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Stretch Hose Analysis Validation Test Report		
DOCUMENT TYPE	DWG NO.	REV
Test Report	3307-00020	A
		Page 1 of 26

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1.0 Test Summary

This document contains a report of test results for the Stretch Hose Analysis Validation Testing performed on Kaust hoses 004 and 007. Two Kaust stretch hoses were horizontally pulled to approximately 100% stretch. One new and one used was tested; the used hose was deployed in the Red Sea for one year. The manufacturing specification for the hoses is included in Appendix A. The objective of the testing was to gather experimental data for the purpose of validating an analytical model of the EOM stretch hose.

2.0 Reference Documents

- 2.1 3307-00012, Stretch Hose FEA Validation Data Test Plan (Rev A)

3.0 Test Samples

No.	Part Description	Part Number	Serial Number
1	50 ft Kaust Stretch Hose, spare (new)	n/a	007
2	50 ft Kaust Stretch Hose, used	n/a	004

4.0 Test Setup

The test setup is shown in Figure 1. One end of the hose was fixed to an anchor using rigging hardware. The other end was attached to a fork truck that provided the stretching force. A 5000lb load cell was placed on the moving end to measure hose tension. The hose was marked at the 15- ft, 25-ft, and 35-ft locations (un-stretched) using a permanent marker.



Figure 1. Test Setup

Each hose was cycled three times; this involved stretching the hose to the maximum length and then relaxing it until the load cell showed no tension on the hose. Measurements were recorded at 10-ft intervals. The hose behavior under load is strongly time-dependent, so efforts were made to be consistent in taking measurements at each data point. Four parameters were recorded – hose tension, hose length, hose diameter, and internal pressure.

Hose tension was recorded using the load cell every 10-s for the first 60-s, then every 30-s after until the load began to reach an asymptote.

Hose length was measured using a tape measure. Measurements from flange-to-flange and from flange to the 15-m, 25-m, and 35-m locations were recorded. The flange-to-flange measurement provides elongation of the entire hose length, while the measurements at marked locations provide elongation of only the center, “stretchy” portion of the hose.

Hose diameter was obtained by wrapping a string five times around the hose and then measuring the length of the string (Figure 2).

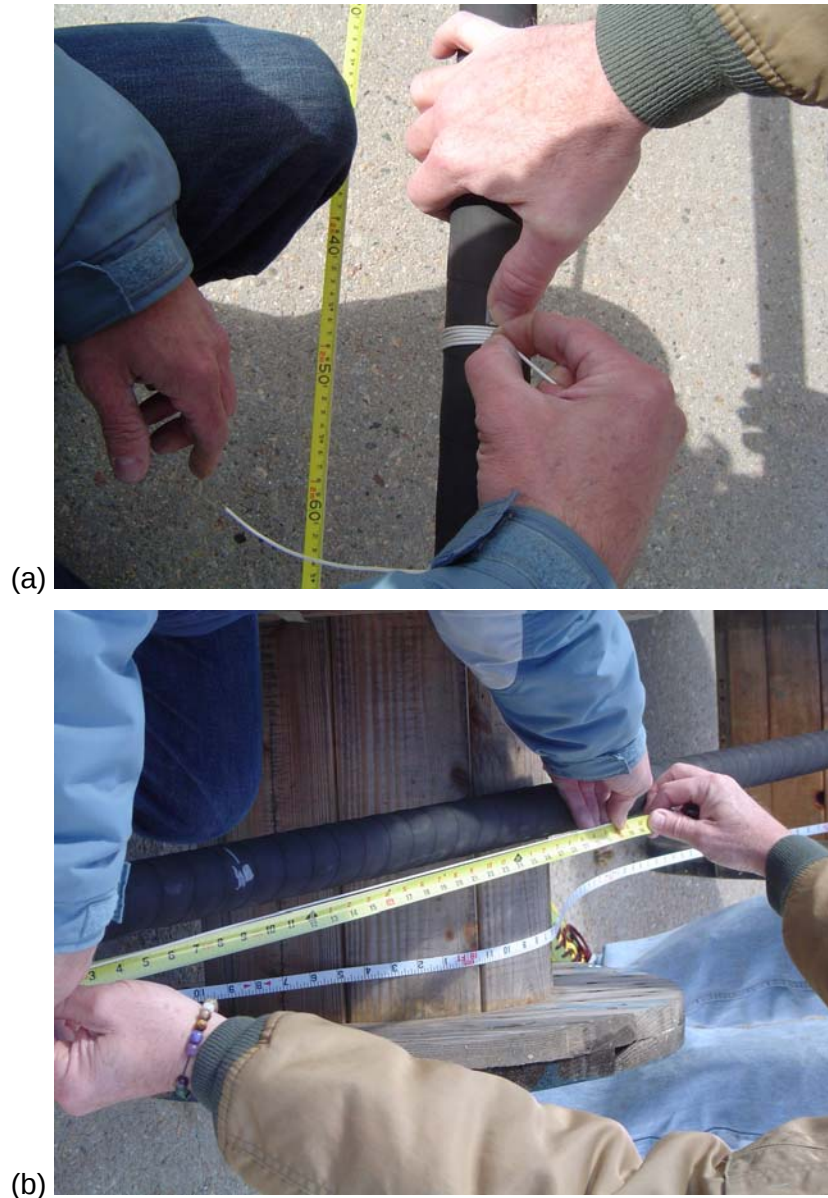


Figure 2. Method for measuring hose diameter: (a) wrapping the string 5 times around the hose, (b) measuring the length of the string

An IntelliSensing PS1 wireless pressure sensor was located on the fixed end to measure internal pressure. The pressure sensor was mounted on the hose coupling through the fill port. Data was transmitted through a MaxStream, Inc. Xbee-PRO-PKG-U wireless base station with a USB interface. Pressure was recorded every 1-2 s using LabView.

5.0 Test Results

Test results are provided for each hose in the following sections. Raw test data is provided in Appendix B.

7.1 New Kaust Hose (007)

The new Kaust hose was tested first. The initial length of the hose was 51.75 ft. The post-test hose length was 54.13 ft. The final length was 52.92 ft (36 hr later). The mean ambient temperature during testing was 50 deg F.

A comparison of pressure and tension measured during testing is shown in Figure 3. During the first cycle, pressure is at a vacuum until the hose is loaded up to 2000 lb, at which point the pressure begins to rapidly increase with each subsequent pull. Similar behavior is seen in the next two cycles, although the pressure spike takes place at a much lower pressure of around 1000 lb.

Tension and hose length are plotted in Figure 4. Tension values were recorded as soon as the hose stopped moving. It is clear from this plot that as the hose is cycled, the load seen by the hose for a given length decreases. For example, the maximum stretch length for Cycle 1 is 100-ft. At this length, there is 3000 lb of load in the hose. On the next cycle, the load at 100-ft stretch is approximately 2500 lb. On the third cycle, the load has dropped off even more to around 1500 lb.

The next four plots required a discrete pressure and tension at each hose length. It was decided that data would be plotted against the initial pressure (immediately after the hose stops moving) as well as the final pressure (at the end of the hold period, typically a few minutes after the hose stops moving). Figures Figure 5 and Figure 6 show initial pressure plotted against hose length and tension. Figures Figure 7 and Figure 8 show final pressure plotted against hose length and tension.

The change in outer hose diameter as the hose is cycled is shown in Figure 9. The data show an almost linear trend as the hose is stretched. Nominal hose diameter is 2.28-in. As the hose stretches, the OD decreases to a minimum of 1.46-in. With each subsequent cycle, the hose remains at a smaller diameter. However, given enough time at rest it is expected the hose would return to the original OD.

During testing, it was noted that the hose made 2-3 rotations as maximum stretch was approached. The rotations were in the counter-clockwise direction around the anchor. These were casual observations, but they indicate a more detailed examination of the residual torque in the hose would be worthwhile.

Following the tests, it was found there was an air volume in the hose column of 400 mL, or 24.4 in³.

