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WIRE ROPE TERMINATIONS

SELECTION AND INSPECTION GUIDE FOR WIRE ROPE TERMINATIONS

VOLUME II

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

by

ENGINEERING SERVICES COMPANY
10916 Middleboro Dr., Damascus, Maryland 20750

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16. Abstract (Limit: 200 words)

This guide considers nine of the many wire rope terminations used in the mining industry so use of the information presented for terminations not specifically addressed can be done, but with some risk. The guide uses pull test data, axial fatigue test data, and data on sensitivity to poor workmanship, to rank the terminations with respect to these performance measures. A selection procedure is suggested and illustrated with an example. Failure data is used to identify the common modes of failure of each termination and thus help the inspector direct attention to the likely location for a failur and describe what should be looked for. The data on which this guide is bas is included so that as new data becomes available, the ranking order can be adjusted accordingly.

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Service life
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Wire rope slings

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DISCLAIMER

FOREWORD

This report was prepared by Engineering Services Company, Damascus, Md. under USBM Contract number H0166079. The contract was initiated under the Metal & Non-Metal Mine Health & Safety Program. It was administered under the technical direction of the Pittsburgh Mining & Safety Research Center with Edwin Ayres acting as Technical Project Officer. Frank Naughton was the contract administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period September 1976 to August 1978. This report was submitted by the authors on August 10, 1978.

The assistance and cooperation of the subcontractors on this project is acknowledged with gratitude. The hospitality of mining personnel during the mine site visits is hopefully repaid by information in this report that may improve the safety of mine workers. The informal participation of several wire rope manufacturers and manufacturers of wire rope terminations is also acknowledged. Finally, a word of thanks to the mining consultant on this project, Mr. Wallace Barlow, who arranged for and participated in the mine site visits.

1.0 WIRE ROPE TERMINATIONS CONSIDERED

This guide considers only nine of the many Wire Rope Terminations (WRTs) used in the mining industry. With some degree of risk the guide may be used for WRTs not specifically considered, but which are similar in construction and operation to one of the nine described in this guide. Use of the 51 mm (2 in.) diameter data for larger diameters also introduces some risk. Since the names and assembly procedures of WRTs are not yet standardized it will first be necessary to illustrate it, name each WRT, and briefly describe how it is formed or attached to a rope. As an aid to using the guide each WRT is assigned a number which will correspond to the order in which the WRTs are described.

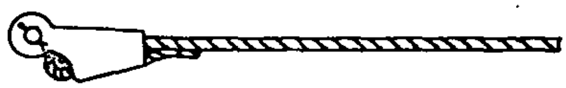
1. FLEMISH LOOP WITH STEEL SLEEVE & THIMBLE

The rope strands are divided into two equal parts which are bent to form a loop and laid back into each other. A thimble is placed inside the loop and a steel sleeve is pressed around the section where the dead end is rolled into the live part of the rope.

2. FLEMISH LOOP WITH STEEL SLEEVE

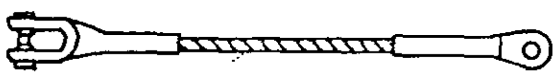
Assembled like WRT Type 1 above without the use of a thimble.

3. WEDGE SOCKET



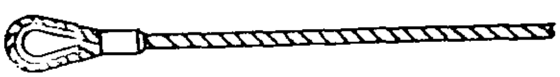
The rope is passed through the base of the socket and turned away from the lugs to form a loop. The wedge is inserted and the loop is pulled tight.

4. SWAGED SOCKET



The rope is inserted to the bottom of the socket cavity and the socket is pressed on the rope.

5. TURN BACK LOOP WITH ALUMINUM SLEEVE & THIMBLE



The rope is formed into a loop around the thimble and an aluminum sleeve is pressed around the section where the dead and live parts of the rope are in contact.

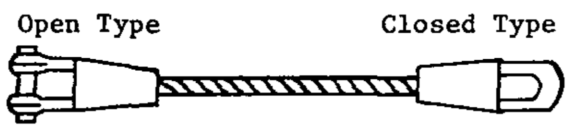
6. THIMBLE SPLICE WITH FOUR TUCKS

The rope is formed into a loop around the thimble then a four tuck splice is made to join the dead part of the rope to the live part.

7. U-BOLT CLIP WITH THIMBLE

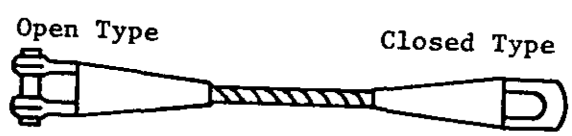
The rope is formed into a loop around the thimble and U-bolt clips are clamped around the live and dead parts of the rope.

8. ZINC POURED SOCKET



The rope is opened, cleaned and treated, and inserted into a RR-S-550 socket. Molten zinc is poured into the socket to hold the rope in the socket once the zinc has congealed.

9. EPOXY RESIN POURED SOCKET



The rope end is opened, cleaned, and inserted into a proprietary long tapered socket. An epoxy resin is poured into the socket and holds the rope in the socket after the resin has cured.

2.0 HOW TO USE THE GUIDE

This publication is not a handbook, but a guide based on information gathered from mine site visits and laboratory testing of nine different wire rope terminations (WRT). This guide is to be used to select a WRT for some application and to inspect a WRT in the field and decide whether replacement is required.

2.1 To use the guide to select a WRT one must first know the application such as one of the representative applications listed below.

