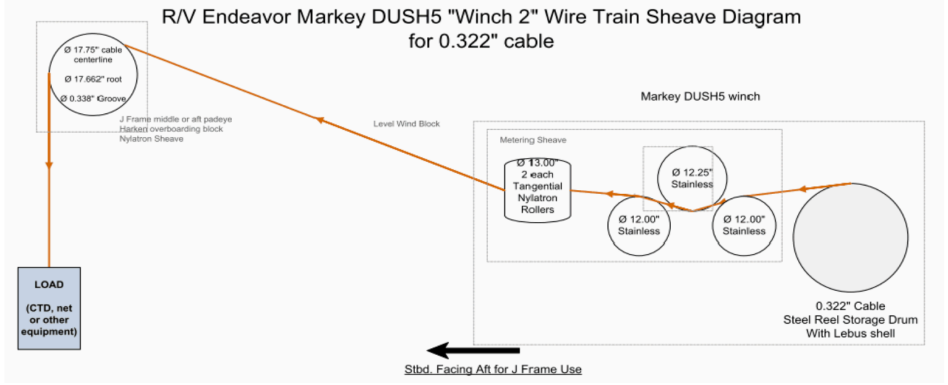
NSF

Synthetic Tension Member Log

- NSF tension member identifier
- Number and/or duration of deployments since last break test
- Maximum tension of EACH deployment
- Line out at time of maximum tension
- Maximum payout of EACH deployment
- Description of sheave train used to over-board the synthetic
- Winch and System manufacturer
- Record of all spooling operations and cutbacks including those due to re-termination

Tension Member Identifier e.g NSF-XX-CXXX	NSF-19-C187
Winch Manuf. and model: e.g.Hawboldt SPRE-2640	WINCH 2, MARKEY DUSH 5

Sheave Train Description:



Cruise No.	Date	Cast #	Cable Length [m]	Max Tension lbs.	Wire Out at Max Tension [m]	Wire In at Max Tension [m]	Max Wire Out [m]	Notes
EN-014	3-Jul-20	1	9855	4398	2800	7055	3000	
EN-014	4-Jul-20	2	9855	3500	1500	8355	1500	
	30-Jul-20		9848					7 m sample cut for Wire Pool
EN-015	21-Aug-20	1	9848	3042	1450	8398	1500	
EN-015	27-Aug-20	2	9848	5345	10	9838	100	
EN-015	29-Aug-20							Cut back 47 m due to tension spike
EN-015	29-Aug-20	3	9801	3495	1700	8101	2000	
EN-015	30-Aug-20	4	9801	4398	2800	7001	3000	

