INMARTECH 2006

2006 International Marine Technicians Symposium

A Summary of Performance Tests Conducted on 3x19 Wire Rope

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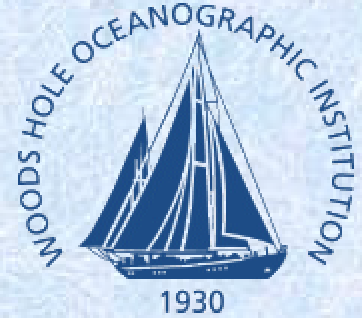
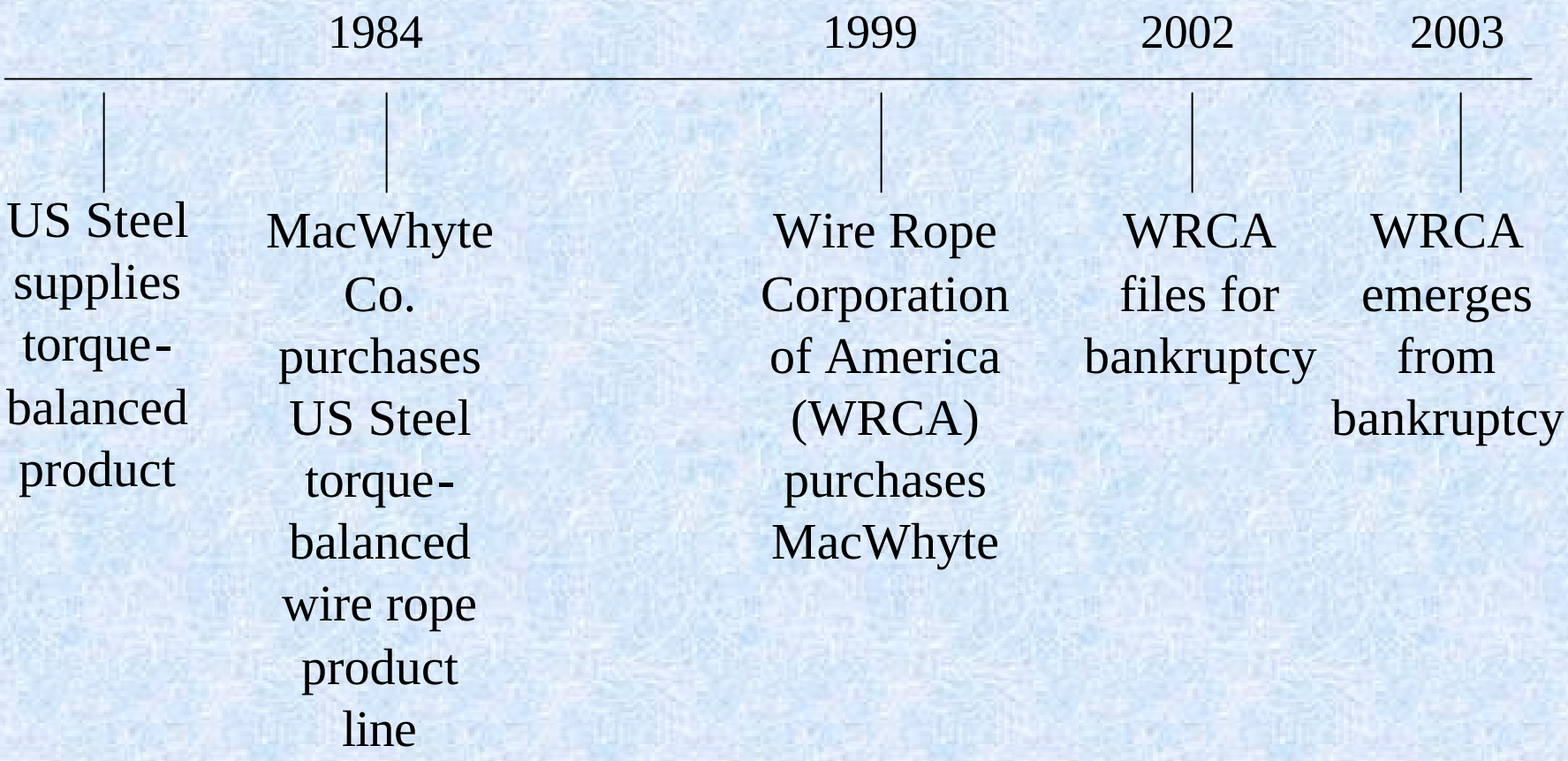


