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STUDY OF HOLDING POWER OF WIRE ROPE CLIPS IN A WIRE ROPE LOOP,(U)
DEC 78 E JACKSON, D SKONECZKA

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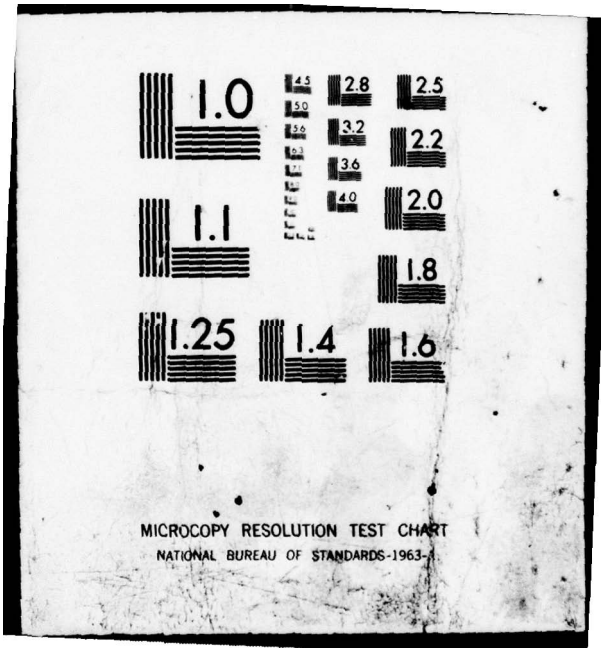
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(6) STUDY OF HOLDING POWER OF WIRE ROPE CLIPS IN A WIRE ROPE LOOP

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(11) DEC[redacted]978

(12) 54 p.

(14) MTMC [redacted]T-TR-73-14-7

(18) SARAC REPORT (19) EVT-18-77-1

DARCOM Ammunition Center

Military Traffic Management Command
Transportation Engineering Agency
Newport News, Virginia 23606

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ABSTRACT

This report documents the results of tests performed on end-over-end wire rope loops made from 3/8, 1/2, and 5/8 inch independent wire rope core (IWRC) and fiber core wire ropes. The tests were performed during September, October, and November 1978 to study the holding power of wire rope clips in a connection of a wire rope loop.

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I. EXECUTIVE SUMMARY

1. SCOPE. This report presents the results of tests performed on 3/8, 1/2, and 5/8 inch independent wire rope core (IWRC) wire rope, and 3/8, 1/2, and 5/8 inch fiber core wire rope. The test samples consisted of end-over-end wire rope loops held together with various numbers of clips.

2. OBJECTIVE. To study the holding power of wire rope clips in a connection of a wire rope loop when the torque on the nuts of the clips is varied.

3. APPROACH. A 50,000 pound capacity tension tester was used to apply forces to a loop of wire rope that was affixed between a stake pocket and a shackle. The tension tester was used to apply a force to the wire rope loop until a predetermined displacement occurred between the wire ropes at the connection or until the wire rope broke.

Instrumentation was used to measure the force into the wire rope loop, displacement between the wire ropes at the connection, and the displacement between the platens on the tester.

4. RESULTS. A small displacement between wire ropes in a connection utilizing Type I wire rope clips does not indicate that the connection has been subjected to its maximum holding force.

Used clips are less effective than new clips.

These laboratory tests show the difficulty that was encountered in obtaining repeatable force vs torque data for wire rope loops.

5. CONCLUSIONS. The maximum holding power of wire rope clips depends upon several factors. Some of these factors are: (1) torque on the nuts of

the clips, (2) alignment of the U-bolt with the base of the clip, (3) displacement of the wire ropes in the connection - the larger the wire rope size, the larger the displacement of the ropes in the junction before the maximum force is reached, (4) the use of new clips, and (5) adequate length of dead end from the clips.

II. INTRODUCTION

To ship cargo by the rail mode of transportation, the freight must be secured in accordance with rules established by the Association of American Railroads (AAR). To demonstrate compliance with those rules the government performs a rail impact test on the item and the proposed restraint system. The test subjects the item and restraint system to shocks produced by a railroad car impacting another railroad car, or cars, at speeds up to eight miles per hour.

One component of a restraint system that is used to secure items, such as wheeled vehicles, on a flatcar is wire rope. Wire rope clips are used to maintain a configuration of the wire rope during shipment of the cargo. Specifications for some of the rail impact tests required that the clips be tightened to such a high torque that the wire rope broke before slipping when it was subjected to shocks of an 8 MPH rail impact.

If a wire rope in a restraint system breaks between origin and destination of the cargo, the probability of an accident is increased by a large percentage. To reduce this probability the wire rope should slip at the clip connection when a force equal to the breaking strength of the wire rope is applied to the configuration.

This report presents the results of laboratory tests performed on 3/8 inch, 1/2 inch, and 5/8 inch wire rope. The testing was conducted during September, October, and November 1978.

III. DESCRIPTION OF TEST MATERIALS AND EQUIPMENT

The material specifications for the wire rope are: steel wire, plain, pre-formed, regular lay, Mac Whyte Wire Rope Co. (or equal), refer to Federal Specification RR-W-410, with a nominal breaking strength as shown below. A section of IWRC rope is shown in Figure 1.

SIZE INCHES	NOMINAL BREAKING STRENGTH, POUNDS	
	INDEPENDENT WIRE ROPE CENTER (IWRC)	FIBER CORE
3/8	13,120	12,200
1/2	23,000	21,400
5/8	35,800	33,400

Thimbles were standard, Type II in accordance with Federal Specification FF-T-276.

Purchase description of the clips was: clips ("U" bolt, Crosby, heavy duty, or equal), reference Federal Specification FF-C-45D, Type I, Class I.

A compression-tension tester was used to apply the forces to each loop of wire rope, refer to Figure 2. Also shown in Figure 2 is a test set-up for a loop of wire rope and the instrumentation that was used to measure the force and displacements. Closer views of the instrumentation are shown in Figures 3 and 4.

Specifications for the test equipment are shown in Table 1. A schematic of the equipment that was used to record the raw data is shown in Figure 5.

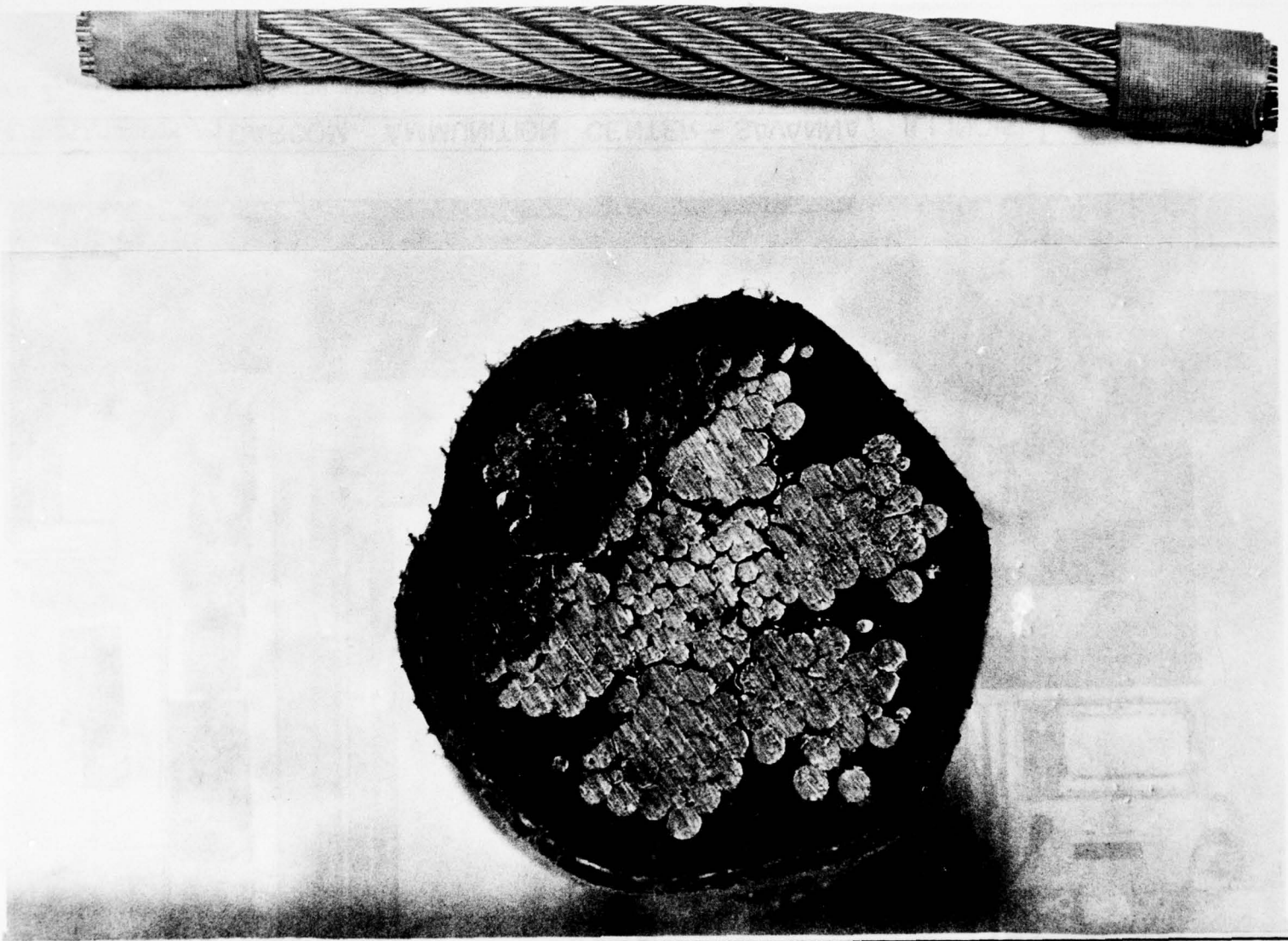

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Figure 1. Side and end views of a 6 x 19 IWRC wire rope.