<u>Surface Mining</u>

Dragline Hoist	Driller Hoist
Dragline Rope	Shovel Boom Hoist
Boom Support	Shovel Bucket Hoist
Sled Haul Line	Shovel Hoist
Hand Rail	Shovel Crowd & Retract
Boom Hoist	Boom Suspension

<u>Underground Mining</u>

Conveyor Roller Support	Haulage Ropes
Brake Car Hoist	Car Unloader
Shaft Hoist	Elevator Hoist
Balance Ropes	

<u>General Mining</u>

Car Retarder	Railroad Car Haulage Rope
Slings	Aerial Tramways

2.2 The load on the WRT from the application can generally be labelled as mainly static (constant), or as dynamic (varying or changing). If the load is considered to be static then the three top ranked WRTs are selected from Table A, "Rank Order of Terminations with Respect to True Efficiency" found in section 3.0 of this guide along with two other tables used in the selection process. If the load is considered to be dynamic then the three top ranked WRTs are selected from Table B, "Rank Order of Terminations with Respect to Service Life." In entering either of the above tables use the rope diameter column closest to the diameter of the rope to be used on the application. The 51 mm (2 in.) column can also be used for rope diameters greater than those considered, recognizing that some risk is involved in such an extrapolation. If the three WRTs were selected from Table A, then of these three retain only the two WRTs with the highest rank based on Table B. Similarly, if the initial three WRTs were selected from Table B, then retain only the two WRTs with the highest rank based on Table A. The user must next decide which of the two assembly conditions identified in Table C exists at the same mine site. Then, of the two WRTs remaining in the initial selection, eliminate the WRT with the lowest rank based on Table C, "Terminations Ranked in Order of Increasing Sensitivity to Poor Workmanship." The remaining WRT is then evaluated against other operating conditions at the mine site, and a decision is made to use this WRT or to reject it. If the WRT is rejected, then return to Table A or B, ignoring the rejected WRT. The procedural steps are outlined in Section 3.0 which also contains Tables A, B, and C.

2.3 To use the guide to inspect a WRT in the field and decide whether replacement is required, Section 4.0 identifies the more common failure locations and characteristic. An inspection procedure is suggested as well as a replacement criteria which is considered safe, yet gets the most use of the WRT.

.0 SELECTION OF A WRT

Using Tables A, B, and C of this section follow the teps listed below to select a WRT for your application.

1. Decide if load condition is primarily a static one or a dynamic one.

2. If the former case holds, then select under the closest rope diameter the top three WRTs as ranked with respect to TE.

3. If the latter case holds, then select under the closest rope diameter the top three WRTs as ranked with respect to SL.

4. If the top three WRTs were selected on the basis of TE, retain the two WRTs with the highest rank based on SL.

5. If the top three WRTs were selected on the basis of SL, retain the two WRTs with the highest rank based on TE.

6. Decide which of the two assembly conditions identified in Table C exist at the mine site.

7. Of the two WRTs remaining in the initial selection, eliminate the WRT with the lowest rank based on sensitivity to poor workmanship.

8. The candidate WRT should then be evaluated for compatibility with other operating conditions.

9. If the candidate WRT is acceptable it is designated the WRT to use.

10. If the candidate WRT is rejected, then return to Step 2 or 3 ignoring the initial candidate and repeat the procedure.

.1 The following is an example of the above selection procedure for a Boom Suspension system with a 25 mm (1 in.) rope.

1. Load is primarily static.

2. Select WRT Types 9, 8, and 4.

3. N/A

4. Retain WRT Types 4 and 9.

5. N/A

6. Skilled Workers or Inspection are available.

7. Eliminate WRT Type 9.

8. WRT Type 4, the Candidate WRT is compatible with other operating conditions.

9. WRT Type 4, Swaged Socket, is the designated one to use.

Suppose that in the above example it was found that there were no Swaged Sockets available in stock. One would then return to Step 2 in the selection procedure to find a new WRT.

2. Select WRT Types 9, 8, 1, 5, and 7.

3. N/A

4. Retain WRT Types 9 and 1.

5. N/A

6. Skilled Workers or Inspection still available.

7. Eliminate WRT Type 1.

8. WRT Type 9, the Candidate WRT is compatible with other operating conditions.

9. WRT Type 9, the Epoxy Resin Poured Socket is the designated one to use.

TABLE A

RANK ORDER OF TERMINATIONS WITH RESPECT TO TRUE EFFICIENCY

Rank	Rope Diameter mm (in.) 13 (½)	19 (3/4)	25 (1)	38 (1½)	51 (2)
I	9	9	9	4	8
II	4	1	8	8	4
III	5,8	2,7	4	1	9
IV	2	4	1,5,7	7,9	7
V	1	5	2	2,5	5
VI	3	8	3	6	2
VII	7	6	6	3	1
VIII	6	3	-	-	6
IX	-	-	-	-	3

TABLE B

RANK ORDER OF TERMINATIONS WITH RESPECT TO SERVICE LIFE

Rank	Rope Diameter mm (in.) 13 (½)	19 (3/4)	25 (1)	38 (1½)	51 (2)
I	4	9	4,9	4	4
II	1	4	1	7	9
III	9	1	5	5	7
IV	2	2	3	2	1
V	5	5	7	1	3
VI	6	7	6	8,9	5
VII	8	8	8	3	6
VIII	3	3	2	6	8
IX	7	6	-	-	2

TABLE C

TERMINATIONS RANKED IN ORDER OF INCREASING SENSITIVITY TO POOR WORKMANSHIP

Rank	With Skilled Workers or Inspection	With Unskilled Workers or No Inspection
I	7	3
II	8	4
III	4	7
IV	5	1
V	9	2
VI	6	5
VII	3	6
VIII	1	9
IX	2	8

WIRE ROPE TERMINATIONS

1 Flemish Loop with Steel Sleeve & Thimble
2 Flemish Loop with Steel Sleeve
3 Wedge Socket
4 Swaged Socket
5 Turn Back Loop with Aluminum Sleeve & Thimble
6 Thimble Splice with Four Tucks
7 U-Bolt Clip with Thimble
8 Zinc Poured Socket
9 Epoxy Resin Poured Socket

