Tension Member Considerations for Seafloor and Subseafloor Sampling

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March 2024

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The Wire Pool supports the tension member needs of the US Academic Research Fleet

- Maintain an Inventory of Wire Rope, Cable and Synthetics
- Coordinate Requests for Tension Members
- Conduct Strength Tests of all Tension Members in Use by the US ARF
- Maintain a Database that provides a cradle to grave history
- Provide support to the RVOC Safety Committee

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General Trend

DO THINGS THAT REQUIRE HIGHER LOADS AND DO IT IN DEEPER WATER

Take longer cores in deeper water.

Dredge up rocks in deeper water.

MOST IMPORTANTLY

Do it all safely.

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Doing it Safely

- UNOLS Research Vessel Safety Standard
  - Standards for the operation of vessels that are part of the US ARF
  - Full compliance is a requirement to maintain status as an ARF vessel.
  - Cover cases where there is a widespread need for guidance
  - Fill a gap not covered by federal laws and USCG regulations, ABS rules etc.

Appendix A of the RVSS

- Establishes safe operating limits for overboard handling systems used on the ARF
- **Applies to tension members distributed by the NSF Wire Pool, those acquired independently by the vessel and those brought on board by any science party or outside organization**.

Appendix B of the RVSS

- Ensure safety of personnel and the integrity of equipment in the practice of deploying oceanographic instrumentation with overboard handling systems used on the ARF

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A Few Definitions

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

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.

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

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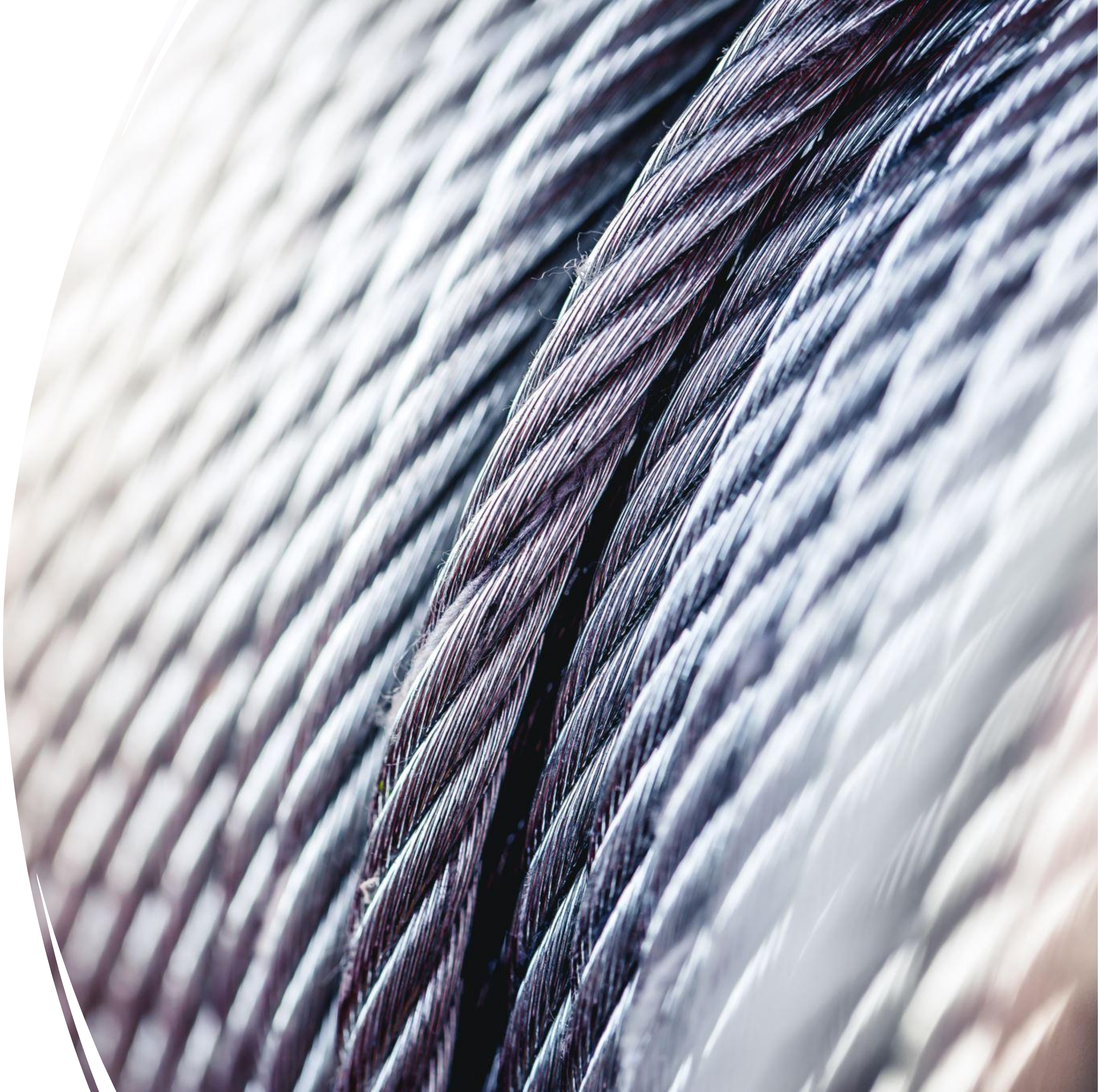
Minimum Factors of Safety per Appendix A

