NATIONAL BUREAU OF STANDARDS REPORT

10 017

Examination of

M513/M514 FUSE SLEEVES

To

Harry Diamond Laboratories

NBS

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

NATIONAL BUREAU OF STANDARDS

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[2] Located at Boulder, Colorado 80302.
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NBS PROJECT
8720641

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Examination of

M513/M514 FUSE SLEEVES

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National Bureau of Standards
Washington, D. C. 20234

Examination of

M513/M514 FUSE SLEEVES

Submitted by

Harry Diamond Laboratories
NBS Project 8720641
HDL Project No. 76779

By

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Reference: (a) HDL Work Order, HDL Project No. 76779.

Material: A total of 102 fuse sleeves fabricated from 2014-T6 aluminum alloy were submitted under reference (a) for examination. The fuse sleeves have a semi-perforation located in the main length of the fuse sleeve. Figure 1 shows three types of semi-perforations that were examined, ZW, N, and ΔHP. The fuse sleeve with a semi-perforation marked NB was not photographed in the as received condition, however a longitudinal view of the semi-perforation will be shown later. The marks ZW, N, ΔHP, and NB are manufacturers' designations for the sleeve. Some of the fuse sleeves had been fired and others had not. Fuse sleeves numbered 63 to 89 were reported by HDL investigators, to have cracks present. A list of the material submitted for examination is shown in table 1.

Purpose: The initial purpose of the investigation was to determine whether there are cracks in the vicinity of the semi-perforation in fuse sleeves 1 to 32. However, additional fuse sleeves were submitted subsequently, 33 to 101, and the purpose of this part of the investigation was to pull these samples in tension until breaking occurred. Among these new samples 33 to 101, there were 47 samples, 43 to 89 that had been fired, and among these 47 there were 27 samples, 63 to 89, that had cracks observed in them by HDL investigators. The tensile tests were conducted to determine the effect of prior firing and an existing crack in the semi-perforation, on the breaking load of the fuse sleeve.

Hardness: Vickers (10 Kg load) hardness determinations were obtained on fuse sleeves 24 to 32. These determinations and their converted values of Rockwell B, are given in table 2. The hardness tests reveal the fuse sleeves to be within the hardness limits for a 2014-T6 aluminum alloy. The hardness limits were obtained from the Metals Handbook, volume 1, Properties and Selection of Metals, 1961.

Metallographic Examination: Fuse sleeves 24 to 32 were given a metallographic examination. The sleeves were cut to reveal sections through the semi-perforations. Cracks, as indicated by the arrows in figures 2 and 3, were observed on the underside of the semi-perforations. In figure 3, the crack appears to have opened more after firing. The fuse sleeves were then sectioned longitudinally through the center of the semi-perforation. Photomicrographs of the sectioned semi-perforations are shown in figures 4 to 8. In figure 4, cracks as indicated by arrows (A), were observed on the underside of the semi-perforations in both the fired and unfired conditions. In figures 5 and 6, cracks, as indicated by arrow (A), were observed on the underside of the fuse sleeves where a sharp radius is present. However, in figure 7, the more generous radii as shown by arrows (A) and (B) in the type ZW semi-perforation appear to have been produced by the manufacturers' processing. Cracks were not found in this fuse sleeve.

Figure 8 is a photomicrograph of type ZW which had been pulled in tension and then longitudinally sectioned. No cracks were observed, however HDL investigators are reported to have observed cracks in this particular fuse sleeve. It is possible that a prior existing crack may have initiated the main fracture and hence would no longer be visible.

In the metallographic examination of fuse sleeves 24,25,26, and 27 (ΔHP's) and 32 (NB), cracks were observed, figures 5 and 6, only at the sharp radii on the underside of the semi-perforations. However, in the fuse sleeves, 28 and 29 (N's), which were metallographically examined, figure 4, the sharp radii existed at the top of the semi-perforation. The areas of sharp radii in type N were crack free, but cracks were observed on the underside of the semi-perforation on the smooth radii indicated by arrows (A) in figure 4.