4.0 INSPECTION OF A WRT

4.1 The impending failure of a WRT can be anticipated and a timely replacement made if inspection is frequent enough, is directed to the common failure location, and the characteristics of the impending failure are recognized. The most common failure location and description are given to Table D "Location and Features of Common WRT Failures" for the nine WRTs considered. Typical WRT failures are illustrated in this section to familiarize new inspectors and an inspection procedure is suggested below. When the inspection finds cracks in the pressed sleeve or socket body, or ten (10) broken wires in the adjoining rope, the WRT should be replaced. The replacement criteria of ten (10) broken wires in the adjoining rope is a conservative rule based on the twenty (20) broken wires used for the axial fatigue tests on which this guide is based. Except for the U-Bolt Clip with Thimble WRT, these ten broken wires will be found in the first rope lay measured from the base of the WRT. These wires will have broken under axial fatigue loading. The above criteria is not the same as that specified by the Code of Federal Regulations, Title 29, Part 1910.184(f)(5)(i). This criteria requires that a wire rope sling be removed from service when it has ten (10) broken wires distributed randomly in one rope lay, or five (5) broken wires in one strand in one rope lay. These wire breaks may be due to reversed bending in the gage area of the sling and do not necessarily reflect on the condition of the WRT.

4.2 Suggested Inspection Procedure

FLEMISH LOOP WITH STEEL SLEEVE & THIMBLE

Examine the thimble for cracks or severe deformation. Either of these conditions require inspection of the wires in the crown of the loop. Also examine the wires at the base of the steel sleeve by bending the rope from side to side and twisting the rope open.

FLEMISH LOOP WITH STEEL SLEEVE

Examine the wires in the crown of the loop, and at the base of the steel sleeve by bending the rope from side to side and twisting the rope open.

WEDGE SOCKET

Examine the socket for cracks and notice whether the position of the wedge is deep enough in the socket to retain the rope. Examine the wires at the base of the socket by bending the rope from side to side and twisting it open.

SWAGED SOCKET

Examine the wires at the base of the socket by bending the rope from side to side and twisting the rope open.

TURN BACK LOOP WITH ALUMINUM SLEEVE & THIMBLE

Examine the sleeve for cracks and the thimble for cracks or severe deformation. If the thimble is damaged examine the wires in the crown of the loop. Examine the wires at the base of the sleeve by bending the rope from side to side and twisting the rope open.

THIMBLE SPLICE WITH FOUR TUCKS

Examine the thimble for cracks or severe deformation and if either exists, examine the wires in the crown of the loop. Examine the wires in the splice area from the base of the thimble to the end of the splice. Use a marline spike or a splicer's dagger to separate the strands. Do not pull on the strands or otherwise shift them from their seated position.

U-BOLT CLIP & THIMBLE

Examine the thimble for cracks or severe deformation and if either exists, examine the wires in the crown of the loop. Examine the wires at the clip furthest from the thimble by removing the clip and then remounting it. Verify that the torque on the nuts agrees with those values given here or those values used by the assembler.

Dia. mm (in.)	Torque joules (ft. lbs.)
13 (½)	88 (65)
14 (9/16)	129 (95)
16 (5/8)	129 (95)
19 (3/4)	177 (130)
22 (7/8)	306 (225)
25 (1)	306 (225)
28 (1-1/8)	306 (225)
32 (1¼)	490 (360)
35 (1-3/8)	490 (360)
38 (1½)	490 (360)
41 (1-5/8)	585 (430)
44 (1-3/4)	802 (590)
51 (2)	1020 (750)

ZINC POURED SOCKET

Examine the wires at the base of the socket by bending the rope from side to side and twisting the rope open.

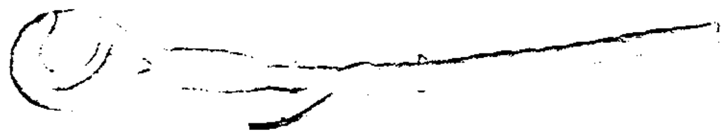
EPOXY RESIN POURED SOCKET

Examine the socket for cracks, removing any galvanizing film if necessary. Examine the wires at the base of the socket by bending the rope from side to side and twisting the rope open.

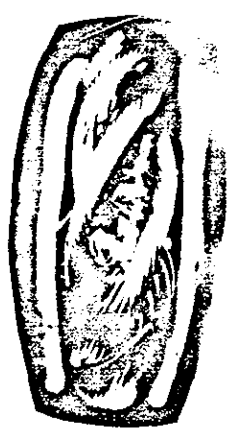
TABLE D LOCATION AND FEATURES OF COMMON WRT FAILURES

Termination Type	Failure Location	Characteristic Features
Flemish Loop with Steel Sleeve & Thimble	Base of Steel Sleeve	Broken wires
Flemish Loop with Steel Sleeve	Crown of Loop	Broken wires
Wedge Socket	Base of Socket	Broken wires on live rope
Swaged Socket	Base of socket & body of rope	Broken wires
Turn Back Loop with Aluminum Sleeve & Thimble	Sleeve body Base of sleeve	Cracks Broken wires
Thimble Splice with Four Tucks	Entire length of splice	Broken wires
U-Bolt Clip with Thimble	Clip closest to main rope	Broken wires on live rope
Zinc Poured Socket	Base of socket	Broken wires
Epoxy Resin Poured Socket	Socket body Body of rope	Cracks Broken wires