Synthetic Tension Member Evaluation

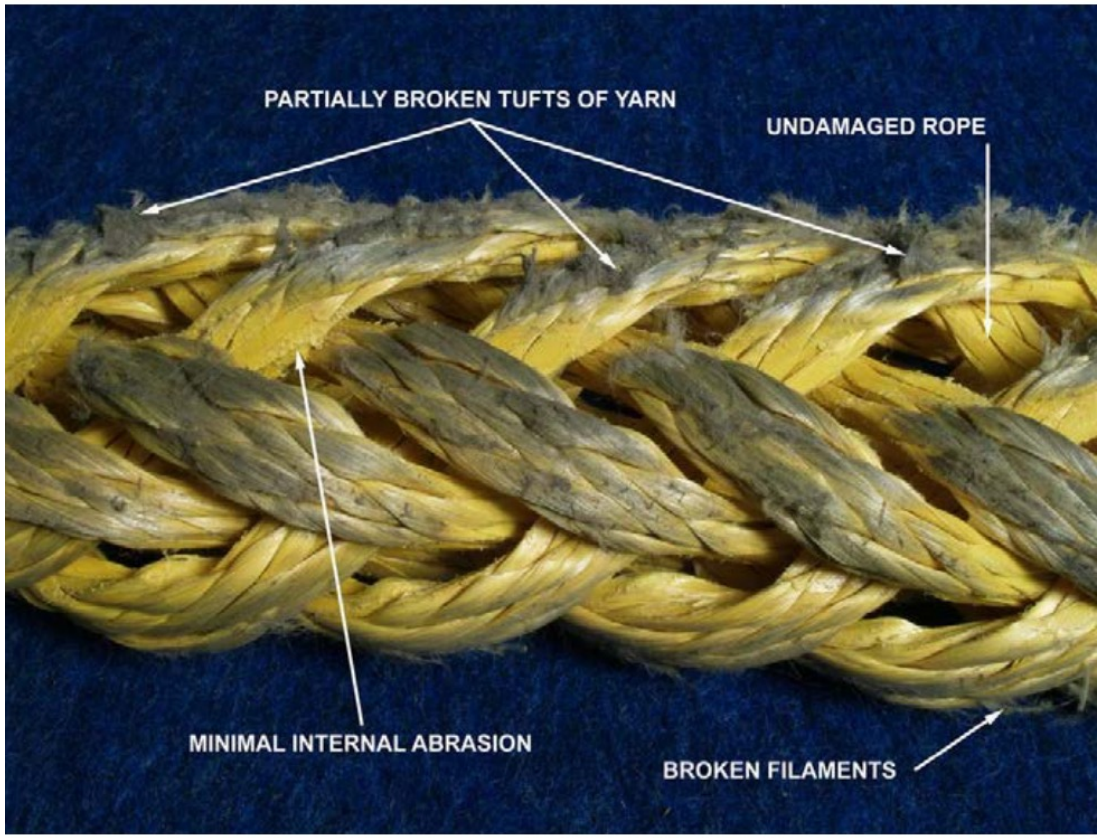
Visual Inspection

UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

NSF

Internal Abrasion

Example of moderate external damage but minimal internal damage



From Cortland Document: Plasma and BOB Tugger Winch Rope Usage, Inspection and Repair Manual, Doc No. ETN-031

UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

NSF

Cuts

Even squared off fiber ends at point of damage
Extent of damage depends on depth, will reduce strength, rope may become unbalanced.

Partially cut strand

From Cortland Document: Plasma and BOB Tugger Winch Rope Usage, Inspection and Repair Manual, Doc No. ETN-031

UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

NSF

Pulls

Object snags a yarn or strand and pulls it away from rope surface forming a loop. Attempt to work the pulled strand back