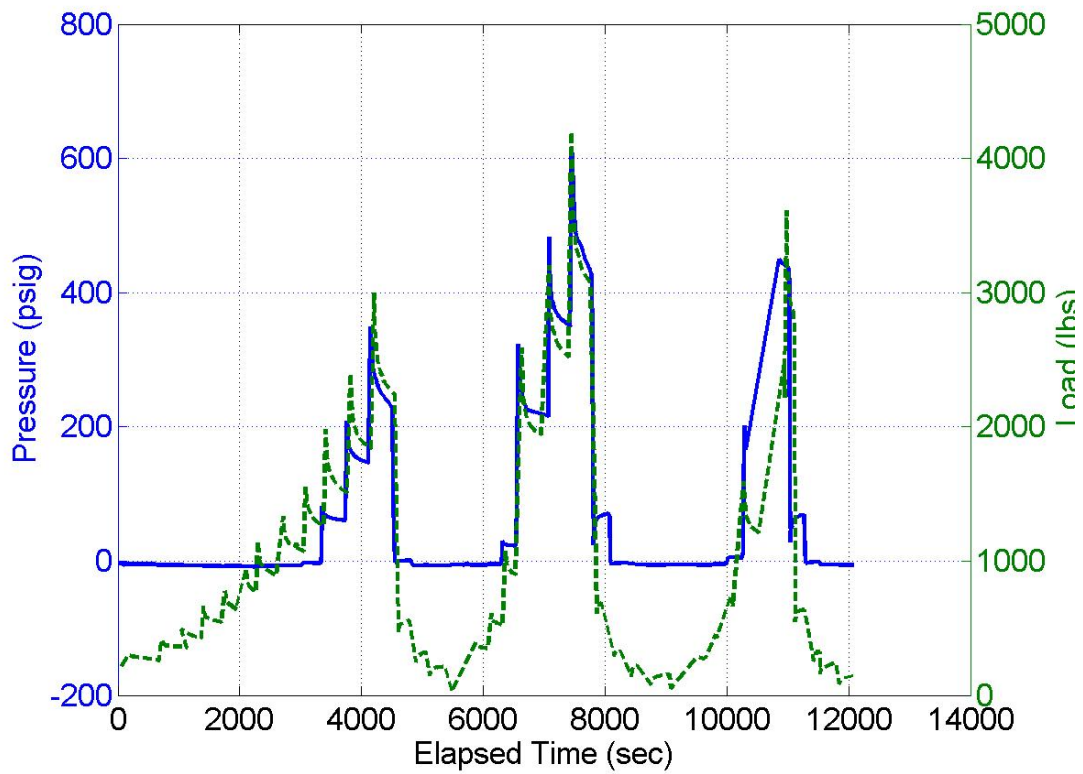


Figure 3. New Kaust (007) – Comparison of pressure and applied tension

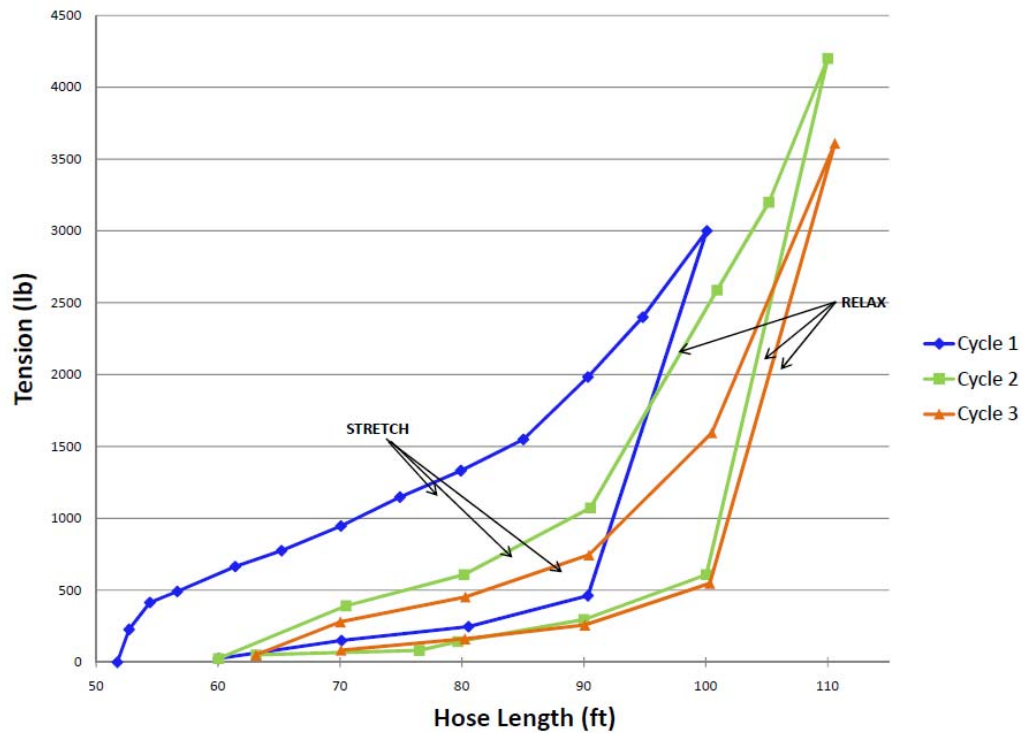


Figure 4. New Kaust (007) – Relationship between tension and hose length

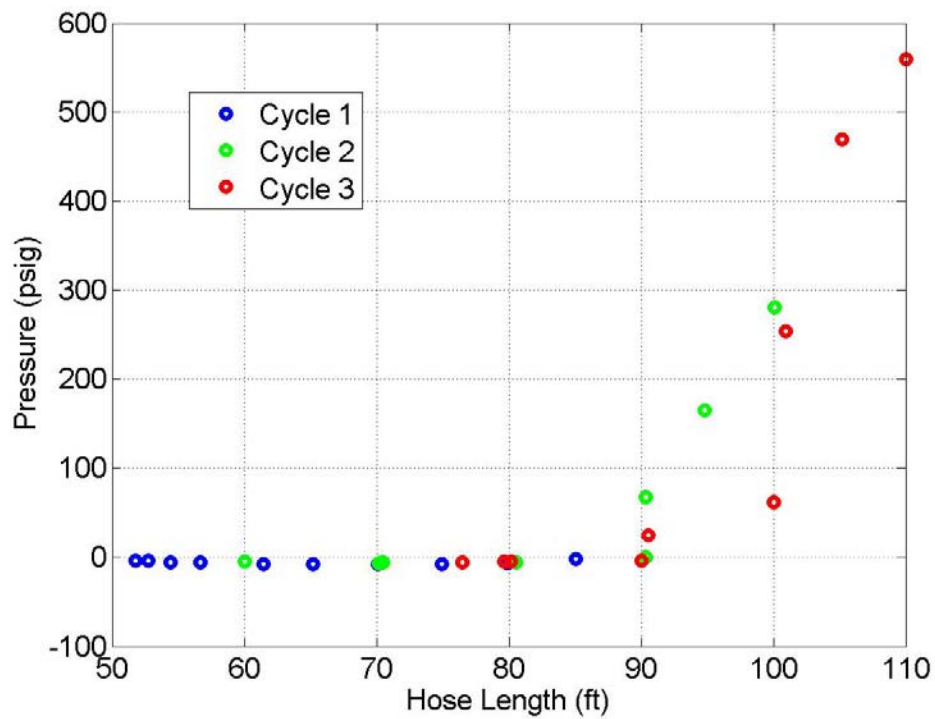


Figure 5. New Kaust (007) - Change in internal pressure with hose length (initial measurement)

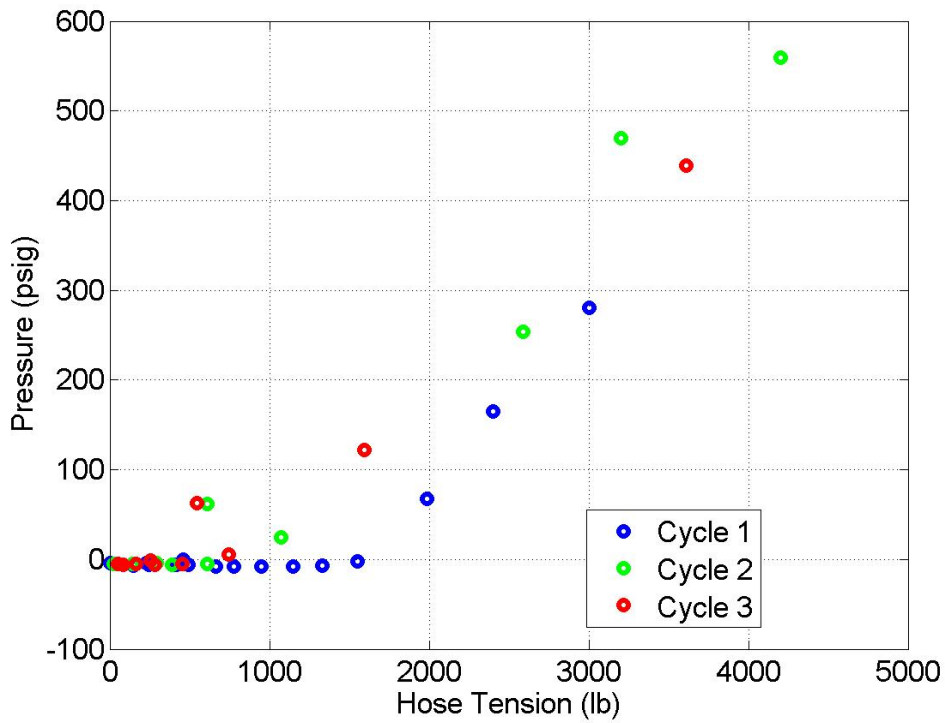


Figure 6. New Kaust (007) - Change in internal pressure with applied tension (initial measurement)

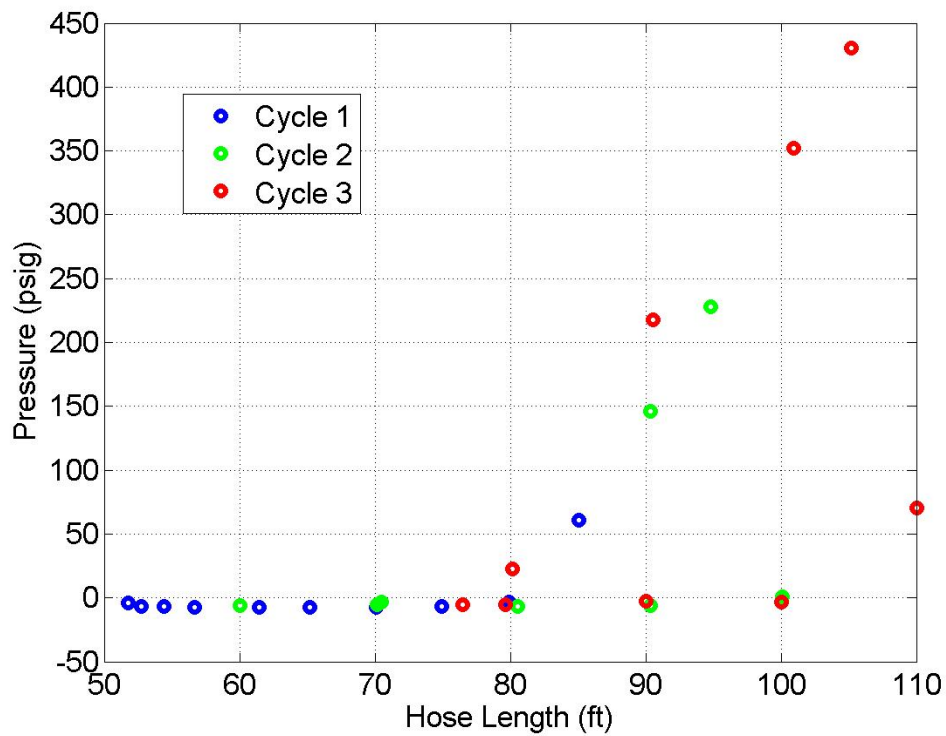


Figure 7. Kaust (007) - Change in internal pressure with hose length (after hold)