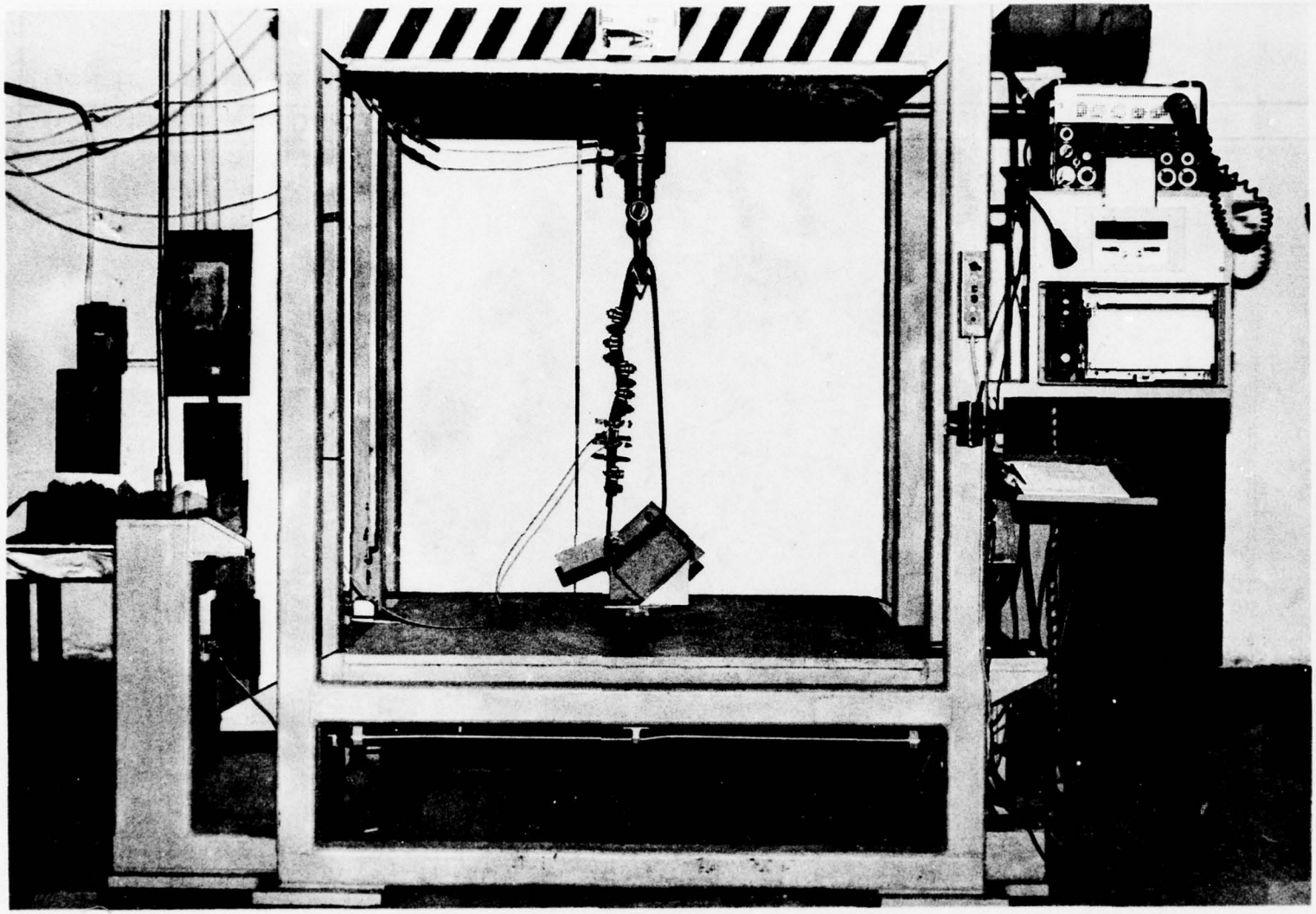

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Figure 2. Tension-compression machine used to apply forces to the wire rope loop.

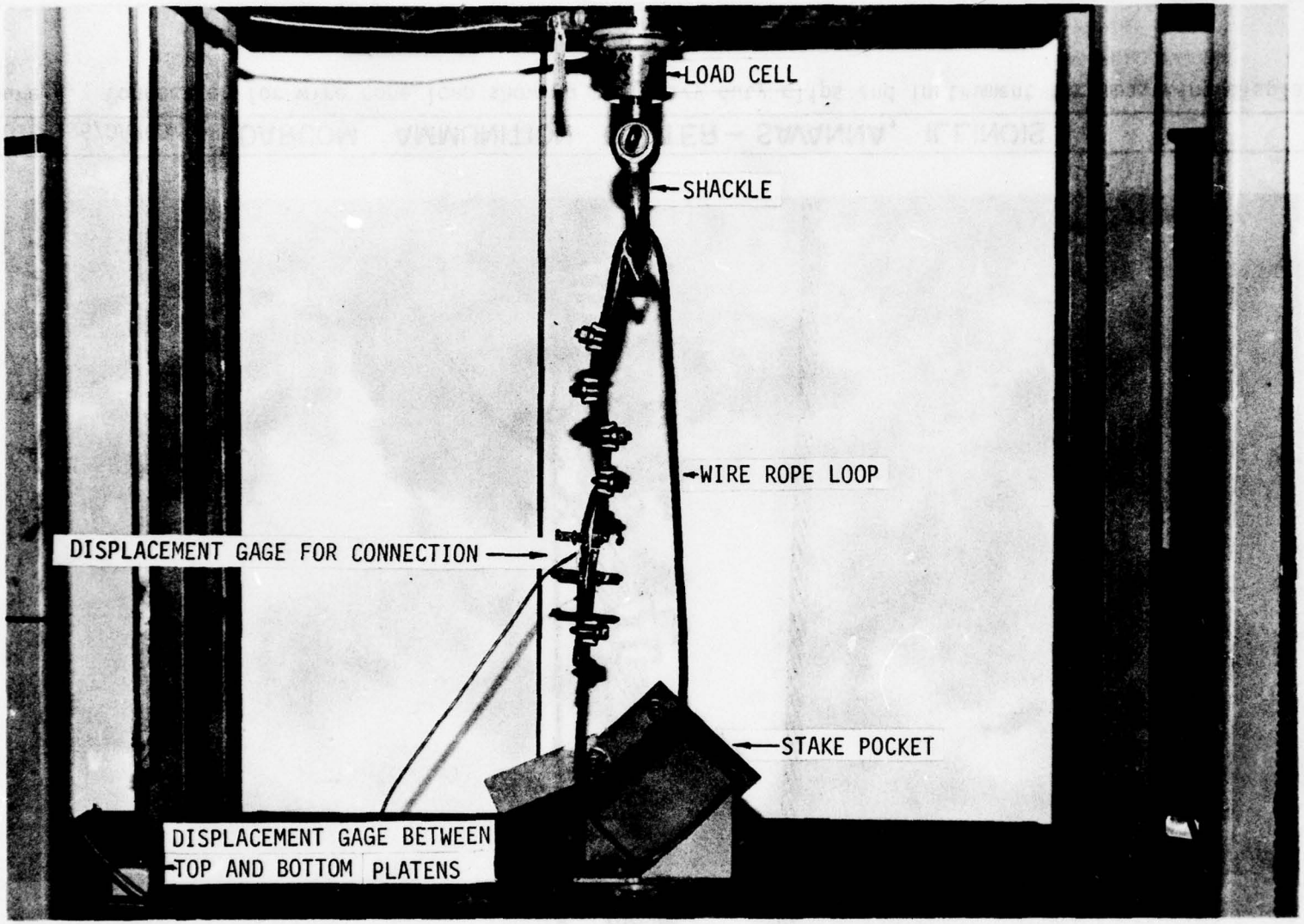

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Figure 3. Instrumentation used to measure force and displacement of the wire rope loop.

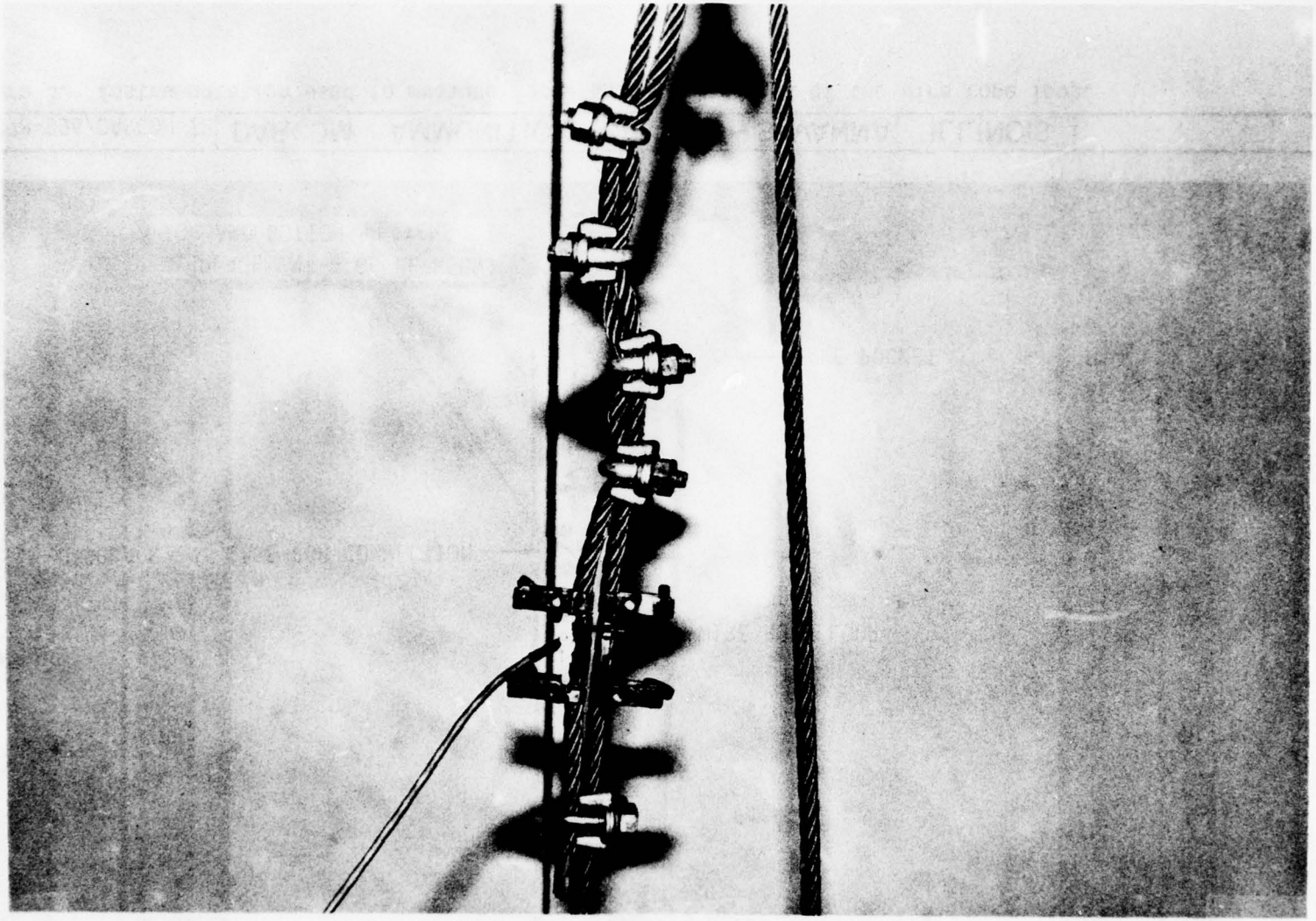

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Figure 4. Connection for wire rope loop showing the heavy duty clips and instrument for measuring displacement.