Illustrations of WRT Failures



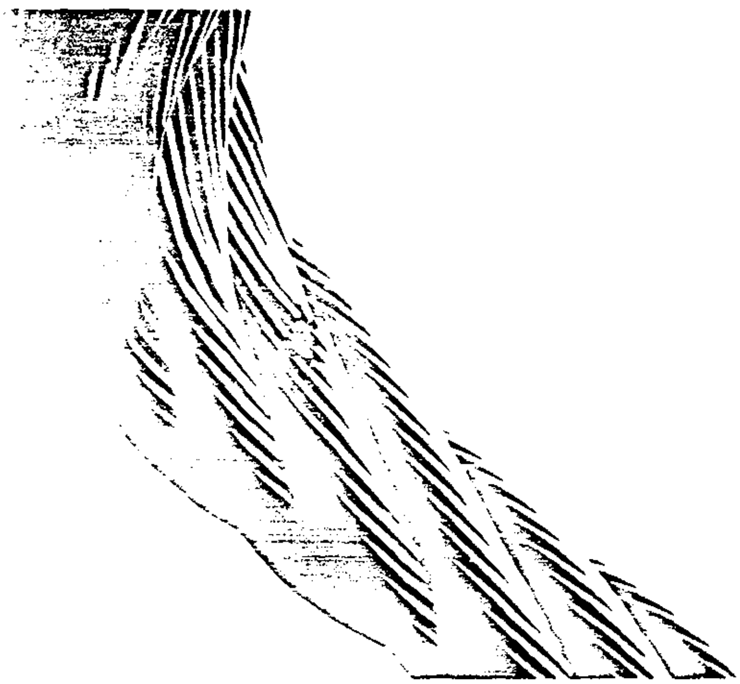
Broken strands and cracked thimble on a Flemish Loop with Steel Sleeve & Thimble.



Broken wires in crown of loop on a Flemish Loop with Steel Sleeve & Thimble where thimble became deformed.

Broken wires on outside of crown of loop on a Flemish Loop with Steel Sleeve.

Broken wires on inside of crown of loop on a Flemish Loop with Steel Sleeve.



Broken wires on the inside of crown of loop on a Flemish Loop with Steel Sleeve.

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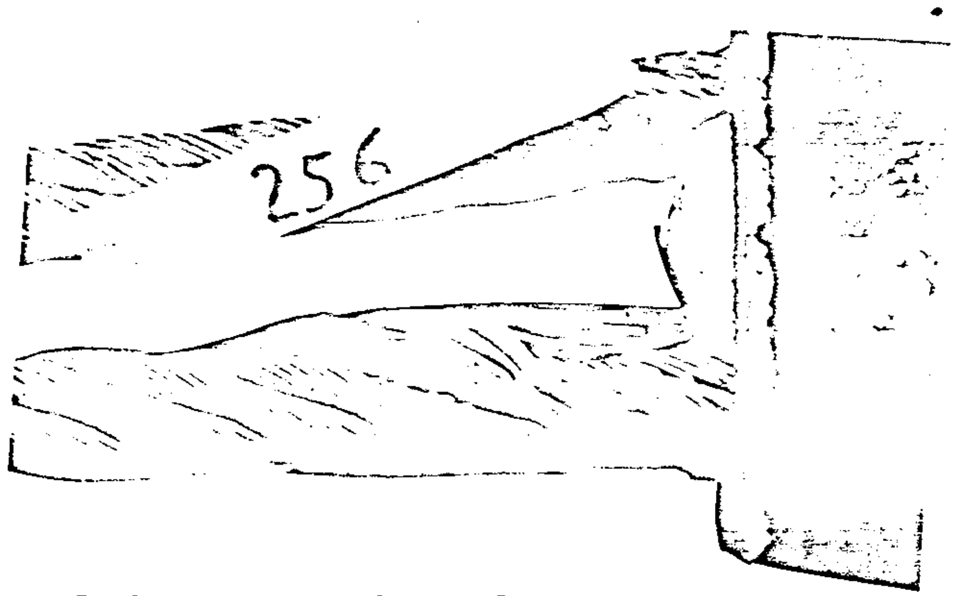
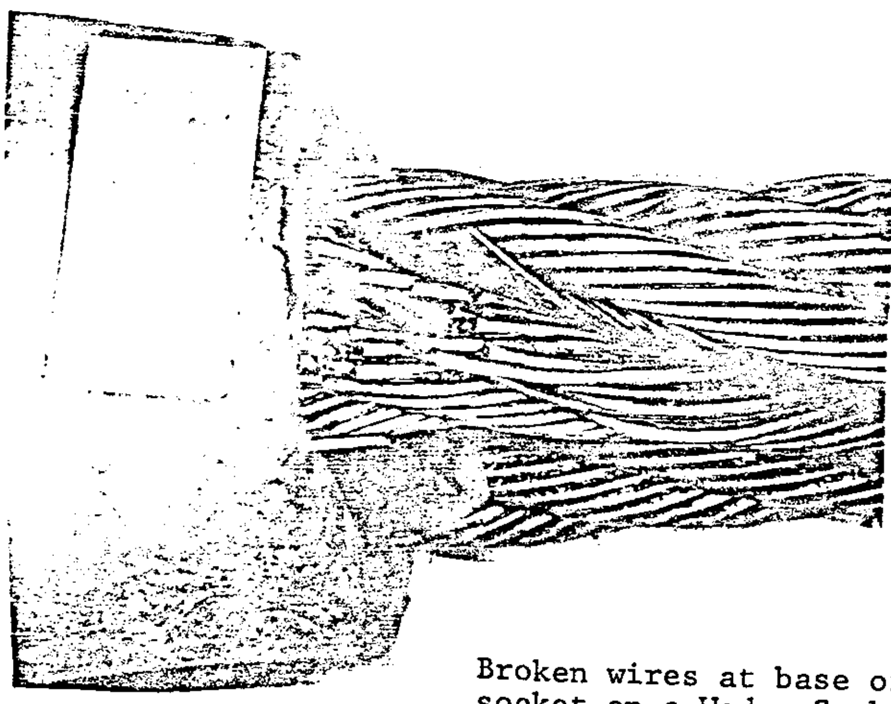
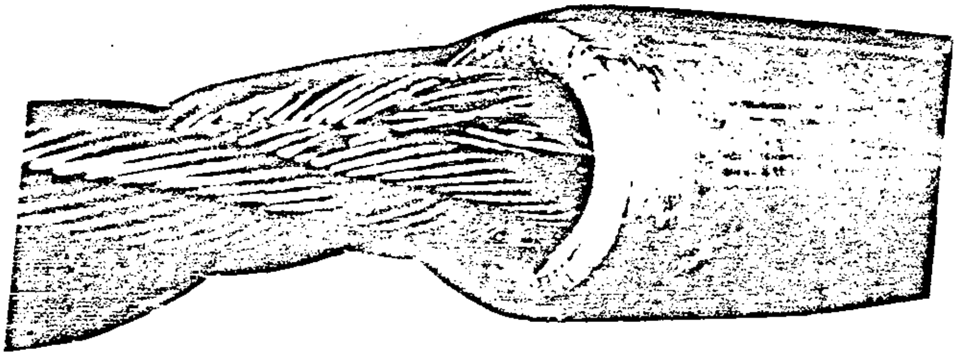