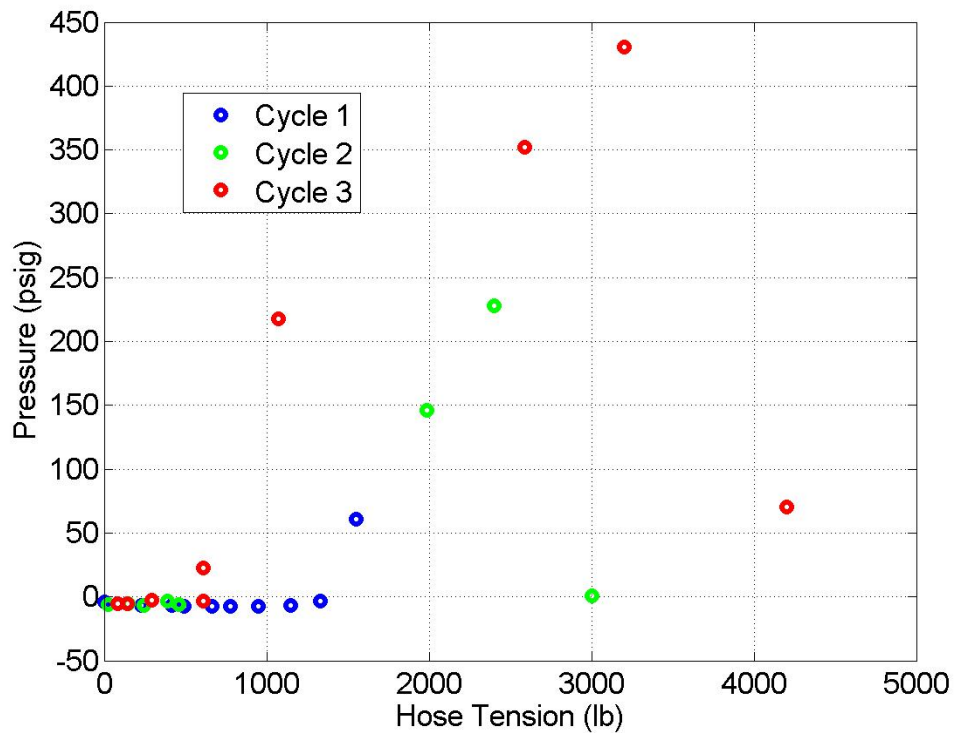
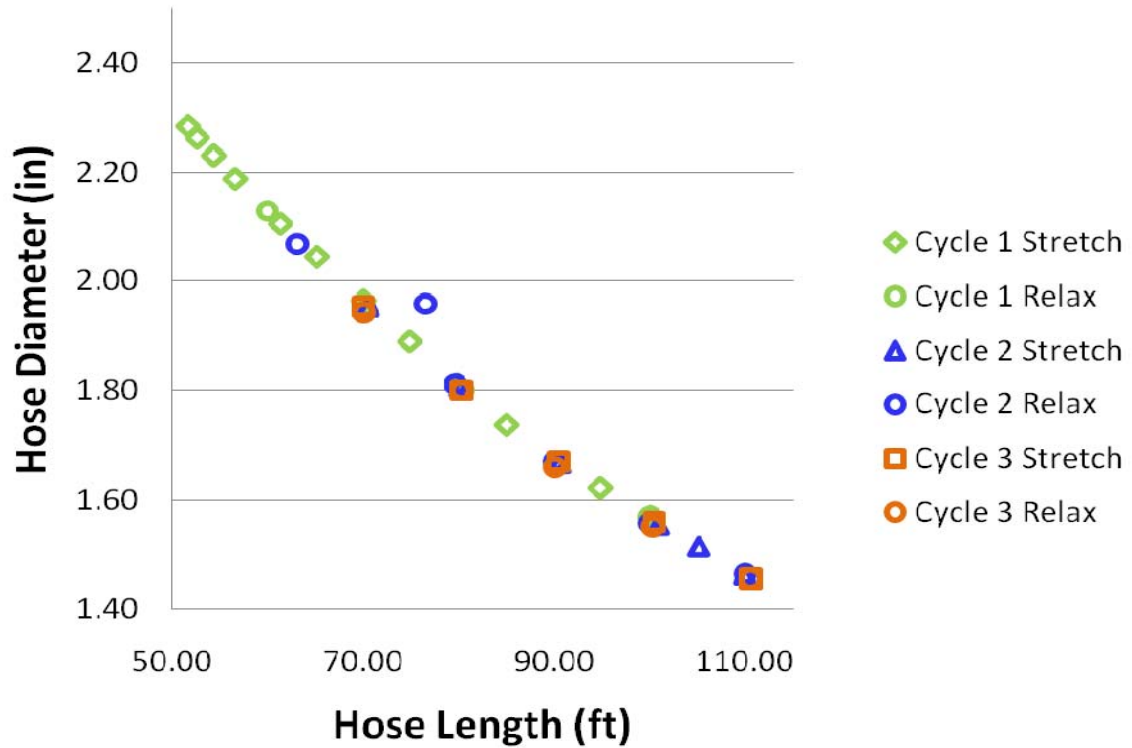


Figure 8. New Kaust (007) - Change in internal pressure with applied tension (after hold)



7.2 Used Kaust Hose (004)

The used Kaust hose was tested next. The initial length of the hose was 56.50 ft. The post-test hose length was 60.88 ft. The final length was 56.83 ft (36 hr later). The mean ambient temperature during testing was 57 deg F.

A comparison of pressure and tension measured during testing is shown in Figure 10Figure 3. During the first cycle, pressure is at a vacuum until the hose is loaded up to 1000 lb, at which point the pressure begins to rapidly increase with each subsequent pull. Similar behavior is seen in the next two cycles. Maximum pressure is 600 psi.

Tension and hose length are plotted in Figure 11. Tension values were recorded as soon as the hose stopped moving. Similar trends are observed as in the new hose, but the differences between cycles are much less.

As before, the next four plots are plotted using the initial and final pressure measurements. Figures Figure 12 and Figure 13 show initial pressure plotted against hose length and tension. Figures Figure 14 and Figure 15 show final pressure plotted against hose length and tension/

The change in outer hose diameter as the hose is cycled is shown in Figure 16. The data show an almost linear trend as the hose is stretched. Nominal hose diameter is 2.01-in. As the hose stretches, the OD decreases to a minimum of 1.32-in.

Following the tests, it was found there was an air volume in the hose column of 450 mL, or 27.5 in³.