TABLE 1

EQUIPMENT AND INSTRUMENT SPECIFICATIONS

INSTRUMENT OR EQUIPMENT	MANUFACTURER	MODEL NUMBER	RATED FULL SCALE OUTPUT	SENSITIVITY OR CHANGE IN OUTPUT NO LOAD TO FULL LOAD	LINEARITY	OTHER INFORMATION
1. Torque Wrench	Jo Line	G1504AFR	150 ft-lb			Calibrated 20 Jan 78 Calibration due 15 Jan 79
2. Sliding Potentiometer	Mallodry Capacitor Co	Malloslide MSC62L	600 OHMS			Tolerance = ± 30% Torque = 2-10 oz
3. Load Cell	Toroid Corp	45-132-BKF	50,000 lbs	1.994 MV/V	< 0.10% F.S.	Repeatability = < 0.05% F.S.
4. Compression-Tension Tester	Ormond, Inc	T (c-T) 2667-50K	50,000 lbs			Infinite range adjustment from 1/10 inch per min to 1-1/4 inch per min
Load Cells	BLH Electronics	C2P1	50,000 lbs	2 MV/V input	0.05% F.S. in comp	Repeatability = 0.02% F.S.
Digital Indicator	BLH Electronics	8,000			± 0.01% of reading ± 1 count	Resolution = better than ± 0.01%
Strip Chart Recorder	Honeywell, Inc	112 single pen				
5. Position Transducer	Transducer Controls Corp	PT-101-20A	20 inch	47.325 MV/V Input	± 0.1% Full	Excitation = 15 Volts AC or DC output resistance = 0-500 OHMS
6. Power Supply	Consolidated Electrodynamics	3-140	Voltage, 24 DC current, 200 MA			Regulation, 0.05% no load to full load 0.03%, with a ± 10% line change
7. Balance Bridge (Universal Signal Conditioning Module)	Consolidated Electrodynamics	8-113-2	Control Bridges up to 1000 OHMS			Compensates for a 10% unbalance of full scale output of bridges.

	INSTRUMENT OR EQUIPMENT	MANUFACTURER	MODEL NUMBER	RATED FULL SCALE OUTPUT	SENSITIVITY OR CHANGE IN OUTPUT NO LOAD TO FULL LOAD	LINEARITY	OTHER INFORMATION
8.	DC Amplifier	Consolidated Electrodynamics	1-168	10 to 500 Volts Accuracy = ± 2% @ DC	Input = 20 MV to 100V Peak, FS (10V) output	± .25% of FS	Output = ± 10 Volts Peak @ 100 MA
9.	FM Record Amplifier	Consolidated Electrodynamics	12-354 B	20 to 27 MA Peak-to-Peak Square		± 0.5% of FS	Input Imped = 10,000 OHMS nominal freq response = DC to 20 KH_z, ± 0.5db
10.	Magnetic Tape Recorder	Bell & Howell	VR - 3360	1-7/8 to 60 IPS			Accuracy = ± 0.25% @ 60 H_z
11.	FM Reproduce Amplifier	Consolidated Electrodynamics	12-357A	± 1.414 V DC (or 1V RMS) FS output for ± 40% deviation of carrier center frequency		± 0.5% Terminal	Signal to noise ratio = 55 db Min. Harmonic Distortion = 1% Max. Frequency response = Uniform within 0.6 db
12.	Oscillograph	Consolidated Electrodynamics	5-133	Transport Speeds = 0.1 to 160 IPS Max writing speed = 90,000 IPS			Timing intervals, 0.001 Sec to 10.0 Sec, 10th line accented
13.	Magnetic Tape	Ampex	746-57G111	1 in X 3600 ft	+ 1 db ± 1		Max input level distortion = 3.5% + 0.3, - no limit. Signal Transfer - 46 db

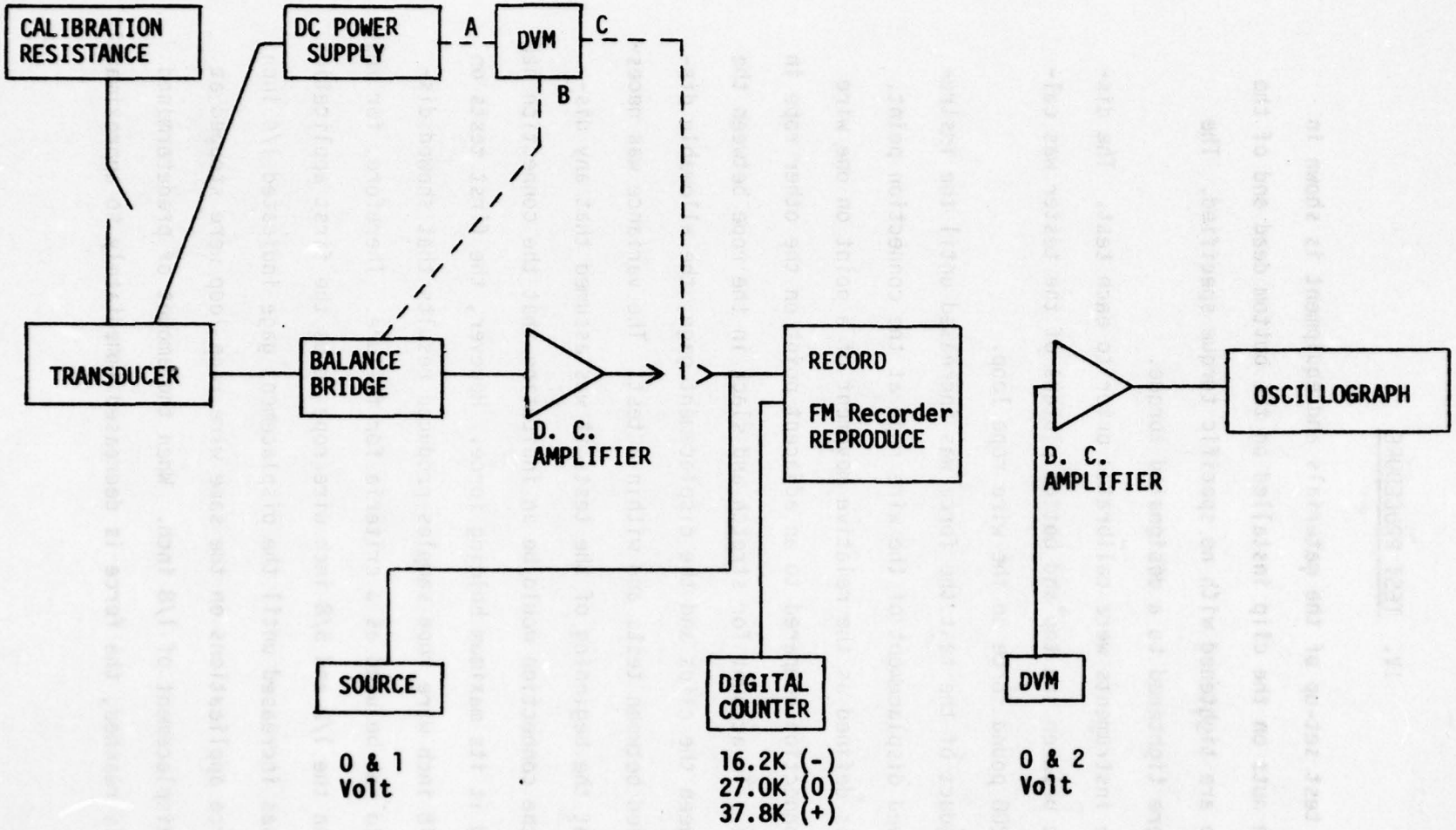

Figure 5. Schematic of equipment used to record raw data from laboratory tests.

IV. TEST PROCEDURE

A typical test set-up of the materials and equipment is shown in Figure 3. The nuts on the clip installed on the bottom dead end of the wire rope loop are tightened with no specific torque specified. The other clips were tightened to a designated torque.

All of the instruments were calibrated prior to each test. The displacement gage between the top and bottom platens of the tester was calibrated with 200 pound force on the wire rope loop.

During conduct of the test the force was increased until the instrumentation showed displacement of the wire rope at the connection point. Displacement is defined as the relative movement of a point on one wire rope in the connection compared to an adjacent point on the other rope in the connection. To account for stretch and slack in the rope between the clips and between the clips and the displacement gage, the allowable displacement varied between tests and within a test. The variance was necessary because at the beginning of the tests it was assumed that any displacement in the connection would be an indication that the connection had been subjected it its maximum holding force. However, the first tests on the 1/2 and 5/8 inch wire rope samples produced results that showed displacement could not be used as a criteria for failure. Therefore, for most of the tests on the 1/2 and 5/8 inch wire rope loops the first application of the force was increased until the displacement gage indicated 1/4 inch. Additional force applications on the same wire rope loop were stopped at an allowable displacement of 1/8 inch. When the amount of predetermined displacement is reached, the force is decreased immediately to approximately 2,000 pounds.

This procedure was used to reduce the total displacement and also to provide a safe environment while the clips are being tightened to the next designated torque.

V. RESULTS AND DISCUSSION

Results from the laboratory tests are shown in Tables A-1 through A-6. Data from these tables were used to show the relationship between the force on the wire rope loop and the torque applied to the clips (see Figures 6 through 11).

Observations of the laboratory tests result in several comments that can be made about wire rope loops held together with wire rope clips.

1. The strands of wire in a regular lay wire rope are aligned almost parallel with the direction of the wire rope. This alignment allows the wire rope to form grooves into the clips rather than to scrape metal from the clips. Note the grooves in the clips shown in Figure 12.

2. The dead end of a wire rope loop should be of sufficient length to prevent unraveling. The wire rope clips that were installed near an unraveled end required a larger number of turns on the nuts to achieve the designated torque when compared to other test samples that had adequate dead ends. This requirement suggests that the clip would lose some of its holding power because of the unraveling. A taped end will require a longer length than a wired end. A 3 to 4 inch taped end is not a sufficient length.

3. A small displacement between wire ropes in a connection is not an indication that the connection has been subjected to its maximum holding force. A 5/8 inch wire rope connection can withstand a displacement of more than one inch before the maximum force is reached (refer to Table A-3). Some of the displacement is attributed to the U-bolt of the clip moving to obtain a good "binding like" alignment with the base of the clip and the two wire ropes in the connection.