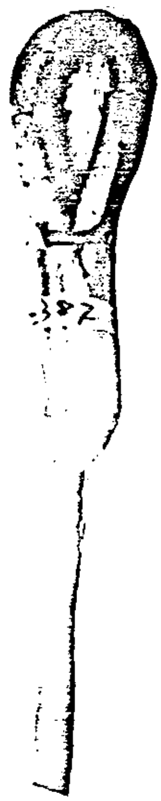
Broken wires at base of
socket on a Wedge Socket.



Broken wires at base of
socket on a Wedge Socket.



Broken wires at base of socket on a Swaged Socket.



Cracked thimble and sleeve on a Turn Back Loop with Aluminum Sleeve.

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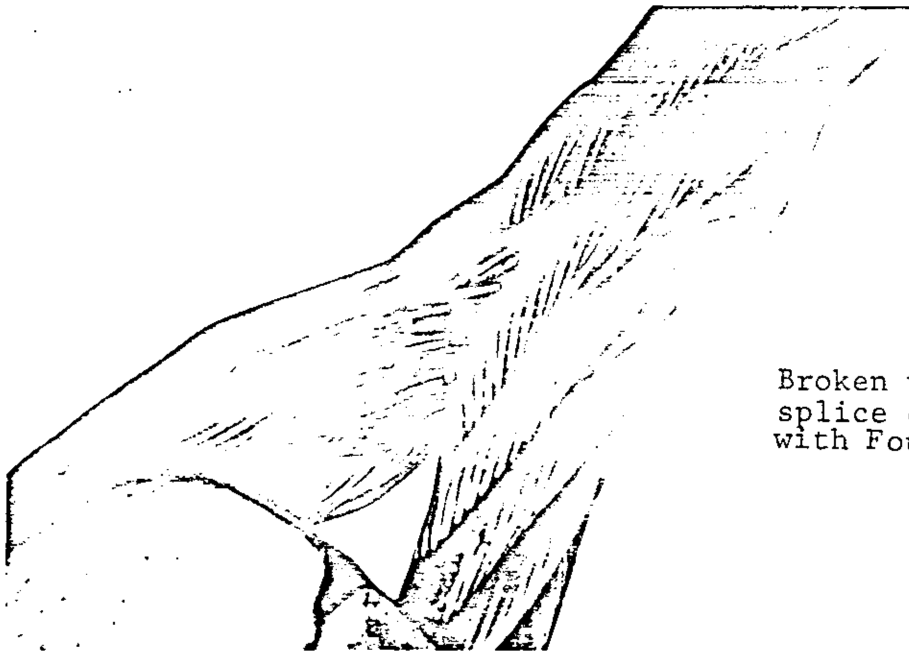
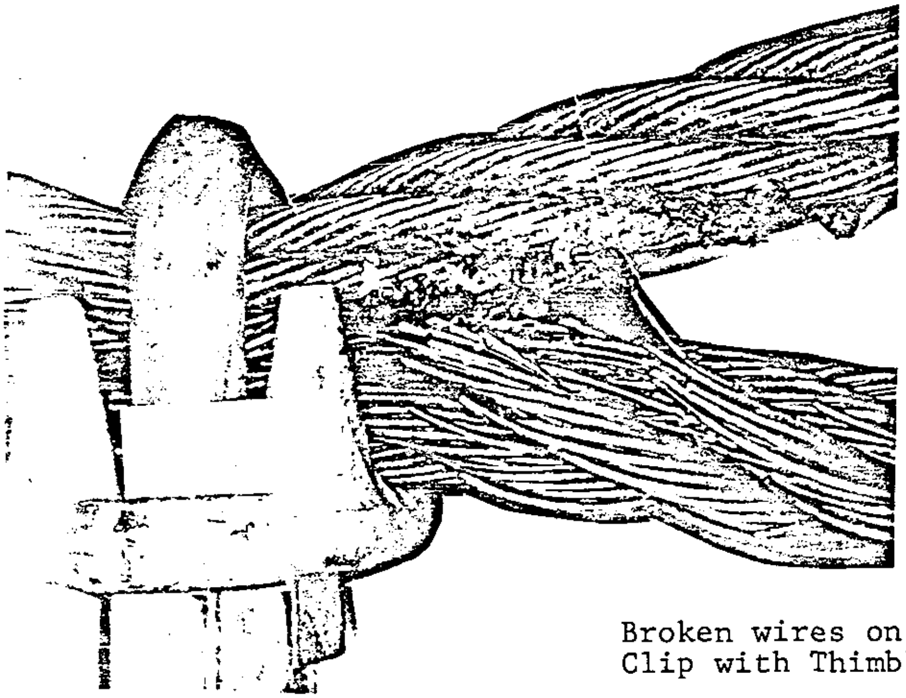
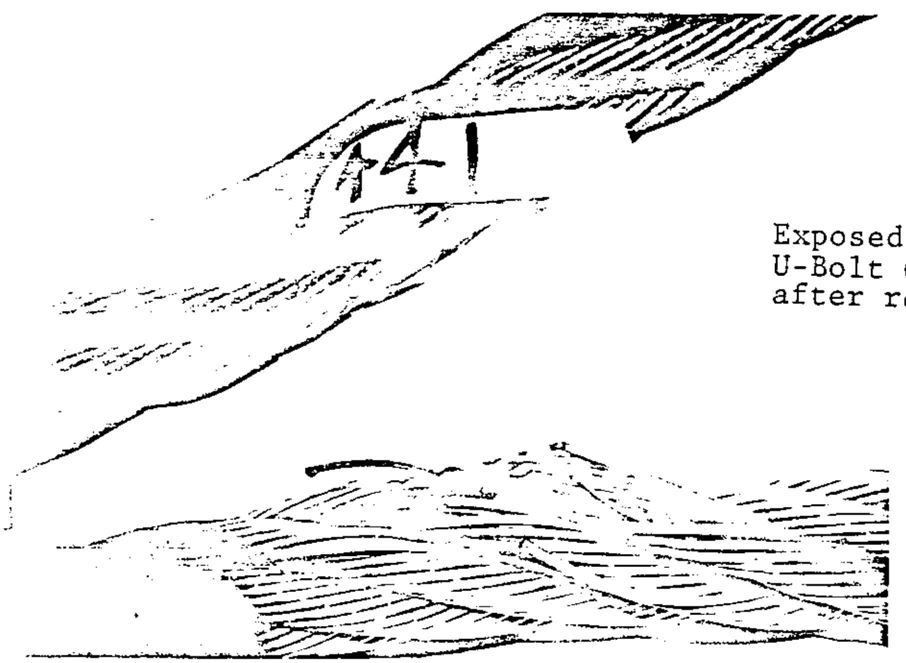