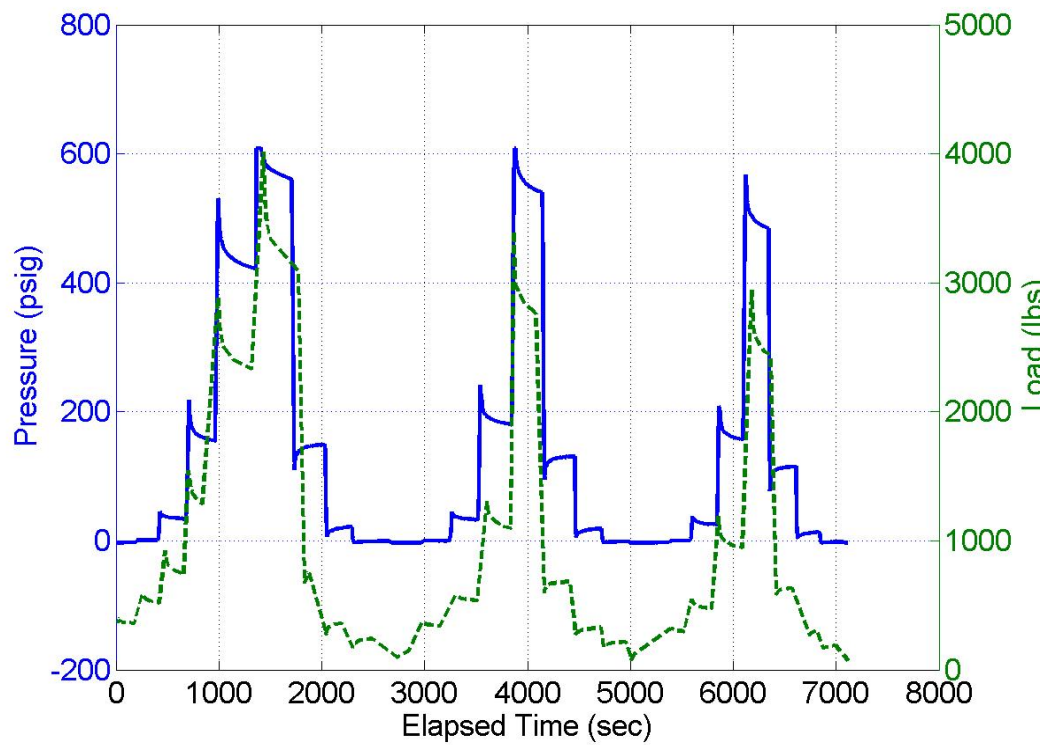


Figure 10. Used Kaust (004) – Comparison of pressure and applied tension

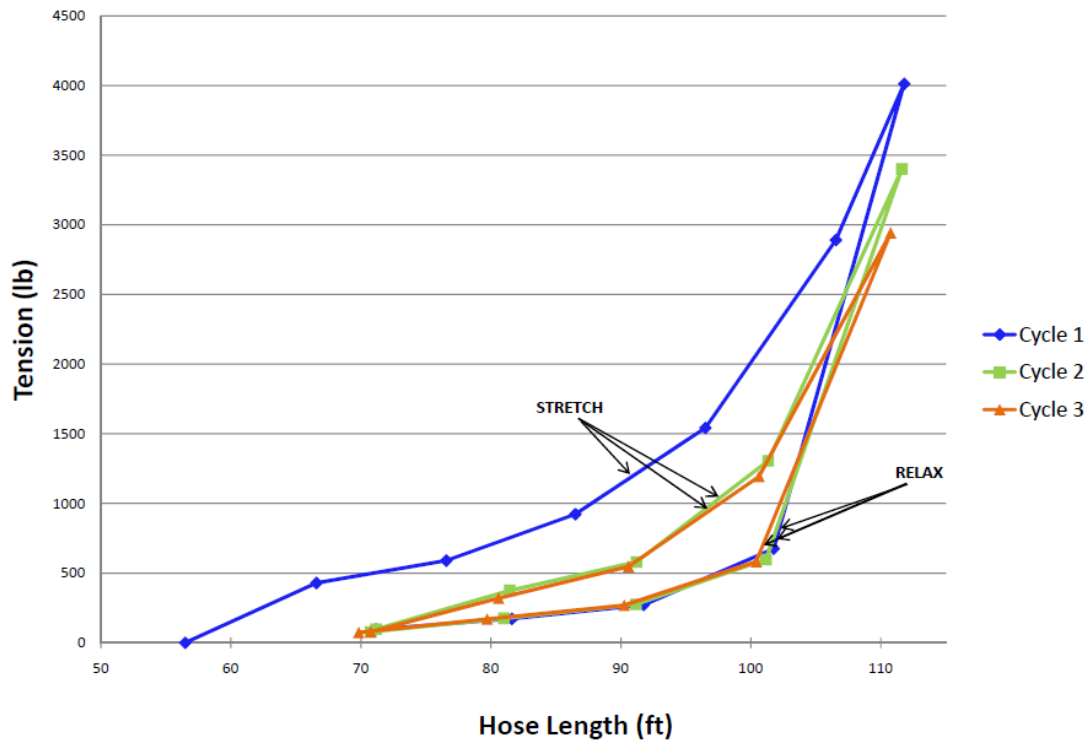


Figure 11. Used Kaust (004) – Relationship between tension and hose length

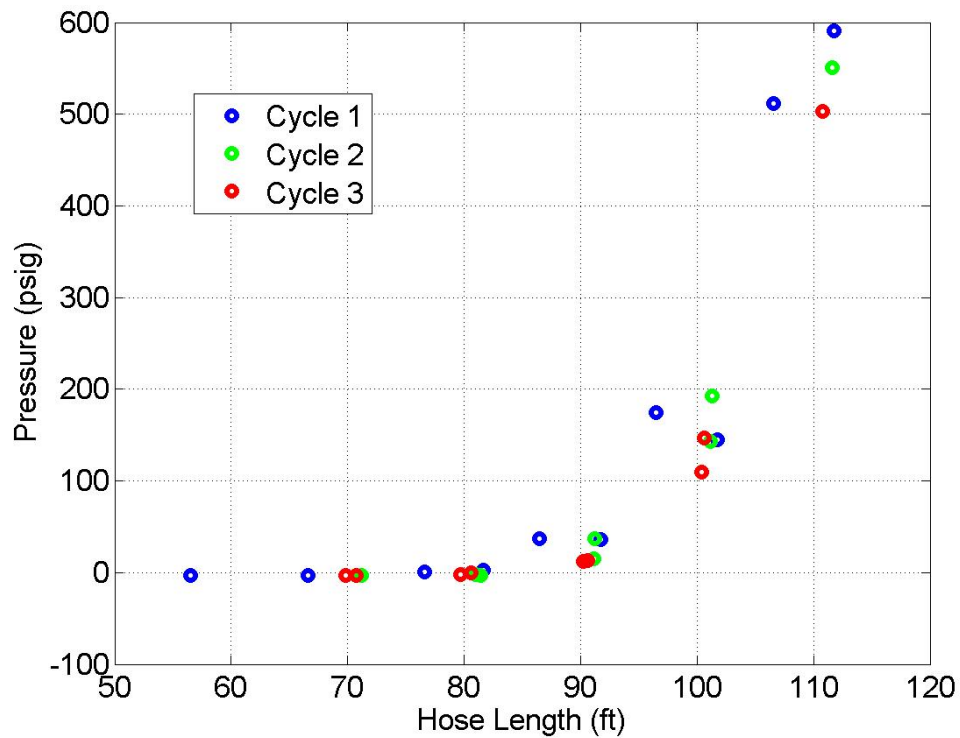


Figure 12. Used Kaust (004) - Change in internal pressure with hose length (initial measurement)

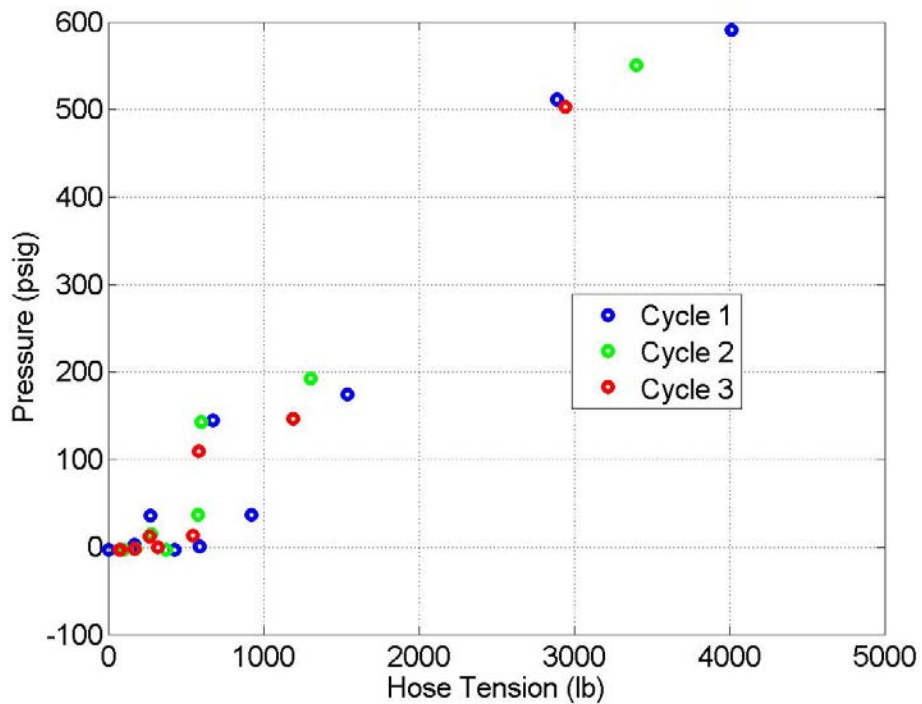


Figure 13. Used Kaust (004) - Change in internal pressure with applied tension (initial measurement)

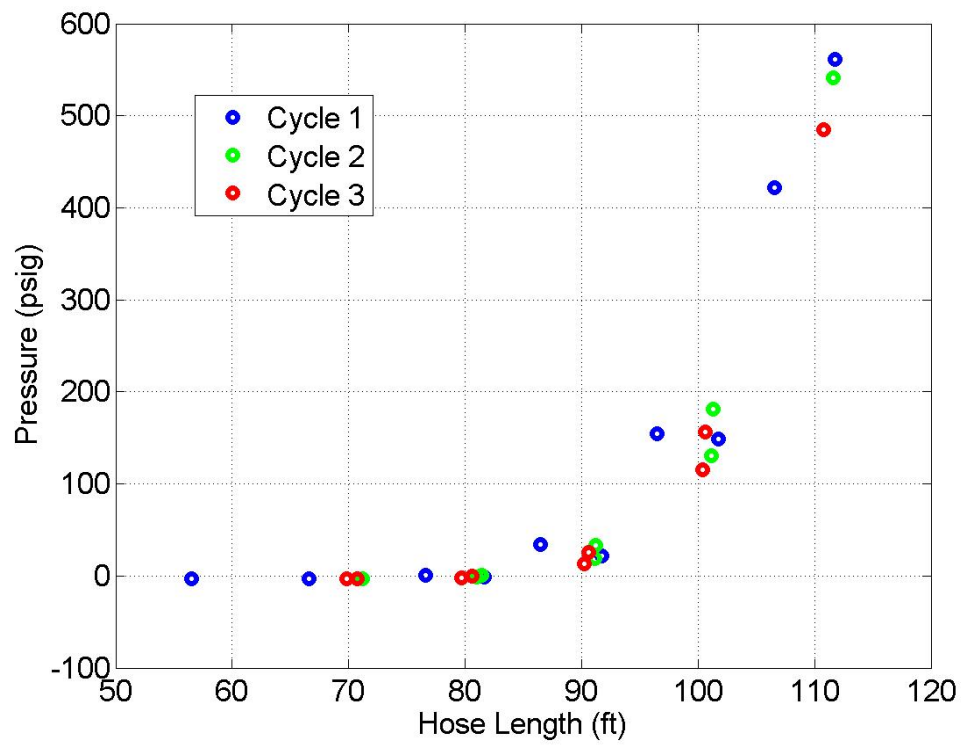


Figure 14. Used Kaust (004) - Change in internal pressure with hose length (after hold)