- Wire Rope: 1.5
  - 9/16” 3x19 21,666 lbs.
- Cable: 2.0
  - .681” Power Optic 21,000 lbs.
- Synthetic Rope: 5.0*
  - 9/16 Plasma 7,580 lbs.

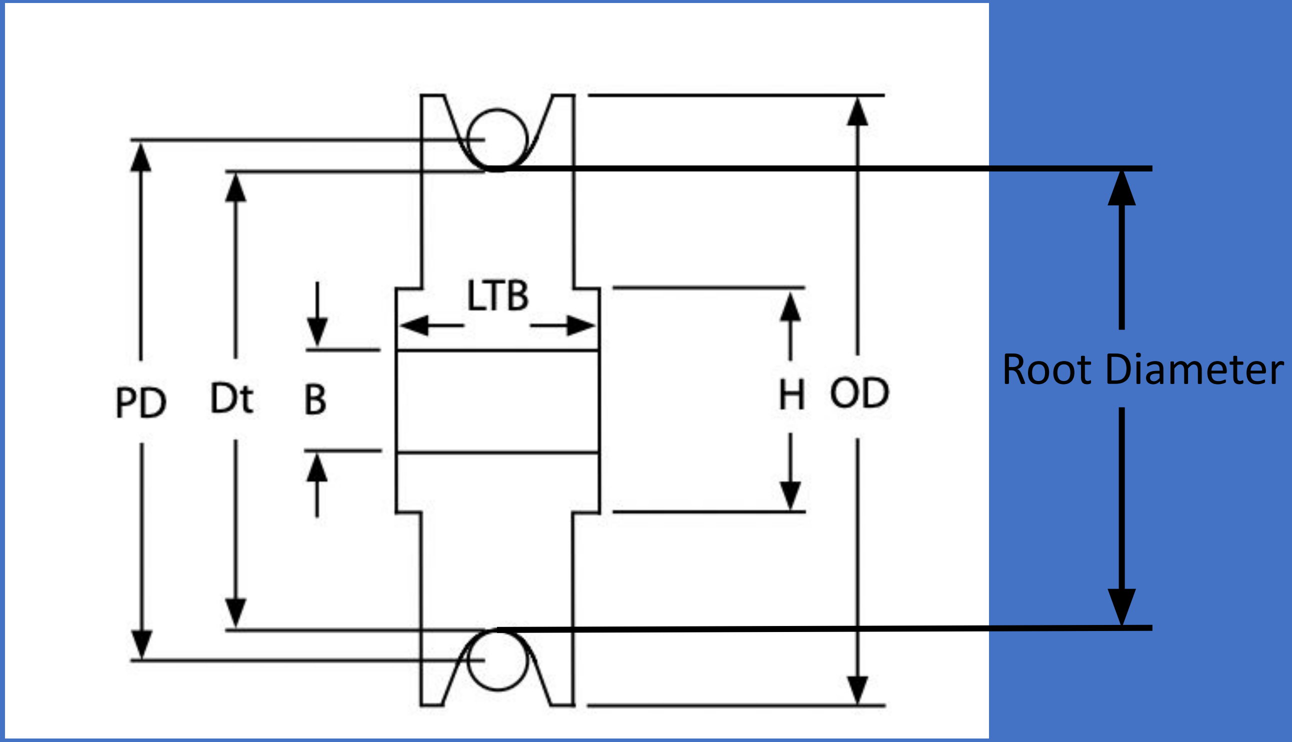
* Exceptions possible with planning

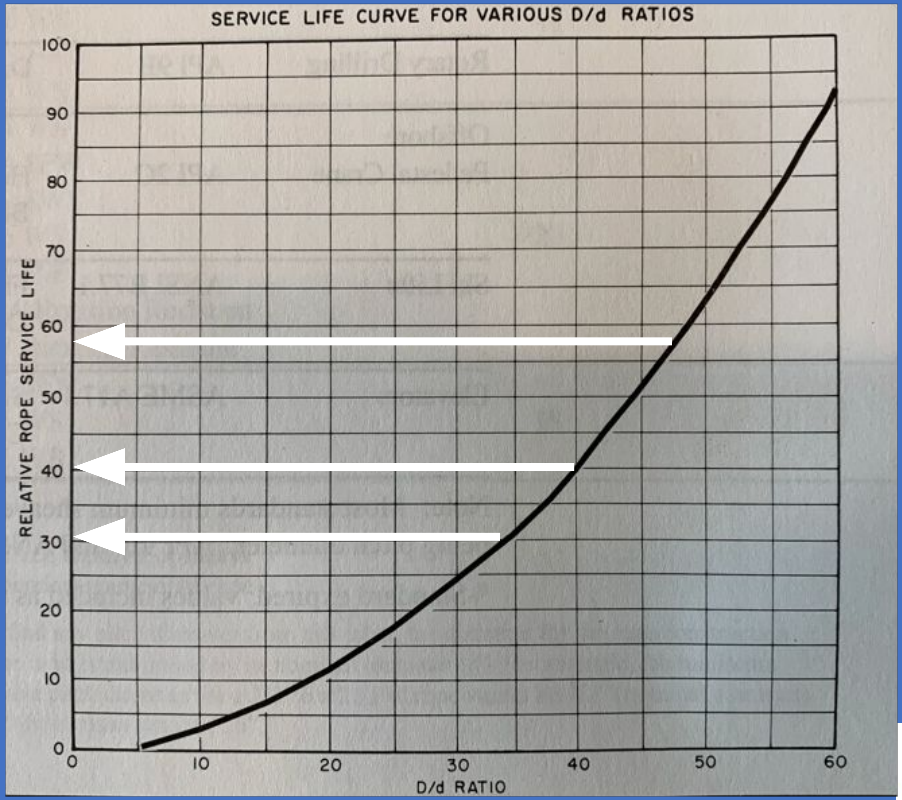


Definition

D/d

Root Diameter of a sheave
Outside diameter of the tension member





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Wire Rope

- Workhorse tension member for the fleet.
- Weight penalty
- Attention to the factor of safety and the loading.
- Little to no consideration given to previous operations*
- A log is maintained but not concerned about it’s previous uses.
- Decades of experience has been the guide.

* Unless there was obvious damage

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Application where Wire Rope was not going to work

- 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.
- 8000 m of 9/16” wire rope weight in water=11,230 lbs.
- 11,230 lbs. + 15,000 lbs. = 26,230 lbs.

$$\text{F of S} = \frac{32{,}500}{26{,}230} = 1.24$$

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Synthetic Rope as an alternative tension member

- Another tool in the toolbox, appropriate for certain jobs.
- Not having the same level of experience, the fleet is proceeding cautiously.

Backing into a solution:

Selection of a tension member based on what the vessel had for existing equipment.

- Capability of the Armstrong's overboard handling system
  - What loads could it withstand?
  - .681" Power optic cable nominal breaking strength of 42,000 lbs.
- Storage Drum capacity
  - 12,000 m of .681
- Sheave characteristics
  - 48" diameter over-boarding sheaves for .681
  - Grooved for .681 cable
- 9/16" diameter Plasma HiCo line: 37,900 lbs. breaking strength could be used with the existing equipment, but could it withstand the planned operations.

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

Appendix A: 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

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Disregarding environmental influences and handling:

ROPE LIFE

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

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.

Synthetic Rope

- 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?**
- Should not be thought of as the same as wire rope.
- Accurate use logs, visual inspection, periodic testing are critical for assessing current rope condition and suitability for next proposed operation.

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

$\frac{D}{d}$ = $\frac{\text{Diameter of sheave}}{\text{diameter of the rope}}$ $\frac{\text{48 inches}}{\text{.5625 inches}}$ = 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 166,000 cycles to failure.