Outline

- Brief History of UNOLS Wire Rope Suppliers
- Concerns
- UNOLS Wire Rope Specification
- Test Program
  - Test facility
  - Samples tested
    - WRCA
    - Loos
  - Tests conducted
    - Description of the test
    - Performance of WRCA samples
    - Performance of Loos samples
  - Test program limitations
- Next Series of Wire Tests

History of Wire Rope Suppliers



Concerns

- Since the product line has changed hands several times, do the products we purchase meet the UNOLS specification for general purpose oceanographic wire rope?

- Given the previously precarious financial history of our current supplier, are there other manufacturers of 3x19 wire rope whose products meet the specification?

Specification for General Purpose Oceanographic Wire Rope

- Dated January 1986
- General Purpose: Serving many varied and unpredictable applications:

Rock dredging	Mid-water trawling
Gravity coring	Dragging operations
Piston coring	Tripod lowerings
Plankton tows	Hydrographic casts

General Elements of the UNOLS Wire Rope Specification

- Rotational stability
- Best possible strength to weight ratio
- Highest elastic limit attainable.
- Flexure tolerance
- Tension cycling
- Service life, minimum of 3 years under “normal” service
- Size specifications, diameter and length

Wire Testing Program
2005

- Conducted by Tension Member Technology in Huntington Beach, CA under the direction of Phil Gibson
- Samples of 3x19 wire from WRCA and Loos Co.
  - WRCA Torque Balanced product
  - WRCA Nilspin Product
  - Loos standard non-rotation product
- Sizes tested:
  - 3/16”, **1/4”**, 3/8”, 7/16”, **1/2”** and **9/16”**
- The 1/4”, 1/2” and 9/16” were unjacketed samples.