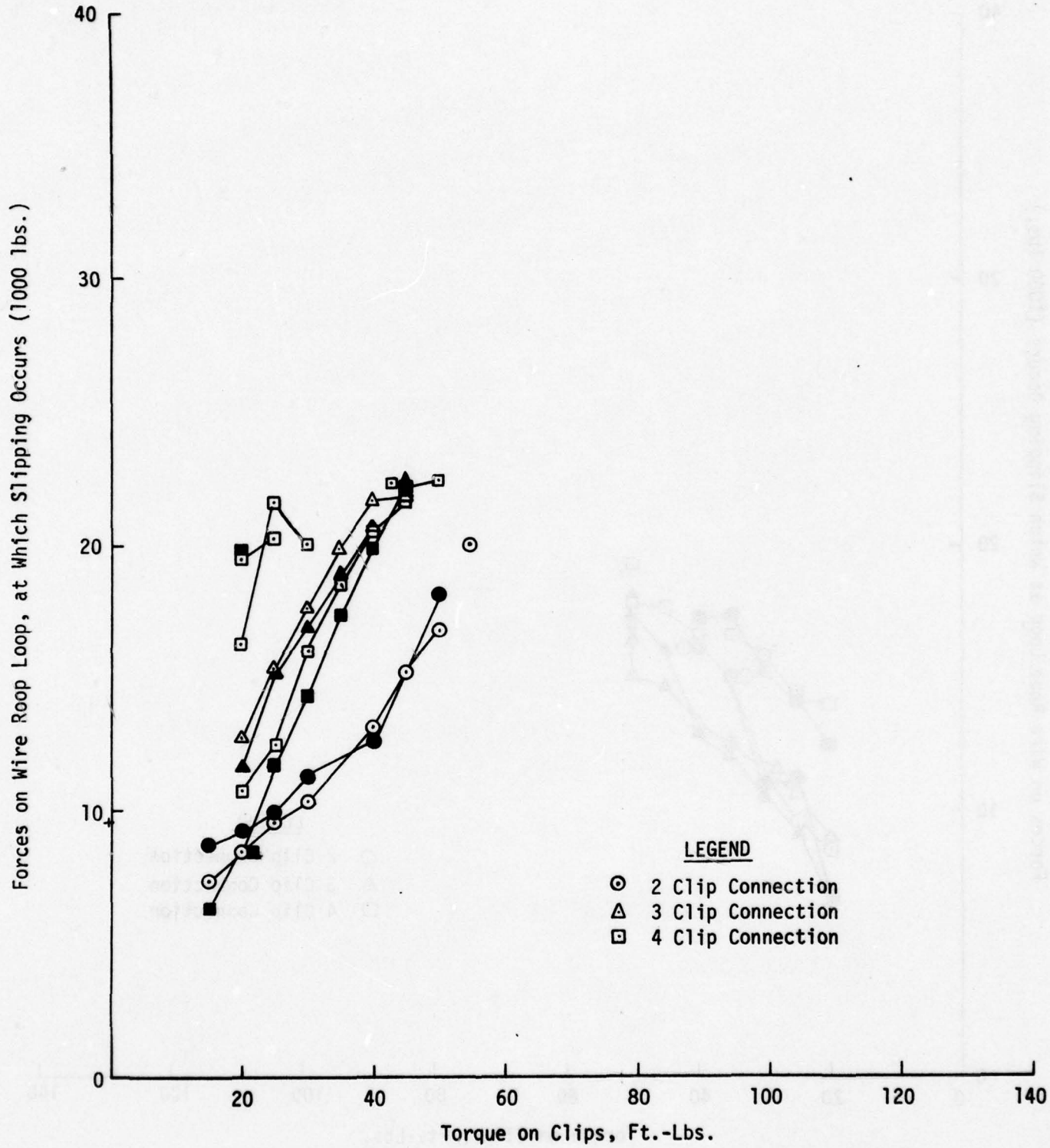

FIGURE 6. Results from Laboratory Tests on Loop of 3/8-Inch IWRC Wire Rope.

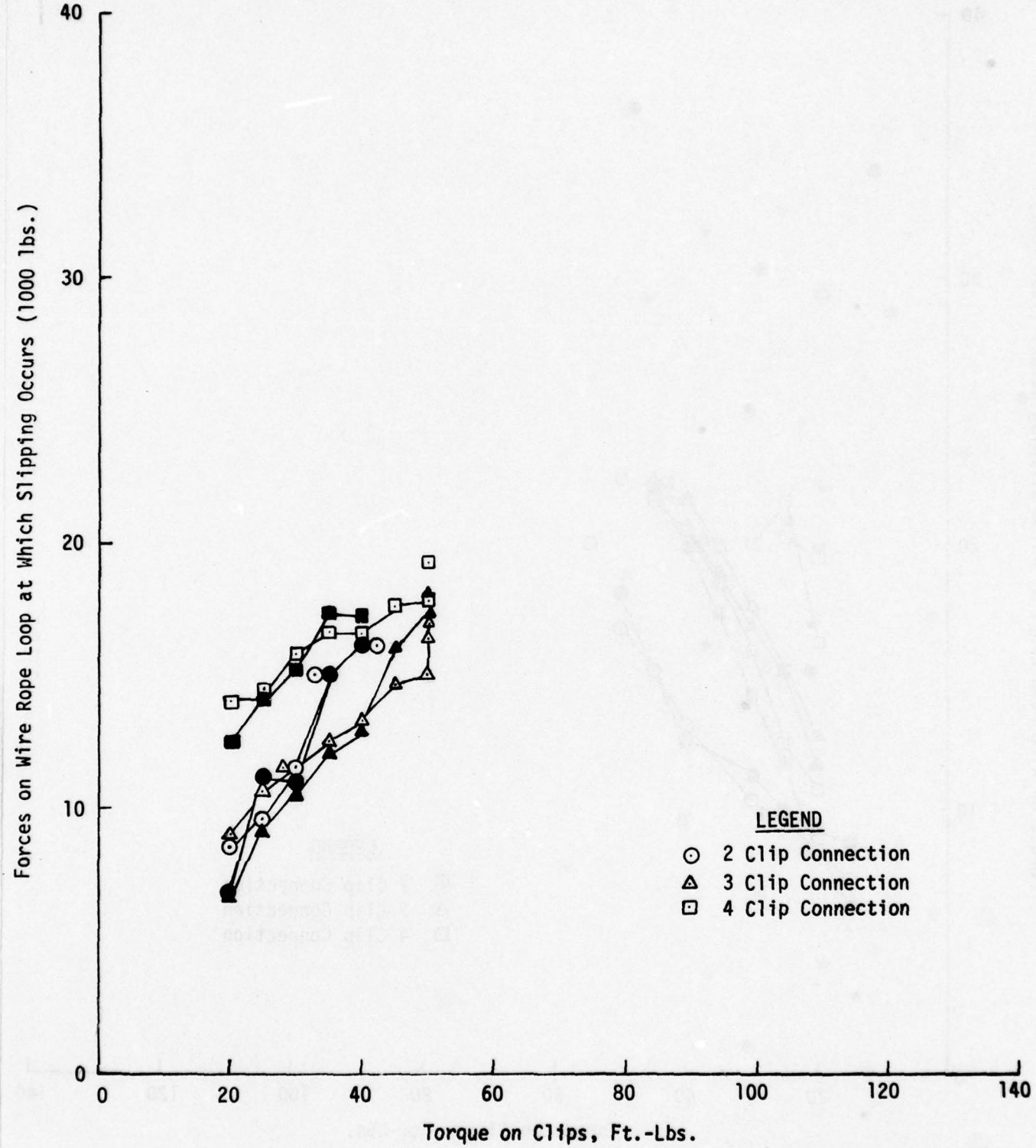

FIGURE 7. Results from Laboratory Tests on Loop of 3/8-Inch Fiber Core Wire Rope

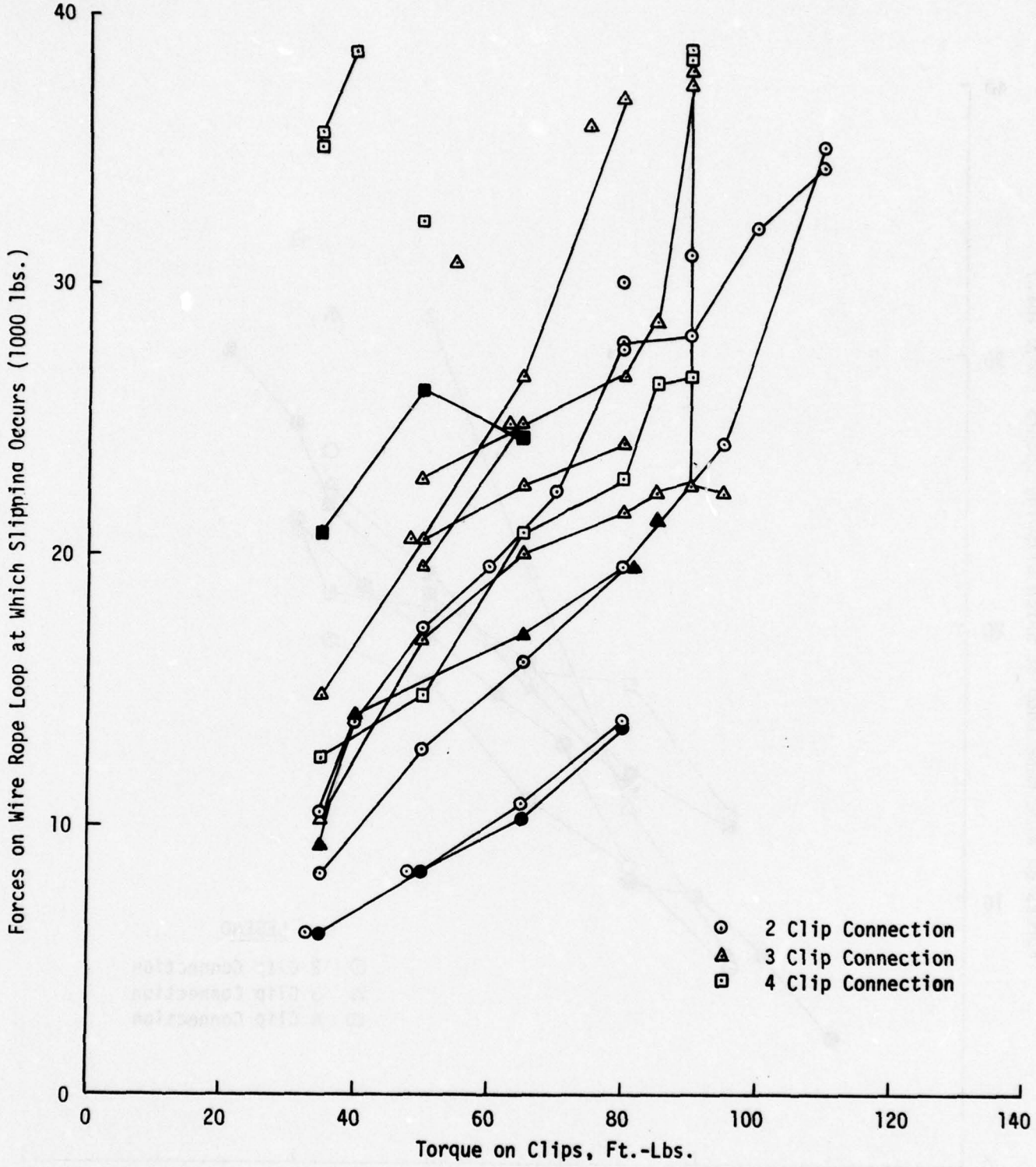

FIGURE 8. Results from Laboratory Tests on Loop of 1/2-Inch IWRC Wire Rope.