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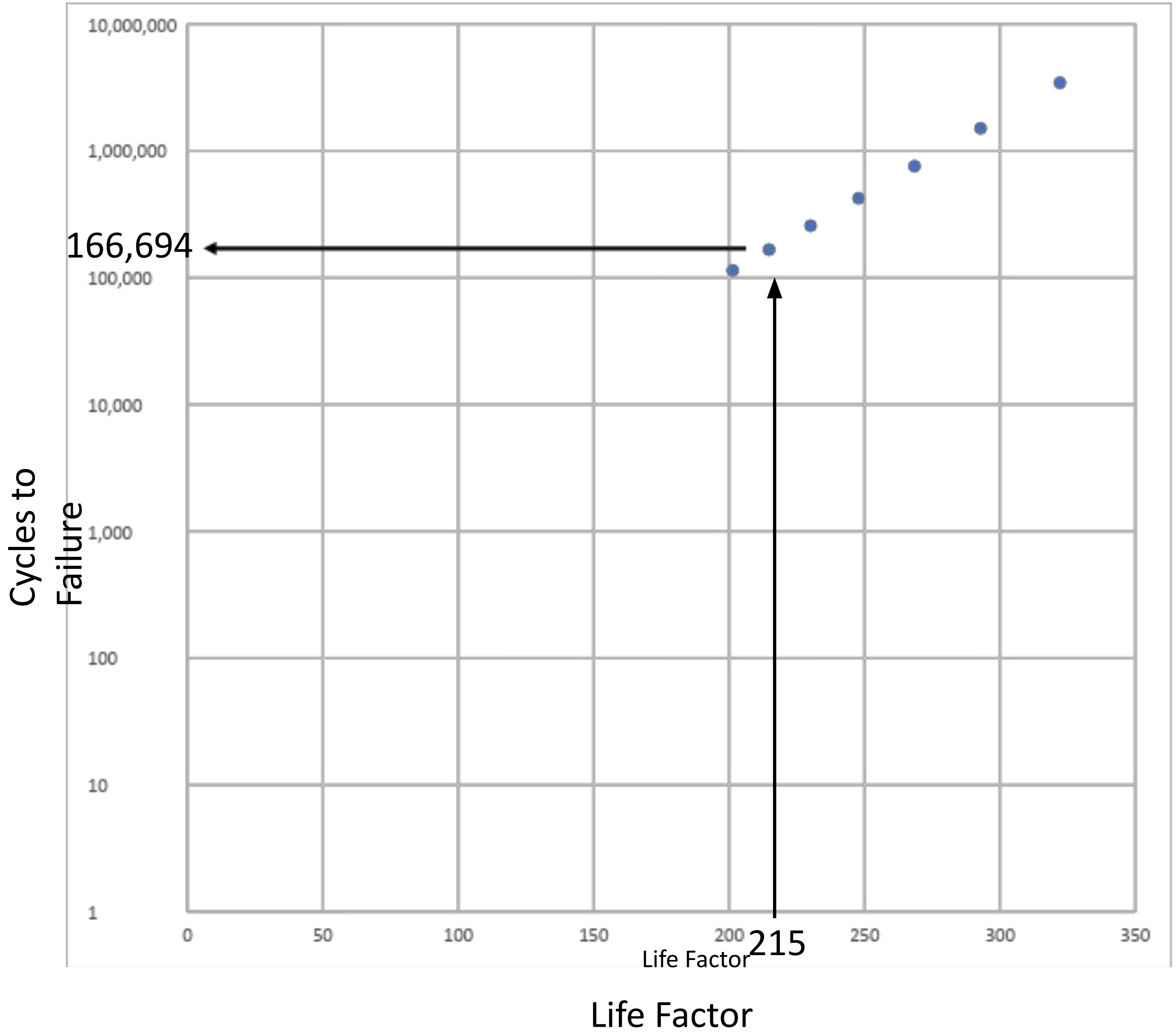
Manufacturer's CBOS Data