Broken wires at top of splice on a Thimble Splice with Four Tucks.

Broken wires in the first tuck on a Thimble Splice with Four Tucks.



Broken wires on a U-Bolt Clip with Thimble.



Exposed broken wires on a U-Bolt Clip with Thimble after removing clip.

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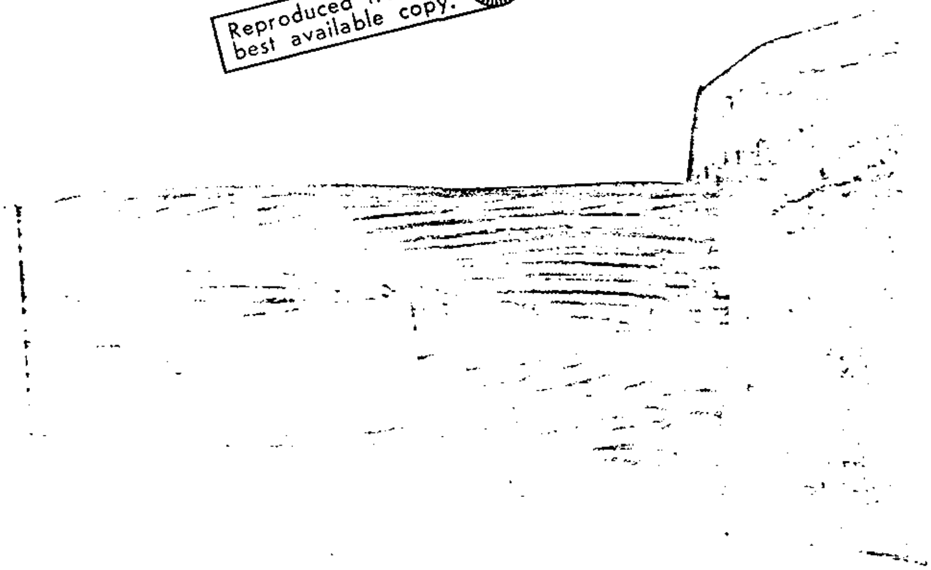
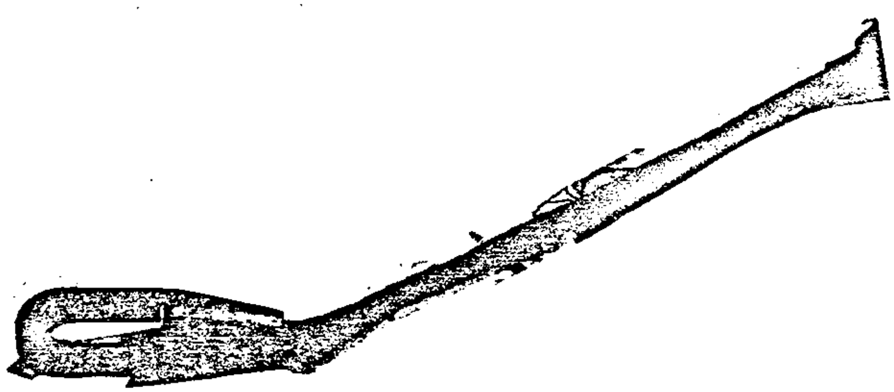
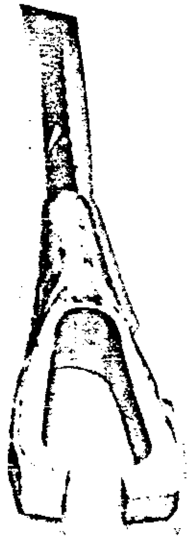