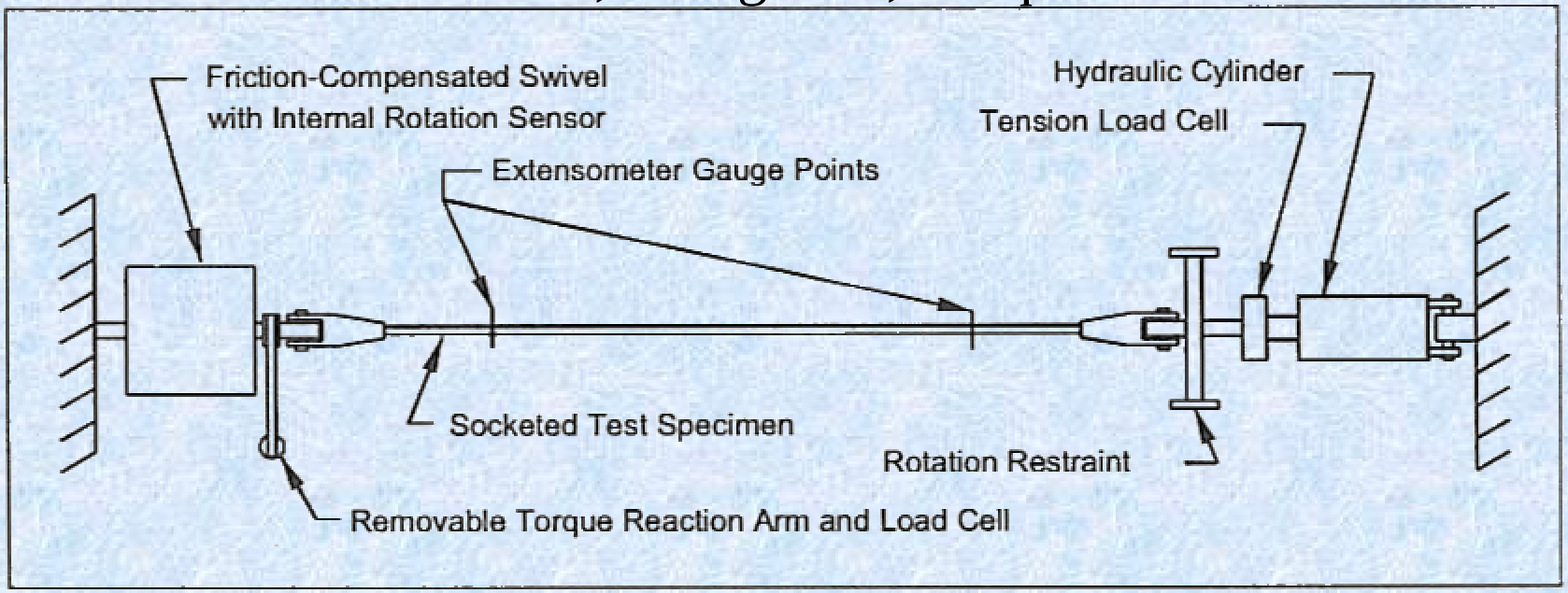
Types of Tests

- Tension, Elongation, Torque, and Rotation (TETR)
- Tension-elongation breaking strength (TEB)
- Cyclic Bend Over Sheave (CBOS)
- Cyclic Straight Tension (CST)

Test Number 1

Tension, Elongation, Torque and Rotation Test

Test Number 1: Tension, Elongation, Torque and Rotation Tests



- Tension applied by hydraulic cylinder and measured by a strain gauge load cell.
- Rotation measured by a friction compensated swivel which uses active compensation to minimize swivel bearing friction.
- Elongation measured by an extensometer attached to the center section of the test specimen.
- Torque measured using a torque reaction arm and load cell attached to the swivel shaft.

Test Number 1 TETR Test Setup

Tension Member Technology
Huntington Beach, CA

Test Number 1
TETR Test Setup

Tension Member Technologies
Huntington Beach, CA

Test Number 1
Tension, Elongation, Torque, and Rotation (TETR) (continued)

- Samples terminated by TMT
- Each of 14 samples repeatedly loaded to a tension of 45% of the rated breaking strength
- Torque arm locked in place while elongation and torque measurements were made and disconnected for the rope rotation measurement.
- Only one sample of each size and manufacturer tested.

UNOLS Performance Specification for Rotation

"The finished rope shall not rotate about its axis more than **5° per foot at 45% of Rated Breaking Strength**. Also, a change in tensile loading equal to 10% of RBS shall not produce axial rotation greater than 1° per foot."

Test Number 1
Tension, Elongation, Torque, Rotation Results
WRCA Ropes

Sample No.	Rope Dia.	Cycle 20 Perm. Rot. Set [deg/ft]	Peak Rotation [deg/ft]	Tension at Peak Rotation [lb]	Rotation at 45% RBS [deg/ft]
01	3/16	-13.86	-3.38	300	-0.14
09†	1/4	-3.55	-1.45	1,400	-1.12
13	**1/4**	**-1.23**	**-1.84**	**2,800**	**-1.76**
25†	3/8	-2.68	5.40	5,300	4.67
37†	7/16	-2.10	2.83	8,300	2.77
47	**1/2**	**0.25**	**6.10**	**10,800**	**5.89**
59	**9/16**	**-2.16**	**-2.88**	**4,700**	**-2.00**