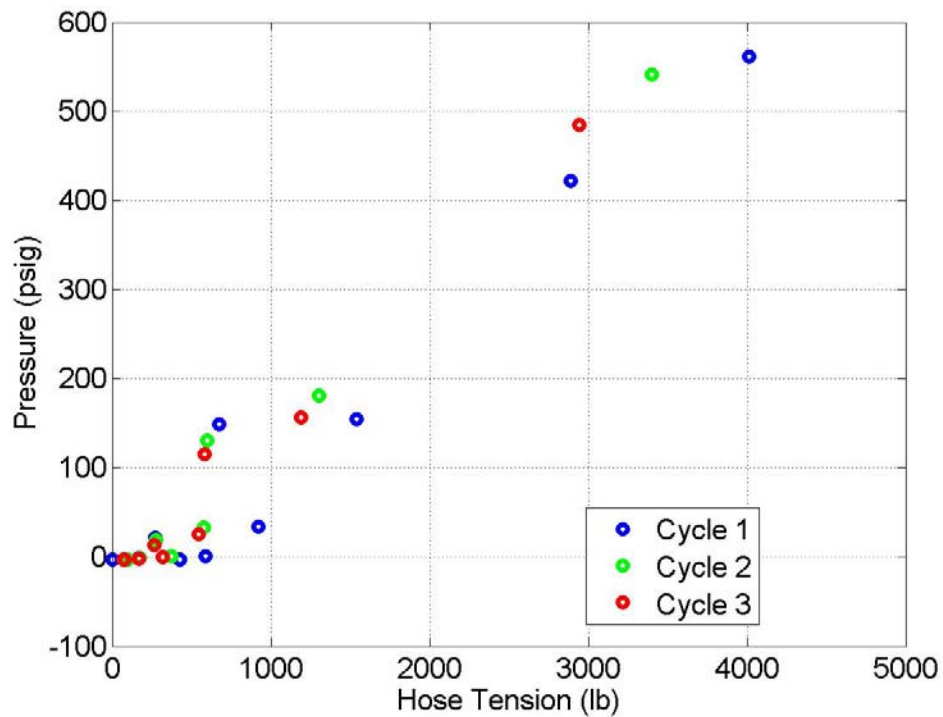


Figure 15. Used Kaust (004) - Change in internal pressure with applied tension (after hold)

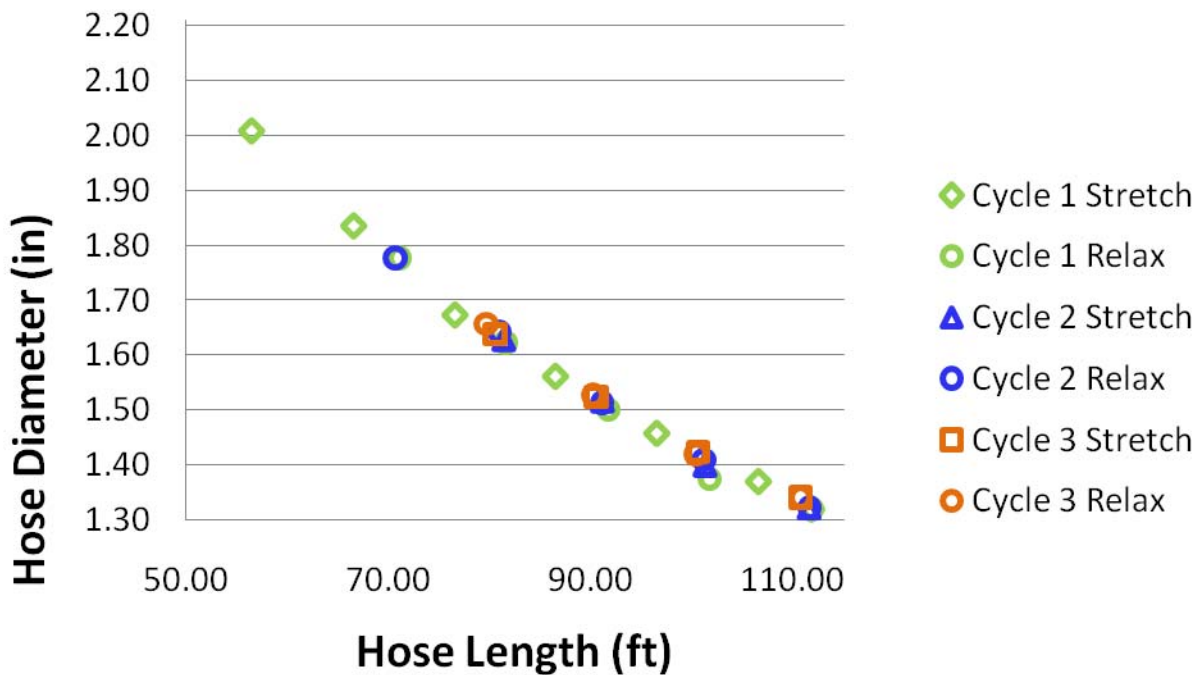


Figure 16. Used Kaust (004) – Change in (average) outer diameter as hose is cycled

6.0 Design Modifications / Corrective Actions

No design changes are required based on the results of this test.

7.0 Conclusions

Several improvements of the experimental setup are suggested for future testing.

First, it is recommended that a more robust data acquisition system is developed. A Labview program should be developed that records tension (from the load cell) and elongation (from the Distometer) in addition to pressure. These measurements must be sampled at the same rate in order to be useful. This would significantly reduce data reduction time and effort, as well as increase the fidelity of the measurements.

Second, it is not necessary to measure the hose diameter in three locations at each data point. Removing this measurement would allow the hoses to be continuously stretched and relaxed (assuming the first point is achieved), and would greatly reduce the test time per hose.

Third, it would be useful to add torque and wall thickness measurements to the test procedure. Torque is important as both hoses rotated as they were stretched, which indicates the hoses are not torque balanced per their design. The data could be used for design as well as help to define boundary conditions for the analytical hose model. Wall thickness would provide information on the changes taking place on the interior of the hose as it is stretched, namely

around the conductors. This may be possible to do with the Dakota Ultrasonics MVX visual ultrasonic thickness gauge.

Finally, test procedures should include checking the hose fill prior to testing. Both of the Kaust hoses were filled a few days prior to testing, but air space was found in both hoses when the fill levels were checked after testing.

8.0 Document Approval

Title	Signature	Date
Design Engineer	(signed) L. O'Hara	05/07/2010
Systems Engineer	D. Peters	
QA/QC Engineer	G. Dussault	

Appendix A. Kaust Hose Specification

HSS 50' Hose, no Conductors,

PAGE 1, REVISION 2

Woods Hole Oceanographic Institution

Assembly Spec WHOI HSS Hose, 1" ID, 50 ft long without Conductors

Part Number: WHOI-HSS-1-50-noC, Specification Page 1, Revision 2, July 8 2008

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Rev.1 July 08, 2008; Change: a) Increase width of Pt 9 to balance Stretch Limiter Torque, b) Modified wrap angles to get equal widths for Pts. 8 and 16, 10 and 13. c) Skim stock change from F029/8567 to improve cord adhesion, d) Correct Nylon callout from 5066 to F066, e) Increased endblock widths to assure coverage over coupling ribs. f) Minor corrections

Step or Part #	Wrap dia. [inch]	Wrap Angle [degree]	Wrap	Thick-ness [inch]	Pitch Length [inch]	Ribbon Width [inch]	Ribbon Length [feet]	HBD Rubber Compound or Reinforcing Material, Notes
1	1.064	0	n.a.	0.064	n.a.	4"2-ply	52.5	8820C, inner liner,
Steps A: Start of Wrapping Five (5) Uninterrupted Strength Member Ribbons								
But-wrap 5 layers F066/8567, 30 cpi nylon continuous strength members, no overlaps allowed								
CHANGE from Normal: Layers end in second valley after hose flange, direction Left to Right (S)								
2	1.16	69.55		0.032	1.36	1.27	303	Layers #2 - 6 all F066/8567
3	1.224	70.7		0.032	1.35	1.27	321	All Layers
4	1.288	69.8		0.032	1.49	1.40	307	continuous,
5	1.352	70.7		0.032	1.49	1.40	321	no overlap splices
6	1.416	71.5		0.032	1.49	1.41	334	allowed

Suggestion: Apply first Binding-in Wire Wraps, ends in 2nd coupling "valley"

Steps B: Start of 4 Stretch Limiter [SL] Wraps, Left to Right (S), see Note 1

Watch out, do not cut into underlying hose layers when trimming ends! Layers #7-12 all F066/8567

	Wrap dia. [inch]	Wrap Angle [degree]	Wrap	Thick-ness [inch]	Pitch Length [inch]	Ribbon Width [inch]	Ribbon Length [feet]	Notes	START at inch from Flange
7	1.48	60		0.032	2.68	2.32	2*9 ft 2"	Highest SL	76
8	1.544	51		0.032	3.93	3.05	2* 7 ft 1"	high SL, same width as Part 16	66
9	1.608	40		0.032	6.02	6.94	2* 6.0 ft	medium SL, wide ribbon balances torque	56
10	1.672	28.9		0.032	9.52	4.60	2*5 ft 4"	low SL	46
11	1.736	0	n.a.	0.032	n.a.	19.00	2* 40"	endblock 1, see Note 2	36
12	1.8	0	n.a.	0.032	n.a.	19.00	2*30"	endblock 2, see Note 2	26

Steps C: Start of 4 Stretch Limiter Cord Piles, Right to Left (Z) Direction. See Note 1

Layers end as usual in first coupling valley next to hose flange, all F066/8824.