In figure 1, 16 of 33 fuse sleeves of type N fracture during tension testing occurred through the area marked by arrow (B), whereas in the other 17 N's fracture occurred at the position indicated by arrow (A). The failure at these two different areas indicated by arrows (B) and (A) in figure 1, could be attributed to the fact that underside of the semi-perforation, figure 4, did not have as sharp a radii as the top of the semi-perforations. The radii that existed at the top of N, figure 4, were apparently equal. Therefore, if cracks were present on the underside of the semi-perforation type N, the fracture would occur through the

sharp radius adjacent to the larger of the pre-existing cracks. In fuse sleeves type ΔHP and NB, which were tested in tension, fracture occurred only through the area indicated by the arrow (A) figures 1, 5 and 6. This area of fracture initiation has sharp radii and apparently had initial cracks present such as those shown in figures 5 and 6, by arrow (A). The presence of a sharp radius and a crack are stress concentrators, and during tensile tests, failure would tend to occur through this area of the semi-perforation. Due to these stress concentrators, the breaking loads obtained on types ΔHP, NB, and N should be lower than those of a fuse sleeve which did not have a sharp radius and a crack present, such as in type ZW, figure 7.

Tensile Tests: Tensile tests were performed on fuse sleeves 33 to 101. A fixture supplied by HDL was used in the test. The fuse sleeve was screwed into the fixture and a rod was then screwed into the fuse sleeve. A tensile testing machine then applied a load to the rod which in turn applied a pulling load to the fuse sleeve, thereby causing failure of the sleeve. Because of the high breaking loads, the fuse sleeves were tested at the Engineering Mechanics Section, NBS. The deflection rate applied to all fuse sleeves tensile tested was approximately 0.05 inch per minute. ASTM Specification B221-68 for extrusions of 2014-T6 aluminum alloy, with a wall thickness up to 0.499 inch thick, require a minimum tensile strength of 60,000 psi. This corresponds in the fuse sleeves to a minimum breaking load of approximately 26,700 pounds. The ASTM Specification B221-68 for elongation of a 2014-T6 extruded aluminum alloy, with a wall thickness of up to .499 inch, requires a minimum elongation in 2 inches of 7 per cent. The elongations for the fuse sleeves tensile tested in our program were not calculated since the semi-perforation acts as a stress concentrator, hence a true value of the elongation could not be determined. In table 3 the extension of a 2 inch gage length of the samples tensile tested is reported. The data indicates the fuse sleeves with the semi-perforation mark of ZW have on the average a higher increase in a 2-inch length than the other samples tensile tested.

The results of the tensile tests indicate the breaking loads of all the samples tested to be above the minimum breaking load. The fuse sleeves which were found to have cracks present, as observed by HDL, also were within ASTM specifications. Whether a fuse sleeve had or had not been fired appeared to have no bearing on the breaking load, for all these fuse sleeves had breaking loads above the specifications. The major significance revealed in the tensile testing is that the fuse sleeves with the manufacturer's designation ZW appear to have a higher breaking load than the other types tested. This condition prevails whether the sample ZW has or has not been fired.

Conclusions:

Cracks were found on the underside of some semi-perforations in both unfired and fired fuse sleeves. Firing appeared to have an effect of opening the cracks somewhat. No cracks were found in sleeves marked ZW and it was ascertained that the semi-perforations in these fuses had more generous radii and hence had been deformed less severely than the others. The design and manufacture of the semi-perforation in type ZW is therefore considered superior to the others examined.

All specimens tested met requirements for hardness. Because of the presence of a notch (semi-perforation), true tensile strength and elongation values could not be obtained and compared with published data. However, the breaking loads reported indicate that true tensile strengths were sufficiently high. All tensile fractures occurred through the semi-perforations, the exact location is assumed to be dependent on whether any existing cracks were present and the geometry of the semi-perforations. Firing did not appreciably effect the observed mechanical properties.