† Jacketed Sample

Test Number 1
Tension, Elongation, Torque, Rotation Results
Loos Ropes

Sample No.	Rope Dia.	Cycle 20 Perm. Rot. Set [deg/ft]	Peak Rotation [deg/ft]	Tension at Peak Rotation [lb]	Rotation at 45% RBS [deg/ft]
05†	3/16	-7.00	-8.41	1,700	-8.27
19	**1/4**	**-2.60**	**-0.63**	**900**	**-0.50**
31†	3/8	-2.10	-7.16	4,800	-7.15
42†	7/16	-1.00	-3.31	9,000	-3.31
53	**1/2**	**-0.90**	**2.22**	**11,100**	**2.11**
65	**9/16**	**-0.50**	**-4.67**	**14,600**	**-4.67**

† Jacketed Sample

Test Number 2

Tension-Elongation Breaking Strength Test

Test Number 2
Tension-Elongation Breaking Strength

- Rope elongation measured with an extensometer with the gauge points attached directly to the center of the sample
- Each of 42 samples were pulled to break in a single load cycle.
- Samples terminated at WHOI
- Performance Specification: Samples are expected to meet the minimum acceptable values for RBS and Elastic Limit

UNOLS Performance Specification
Breaking Strength and Elastic Limit

Wire Size	Breaking Strength (min) [lbs]	Elastic Limit [lbs]
3/16”	4,000	3,000
1/4”	6,750	5,000
3/8”	14,800	11,100
1/2”	25,700	19,300
9/16”	32,500	24,400

Test Number 2
TEB Test Setup

Tension Member Technologies
Huntington Beach, CA

Test Number 2

Breaking Strength and Elastic Limit Results

WRCA Ropes

WRCA Ropes					
Sample No.	Rope Dia.	Breaking Strength [lbs]	Required Breaking Strength [lbs]	Elastic Limit [lbs]	Specified Elastic Limit [lbs]
2	3/16	4,600	4,000	3,200	3,000
3	3/16	4,650		3,000	
4	3/16	4,650		3,000	
10	1/4	8,100	6,750	5,000	5,000
11	1/4	8,050		5,400	
12	1/4	8,000		5,000	
14	**1/4**	**7,550**	**6,750**	**5,400**	**5,000**
15	**1/4**	**7,450**		**5,700**	
16	**1/4**	**7,500**		**5,500**	
26	3/8	15,600	14,800	12,300	11,100
27	3/8	15,750		13,100	
28	3/8	15,800		11,100	
38	7/16	21,900	20,000	18,000	15,000
39	7/16	21,400		15,000	
40	7/16	21,000		15,000	
48	**1/2**	**22,800**	**26,000**	**19,000**	**19,700**
49	**1/2**	**22,600**		**18,700**	
50	**1/2**	**21,300**		**19,200**	
60	**9/16**	**30,800**	**32,500**	**23,800**	**24,400**
61	**9/16**	**28,350**		**24,400**	
62	**9/16**	**28,000**		**22,600**	

Test Number 2

Breaking Strength and Elastic Limit

Loos Ropes

Loos Ropes					
Sample No.	Rope Dia.	Breaking Strength [lbs]	Required Breaking Strength [lbs]	Elastic Limit [lbs]	Specified Elastic Limit [lbs]
6	3/16	4,650	4,000	3,500	3,000
7	3/16	4,900		3,000	
8	3/16	4,900		4,000	
20	**1/4**	**7,900**	**6,750**	**4,200**	**5,000**
21	**1/4**	**7,850**		**3,200**	
22	**1/4**	**7,900**		**4,000**	
32	3/8	14,450	14,800	8,000	11,100
33	3/8	14,200		9,400	
34	3/8	14,150			
43	7/16	20,900	20,000	13,500	15,000
44	7/16	21,150			
45	7/16	21,150			
54	**1/2**	**26,550**	**26,000**	**17,800**	**19,700**
55	**1/2**	**25,650**			
56	**1/2**	**26,400**		**17,200**	
66	**9/16**	**33,500**	**32,500**	**18,200**	**24,400**
67	**9/16**	**33,100**		**16,300**	
68	**9/16**	**33,400**		**18,200**	