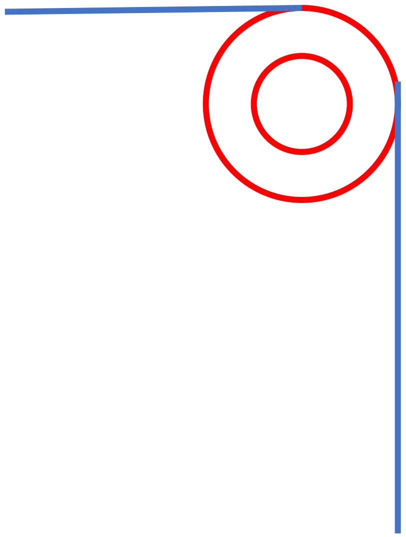


R/V Neil Armstrong Coring Cruise

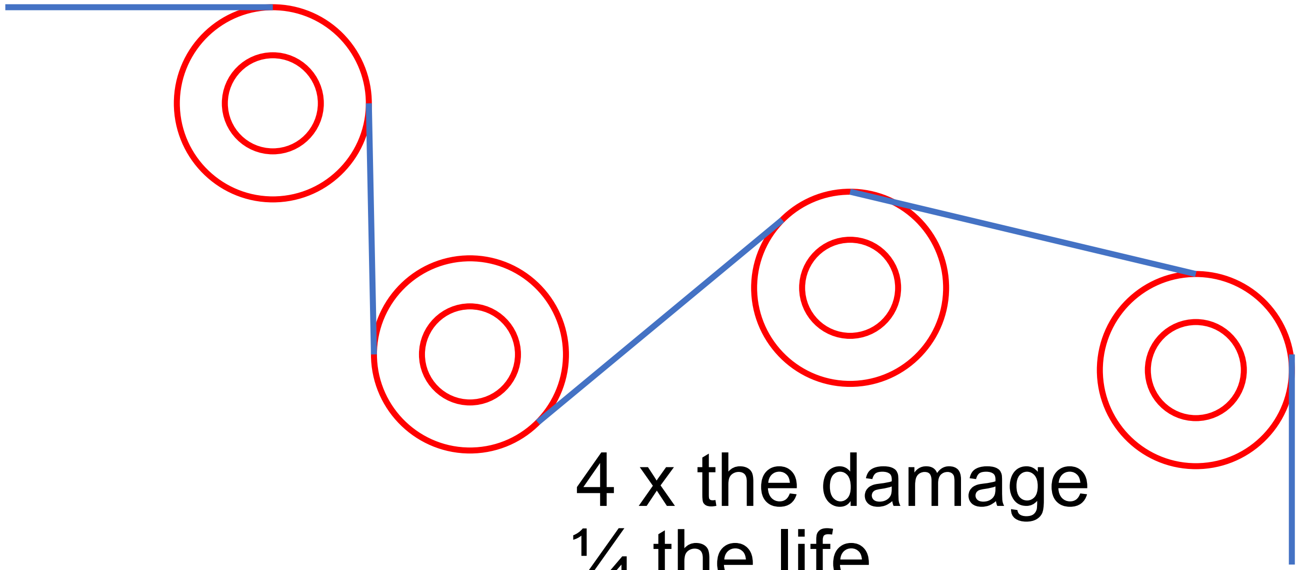
Rope Life → Sheave diameter & Load

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

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Not the best approach

- Noncompliance with Appendix A required a waiver.
  - Time consuming process
  - Uncertain outcome
- Potential to compromise the at-sea operations
  - Limited by the minimum acceptable F of S
  - If conditions are worse than expected
    - Can’t meet science objectives
    - Jeopardizes the safety of personnel
    - Potential loss of equipment