Of all specimens tested in tension, type ZW had, on average, slightly better properties. This is probably due to the less severe deformation and angles of the semi-perforation.

Table 1. Fuse Sleeve Designation and Examination Requested.

Sample Number	Manufacturers Designation	Fired	Not Fired	Examination Requested
1	ZW	X		Observe if cracks are in vicinity of semi-perforation.
2	ZW	X		Macro-etch of semi-perforation.
3	ZW		X	Same as #1.
4	ZW		X	" " "
5	ZW	X		Macro-etch of semi-perforation.
6	ZW	X		Same as #1.
7	ZW	X		" " "
8	ΔHP	X		" " "
9	ΔHP	X		" " "
10	N		X	" " "
11	ΔHP		X	Tensile test
12	ZW		X	" "
13	ZW		X	" "
14	N		X	" "
15	ΔHP		X	" "
16	N		X	" "
17	N	X		" "
18	N	X		" "
19	ZW	X		" "
20	ZW	X		" "
21	ΔHP	X		" "
22	ΔHP	X		" "
23	None, similar to NB	X		" "
24	ΔHP		X	Metallographic examination of perforation, also hardness measurements.
25	ΔHP		X	Same as #24
26	ΔHP	X		" " "
27	ΔHP	X		" " "
28	N		X	" " "
29	N	X		" " "
30	ZW	X		" " "
31	ZW		X	" " "
32	NB		X	" " "
33	N		X	Tensile test
34	N		X	" "
35	N		X	" "
36	N		X	" "
37	N		X	" "
38	N		X	" "
39	N		X	" "
40	N		X	" "
41	N		X	" "
42	N		X	" "
43	ZW	X		" "
44	ZW	X		" "
45	ZW	X		" "

Table 1. Continued

Sample Number	Manufacturers Designation	Fired	Not Fired	Examination Requested
46	ZW	X		Tensile test
47	ZW	X		" "
48	ZW	X		" "
49	ZW	X		" "
50	ZW	X		" "
51	ZW	X		" "
52	ZW	X		" "
53	ΔHP	X		" "
54	ΔHP	X		" "
55	ΔHP	X		" "
56	ΔHP	X		" "
57	ΔHP	X		" "
58	ΔHP	X		" "
59	ΔHP	X		" "
60	ΔHP	X		" "
61	ΔHP	X		" "
62	N	X		" "
63	N	X		" "
64	N	X		" "
65	N	X		" "
66	N	X		" "
67	N	X		" "
68	N	X		" "
69	N	X		" "
70	N	X		" "
71	N	X		" "
72	N	X		" "
73	N	X		" "
74	N	X		" "
75	N	X		" "
76	N	X		" "
77	N	X		" "
78	N	X		" "
79	N	X		" "
80	N	X		" "
81	N	X		" "
82	N		X	" "
83	ZW	X		" "
84	ZW	X		" "
85	ZW	X		" "
86	ZW	X		" "
87	ZW	X		" "
88	ΔHP	X		" "
89	ΔHP	X		" "

Table 1. Continued

Sample Number	Manufacturers Designation	Fired	Not Fired	Examination Requested
90	NB		X	Tensile test
91	NB		X	" "
92	NB		X	" "
93	NB		X	" "
94	NB		X	" "
95	NB		X	" "
96	NB		X	" "
97	NB		X	" "
98	NB		X	" "
99	NB		X	" "
100	N		X	" "
101	N		X	" "
102	N		X	Metallographic examination

Table 2. Hardness* of Fuse Sleeves

Sample Number	Manufacturers Designation	Fired	Not Fired	VHN	Rb
24	ΔHP		X	161	83.5
25	ΔHP	X		172	87.0
26	ΔHP	X		161	83.5
27	ΔHP		X	175	87.0
28	N	X		155	82.0
29	N		X	158	83.0
30	ZW	X		163	84.0
31	ZW		X	161	83.5
32	NB		X	161	83.5

* The ASM Committee on Properties of Aluminum Alloys, states that for a 2014-T6 aluminum alloy, a BHN 135 (500 Kg load 10 mm ball)should be obtained as a hardness value. This BHN 135 corresponds to a Rockwell B of 82.