Test Number 3

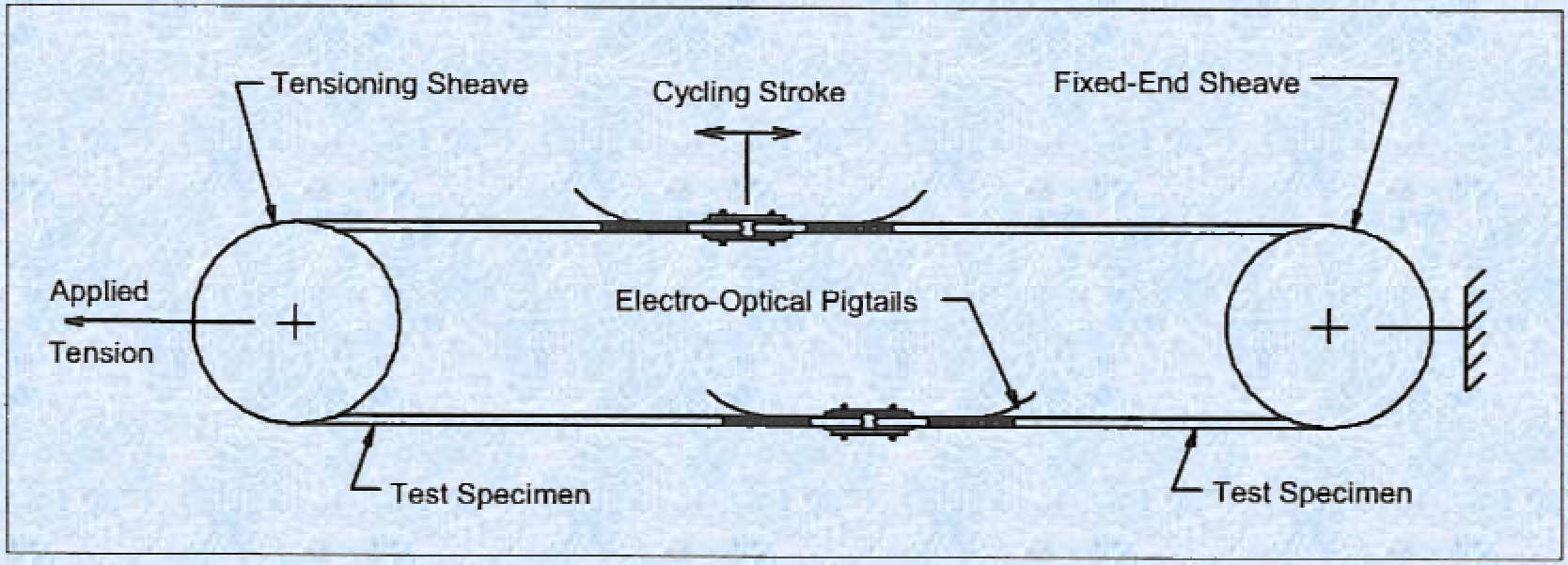
Cyclic Bend Over Sheave Test

Test Number 3
Cyclic Bend Over Sheave

- Samples tested over a pair of sheaves having a pitch diameter 30 times the nominal rope diameter, and groove diameter 5% larger than the nominal rope diameter.

- Samples tensioned to 40% of the breaking strength at a cycling rate of 500 bending cycles per hour.

Test Number 3
Cyclic Bend Over Sheave
Fatigue Test



- Motor attached to one sheave to drive the samples.
- A section of each sample passed onto, around and off of the sheave during each stroke (straight, bent, straight cycle with each stroke).

UNOLS Performance Specification for Flexure Tolerance

"Withstand **= 50,000 flexure cycles over sheaves 30 times the wire O.D. at 35-40% of the RBS** without failure of individual wires. Degradation in strength shall not exceed 5% of RBS. This is estimated to be 150% of flexures in a sheave train for 500 casts to oceanic depths. (Includes flexures at the over-boarding sheave due to ship motion.)"