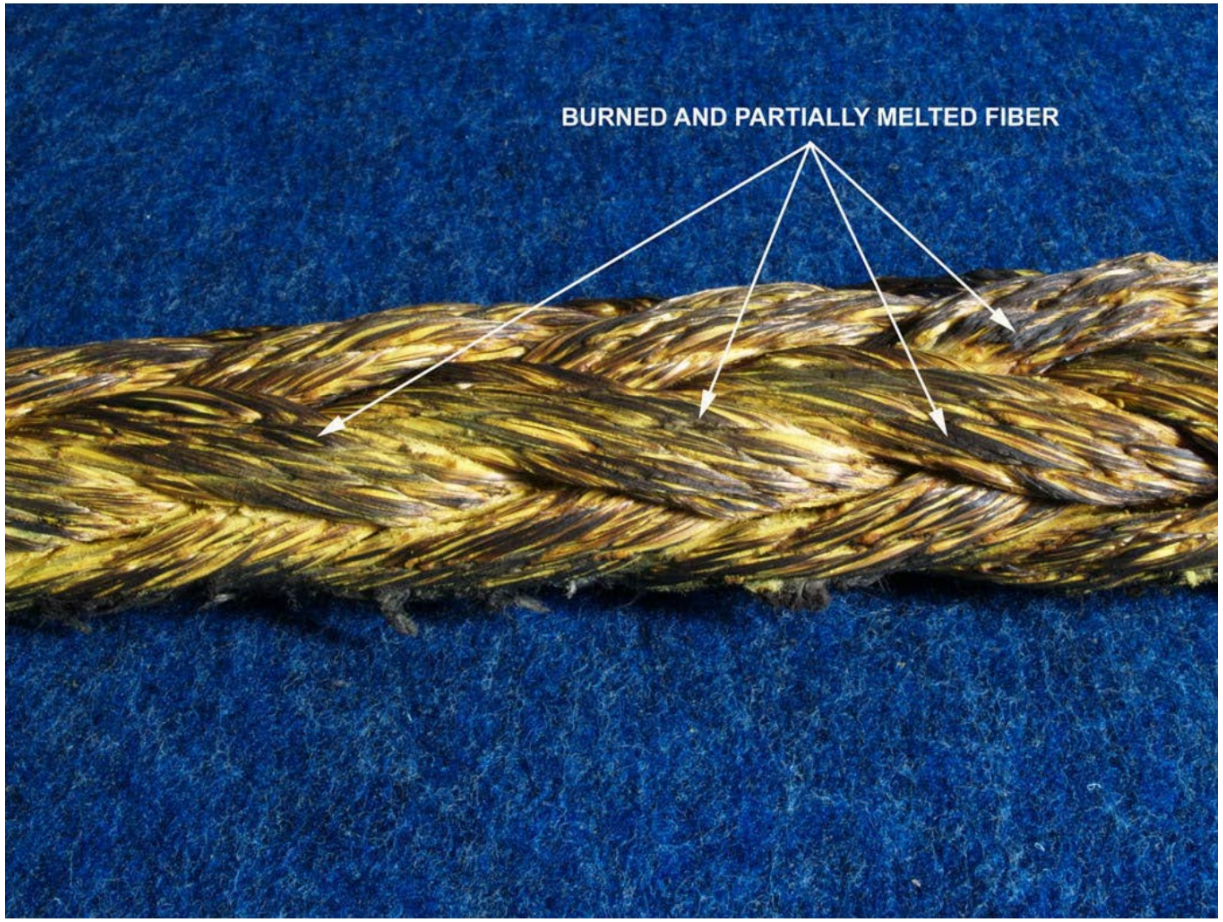
Pulled strand

From Cortland Document: Plasma and BOB Tugger Winch Rope Usage, Inspection and Repair Manual, Doc No. ETN-031

Burns

All synthetic fiber can melt due to frictional heating.
Glassy fused area on the rope's surface.

Example of burned and partially melted fiber



From Cortland Document: Plasma and BOB Tugger Winch Rope Usage, Inspection and Repair Manual, Doc No. ETN-031

UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

NSF

Uneven diameter

Distortion, significant diameter change, inconsistency in overall measurements will decrease the performance of the rope.

From: Samson Rope User's Manual, Guide to Rope Selection, Handling, Inspection and Retirement, Page 48

Contaminants

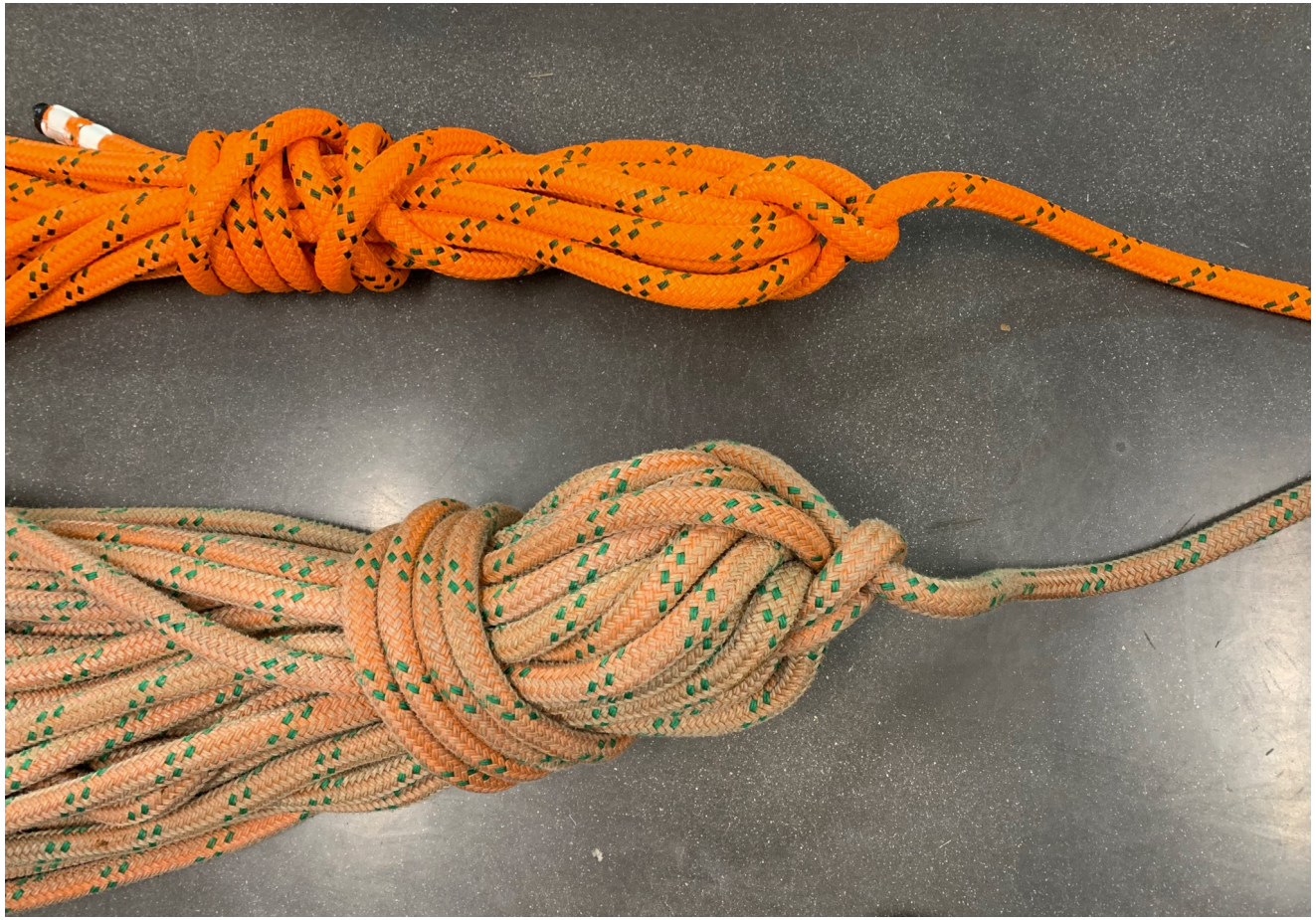
- Abrasive contaminants such as sand blast grit or rust can damage internal fibers.
- Exposure to common chemicals, and petroleum products should be avoided.
- Discoloration with suspected chemical exposure are reasons for removal.

UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

NSF

Discoloration

UV exposure tends to cause discoloration. Long periods of exposure will decrease the overall strength. Chemicals may cause discoloration



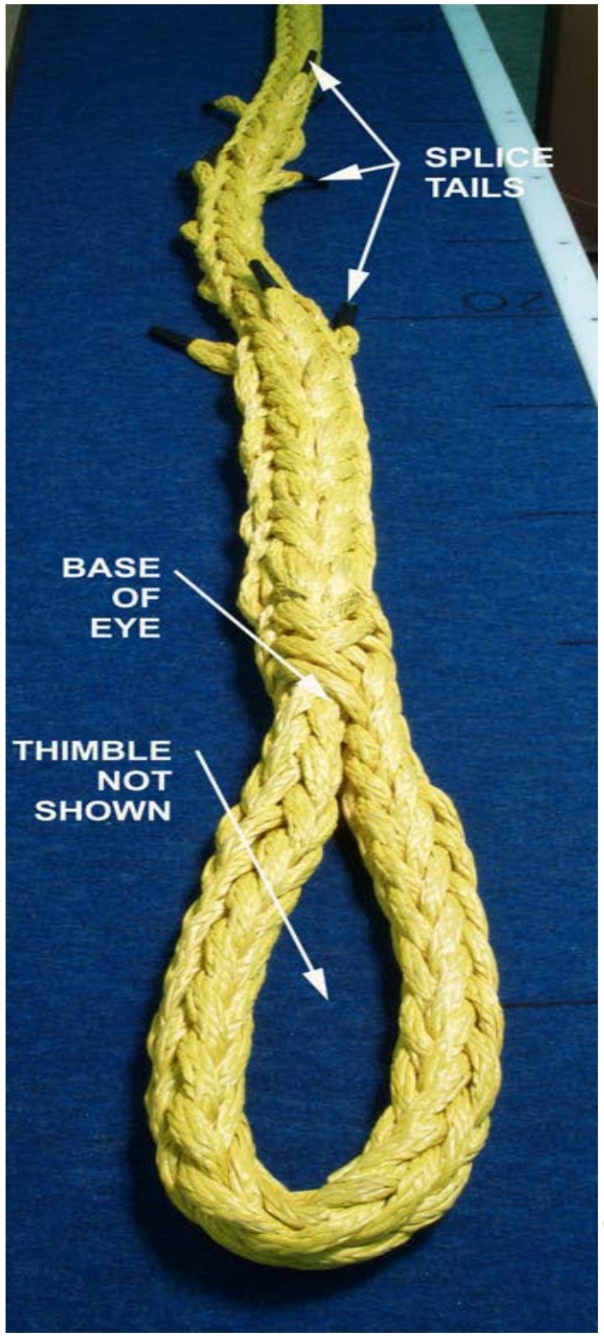
UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

NSF

Splice condition

- Signs of abrasion, cuts, dirt
- Accepted splicing procedure utilized
- Seated properly in the thimble and not cocked
- Splice tails exposed without any slippage

Example of an eye splice



UNOLS
UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

NSF


Questions?