Watch out, do not cut into underlying hose layers when trimming ends! Layers #13-16 all F066/8567

Wrap direction change from: "left to right (S)" to: "right to left" (Z) direction

	Wrap dia. [inch]	Wrap Angle [degree]	Wrap	Thick-ness [inch]	Pitch Length [inch]	Ribbon Width [inch]	Ribbon Length [feet]	Notes	START at inch from Flange
13	1.736	32.5		0.032	8.56	4.60	2* 5 ft 5"	low SL,	46
14	1.8	42		0.032	6.28	4.20	2* 6 ft 2"	medium SL,	56
15	1.864	52		0.032	4.58	3.61	2* 7 ft 5"	high SL,	66
16	1.928	59.75		0.032	3.53	3.05	2* 9 ft 9"	highest SL, Same width as Part 8	76

This completes the Application of Coupling-to-Hose Stretch Limiter

Suggestion: Apply second Binding-in Wire Wrap, end in 1st coupling valley next to Flange

Step D: Add Separation Layer in Center Length, start 76" from Flange next to Part 16

Watch out, do not cut into underlying hose when trimming ends!

17	1.512	0	n.a.	0.064	n.a.	4"2-ply	89.5	8820C Separation layer, see Note 3
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Steps E: Start of Wrapping Four (4) Uninterrupted Strength Member Ribbons

(Note: Wrap Diameters from now on are those of the compliant center section)

18	1.608	69.4		0.032	1.90	1.78	301	Layers #18-21 all F066/8567,
19	1.672	70.2		0.032	1.89	1.78	313	no splicing allowed.
20	1.736	69.4		0.032	2.05	1.92	301	
21	1.800	70.2		0.032	2.04	1.92	313	

Suggestion: Apply third Binding-in Wire Wraps

Continue on page 2

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**HSS 50' Hose, no Conductors,
PAGE 2, REVISION 2**

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Woods Hole Oceanographic Institution
Assembly Spec WHOI HSS Hose, 1" ID, 50 ft, without Conductors
Part Number: WHOI-HSS-1-50-noC, Page 2

Rev. 2, July 08, 2008: Change: a) Increase width of Pt 9 to balance Stretch Limiter Torque, b) Modified wrap angles to get equal widths for Pts. 8 and 16, 10 and 13. c) Skim stock change from FO29/8567 to improve cord adhesion, d) Correct Nylon callout from 5066 to F066, e) Increased enblock widths to assure coverage over coupling ribs. F) Minor corrections

Step or Part #	Wrap dia. [inch]	Wrap Angle [degree]	Wrap	Thick-ness [inch]	Pitch Length [inch]	Ribbon Width [inch]	Ribbon Length [feet]	HBD Rubber Compound or Reinforcing Material, Notes
Step F: Cover Strength Members with Rubber Jacket								
22	1.896	0	n.a.	0.064	n.a.	4**2-ply	105	8820C, Outer Jacket
Step G: Apply Kevlar Endblock and counter-helical Kevlar Layers								
23	1.992	0	n.a.	0.032	n.a.	21	2*2 ft	F066/8824, Endblock 3
24	1.992	73.5		0.032	1.85	1.78	370	FO29/8567 Kevlar, Note 4:
25	2.088	0	n.a.	0.064	n.a.	4**2-ply	105	8820C Separation layer
26	2.184	74.5		0.032	1.84	1.78	393	FO29/8567 Kevlar, see note 4
Step H: Finally: Apply outer Jacket, smooth out Rubber Gaps at Couplings, emboss & shrinkwrap hose								
29	2.312	0	n.a.	0.096	n.a.	4**3-ply	105	8820C, Outer Jacket

Hose outer diameter is ~ 2.41 inch in compliant center section

Notes and Explanations

Note 1: To balance inner and outer torque, ribbon Part 9 is cut 6.94" wide, wrap with 6.0" pitch length with overlap to generate additional torque of the inner stretch limiter assembly.

Note 2: End-Blocks (Part 11 and 12) can either be **F065/8567** Nylon or similar Polyester woven cord

Note 3: Part 17: Apply rubber layer starting abt. 6 ft 4" from each hose end.

Fill valley with Part 17 between layers 16 at each hose end.

When trimming stock to fit between cord plies, **do not cut into cord plies below**

Note 4 for Kevlar layers: Kevlar layers only can include overlap splicing.

Note 5 for all spiraled layers: The called out wrap angle refers to its position in central compliant hose section for main strength members (Parts 2-5 and 18-21). For the Stretch Limiter layers the wrap angles (Parts 7-10 and 13-16) refer to their start at their positions furthest away from the couplings. All wrap angles need to be approximately maintained in the stretch limiter areas as they increase pitch diameters and pitch lengths near the hose ends.

Note 6, Brand Hose: Emboss HSS-noC and Serial # (01, 02,) near one hose end, apply date of manufacturing (Quarter/Year) near other end. Apply ~20" from hose ends ~ parallel to hose axis .

Questions: Walter Paul at WHOI, phone 508-289-3506 or e-mail <wpaul@whoi.edu> , or
Don Peters, phone 508-289-3377 , or e-mail <dpeters@whoi.edu>

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Appendix B. Raw Test Data

Table A.1 New Kaust (007) General

Start Length	51.75	ft	(measured prior to test)
End Length	54.13	ft	(measured 3 hr later)
Final Length	52.92	ft	(measured 36 hr later)
Air Volume	400	mL	(measured 36 hr later)

Table A.2 New Kaust (007) Load Data

CYCLE 1								
	Elapsed Time	Load				Elapsed Time	Load	
Time	(s)	(lb)	Pull		Time	(s)	(lb)	Pull
8:34:40	0:00:00	227	2		9:11:30	0:36:50	789	
8:35:30	0:00:50	205			9:12:30	0:37:50	767	
8:37:30	0:02:50	298			9:13:00	0:38:20	1148	8
8:38:30	0:03:50	289			9:13:10	0:38:30	1054	
8:41:30	0:06:50	278			9:13:20	0:38:40	1020	
8:46:00	0:11:20	262			9:13:30	0:38:50	998	
8:46:30	0:11:50	415	3		9:13:45	0:39:05	981	
8:47:00	0:12:20	380			9:14:00	0:39:20	971	
8:47:30	0:12:50	369			9:15:00	0:40:20	934	
8:53:30	0:18:50	355			9:16:00	0:41:20	924	
8:52:00	0:17:20	492	4		9:17:00	0:42:20	906	
8:53:00	0:18:20	470			9:18:00	0:43:20	889	
8:54:30	0:19:50	452			9:19:50	0:45:10	1332	9
8:55:00	0:20:20	440			9:20:00	0:45:20	1246	
8:57:30	0:22:50	428			9:20:10	0:45:30	1210	
8:58:00	0:23:20	665	5		9:20:20	0:45:40	1194	
8:58:30	0:23:50	595			9:20:30	0:45:50	1180	
8:58:45	0:24:05	584			9:20:40	0:46:00	1169	
8:59:00	0:24:20	576			9:20:50	0:46:10	1160	
9:01:00	0:26:20	556			9:21:00	0:46:20	1152	
9:03:00	0:28:20	545			9:21:30	0:46:50	1130	
9:04:00	0:29:20	775	6		9:24:00	0:49:20	1125	
9:04:20	0:29:40	730			9:22:35	0:47:55	1110	
9:04:30	0:29:50	708			9:23:00	0:48:20	1106	
9:04:45	0:30:05	687			9:23:30	0:48:50	1098	
9:06:00	0:31:20	661			9:24:00	0:49:20	1092	
9:07:00	0:32:20	639			9:24:30	0:49:50	1085	
9:09:45	0:35:05	947	7		9:25:00	0:50:20	1080	
9:09:50	0:35:10	873			9:25:30	0:50:50	1073	
9:10:00	0:35:20	844			9:26:00	0:51:20	1549	10
9:10:10	0:35:30	836			9:26:20	0:51:40	1452	
9:10:30	0:35:50	816			9:26:30	0:51:50	1423	

Table A.2 (cont)