Test Number 3
Cyclic Bend Over Sheave Test Results
WRCA Ropes

Sample No.	Rope Dia.	Applied Tension	Bend Cycles Completed Before Break*
18	**1/4**	**2,700**	**4,460**
30	3/8	5,920	5,008
52	**1/2**	**10,400**	**3,964**
64	**9/16**	**13,000**	**5,242**

* Specification calls for a minimum of 50,000 cycles

Test Number 3
Cyclic Bend Over Sheave Test Results
Loos Ropes

Sample No.	Rope Dia.	Applied Tension	Bend Cycles Completed Before Break*
24	**1/4**	**2,700**	**12,142**
36	3/8	5,920	3,958
58	**1/2**	**10,400**	**3,702**
70	**9/16**	**13,000**	**4,552**

* Specification calls for a minimum of 50,000 cycles

Test Number 4

Cyclic Straight Tension Test

Test Number 4
Cyclic Straight Tension (CST)

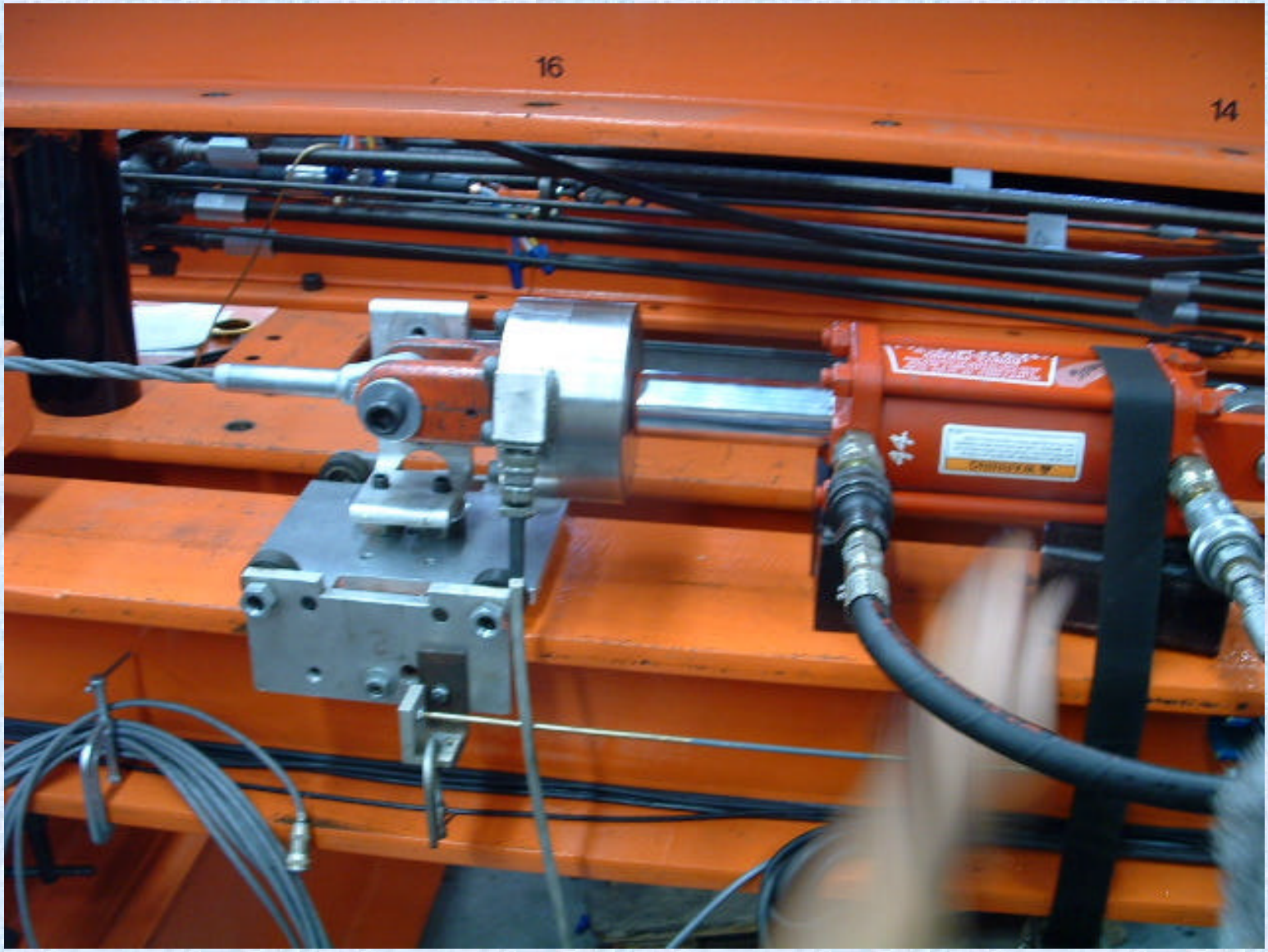
- Horizontal orientation with a strain gauge load cell to a servo controlled hydraulic cylinder.
- Tensioned between a near zero tension to 40% of the rated breaking strength at a rate of 1200 load cycles per hour.