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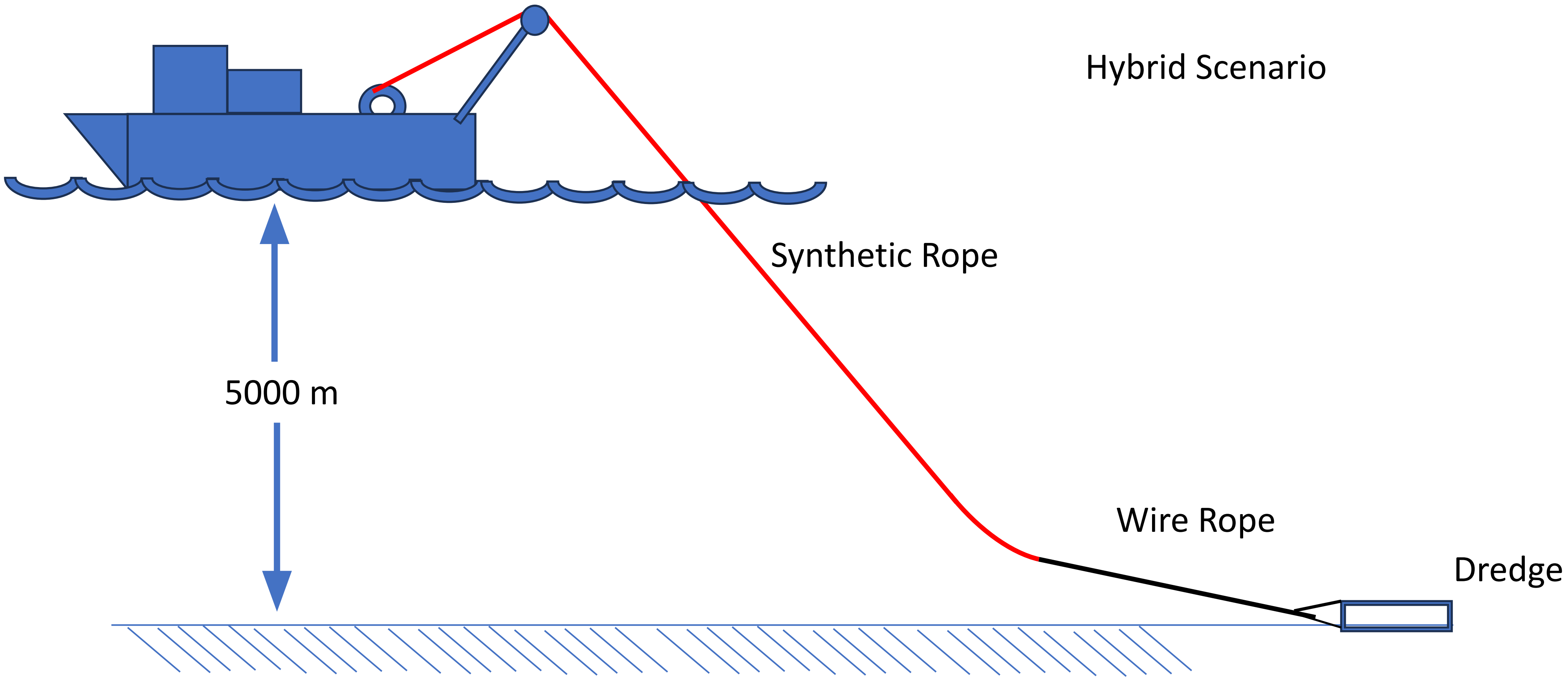
Determine what you want to do and specify the equipment needed to do it.



Dredging with a Combination of Synthetic and Wire rope		
Water depth of 5000 meters		
Weight of 5000 m of synthetic in seawater	0	
Weight of 1000 m 9/16" wire rope in seawater = 1.404lbs/m *1000 m	1404	
Weight of sample in seawater	1000	
Weight of dredge in seawater	857	
Static Load		**3,261**
Pound mass of 5000 m synthetic	3828	
Pound mass of 1000 m 9/16" wire rope	1614	
Pound mass of sample	1500	
Pound mass of dredge	1000	
Total Mass of System	7942	
Dyanmic Load (multiply Mass Total by .75 for g=1.75		**5,957**
Transient Load to pull through outcrops	10000	**10,000**
Estimated Maximum Tension Pound-force		**19,218**
Factor of safety of 5		**96,088**

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Nominal Diameter (inches)	Size (circ in.)	Approximate Weight (lbs/100ft)	Minimum Tensile Strength Spliced Rope (lbs)	Minimum Tensile Strength ISO Unspliced Rope (lbs)
0.04	0.12	0.05	270	300
0.05	0.15	0.07	390	430
0.06	0.18	0.1	475	525
0.07	0.21	0.14	750	830
0.1	0.3	0.27	1,400	1,550
1/8	3/8	0.54	2,800	3,100
3/16	9/16	1.12	5,500	6,100
1/4	3/4	1.6	8,000	8,890
5/16	15/16	2.5	11,700	13,000
3/8	1-1/8	3.7	17,500	19,400
ABS Type Approval and DNV Type Approval Type Approved Sizes				
7/16	1-1/4	4.2	21,000	23,400
1/2	1-1/2	6.4	31,300	34,800
9/16	1-3/4	7.9	37,900	42,100
5/8	2	10.6	51,400	57,100
3/4	2-1/4	13.3	68,500	76,300
13/16	2-1/2	15.9	74,000	82,200
7/8	2-3/4	19.6	92,600	102,900
1	3	23.4	110,000	122,100
1-1/16	3-1/4	27.5	129,200	143,500

A better approach:

- Don’t limit yourself to only the tools that will fit in the toolbox you have.
- Identify the right tool for the job and then get the appropriate size toolbox.