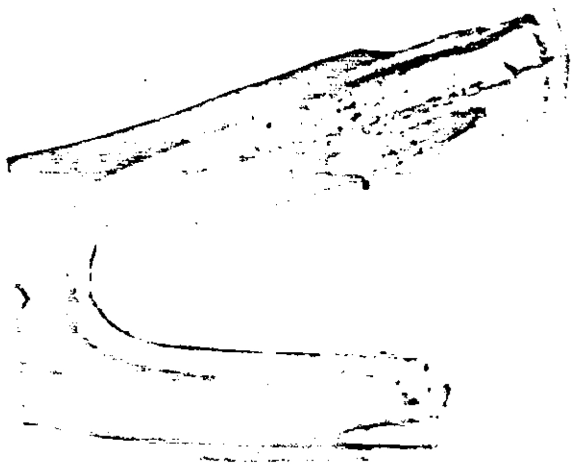
Broken wires at base of
socket on a Zinc Poured
Socket.



Broken strands at base of
socket on a Zinc Poured
Socket.



Cracked socket on an Epoxy
Resin Poured Socket.



Cracked socket on an Epoxy
Resin Poured Socket.

5.0 TEST DATA USED IN PREPARING GUIDE

The laboratory test data used to prepare Tables A, B, and C are included in the guide. Those interested can judge for themselves the rank assigned to each WRT with respect to the three factors of interest, True Efficiency (TE), Service Life (SL), and Sensitivity to Poor Workmanship. Should new or additional data become available then the selection guide tables can be updated as appropriate. The data base for Table D is also included in the guide. The test data is presented in the following six tables which are self explanatory.

TABLE E

TRUE EFFICIENCY OF WIRE ROPE TERMINATIONS AVERAGED OVER CLASS AND CONSTRUCTION [(a)]

Wire Rope Diameter	Wire Rope Construction	Termination Type [(b)] 1	2	3	4	5	6	7	8	9
13 mm (½ in.)	Lang	88	88	80	94	92	70	79	88	96
	Regular	88	90	84	95	92	76	81	95	96
	Mean	88	89	82	94	92	73	80	92	96
19 mm (3/4 in.)	Lang	84	82	80	84	82	76	90	78	92
	Regular	96	93	74	89	86	81	85	86	98
	Mean	90	88	77	86	84	78	88	82	95
25 mm (1 in.)	Lang	86	79	81	90	88	68	88	92	93
	Regular	94	88	76	96	92	80	91	96	98
	Mean	90	84	78	93	90	74	90	94	96
38 mm (1½ in.)	Lang	89	81	68	91	82	67	86	94	87
	Regular	90	91	73	98	90	82	91	92	90
	Mean	90	86	70	94	86	74	89	93	89
51 mm (2 in.)	Lang	84	86	71	90	86	68	90	98	88
	Regular	81	82	61	98	88	80	91	99	98
	Mean	82	84	66	94	87	74	90	98	93

(a) True Efficiency is defined as the termination's breaking load divided by the rope's True Breaking Load.

(b) Wire Rope Terminations

1 Flemish Loop with Steel Sleeve & Thimble
2 Flemish Loop with Steel Sleeve
3 Wedge Socket
4 Swaged Socket
5 Turn Back Loop with Aluminum Sleeve & Thimble
6 Thimble Splice with Four Tucks
7 U-Bolt Clip with Thimble
8 Zinc Poured Socket
9 Epoxy Resin Poured Socket

TABLE F SERVICE LIFE OF WIRE ROPE TERMINATIONS[a]

Wire Rope		Termination Type[b]								
Diameter	Construction	1	2	3	4	5	6	7	8	9
13 mm (½ in.)	Lang	676	294	128	574	292	160	203	70	653
	Regular	603	293	142	10^6	342	214	85	163	252
		817	538	189	10^6	480	337	91	183	10^6
	mean	710	416	166	10^6	411	276	88	173	625
19 mm (3/4 in.)	Lang	173	168	129	277	135	105	121	54	195
	Regular	309	283	83	278	223	76	172	136	598
		358	294	99	524	230	102	241	225	10^6
	mean	334	289	91	401	226	89	206	180	799
25 mm (1 in.)	Lang	298	47	381	900	191	33	228	39	10^6
	Regular	482	42	245	900	204	40	196	42	10^6
		536	49	327	900	509	114	267	56	10^6
	mean	509	46	286	900	356	77	232	49	10^6
38 mm (1½ in.)	Lang	457	404	215	385	342	75	305	89	472
	Regular	197	241	201	460	351	65	327	177	214
		334	317	205	466	383	121	432	294	240
	mean	266	279	203	463	367	93	759	236	227
51 mm (2 in.)	Lang	272	40	226	140	87	39	146	200	133
	Regular	162	27	138	456	106	43	223	26	203
		201	29	190	549	141	46	231	52	304
	mean	182	28	164	502	124	44	227	39	254

(a) Service Life is expressed as the number of cycles to failure x 10^3, except for run out values of 1 million cycles (10^6).

(b) WIRE ROPE TERMINATIONS

1 Flemish Loop with Steel Sleeve & Thimble
2 Flemish Loop with Steel Sleeve
3 Wedge Socket
4 Swaged Socket
5 Turn Back Loop with Aluminum Sleeve & Thimble
6 Thimble Splice with Four Tucks
7 U-Bolt Clip with Thimble
8 Zinc Poured Socket
9 Epoxy Resin Poured Socket