UNOLS Performance Specification for Tension Cycling

"Withstand = **50,000 cycles in tension from 0 to 40% of the RBS** at an 8 second period without failure of individual wires. Degradation in strength shall not exceed 5% of the RBS. This value is considered to be representative of tension variations due to ship motion and pay-out / haul-in speeds for 500 casts to oceanic depths."

Test Number 4
CST Test Setup

Tension Member Technologies
Huntington Beach, CA



Test Number 4
Cyclic Straight Tension Test Results
WRCA Ropes

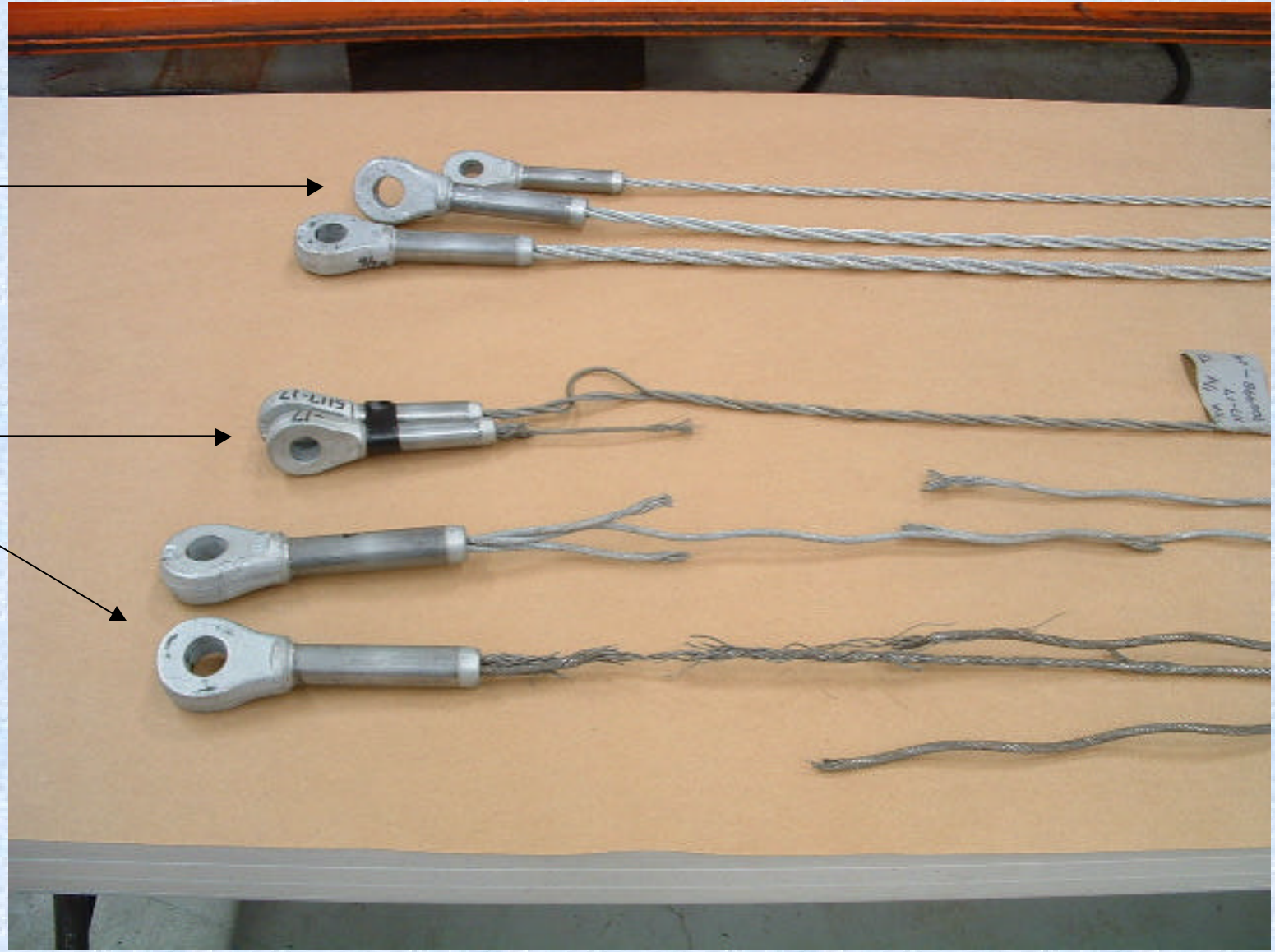
Sample No.	Rope Diameter [in]	Max. Tension [lbs]	Load cycles Completed [lbs]
17	**1/4**	**2,700**	**47,649**
29	3/8	5,920	40,108
41	7/16	8,000	27,171
51	**1/2**	**10,400**	**20,728**
63	**9/16**	**13,000**	**22,573**