Questions?

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Impact of Groove Diameter On Rope Life

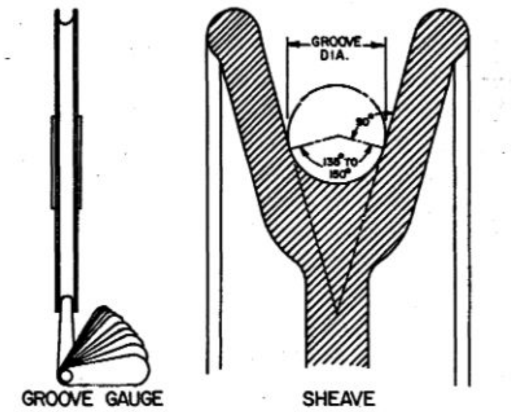
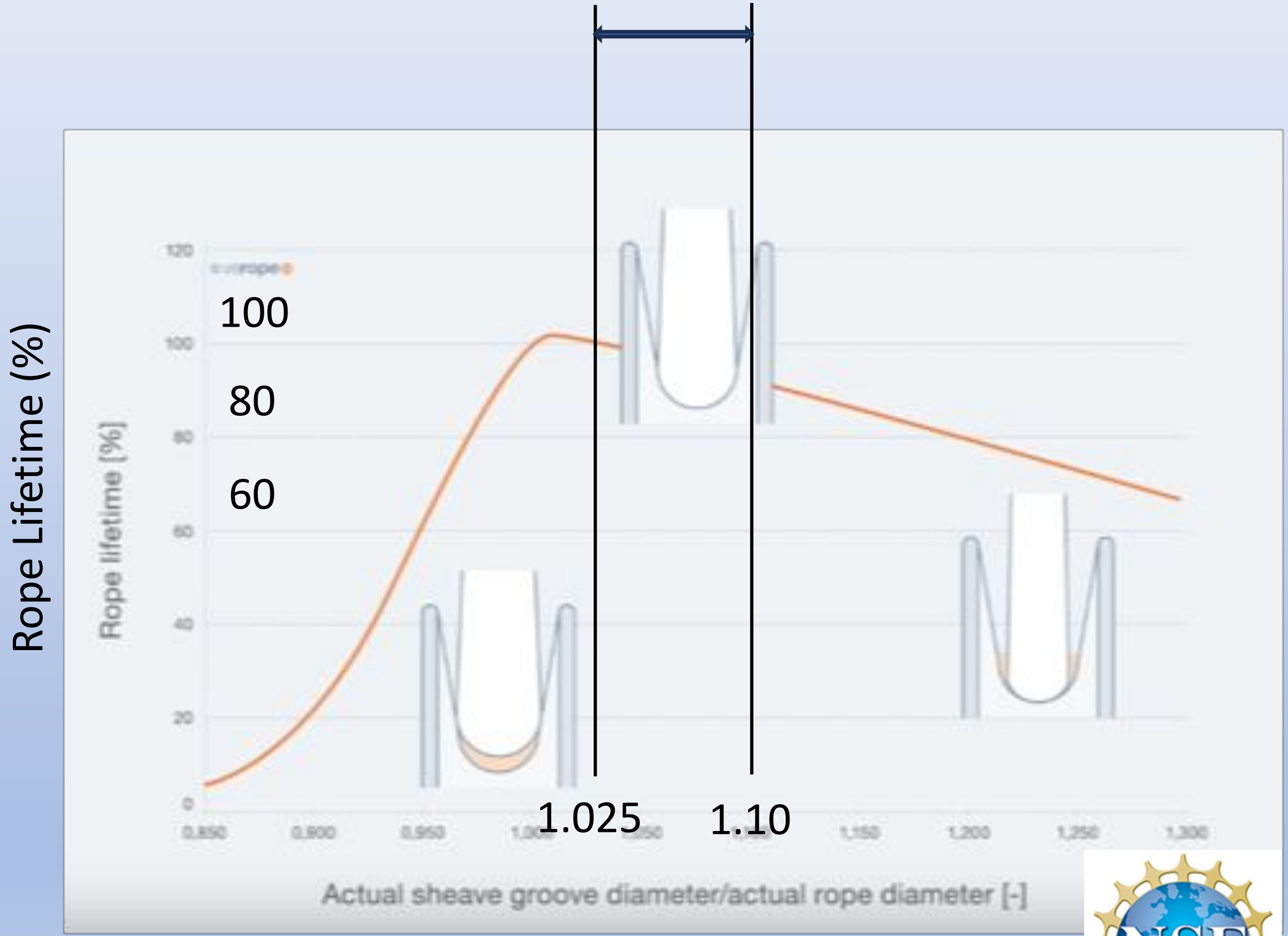