CYCLE 1								
	Elapsed Time	Load				Elapsed Time	Load	
Time	(s)	(lb)	Pull		Time	(s)	(lb)	Pull
9:26:40	0:52:00	1413			9:41:00	1:06:20	1905	
9:26:50	0:52:10	1386			9:41:30	1:06:50	1892	
9:27:00	0:52:20	1376			9:42:00	1:07:20	1874	
9:27:30	0:52:50	1345			9:42:30	1:07:50	1868	
9:28:00	0:53:20	1321			9:43:00	1:08:20	1856	
9:28:30	0:53:50	1306			9:43:30	1:08:50	1846	
9:29:00	0:54:20	1295			9:44:00	1:09:20	1838	
9:29:30	0:54:50	1284			9:44:45	1:10:05	3000	13
9:30:00	0:55:20	1278			9:44:55	1:10:15	2762	
9:30:30	0:55:50	1267			9:45:05	1:10:25	2664	
9:31:00	0:56:20	1263			9:45:15	1:10:35	2595	
9:31:35	0:56:55	1984	11		9:45:25	1:10:45	2553	
9:31:45	0:57:05	1789			9:45:35	1:10:55	2524	
9:31:55	0:57:15	1745			9:45:45	1:11:05	2496	
9:32:05	0:57:25	1716			9:45:55	1:11:15	2472	
9:32:15	0:57:35	1702			9:46:30	1:11:50	2405	
9:32:25	0:57:45	1678			9:47:00	1:12:20	2373	
9:32:35	0:57:55	1665			9:47:30	1:12:50	2336	
9:32:45	0:58:05	1650			9:48:00	1:13:20	2315	
9:33:00	0:58:20	1635			9:48:30	1:13:50	2298	
9:33:30	0:58:50	1615			9:49:00	1:14:20	2281	
9:34:00	0:59:20	1591			9:50:20	1:15:40	2243	
9:34:30	0:59:50	1572			9:51:20	1:16:40	462	14
9:35:00	1:00:20	1558			9:51:30	1:16:50	499	
9:35:30	1:00:50	1547			9:51:40	1:17:00	510	
9:36:00	1:01:20	1529			9:51:50	1:17:10	519	
9:36:30	1:01:50	1526			9:52:00	1:17:20	524	
9:37:00	1:02:20	1513			9:52:10	1:17:30	530	
9:37:30	1:02:50	1509			9:52:20	1:17:40	534	
9:38:20	1:03:40	2400	12		9:52:30	1:17:50	535	
9:38:30	1:03:50	2183			9:53:00	1:18:20	545	
9:38:40	1:04:00	2116			9:53:30	1:18:50	550	
9:38:50	1:04:10	2081			9:54:00	1:19:20	553	
9:39:00	1:04:20	2047			9:54:30	1:19:50	557	
9:39:10	1:04:30	2022			9:56:15	1:21:35	247	15
9:39:20	1:04:40	2004			9:56:25	1:21:45	268	
9:39:30	1:04:50	1990			9:56:35	1:21:55	281	
9:39:40	1:05:00	1973			9:56:45	1:22:05	288	
9:40:00	1:05:20	1950			9:56:55	1:22:15	292	
9:40:30	1:05:50	1924			9:57:30	1:22:50	305	

Table A.2 (cont)

CYCLE 1					CYCLE 2			
Time	Elapsed Time (s)	Load (lb)	Pull		Time	Elapsed Time (s)	Load (lb)	Pull
9:58:00	1:23:20	311			10:21:25	0:08:50	956	
9:58:30	1:23:50	318			10:21:30	0:08:55	947	
9:59:00	1:24:20	319			10:22:00	0:09:25	930	
10:00:00	1:25:20	150	16		10:22:30	0:09:55	912	
10:00:10	1:25:30	173			10:23:30	0:10:55	897	
10:00:20	1:25:40	185			10:25:10	0:12:35	2588	21
10:00:30	1:25:50	186			10:25:20	0:12:45	2318	
10:00:40	1:26:00	190			10:25:30	0:12:55	2233	
10:00:50	1:26:10	194			10:25:40	0:13:05	2192	
10:01:00	1:26:20	196			10:25:50	0:13:15	2155	
10:01:30	1:26:50	204			10:26:00	0:13:25	2132	
10:02:00	1:27:20	208			10:26:30	0:13:55	2063	
10:02:30	1:27:50	209			10:27:00	0:14:25	2040	
10:03:30	1:28:50	214			10:27:30	0:14:55	2012	
10:04:00	1:29:20	215			10:28:00	0:15:25	1997	
10:06:00	1:31:20	25	17		10:28:30	0:15:55	1978	
CYCLE 2					10:29:30	0:16:55	1955	
10:12:35	0:00:00	392	18		10:30:30	0:17:55	1943	
10:12:45	0:00:10	374			10:32:40	0:20:05	3200	22
10:12:55	0:00:20	368			10:32:50	0:20:15	2949	
10:13:05	0:00:30	366			10:33:00	0:20:25	2839	
10:13:15	0:00:40	363			10:33:30	0:20:55	2753	
10:13:30	0:00:55	361			10:33:40	0:21:05	2723	
10:14:00	0:01:25	356			10:34:00	0:21:25	2698	
10:15:00	0:02:25	353			10:34:30	0:21:55	2650	
10:15:30	0:02:55	350			10:35:00	0:22:25	2611	
10:16:00	0:03:25	349			10:35:30	0:22:55	2594	
10:16:50	0:04:15	608	19		10:36:00	0:23:25	2575	
10:17:00	0:04:25	574			10:36:30	0:23:55	2560	
10:17:10	0:04:35	562			10:37:00	0:24:25	2545	
10:17:30	0:04:55	549			10:38:00	0:25:25	2518	
10:18:00	0:05:25	540			10:38:45	0:26:10	4200	23
10:18:30	0:05:55	535			10:39:00	0:26:25	3800	
10:19:00	0:06:25	529			10:39:05	0:26:30	3640	
10:19:30	0:06:55	527			10:39:10	0:26:35	3583	
10:20:00	0:07:25	520			10:39:45	0:27:10	3384	
10:20:45	0:08:10	1074	20		10:40:00	0:27:25	3328	
10:20:55	0:08:20	1015			10:40:40	0:28:05	3265	
10:21:05	0:08:30	985			10:41:00	0:28:25	3232	
10:21:15	0:08:40	965			10:41:30	0:28:55	3179	

Table A.2 (cont)

CYCLE 2					CYCLE 3			
Time	Elapsed Time (s)	Load (lb)	Pull		Time	Elapsed Time (s)	Load (lb)	Pull
10:42:00	0:29:25	3151			11:26:50	0:13:50	1319	
10:44:00	0:31:25	3062			11:27:00	0:14:00	1307	
10:45:45	0:33:10	608	24		11:27:30	0:14:30	1275	
10:46:00	0:33:25	645			11:28:00	0:15:00	1251	
10:46:15	0:33:40	664			11:30:00	0:17:00	1214	
10:46:30	0:33:55	676			11:37:00	0:24:00	2485	33?
10:47:00	0:34:25	687			11:37:10	0:24:10	2219	
10:50:30	0:37:55	295	25		11:37:35	0:24:35	3610	33
10:50:45	0:38:10	314			11:37:45	0:24:45	3238	
10:51:00	0:38:25	322			11:37:55	0:24:55	3132	
10:51:30	0:38:55	334			11:38:05	0:25:05	3059	
10:52:00	0:39:25	342			11:38:15	0:25:15	3012	
10:55:15	0:42:40	143	26		11:38:25	0:25:25	2967	
10:55:30	0:42:55	188			11:39:00	0:26:00	2892	
10:55:45	0:43:10	212			11:39:30	0:26:30	2849	
10:56:00	0:43:25	215			11:39:45	0:26:45	2723	
10:56:15	0:43:40	218			11:40:00	0:27:00	548	34
10:56:30	0:43:55	218			11:40:15	0:27:15	607	
10:56:45	0:44:10	220			11:40:30	0:27:30	617	
11:00:30	0:47:55	81	27		11:41:00	0:28:00	625	
11:01:00	0:48:25	120			11:41:30	0:28:30	629	
11:01:30	0:48:55	130			11:42:30	0:29:30	637	
11:02:30	0:49:55	144			11:45:00	0:32:00	258	35
11:05:30	0:52:55	157			11:45:30	0:32:30	278	
11:06:00	0:53:25	50	28		11:45:45	0:32:45	326	
CYCLE 3					11:46:45	0:33:45	327	
11:13:00	0:00:00	280	29		11:46:50	0:33:50	162	36
11:13:30	0:00:30	282			11:47:00	0:34:00	193	
11:15:00	0:02:00	271			11:47:10	0:34:10	198	
11:15:30	0:02:30	280			11:47:30	0:34:30	202	
11:18:20	0:05:20	453	30		11:48:00	0:35:00	208	
11:18:30	0:05:30	439			11:51:00	0:38:00	243	
11:18:40	0:05:40	428			11:52:00	0:39:00	83	37
11:22:30	0:09:30	745	31		11:53:00	0:40:00	125	
11:23:00	0:10:00	668			11:56:00	0:43:00	145	
11:26:00	0:13:00	1596	32					
11:26:10	0:13:10	1437						
11:26:20	0:13:20	1399						
11:26:30	0:13:30	1350						
11:26:40	0:13:40	1323						

Table A.3 New Kaust (007) Length and Diameter Measurements

	Pull	End-to-End Length (ft)	Center Length (ft)	Avg Circum. (in)	Avg Diameter (in)	Avg Diameter - Corrected (in)
stretch	1	56.50	20.00	6.64	2.11	2.01
stretch	2	66.58	24.42	6.10	1.94	1.83
stretch	3	76.58	28.83	5.59	1.78	1.67
stretch	4	86.50	33.04	5.24	1.67	1.56
stretch	5	96.50	37.16	4.92	1.57	1.46
stretch	6	106.54	41.22	4.64	1.48	1.37
stretch	7	111.79	47.54	4.48	1.43	1.32
relax	8	101.75	39.55	4.66	1.48	1.38
relax	9	91.75	32.76	5.05	1.61	1.50
relax	10	81.63	31.02	5.43	1.73	1.62
relax	11	71.17	26.42	5.92	1.88	1.78
stretch	12	81.46	31.00	5.45	1.73	1.63
stretch	13	91.21	35.18	5.10	1.62	1.52
stretch	14	101.33	39.24	4.73	1.51	1.40
stretch	15	111.63	43.41	4.49	1.43	1.32
relax	16	101.17	39.35	4.77	1.52	1.41
relax	17	91.17	35.23	5.09	1.62	1.51
relax	18	81.00	30.88	5.49	1.75	1.64
relax	19	70.75	26.38	5.92	1.88	1.78
stretch	20	80.58	30.68	5.48	1.75	1.64
stretch	21	90.58	34.90	5.13	1.63	1.52
stretch	22	100.63	39.01	4.81	1.53	1.42
stretch	23	110.75	43.05	4.55	1.45	1.34
relax	24	100.42	39.06	4.80	1.53	1.42
relax	25	90.25	34.82	5.13	1.63	1.53
relax	26	79.71	30.29	5.54	1.76	1.66
relax	27	69.83	25.91	0.00	0.00	0.00