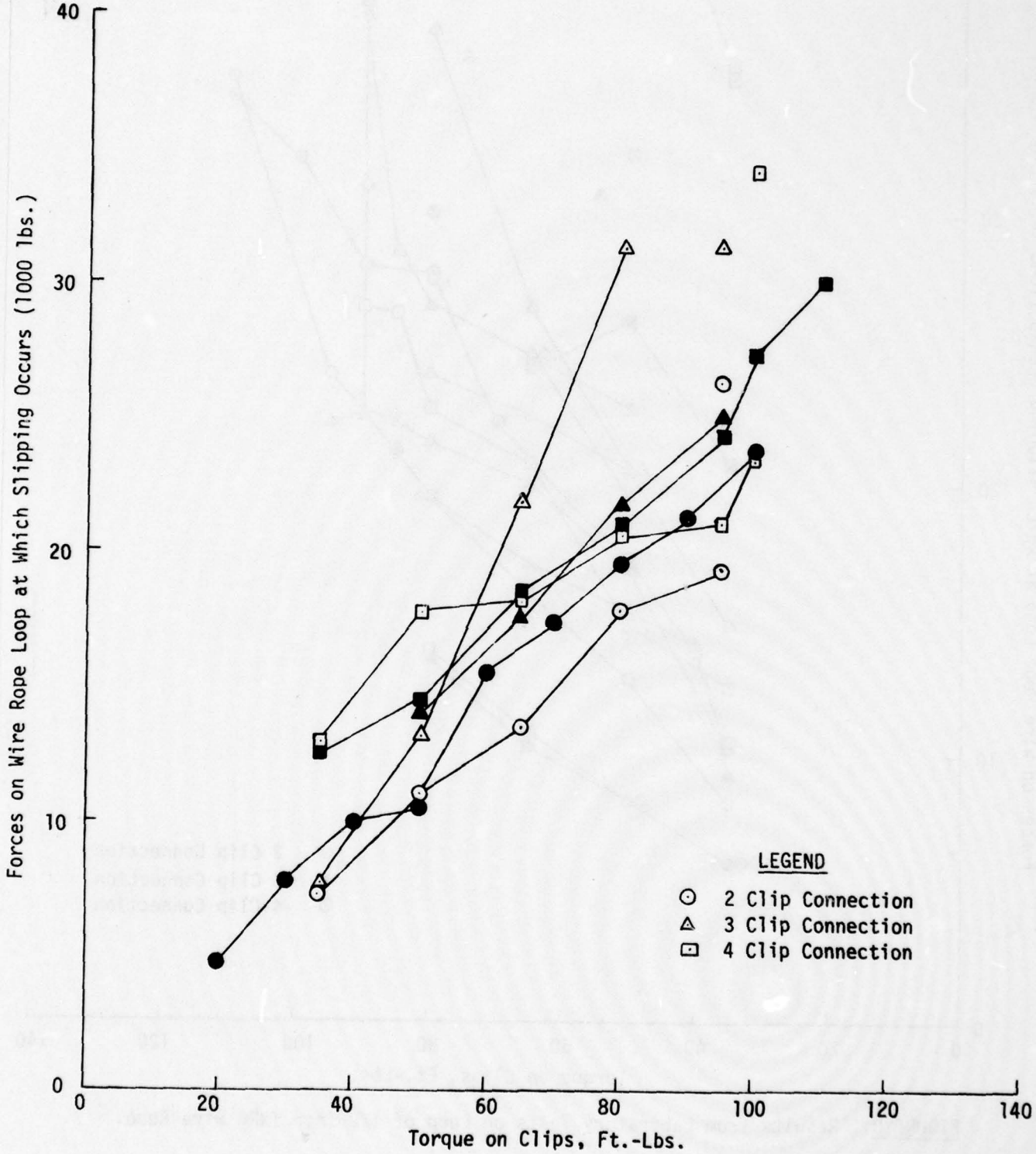

FIGURE 9. Results from Laboratory Tests on Loop of 1/2-Inch Fiber Core Wire Rope.

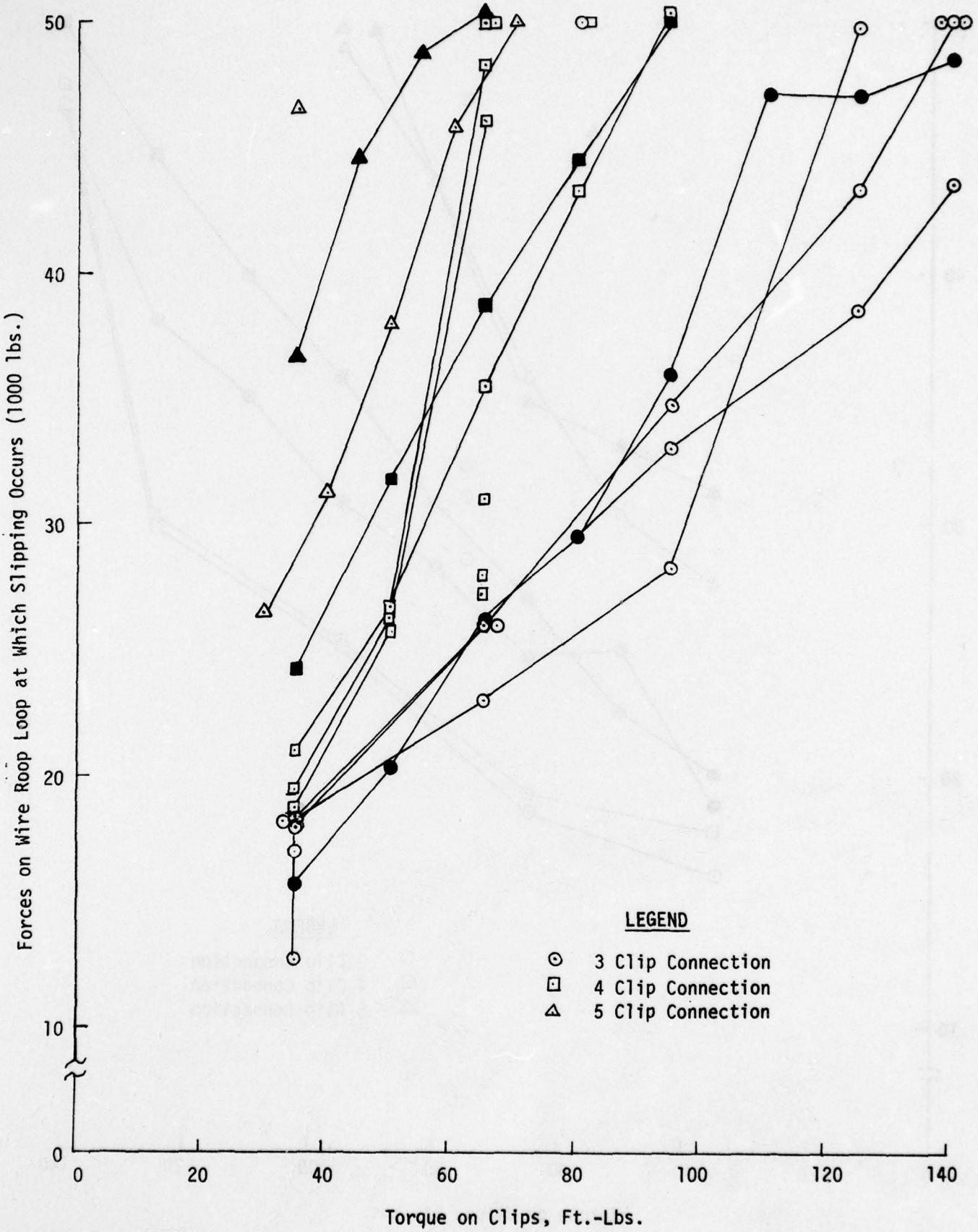

FIGURE 10. Results from Laboratory Tests on Loop of 5/8-Inch IWRC Wire Rope.

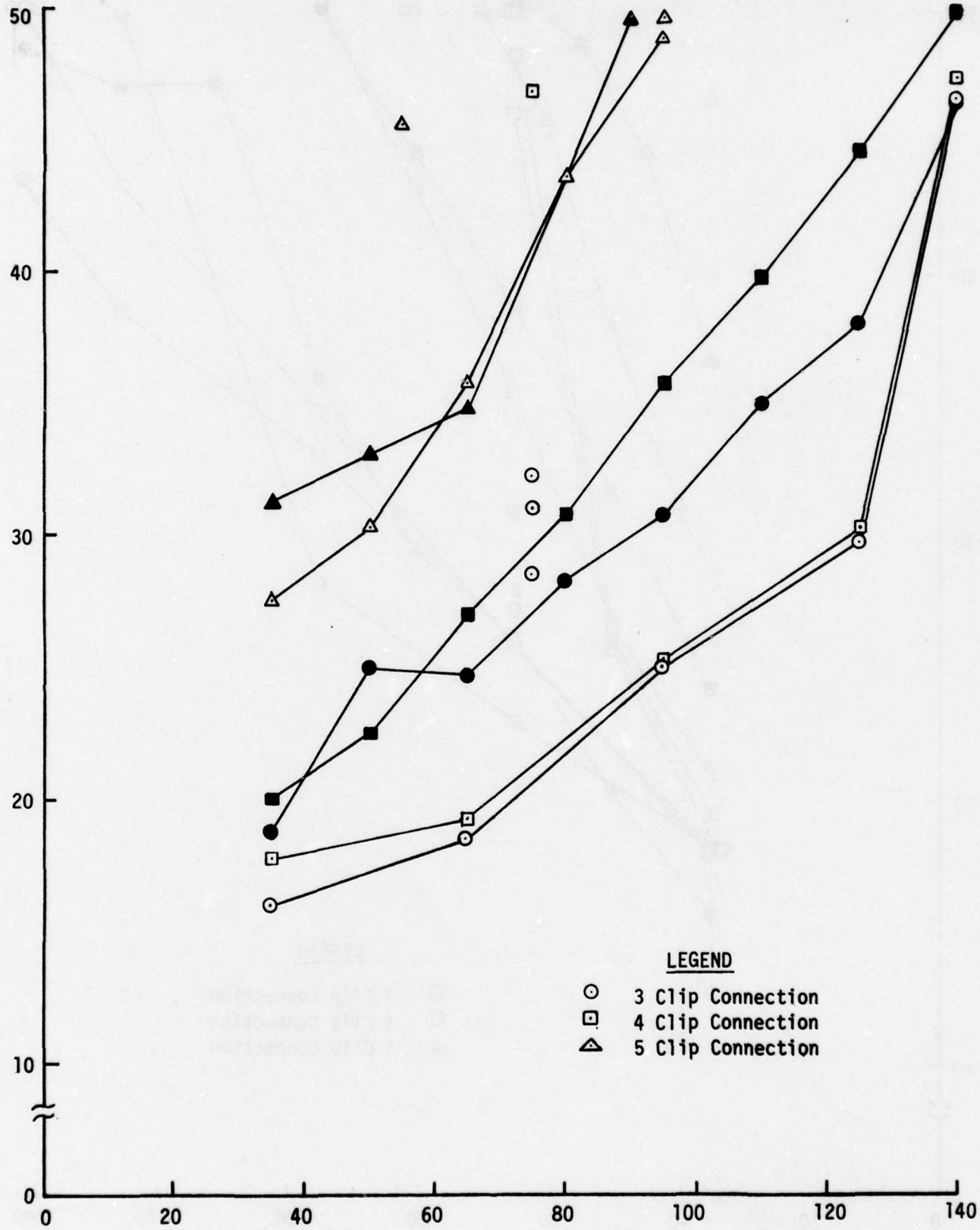

FIGURE 11. Results from Laboratory Tests on Loop of 5/8-Inch Fiber Core Wire Rope.