FIGURE 1-16
SHEAVE GROOVE DIMENSIONS



$\frac{\text{Sheave groove diameter}}{\text{Rope diameter}}$

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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

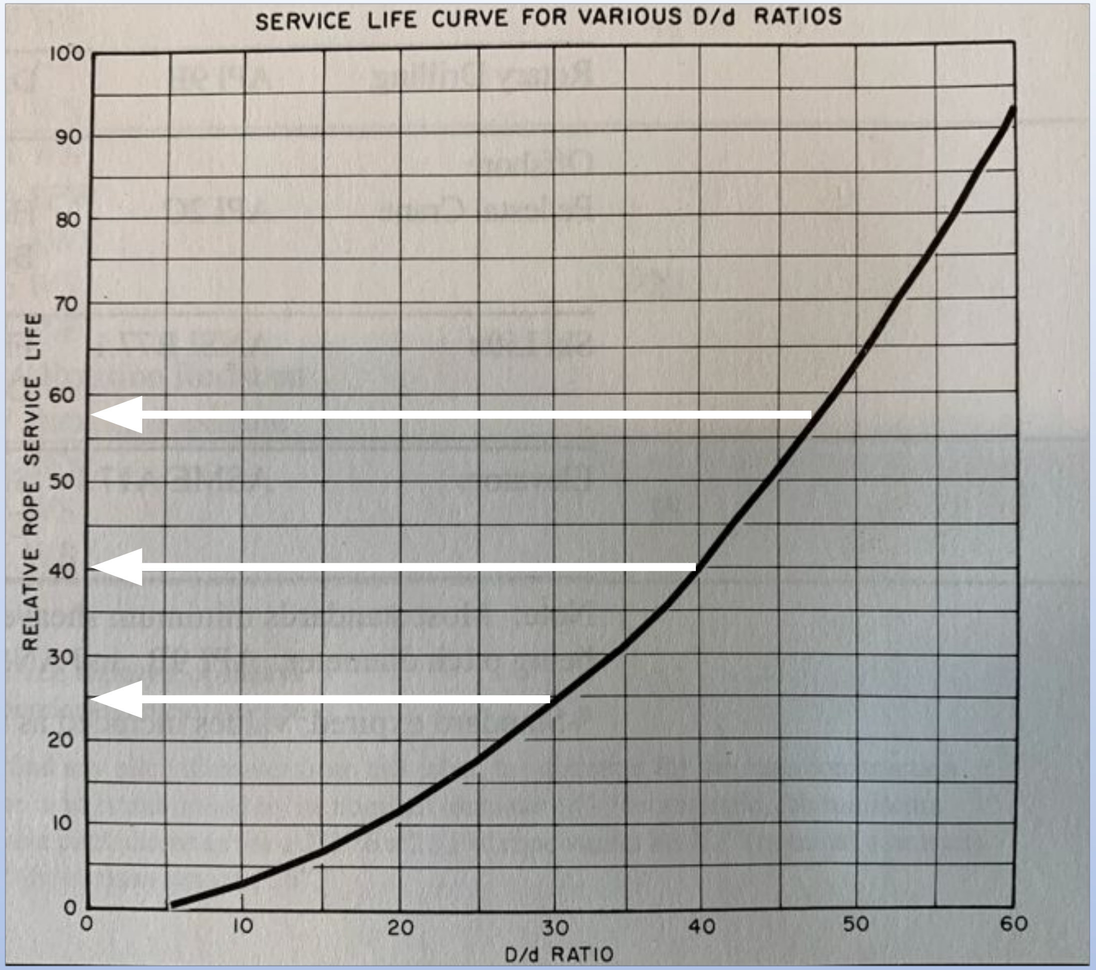
¼” 12” diameter sheave, D/d=48

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