Test Number 4
Cyclic Straight Tension Test Results
Loos Ropes

Sample No.	Rope Diameter [in]	Max. Tension [lbs]	Load cycles Completed [lbs]
23	**1/4**	**2,700**	**50,000**
35	3/8	5,920	50,000
46	7/16	8,000	50,000
57	**1/2**	**10,400**	**50,000**
69	**9/16**	**13,000**	**25,708**

Test Number 4
CST Test Samples

Tension Member Technologies
Huntington Beach, CA



Test Number 4
CST Test Samples

Tension Member Technologies
Huntington Beach, CA

Testing Program Limitations

- Limited number of duplicate samples
- Duplicate samples from same production run

Next Series of Wire Tests

- For 9/16” diameter 3x19 Trawl Wire
- Use CBOS to estimate rope fatigue life for a range of tensions and sheave diameters.
- Relate loading and sheave size in terms of “Life Factor”
- Life Factor = $\frac{\text{Rope Breaking Strength}}{\text{Load}} \times \frac{D}{d}$

  >LF Low loads and large sheave dia.

  <LF High loads and small sheave dia.

Next Series of Wire Tests
(continued)

- The CBOS tests conducted for a range of “life factors” until rope failure will provide the number of bend cycles to rope failure.
- Develop a relationship between “Life Factor” and rope fatigue life.
- Use relationship as a predictive tool to aid in determining when the rope should be considered for retirement.

Next Series of Wire Tests

(continued)

- Repeat the previous tests but stop after reaching half the bend cycles and break the sample. Provides residual strength at the half way point.
- Repeat again but stop after 3/4 of the ropes life and break the sample.
- Yield information about how rope strength diminishes with increasing bend cycles.

Discussion Topics

None of the wire ropes tested met all the UNOLS wire rope specifications.

- Is the situation as bad as it seems?
- Are these results consistent with field experience?
- Given the field performance of these ropes, is the current specification too demanding?
- Do these test results indicate the need for a re-evaluation of the current specification?
- In future purchases, how do we make sure we get what we think we are getting?

Thank you

Any additional questions?