Table 3. Tensile Results

Sample Number	Breaking Load (pounds)	Fired	Not Fired	Extension of a 2" length	Manufacturers Designation
11	30,425		X	(a)	ΔHP
12	31,700		X	(a)	ZW
13	32,950		X	(a)	ZW
14	30,225		X	(a)	N
15	30,600*		X	(a)	ΔHP
16	31,200		X	(a)	N
17	31,150	X		(a)	N
18	31,225*	X		(a)	N
19	30,900	X		(a)	ZW
20	30,150	X		(a)	ZW
21	30,450	X		(a)	ΔHP
22	30,900	X		(a)	ΔHP
23	31,875	X		(a)	NB
33	28,100		X	0.00	N
34	30,100		X	0.01	N
35	28,550		X	0.02	N
36	30,650		X	0.02	N
37	29,000		X	0.01	N
38	28,000		X	0.00	N
39	28,700		X	0.00	N
40	28,475		X	0.02	N
41	30,525		X	0.03	N
42	30,000		X	0.00	N
43	32,150	X		0.02	ZW
44	33,400	X		0.04	ZW
45	32,700	X		0.02	ZW
46	31,350	X		0.01	ZW
47	32,300	X		0.00	ZW
48	32,900	X		0.03	ZW
49	31,800	X		0.04	ZW
50	32,000	X		0.03	ZW
51	32,350	X		0.02	ZW
52	32,250	X		0.02	ZW
53	30,900	X		0.01	ΔHP
54	30,650	X		0.00	ΔHP
55	30,425	X		0.02	ΔHP
56	29,575	X		0.01	ΔHP
57	29,850	X		0.02	ΔHP
58	30,250	X		0.00	ΔHP
59	30,850	X		0.01	ΔHP
60	30,400	X		0.01	ΔHP
61	29,700	X		0.01	ΔHP
62	30,700	X		0.02	N
63	31,175	X		0.04	N

* Yield load.

(a) Not determined.

Table 3. Continued

Sample Number	Breaking Load (pounds)	Fired	Not Fired	Extension of a 2 " length	Manufacturers Designation
64	31,050	X		0.03	N
65	29,550	X		0.01	N
66	31,425	X		0.02	N
67	30,700	X		0.03	N
68	31,350	X		0.05	N
69	28,475	X		0.00	N
70	30,050	X		0.01	N
71	29,350	X		0.03	N
72	28,950	X		0.00	N
73	29,750	X		0.03	N
74	31,000	X		0.03	N
75	30,500	X		0.02	N
76	31,400	X		0.06	N
77	29,700	X		0.04	N
78	31,600	X		0.04	N
79	29,750	X		0.00	N
80	29,500	X		0.03	N
81	28,650	X		0.04	N
82	28,650		X	0.02	N
83	33,200	X		0.02	ZW
84	32,000	X		0.02	ZW
85	31,150	X		0.04	ZW
86	31,600	X		0.02	ZW
87	32,975	X		0.01	ZW
88	30,900	X		0.01	ΔHP
89	30,500	X		0.01	ΔHP
90	28,025		X	0.00	NB
91	29,050		X	0.00	NB
92	29,100		X	0.00	NB
93	28,925		X	0.00	NB
94	28,750		X	0.00	NB
95	29,350		X	0.00	NB
96	28,500		X	0.00	NB
97	29,650		X	0.00	NB
98	28,900		X	0.00	NB
99	29,900		X	0.00	NB
100	30,050		X	0.02	N
101	28,025		X	0.02	N