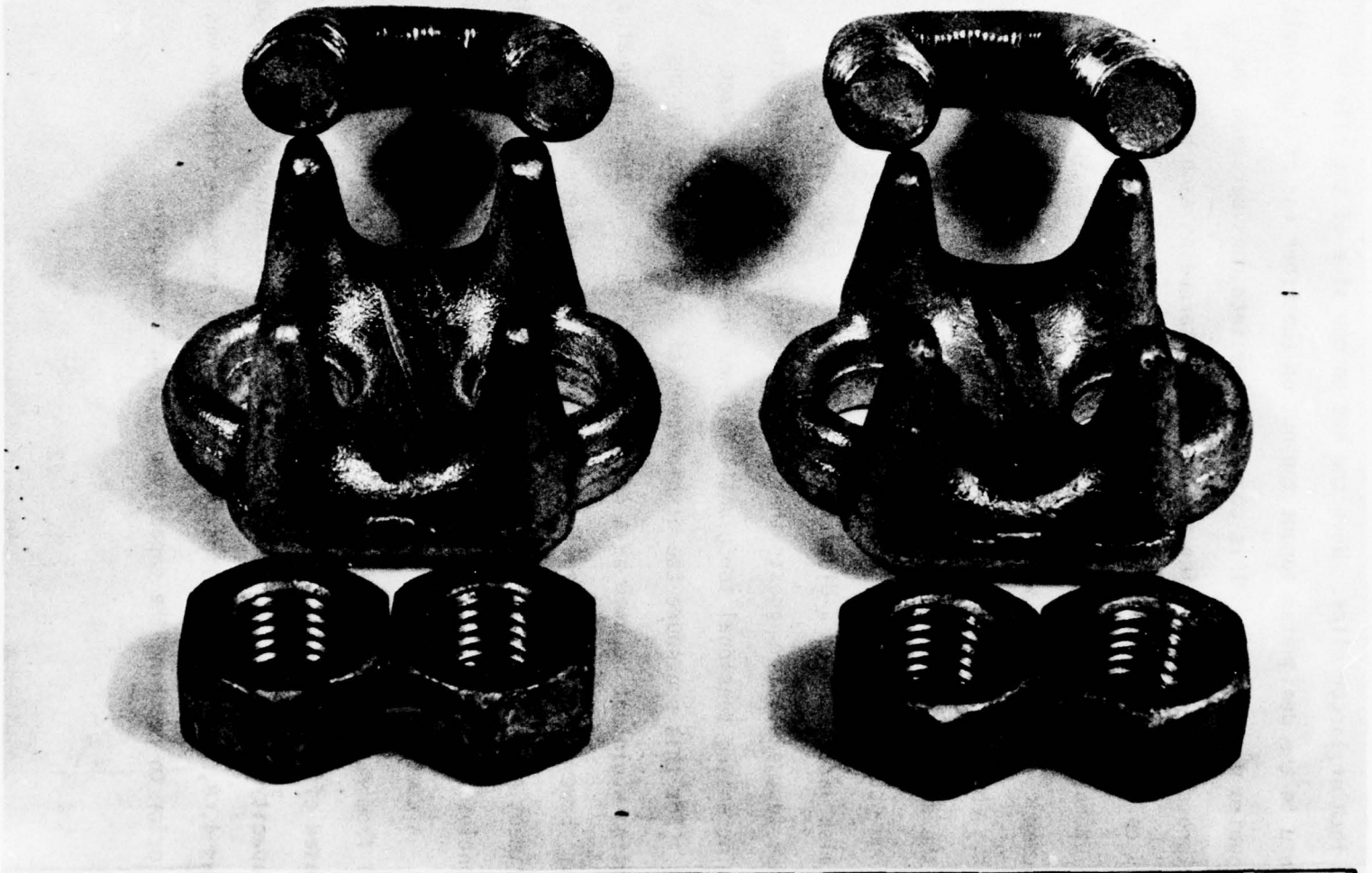

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Figure 12. Comparison of used clips.

4. Low torques, such as 10 and 15 ft-lbs, are time consuming to apply to 3/8 inch or larger clips. When the nut on one side of the clip is tightened to the designated torque the nut on the other end of the U-bolt will require retightening. This comment takes into consideration the proper procedure for tightening the nuts - the torque on each nut is increased on an alternate basis.

5. When the dead end of a wire rope connection is used to indicate displacement, the elasticity of the wire rope must be taken into consideration. Observe the location of the displacement gage in Figure 4. Since the dead end of the connection will not stretch and the adjacent live rope would stretch when a force is applied to the loop, there could be a false indication of a displacement in the connection.

Post test analysis suggests that each test loop should be subjected to an increasing tensional force until failure or excessive slippage occurs. For this procedure the displacement of the wire ropes in the connection would not be used as a criteria for failure for the designated torque. However, we do not feel that the possibility of error in the measurement of displacements for these tests nullifies the conclusions since the conclusions are based on trends in the data rather than absolute values.

6. A comparison of data in Table A-3 (for torques applied to four clips) from runs 4, 8, and 9 against data from runs 5 and 10 shows the decreased efficiency of used clips. In runs 5 and 10 (using new clips), the capacity of the test equipment was reached without excessive slippage. In runs 4, 8, and 9 (using clips from prior runs) excessive slippage was noted prior to reaching the capacity of the test equipment.

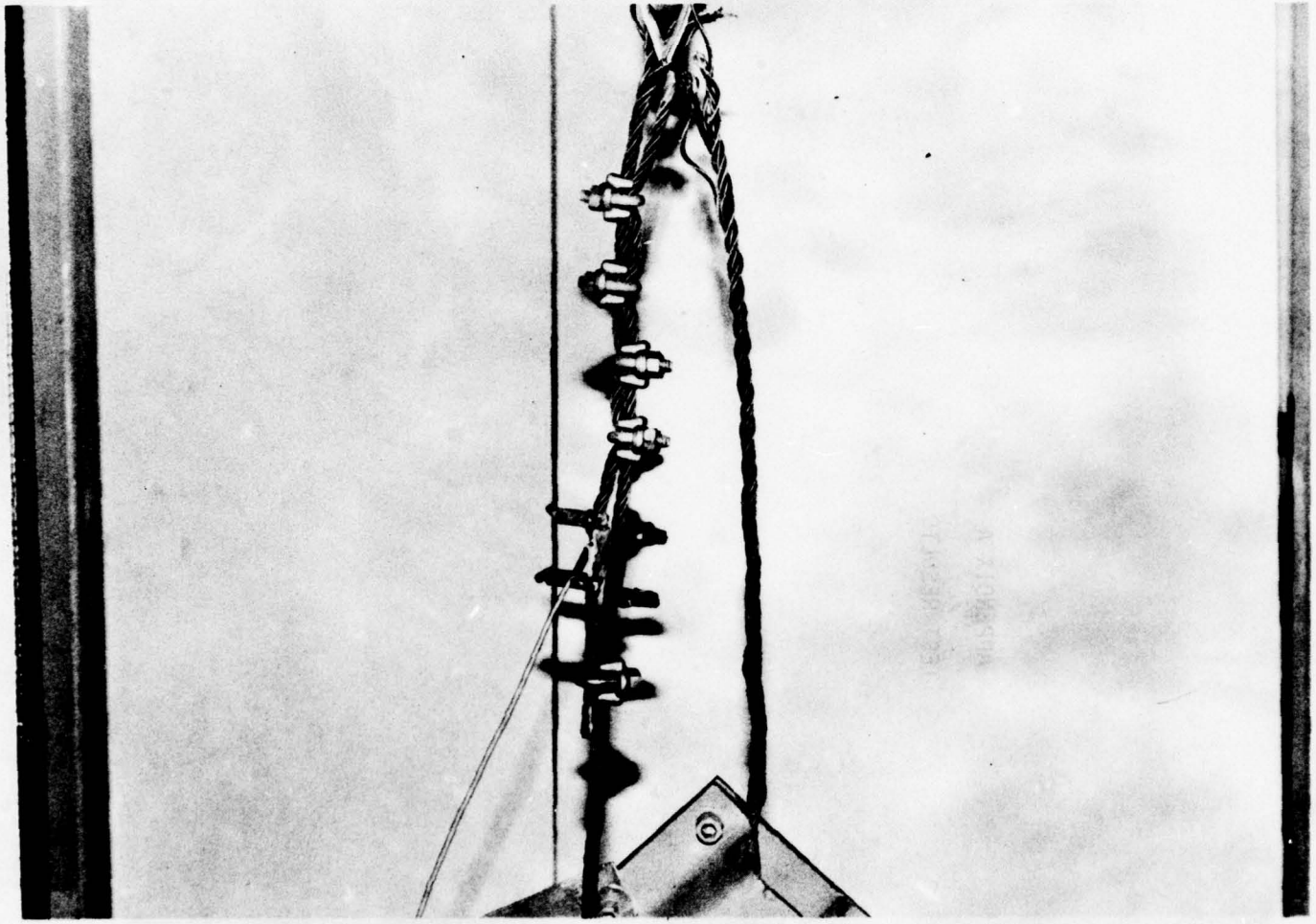

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Figure 13. A broken, failed, wire rope loop.

APPENDIX A

TEST RESULTS

TABLE A-1

TEST RESULTS FOR CLIPS ON 3/8 INCH IWRC WIRE ROPE

TORQUE APPLIED TO 2 CLIPS

RUN		15 ft-lbs	20 ft-lbs	25 ft-lbs	30 ft-lbs	40 ft-lbs	50 ft-lbs	55 ft-lbs	REASON FOR FAILURE
1	Force, lbs	8750	9250	10000	11375	12625	18125		Clip broke @ 55 ft-lbs
	*Displacement (loop), in	1.13	1.27	1.33	1.50	1.60	1.93		
	*Displacement (connection), in	0.15	0.24	0.32	0.47	0.55	0.86		
2	Force, lbs	7375	8500	9625	10375	13125	15125	16750	Clip broke @ 60 ft-lbs
	Displacement (loop), in	1.43	1.49	1.59	1.65	1.75	1.89	1.93	
	Displacement (connection), in	0.16	0.26	0.49	0.53	0.59	0.64	0.68	
3	Force, lbs							20000	Wire rope broke @ stake pocket
	Displacement (loop), in							1.39	

TORQUE APPLIED TO 3 CLIPS

RUN		20 ft-lbs	25 ft-lbs	30 ft-lbs	35 ft-lbs	40 ft-lbs	45 ft-lbs		REASON FOR FAILURE
1	Force, lbs	11625	15125	16875	18875	20625			Clip broke @ 45 ft-lbs
	Displacement (loop), in	1.32	1.48	1.56	1.65	1.75			
	Displacement (connection), in	0.20	0.32	0.38	0.43	0.48			
2	Force, lbs	12750	15375	17625	19875	21625	21750		Wire rope broke @ stake pocket
	Displacement (loop), in	1.48	1.61	1.71	1.79	1.88	1.88		
	Displacement (connection), in	0.18	0.25	0.31	0.36	0.40	0.43		
3	Force, lbs						22375		Wire rope broke @ shackle
	Displacement (loop), in						1.36		