TABLE G

TRUE EFFICIENCY OF STANDARD AND MODIFIED TERMINATIONS

Wire Rope Dia. mm (in.)	13 (½)				25 (1)				51 (2)			
Assembly Procedure	Stnd x	Stnd $\bar{x}$	Mod 1	Mod 2	Stnd x	Stnd $\bar{x}$	Mod 1	Mod 2	Stnd x	Stnd $\bar{x}$	Mod 1	Mod 2
Flemish Loop With	88				94				70			
Steel Sleeve	88	89	86	82	94	94	83	84	75	75	75	16
& Thimble	90				94				79			
Flemish Loop With	90				87				79			
Steel Sleeve	91	91	88	84	88	88	85	35	80	81	36	7
	93				88				85			
	79				77				57			
Wedge Socket	86	84	69	85	77	79	74	84	58	60	60	57
	88				84				64			
	95				91				97			
Swaged Socket	98	97	98	97	99	96	99	60	94	97	94	92
	98				99				97			
Turn Back Loop	91				90				78			
With Aluminum	93	93	87	92	92	92	92	94	90	87	76	91
Sleeve & Thimble	94				94				92			
Thimble Splice	76				76				63			
With Four Tucks	77	77	73	78	83	81	70	85	77	75	45	70
	79				85				84			
U-Bolt Clip With	79				93				59			
Thimble	83	82	80	80	95	95	92	97	77	76	85	77
	84				96				93			
Zinc Poured	60				97				98			
Socket	88	81	84	83	97	97	99	100	99	99	98	99
	96				98				99			
Epoxy Resin	84				99				80			
Poured Socket	98	94	0	0	99	99	57	82	99	93	26	95
	100				99				100			

TABLE H SERVICE LIFE OF STANDARD AND MODIFIED TERMINATIONS[(a)]

Wire Rope Dia. mm (in.)	13 (½)			25 (1)			51 (2)		
Assembly Procedure	Stnd	Mod 1	Mod 2	Stnd	Mod 1	Mod 2	Stnd	Mod 1	Mod 2
Flemish Loop With Steel Sleeve & Thimble	603 817	382	.70	482 536	611	0	162 201	0	0
Flemish Loop With Steel Sleeve	293 538	222	0	42 49	12	0	27 29	0	0
Wedge Socket	142 189	78	43	245 327	74	356	138 190	34	93
Swaged Socket	10^6 10^6	600	10^6	900 900	900	429	457 549	702	341
Turn Back Loop With Aluminum Sleeve & Thimble	342 480	396	346	204 509	112	229	106 141	126	28
Thimble Splice With Four Tucks	214 337	451	78	40 114	17	79	43 46	0	39
U-Bolt Clip With Thimble	85 91	109	143	196 267	168	251	223 231	163	209
Zinc Poured Socket	163 183	134	138	42 56	37	42	26 52	36	50
Epoxy Resin Poured Socket	252 10^6	287	149	10^6 10^6	296	110	203 304	0	568

[(a)] Service Life of Regular 6x19 specimens expressed as the number of cycles to failure x 10^3, except for run out values of 1 million cycles (10^6).

TABLE I WRT FAILURE MODES FOR PULL TESTS

Termination Type/Failure Mode	Percent of Total
Flemish Loop with Steel Sleeve & Thimble	
Multiple strand breaks inside or at base of steel sleeve	83%
Multiple strand breaks in gage area	13%
Rope pulled out of loop	4%
Flemish Loop with Steel Sleeve	
Multiple strand breaks inside or at base of steel sleeve	82%
Multiple strand breaks in gage area	8%
Multiple strand breaks in crown of loop	6%
Rope pulled out of loop	4%
Wedge Socket	
Multiple strand breaks inside or at base of socket	72%
Socket cracked	19%
Wedge pulled out of socket	9%
Swaged Socket	
Multiple strand breaks inside or at base of socket	76%
Multiple strand breaks in gage area	19%
Rope pulled out of socket	5%
Turn Back Loop with Aluminum Sleeve & Thimble	
Multiple strand breaks inside or at base of aluminum sleeve	89%
Aluminum sleeve cracked	7%
Multiple strand breaks	4%
Thimble Splice with Four Tucks	
Multiple strand breaks in splice	95%
Multiples strand breaks in gage area	5%
U-Bolt Clip with Thimble	
Multiple strand breaks at clip furthest from thimble	90%
Multiple strand breaks at clip second furthest from thimble	5%
Rope pulled out of clips	5%
Zinc Poured Socket	
Multiple strand breaks inside or at base of socket	55%
Multiple strand breaks in gage area	40%
Rope pulled out of socket	5%
Epoxy Resin Poured Socket	
Multiple strand breaks in gage area	48%
Multiple strand breaks inside or at base of socket	27%
Rope pulled out of socket	18%
Socket cracked	7%

TABLE J WRT FAILURE MODES FOR FATIGUE TESTS

Termination Type/Failure Mode	Percent of Total
Flemish Loop with Steel Sleeve & Thimble	
Multiple strand breaks inside or at base of steel sleeve	88%
Multiple strand breaks in gage area	6%
Thimble cracked and strands in crown of loop broke	6%
Flemish Loop with Steel Sleeve	
Multiple strand breaks in the crown of the loop	87%
Multiple strand breaks inside or at base of steel sleeve	13%
Wedge Socket	
Multiple strand breaks inside or at base of socket	94%
Socket cracked	6%
Swaged Socket	
Multiple strand breaks inside or at base of socket	46%
No strand breaks; run out	27%
Multiple strand breaks in gage area	27%
Turn Back Loop with Aluminum Sleeve	
Aluminum sleeve cracked	53%
Multiple strand breaks inside or at base of aluminum sleeve	47%
Thimble Splice with Four Tucks	
Multiple strand breaks in splice	100%
U-Bolt Clip with Thimble	
Multiple strand breaks at clip furthest from thimble	80%
Multiple strand breaks inside or at base of swaged socket	14%
Rope pulled out of swaged socket	6%
Zinc Poured Socket	
Multiple strand breaks inside or at base of socket	100%
Epoxy Resin Poured Socket	
Socket cracked	72%
No strand breaks ; run out	22%
Multiple strand breaks in gage area	6%