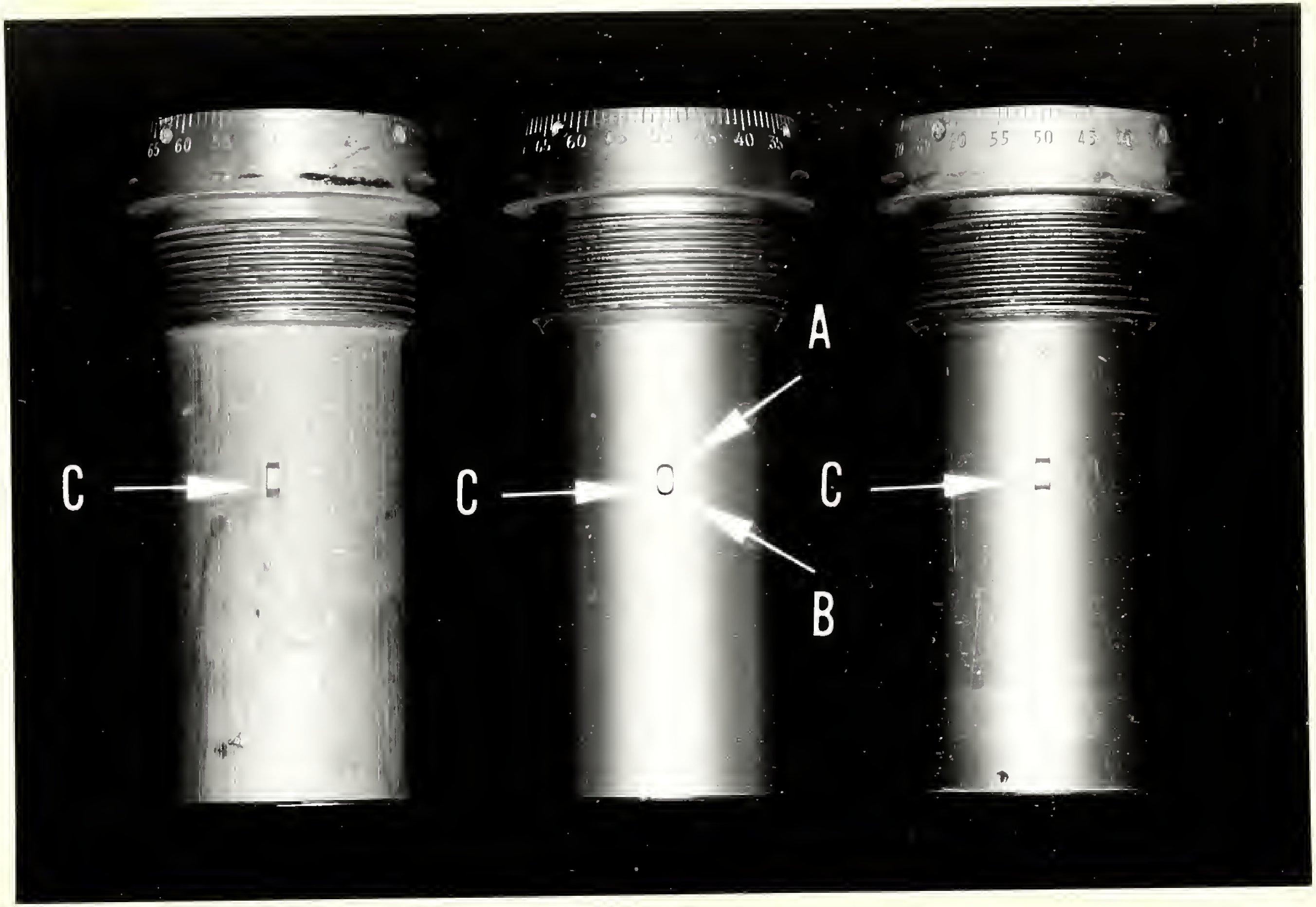


Figure 1. Fuse sleeves in the as received condition. Sleeve on left is type ΔHP, in the middle, type N, and on the right, type ZW. The arrows (C) indicate the item, the semi-perforation, which was investigated on each of the fuse sleeves submitted. Arrow (A) indicates the area through which 53 fuse sleeves, type ΔHP, N and NB, failed during tensile testing. Arrow (B) indicates the area through which 16 of 33 type N fuse sleeves failed during tensile tests.