Table A.4 Used Kaust (004) General

Start Length	56.50	ft	(measured prior to test)
End Length	60.88	ft	(measured after test)
Final Length	56.83	ft	(measured 36 hr later)
Air Volume	450	mL	(measured 36 hr later)

Table A.5 Used Kaust (004) Load Data

CYCLE 1								
	Elapsed Time (s)	Load (lb)	Pull			Elapsed Time (s)	Load (lb)	Pull
Time					Time			
1:03:30	0:00:00	429	2		1:20:20	0:16:50	2623	
1:03:40	0:00:10	403			1:20:30	0:17:00	2587	
1:03:50	0:00:20	370			1:20:40	0:17:10	2538	
1:04:00	0:00:30	384			1:20:50	0:17:20	2511	
1:04:10	0:00:40	378			1:21:00	0:17:30	2495	
1:04:30	0:01:00	371			1:22:30	0:19:00	2403	
1:05:00	0:01:30	367			1:25:30	0:22:00	2332	
1:05:30	0:02:00	365			1:27:25	0:23:55	4011	7
1:06:30	0:03:00	359			1:27:35	0:24:05	3701	
1:07:45	0:04:15	590	3		1:27:45	0:24:15	3523	
1:07:55	0:04:25	573			1:27:55	0:24:25	3459	
1:08:05	0:04:35	557			1:28:30	0:25:00	3337	
1:08:15	0:04:45	552			1:33:00	0:29:30	3091	
1:08:30	0:05:00	542			1:34:00	0:30:30	675	8
1:09:00	0:05:30	533			1:34:30	0:31:00	720	
1:10:30	0:07:00	517			1:34:40	0:31:10	755	
1:11:30	0:08:00	923	4		1:37:30	0:34:00	272	9
1:11:40	0:08:10	851			1:37:40	0:34:10	305	
1:11:50	0:08:20	817			1:37:50	0:34:20	322	
1:12:00	0:08:30	805			1:38:00	0:34:30	332	
1:12:30	0:09:00	785			1:39:00	0:35:30	353	
1:13:00	0:09:30	765			1:40:00	0:36:30	360	
1:14:30	0:11:00	741			1:41:50	0:38:20	172	10
1:15:15	0:11:45	1542	5		1:42:00	0:38:30	200	
1:15:35	0:12:05	1405			1:42:10	0:38:40	206	
1:15:45	0:12:15	1382			1:42:30	0:39:00	209	
1:16:00	0:12:30	1356			1:43:00	0:39:30	229	
1:16:30	0:13:00	1326			1:44:00	0:40:30	236	
1:17:00	0:13:30	1298			1:45:00	0:41:30	240	
1:17:30	0:14:00	1283			1:49:00	0:45:30	97	11
1:20:00	0:16:30	2890	6		1:51:00	0:47:30	148	
1:20:10	0:16:40	2690						

Table A.5 (cont)

CYCLE 2				CYCLE 2			
Time	Elapsed Time (s)	Load (lb)	Pull	Time	Elapsed Time (s)	Load (lb)	Pull
1:53:10	0:49:40	375	12	2:26:00	1:22:30	217	
1:53:20	0:49:50	365		2:27:00	1:23:30	78	19
1:53:30	0:50:00	361		2:27:30	1:24:00	122	
1:54:00	0:50:30	350		CYCLE 3			
1:56:00	0:52:30	340		2:33:20	1:29:50	320	20
1:58:30	0:55:00	580	13	2:34:30	1:31:00	302	
1:59:10	0:55:40	559		2:35:00	1:31:30	301	
1:59:30	0:56:00	553		2:35:30	1:32:00	293	
2:00:00	0:56:30	549		2:36:45	1:33:15	547	21
2:02:00	0:58:30	538		2:36:55	1:33:25	523	
2:03:35	1:00:05	1305	14	2:37:05	1:33:35	513	
2:03:55	1:00:25	1208		2:37:15	1:33:45	508	
2:04:05	1:00:35	1197		2:37:30	1:34:00	496	
2:04:45	1:01:15	1157		2:38:00	1:34:30	490	
2:04:55	1:01:25	1152		2:38:30	1:35:00	484	
2:06:00	1:02:30	1112		2:39:30	1:36:00	478	
2:07:30	1:04:00	1097		2:40:00	1:36:30	475	
2:08:00	1:04:30	3400	15	2:41:05	1:37:35	1193	22
2:08:02	1:04:32	3005		2:41:15	1:37:45	1059	
2:08:45	1:05:15	2929		2:41:25	1:37:55	1049	
2:09:00	1:05:30	2903		2:41:45	1:38:15	1018	
2:09:45	1:06:15	2829		2:42:00	1:38:30	999	
2:11:00	1:07:30	2785		2:42:30	1:39:00	985	
2:11:30	1:08:00	2759		2:43:00	1:39:30	970	
2:12:50	1:09:20	597	16	2:43:30	1:40:00	961	
2:13:00	1:09:30	629		2:44:00	1:40:30	955	
2:13:10	1:09:40	643		2:45:00	1:41:30	943	
2:13:20	1:09:50	652		2:46:30	1:43:00	2942	23
2:13:30	1:10:00	659		2:46:40	1:43:10	2660	
2:14:00	1:10:30	669		2:46:50	1:43:20	2629	
2:17:00	1:13:30	685		2:47:00	1:43:30	2592	
2:17:55	1:14:25	276	17	2:47:30	1:44:00	2540	
2:18:30	1:15:00	299		2:48:00	1:44:30	2500	
2:19:00	1:15:30	310		2:48:30	1:45:00	2465	
2:22:00	1:18:30	329		2:49:00	1:45:30	2454	
2:22:30	1:19:00	176	18	2:49:30	1:46:00	2438	
2:22:40	1:19:10	194		2:50:25	1:46:55	582	24
2:23:00	1:19:30	196		2:51:00	1:47:30	618	
2:24:00	1:20:30	209		2:51:30	1:48:00	625	
2:25:00	1:21:30	213		2:52:00	1:48:30	622	

Table A.5 (cont)

CYCLE 3								
Time	Elapsed Time (s)	Load (lb)	Pull					
2:52:30	1:49:00	631						
2:53:00	1:49:30	633						
2:55:50	1:52:20	268	25					
2:56:00	1:52:30	277						
2:56:10	1:52:40	284						
2:56:30	1:53:00	291						
2:57:00	1:53:30	306						
2:58:00	1:54:30	170	26					
3:00:00	1:56:30	190						
3:02:00	1:58:30	74	27					

Table A.6 Used Kaust (004) Length and Diameter Measurements

	Pull	End-to-End Length (ft)	Center Length (ft)	Avg Circum. (in)	Avg Diameter (in)	Avg Diameter - Corrected (in)
tensioned	1	51.75	20.00	7.51	2.39	2.28
stretch	2	52.71	21.23	7.44	2.37	2.26
stretch	3	54.42	22.08	7.34	2.34	2.23
stretch	4	56.67	23.25	7.21	2.29	2.19
stretch	5	61.42	25.50	6.95	2.21	2.11
stretch	6	65.21	27.56	6.76	2.15	2.04
stretch	7	70.08	30.15	6.51	2.07	1.96
stretch	8	74.92	32.58	6.28	2.00	1.89
stretch	9	79.92	33.84	6.03	1.92	1.81
stretch	10	85.04	37.59	5.79	1.84	1.74
stretch	11	90.33	40.22	5.58	1.78	1.67
stretch	12	94.83	42.51	5.43	1.73	1.62
stretch	13	100.08	45.08	5.27	1.68	1.57
relax	14	90.33	40.26	5.58	1.77	1.67
relax	15	80.54	35.45	5.99	1.91	1.80
relax	16	70.13	30.09	6.48	2.06	1.95
relax	17	60.04	24.90	7.03	2.24	2.13
stretch	18	70.50	30.29	6.48	2.06	1.95
stretch	19	80.17	35.33	6.01	1.91	1.81
stretch	20	90.54	40.58	5.58	1.77	1.67
stretch	21	100.92	45.60	5.22	1.66	1.55
stretch	22	105.17	47.66	5.09	1.62	1.51
stretch	23	110.00	50.08	4.93	1.57	1.46
relax	24	100.04	45.50	5.23	1.66	1.56
relax	25	90.00	40.41	5.58	1.78	1.67
relax	26	79.67	31.34	6.03	1.92	1.81
relax	27	76.50	29.83	6.49	2.07	1.96
relax	28	63.13	26.34	6.83	2.18	2.07
stretch	29	70.04	30.30	6.48	2.06	1.95
stretch	30	80.29	35.35	5.99	1.91	1.80
stretch	31	90.42	40.61	5.58	1.78	1.67
stretch	32	100.50	45.58	5.23	1.67	1.56
stretch	33	110.58	50.52	4.91	1.56	1.46
relax	34	100.33	45.78	5.21	1.66	1.55
relax	35	90.08	40.52	5.55	1.77	1.66
relax	36	80.25	35.43	5.99	1.91	1.80
relax	37	70.08	30.13	6.44	2.05	1.94