* All displacement include elastic stretch of wire rope

TORQUE APPLIED TO 4 CLIPS

RUN		15 ft-lbs	20 ft-lbs	25 ft-lbs	30 ft-lbs	35 ft-lbs	40 ft-lbs	45 ft-lbs	50 ft-lbs	REASON FOR FAILURE
1	Force, lbs	6375	8500	11750	14375	17375	19875	22250	22375	Wire rope broke @ shackle
	Displacement (loop), in	0.99	1.04	1.13	1.21	1.28	1.33	1.43	1.44	
	Displacement (connection), in	0.17	0.28	0.34	0.41	0.47	0.51	0.54	0.56	
2	Force, lbs		10750	12500	16000	18500	20500	21625		Clip broke @ 50 ft-lbs
	Displacement (loop), in		1.03	1.08	1.17	1.24	1.31	1.35		
	Displacement (connection), in		0.24	0.31	0.36	0.52				
3	Force, lbs							22250		Wire rope broke @ stake pocket
	Displacement (loop), in							1.34		
4	Force, lbs		16350	21600	20000					Wire rope broke @ shackle
	Displacement (loop), in		1,26	1.46	1.44					
	Displacement (connection), in		0,14	0.24	0.29					
5	Force, lbs		19500	20250						Wire rope broke @ shackle
	Displacement (loops), in		1,54	1.60						
	Displacement (connection), in		0.13	0.21						
6	Force, lbs		19750							Wire rope broke @ shackle
	Displacement (loop), in		1.42							
	Displacement (connection), in		0.0							

TABLE A-2

TEST RESULTS FOR CLIPS ON 1/2 INCH IWRC WIRE ROPE

TORQUE APPLIED TO 2 CLIPS

RUN		35 ft-lbs	40 ft-lbs	50 ft-lbs	60 ft-lbs	65 ft-lbs	70 ft-lbs	80 ft-lbs	90 ft-lbs	100 ft-lbs	110 ft-lbs	REASON FOR FAILURE
1	Force, lbs	6000		8250		10250		13500				Clip broke @ 95 ft-lbs
	Displacement (loop), in	1.18		1.32		1.40		1.52				
	Displacement (connection), in	0.26		0.34		0.39		0.46				
2	Force, lbs	6000		8250		10750		13750				Clip broke @ 95 ft-lbs
	Displacement (loop), in	1.22		1.38		1.48		1.60				
	Displacement (connection), in	0.18		0.28		0.36		0.42				
3	Force, lbs							30000				Wire rope slipped
	Displacement (loop), in							2.30				
4	*Force, lbs	10500	13750	17250	19500		22250	27750	28000	32000	34250	Wire rope broke @ shackle
	Displacement (loop), in	1.74	1.88	1.98	2.06		2.16	2.42	2.46	2.58	2.68	
	Displacement (connection), in	0.28	0.33	0.47	0.53		0.62	0.87	0.98	1.07	1.16	
5	*Force, lbs	8250		12750		16000		19500 (95)	24000		35000	Wire rope broke @ shackle
	Displacement (loop), in	1.58		1.76		1.84		1.96	2.06		2.64	
	Displacement (connection), in	0.19		0.38		0.46		0.54	0.63		1.16	

*Test was run with 2 used clips

TORQUE APPLIED TO 2 CLIPS

RUN		35 ft-lbs	40 ft-lbs	50 ft-lbs	60 ft-lbs	65 ft-lbs	70 ft-lbs	80 ft-lbs	90 ft-lbs	100 ft-lbs	110 ft-lbs	REASON FOR FAILURE
6	Force, lbs							27500				Excessive slippage
	Displacement (loop), in							1.86				
	Displacement (connection), in							1.25				
7	Force, lbs								31000			Wire rope broke @ stake pocket
	Displacement (loop), in								2.06			
	Displacement (connection), in								0.57			

TORQUE APPLIED TO 3 CLIPS

RUN		35 ft-lbs	50 ft-lbs	65 ft-lbs	80 ft-lbs	85 ft-lbs	90 ft-lbs	95 ft-lbs	REASON FOR FAILURE
1	Force, lbs	9250	14000	17000	19500	21250			Broke clip @ 90 ft-lbs
	Displacement (loop), in	1.22	1.38	1.48	1.46	1.48			
	Displacement (connection), in	0.13	0.22	0.25	0.27	0.28			
2	Force, lbs	10250	16750	20000	21500	22250	22500	22250	Broke clip @ 100 ft-lbs
	Displacement (loop), in	1.40	1.72	1.82	1.84	1.88	1.90	1.86	
	Displacement (connection), in	0.11	0.18	0.25	0.27	0.28	0.28	0.28	
3	Force, lbs						37750		Wire rope broke @ stake pocket
	Displacement (loop), in						2.18		
4	Force, lbs		22750	24750	26500	28500	37250		Wire rope broke @ shackle
	Displacement (loop), in		1.46	1.50	1.48	1.52	1.84		
	Displacement (connection), in		0.19	0.23	0.27	0.28	0.40		

TORQUE APPLIED TO 3 CLIPS

RUN		35 ft-lbs	50 ft-lbs	65 ft-lbs	80 ft-lbs	85 ft-lbs	85 ft-lbs	90 ft-lbs	95 ft-lbs	REASON FOR FAILURE
5	Force, lbs	20500	22500	24000						Clip broke @ 85 ft-lbs
	Displacement (loop), in	1.62	1.70	1.92						
	Displacement (connection), in	0.21	0.31	0.33						
6	Force, lbs		19500	24750						Clip broke @ 80 ft-lbs
	Displacement (loop), in		1.42	1.56						
	Displacement (connection), in		0.30	0.40						
7	Force, lbs	14750	20500	26500	36750					Wire rope broke @ shackle
	Displacement (loop), in	1.82	1.96	2.08	2.44					
	Displacement (connection), in	0.39	0.55	0.62	0.798					
8	Force, lbs				(75) 35750					Wire rope broke @ shackle
	Displacement (loop), in				1.92					
	Displacement (connection), in				0.27					
9	Force, lbs		(55) 30750							Wire rope broke @ shackle
	Displacement (loop), in		2.36							
	Displacement (connection), in		0.50							

TORQUE APPLIED TO 4 CLIPS

RUN		35 ft-lbs	40 ft-lbs	50 ft-lbs	65 ft-lbs	80 ft-lbs	85 ft-lbs	90 ft-lbs	90 ft-lbs	REASON FOR FAILURE
1	Force, lbs	20750		26000	24250					Broke clip @ 80 ft-lbs
	Displacement (loop), in	1.20		1.28	1.24					
	Displacement (connection), in	0.17		0.24	0.25					
2	Force, lbs	12500*		14750	20750	22750	26250	26500	38500	Wire rope broke @ stake pocket
	Displacement (loop), in	2.30		2.32	2.44	2.48	2.56	2.52	2.90	
	Displacement (connection), in	0.23		0.28	0.30	0.33	0.36	0.37	0.46	
3	Force, lbs							38250		Wire rope broke @ shackle
	Displacement (loop), in							1.70		
4	Force, lbs	35500	38500							Wire rope broke @ shackle
	Displacement (loop), in	1.80	1.86							
	Displacement (connection), in	0.27	0.36							
5	Force, lbs	35000								Wire rope broke @ shackle
	Displacement (loop), in	2.50								
	Displacement (connection), in	0.68								
6	Force, lbs			32250						Wire rope broke @ shackle
	Displacement (loop), in			2.42						
	Displacement (connection), in			0.22						

* A 9250 lb force was inadvertently applied prior to the clips being torqued to 35 ft-lbs

TABLE A-3

TEST RESULTS FOR CLIPS ON 5/8 INCH IWRC WIRE ROPE

TORQUE APPLIED TO 3 CLIPS

RUN		35 ft-lbs	50 ft-lbs	65 ft-lbs	80 ft-lbs	95 ft-lbs	110 ft-lbs	125 ft-lbs	140 ft-lbs	REASON FOR FAILURE
1	Force, lbs	15750	20250	26250	29500	36000	47000	47000	48500	Capacity of equipment
	Displacement (loop), in	1.98	2.14	2.28	2.36	2.48	2.90	2.96	3.00	
	Displacement (connection), in	0.27	0.37	0.46	0.54	0.62	0.90	0.99	1.07	
2	Force, lbs	14250		20500		30250	34000	41500	49000	Capacity of equipment
	Displacement (loop), in	1.80		1.94		2.12	2.16	2.32	2.52	
	Displacement (connection), in	0.27		0.36		0.46	0.49	0.54	0.61	
3	Force, lbs								50000	Capacity of equipment
	Displacement (loop), in								2.14	
4	Force, lbs				50000					Capacity of equipment
	Displacement (loop), in				2.52					
5	Force, lbs	18250		23000		28250		49750		Capacity of equipment
	Displacement (loop), in	1.84		1.96		2.04		2.48		
	Displacement (connection), in	0.45		0.52		0.54		0.56		
		35 (1st)	35 (2nd)				(125)	140 (1st)	140 (2nd)	
6	Force, lbs	17000	18250	26000		33000	38500	43500	50000	Capacity of equipment
	Displacement (loop), in	1.70	1.76	1.88		1.96	2.06	2.12	2.24	
	Displacement (connection), in	0.27	0.33	0.42		0.46	0.48	0.51		

TORQUE APPLIED TO 3 CLIPS

RUN		35 ft-lbs	35 ft-lbs	65 ft-lbs	80 ft-lbs	95 ft-lbs	110 ft-lbs	125 ft-lbs	140 ft-lbs	REASON FOR FAILURE
7	Force, lbs	12750	18000	26000		34750		43250	50000	Capacity of equipment
	Displacement (loop), in	1.56	1.82	2.10		2.28		2.42	2.56	
	Displacement (connection), in	0.27	0.59	0.86		0.95		1.05	1.13	

TORQUE APPLIED TO 4 CLIPS

RUN		35 ft-lbs	50 ft-lbs	65 ft-lbs	80 ft-lbs	95 ft-lbs	REASON FOR FAILURE
1	Force, lbs	24250	31750	38750	44500	50000	Capacity of equipment
	Displacement (loop), in	1.20	1.34	1.48	1.58	1.68	
	Displacement (connection), in	0.27	0.38	0.47	0.54	0.59	
2	Force, lbs	21000	26750	35500	43250	50250	Capacity of equipment
	Displacement (loop), in	1.32	1.44	1.60	1.72	1.86	
	Displacement (connection), in	0.27	0.36	0.46	0.54	0.62	
3	Force, lbs				50000		Capacity of equipment
	Displacement (loop), in				1.90		
4	*Force, lbs			31000			Excessive slippage
	Displacement (loop), in			2.02			
5	Force, lbs			50000			Capacity of equipment
	Displacement (loop), in			2.10			
6	Force, lbs	18750	25750	46000			Excessive slippage
	Displacement (loop), in	1.36	1.50	2.32			
	Displacement (connection), in	0.27	0.37				