Figure 2. Photograph of underside of semi-perforation type ΔHP. Arrow indicates crack location. Unetched, X 20.

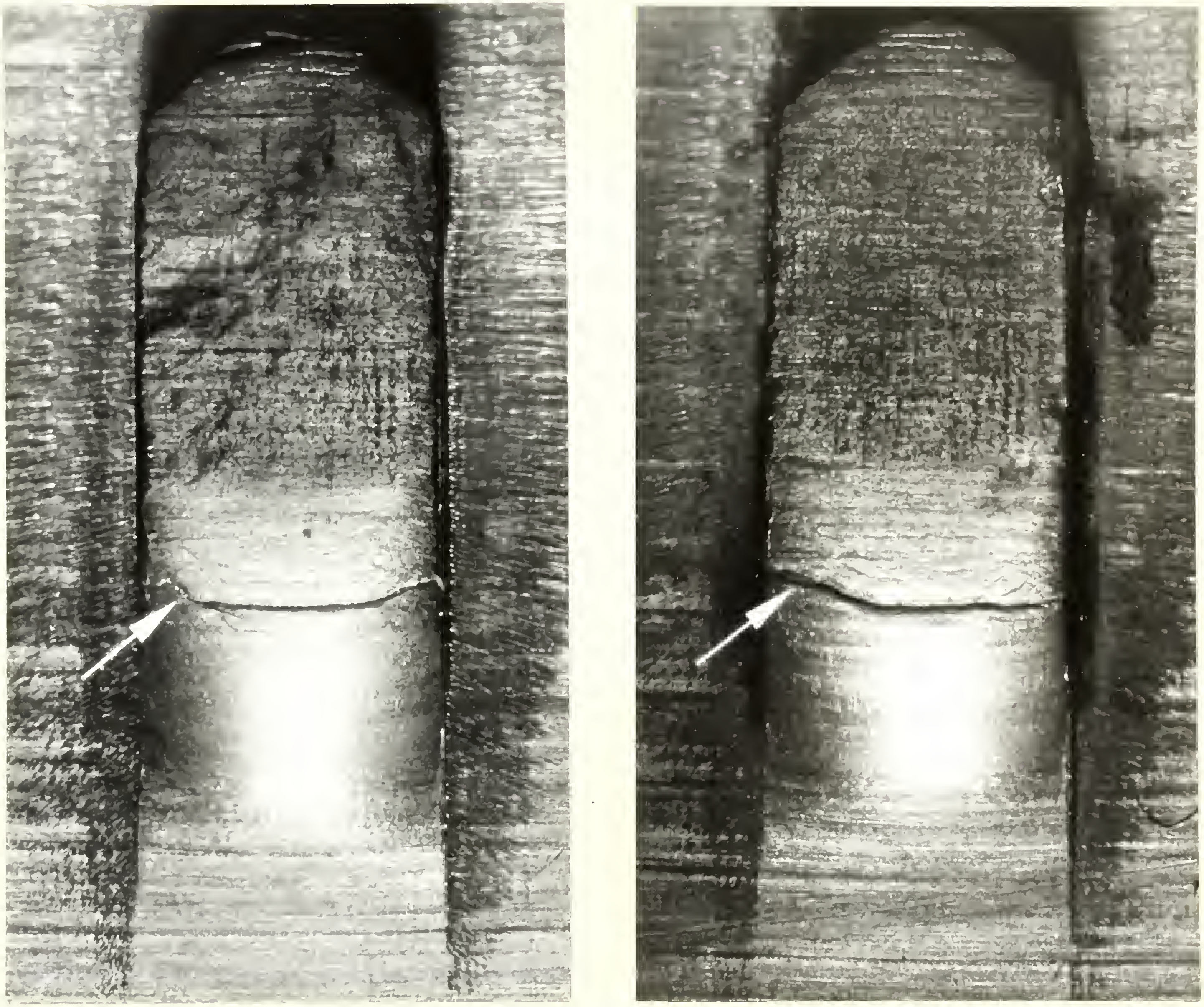
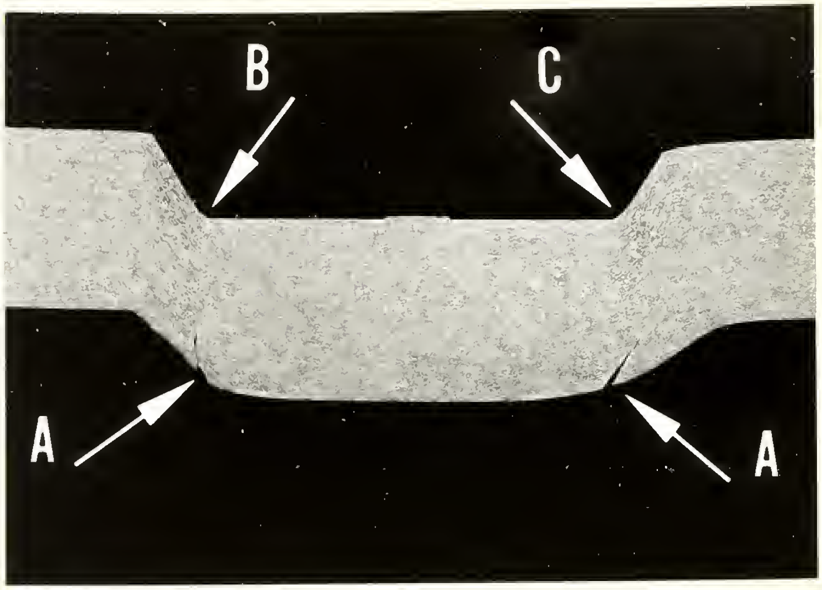