*Test was run with 4 used clips

TORQUE APPLIED TO 4 CLIPS

RUN		35 ft-lbs	50 ft-lbs	65 ft-lbs	80 ft-lbs	95 ft-lbs	REASON FOR FAILURE
7	Force, lbs	19500	26250	48250			Excessive slippage
	Displacement (loop), in	0.27	0.38				
8	*Force, lbs			27250			Excessive slippage
	Displacement (loop), in			1.96			
	Displacement (connection), in			0.76			
9	*Force, lbs			28000			Excessive slippage
	Displacement (loop), in			1.80			
10	Force, lbs			50000			Capacity of equipment
	Displacement (loop), in			2.44			
	Displacement (connection), in			0.88			

*Test was run with 4 used clips

TORQUE APPLIED TO 5 CLIPS

RUN		35 ft-lbs	40 ft-lbs	45 ft-lbs	50 ft-lbs	55 ft-lbs	60 ft-lbs	65 ft-lbs	70 ft-lbs	REASON FOR FAILURE
1	Force, lbs	36750		44500		48750		50500		Capacity of equipment
	Displacement (loop), in	1.62		1.78		1.88		1.90		
	Displacement (connection), in	0.27		0.37		0.46		0.51		

TORQUE APPLIED TO 5 CLIPS

RUN		30 ft-lbs	40 ft-lbs	45 ft-lbs	50 ft-lbs	55 ft-lbs	60 ft-lbs	65 ft-lbs	70 ft-lbs	REASON FOR FAILURE
2	Force, lbs	26500	31250		38000		45750		50000	Capacity of equipment
	Displacement (loop), in	1.60	1.68		1.78		1.92		2.02	
	Displacement (connection), in	0.39	0.46		0.54		0.62		0.67	
3	Force, lbs	(35) 46500								Excessive slippage
	Displacement (loop), in	2.98								

TABLE A-4

TEST RESULTS FOR CLIPS ON 3/8 INCH FIBER CORE WIRE ROPE

TORQUE APPLIED TO 2 CLIPS

RUN		20 ft-lbs	25 ft-lbs	30 ft-lbs	35 ft-lbs	40 ft-lbs	REASON FOR FAILURE
1	Force, lbs	6750	11125	11000	15000	16250	Wire rope broke @ shackle
	Displacement (loop), in	0.91	1.19	1.37	1.59	1.77	
	Displacement (connection), in	0.23	0.24	0.47	0.53		
2	Force, lbs	8625	9625	11500	15000		Wire rope broke @ shackle
	Displacement (loop), in	1.45	1.53	1.83	2.09		
	Displacement (connection), in	0.26	0.59				
3	Force, lbs					16250	Wire rope broke @ shackle
	Displacement (loop), in					1.31	

TORQUE APPLIED TO 3 CLIPS

RUN		20 ft-lbs	25 ft-lbs	30 ft-lbs	35 ft-lbs	40 ft-lbs	45 ft-lbs	50 ft-lbs	50 ft-lbs	REASON FOR FAILURE
1	Force, lbs	6652	9250	10500	12000	12875	16000	17375	18000	Wire rope broke @ shackle
	Displacement (loop), in	1.15	1.24	1.28	1.32	1.37	1.44	1.49	1.53	
	Displacement (connection), in	0.50	0.28	0.34	0.38	0.42	0.49	0.54		
2	Force, lbs	9000	10625	11500	12500	13250	14625	15000	16375	Wire rope broke @ stake pocket
	Displacement (loop), in	1.40	1.47	1.51	1.53	1.56	1.59	1.64	1.69	
	Displacement (connection), in	0.20	0.28	0.32	0.36	0.38	0.41	0.42		

TORQUE APPLIED TO 3 CLIPS

RUN		20 ft-lbs	25 ft-lbs	30 ft-lbs	35 ft-lbs	40 ft-lbs	45 ft-lbs	50 ft-lbs	50 ft-lbs	REASON FOR FAILURE
3	Force, lbs							17000		Wire rope broke
	Displacement (loop), in							1.40		
	Displacement (connection), in							0.18		

TORQUE APPLIED TO 4 CLIPS

RUN		20 ft-lbs	25 ft-lbs	30 ft-lbs	35 ft-lbs	40 ft-lbs	45 ft-lbs	50 ft-lbs	REASON FOR FAILURE
1	Force, lbs	12500	14000	15250	17375	17250			Wire rope broke @ stake pocket
	Displacement (loop), in	1.00	1.04	1.12	1.17	1.19			
	Displacement (connection), in	0.18	0.25	0.28	0.32	0.34			
2	Force, lbs	14000	14125	15875	16625	16625	17625	17875	Wire rope broke @ shackle
	Displacement (loop), in	1.55	1.56	1.61	1.63	1.61	1.64	1.64	
	Displacement (connection), in	0.22	0.28	0.32	0.36	0.37	0.40	0.42	
3	Force, lbs							19250	Wire rope broke @ shackle
	Displacement (loop), in							1.20	

TABLE A-5

TEST RESULTS FOR CLIPS ON 1/2 INCH FIBER CORE WIRE ROPE

TORQUE APPLIED TO 2 CLIPS

RUN		20 ft-lbs	30 ft-lbs	60 ft-lbs	70 ft-lbs	80 ft-lbs	90 ft-lbs	100 ft-lbs	REASON FOR FAILURE
1	*Force, lbs	4750	7750	15500	17375	19500	21250	23750	Clip broke @ 110 ft-lbs
	Displacement (loop), in	1.31	1.51	1.87	1.92	1.96	1.99	2.04	
	Displacement (connection), in	0.19	0.17	0.78	0.85	0.89	0.90	0.95	
2	Force, lbs		(35) 7250	(50) 11000	(65) 13500	17750	(95) 19250		Clip broke @ 100 ft-lbs
	Displacement (loop), in		0.91	0.97	1.05	1.19	1.23		
	Displacement (connection), in		0.21	0.27	0.33	0.41	0.46		
3	Force, lbs						(95) 26250		Excessive slippage
	Displacement (loop), in						2.07		

* Data was lost for 40 and 50 ft-lb torques.

TORQUE APPLIED TO 3 CLIPS

RUN		35 ft-lbs	50 ft-lbs	65 ft-lbs	80 ft-lbs	95 ft-lbs	100 ft-lbs	REASON FOR FAILURE
1	Force, lbs		14000	17500	21750	25000		Clip broke @ 100 ft-lbs
	Displacement (loop), in		0.92	1.01	1.05	1.20		
	Displacement (connection), in		0.22	0.27	0.32	0.35		
2	Force, lbs	7750	13250	21750	32250			Wire rope broke @ stake pocket
	Displacement (loop), in	0.79	0.99	1.25	1.60			
	Displacement (connection), in	0.11	0.18	0.24	0.29			

TORQUE APPLIED TO 3 CLIPS

RUN		35 ft-lbs	50 ft-lbs	65 ft-lbs	80 ft-lbs	95 ft-lbs	100 ft-lbs	REASON FOR FAILURE
3	Force, lbs					31250		Wire rope broke @ stake pocket
	Displacement (loop), in					1.23		

TORQUE APPLIED TO 4 CLIPS

RUN		35 ft-lbs	50 ft-lbs	65 ft-lbs	80 ft-lbs	95 ft-lbs	100 ft-lbs	110 ft-lbs	REASON FOR FAILURE
1	Force, lbs	12500	14500	18500	21000	24250	27250	30000	Clip broke @ 115 ft-lbs
	Displacement (loop), in	1.01	1.04	1.16	1.20	1.27	1.32	1.37	
	Displacement (connection), in	0.18	0.24	0.28	0.33	0.35	0.38	0.41	
2	Force, lbs	13000	17750	18250	20500	21000	23500		Clip broke @ 110 ft-lbs
	Displacement (loop), in	0.83	0.93	0.93	0.97	0.97	1.04		
	Displacement (connection) in	0.13	0.21	0.23	0.28	0.32	0.34		
3	Force, lbs						34000		Wire rope broke @ stake pocket
	Displacement (loop), in						1.36		
4	Force, lbs						35000		Wire rope broke @ stake pocket
	Displacement (loop), in						1.25		

TABLE A-6

TEST RESULTS FOR CLIPS ON 5/8 INCH FIBER CORE WIRE ROPE

TORQUE APPLIED TO 3 CLIPS

RUN		35 ft-lbs	50 ft-lbs	65 ft-lbs	80 ft-lbs	95 ft-lbs	110 ft-lbs	125 ft-lbs	140 ft-lbs	REASON FOR FAILURE
1	Force, lbs	18750	25000	24700	28250	30750	35000	38000	46250	Excessive slippage
	Displacement (loop), in	2.38	2.70	2.74	2.78	2.88	2.94	3.02	3.22	
	Displacement (connection), in	0.27	0.54	0.62	0.68					
2	Force, lbs	16000		18500		25000		29750	46500	Excessive slippage
	Displacement (loop), in	2.44		2.48		2.64		2.70	3.16	
3	Force, lbs				(75) 31000					Excessive slippage
	Displacement (loop), in				2.94					
4	Force, lbs				(75) 28500					Excessive slippage
	Displacement (loop), in				2.52					
5	*Force, lbs				(75) 32250					Excessive slippage
	Displacement (loop), in				3.06					

* Force was applied and reduced without changing the torque. Maximum and reduced forces for each application were: 9250, 1000, 19750, 750, 28500, 500, 32250.

TORQUE APPLIED TO 4 CLIPS

RUN		35 ft-lbs	50 ft-lbs	65 ft-lbs	80 ft-lbs	95 ft-lbs	110 ft-lbs	125 ft-lbs	140 ft-lbs	REASON FOR FAILURE
1	Force, lbs	20000	22500	27000	30750	35750	39750	44500	49750	Capacity of equipment
	Displacement (loop), in	2.34	2.40	2.50	2.58	2.64	2.74	2.82	2.96	
	Displacement (connection), in	0.36	0.45	0.54	0.62					

TORQUE APPLIED TO 4 CLIPS

RUN		35 ft-lbs	50 ft-lbs	65 ft-lbs	80 ft-lbs	95 ft-lbs	110 ft-lbs	125 ft-lbs	140 ft-lbs	REASON FOR FAILURE
2	Force, lbs	17750		19250		25250		30250	47250	Wire rope broke @ stake pocket
	Displacement (loop), in	2.42		2.44		2.54		2.62	3.06	
	Displacement (connection), in	0.39		0.47		0.54				
3	Force, lbs				(75) 46750					
	Displacement (loop), in				3.06					
	Displacement (connection), in				1.10					

TORQUE APPLIED TO 5 CLIPS

RUN		35 ft-lbs	50 ft-lbs	65 ft-lbs	80 ft-lbs	90 ft-lbs	95 ft-lbs	95 ft-lbs	REASON FOR FAILURE
1	Force, lbs	31250	33000	34750		49500			Capacity of equipment
	Displacement (loop), in	2.62	2.66	2.68		2.98			
	Displacement (connection), in	0.37	0.45	0.54		0.56			
2	Force, lbs	27500	30250	35750	43500		48750	49500	Capacity of equipment
	Displacement (loop), in	2.72	2.76	2.86	3.02		3.14	3.16	
	Displacement (connection), in	0.37	0.46	0.53	0.62		0.69	0.74	
3	Force, lbs		(55) 45500						Wire rope broke @ stake pocket
	Displacement (loop), in		2.86						

APPENDIX B

APPENDIX B

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