Figure 3. Photographs of underside of semi-perforation of type N. Photograph on left is of the unfired condition, on the right, of the fired condition. Arrows indicate cracks. Unetched, X 20.



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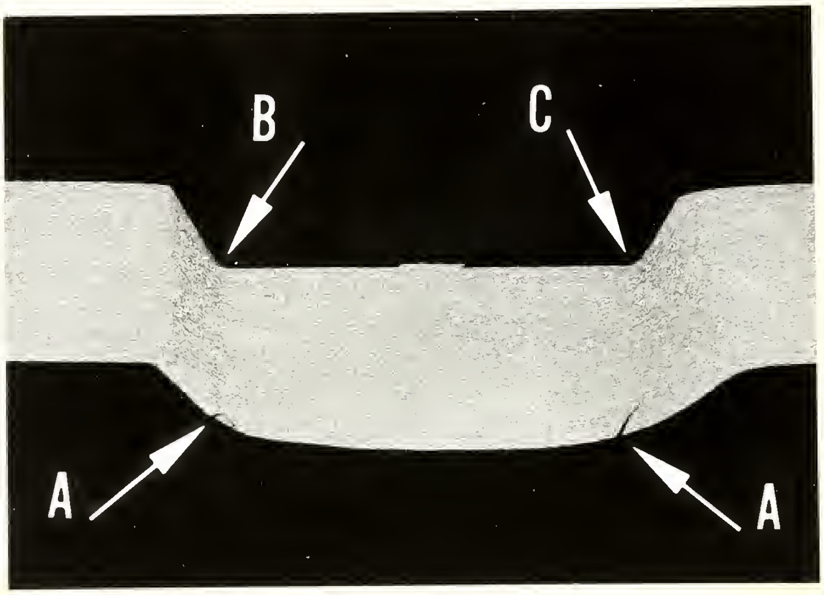

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Figure 4. Longitudinal sections of fuse sleeves type N, not tensile tested. Photograph (1) is of the fired condition, and (2) of the unfired condition. Arrows (A) indicate location of cracks observed on the underside of the fuse sleeves. Arrows (B) and (C) are locations of sharp radius. Sixteen type N fuse sleeves failed through area (C) and seventeen failed through area (B) during tensile tests. Etched, Keller's, X 12.

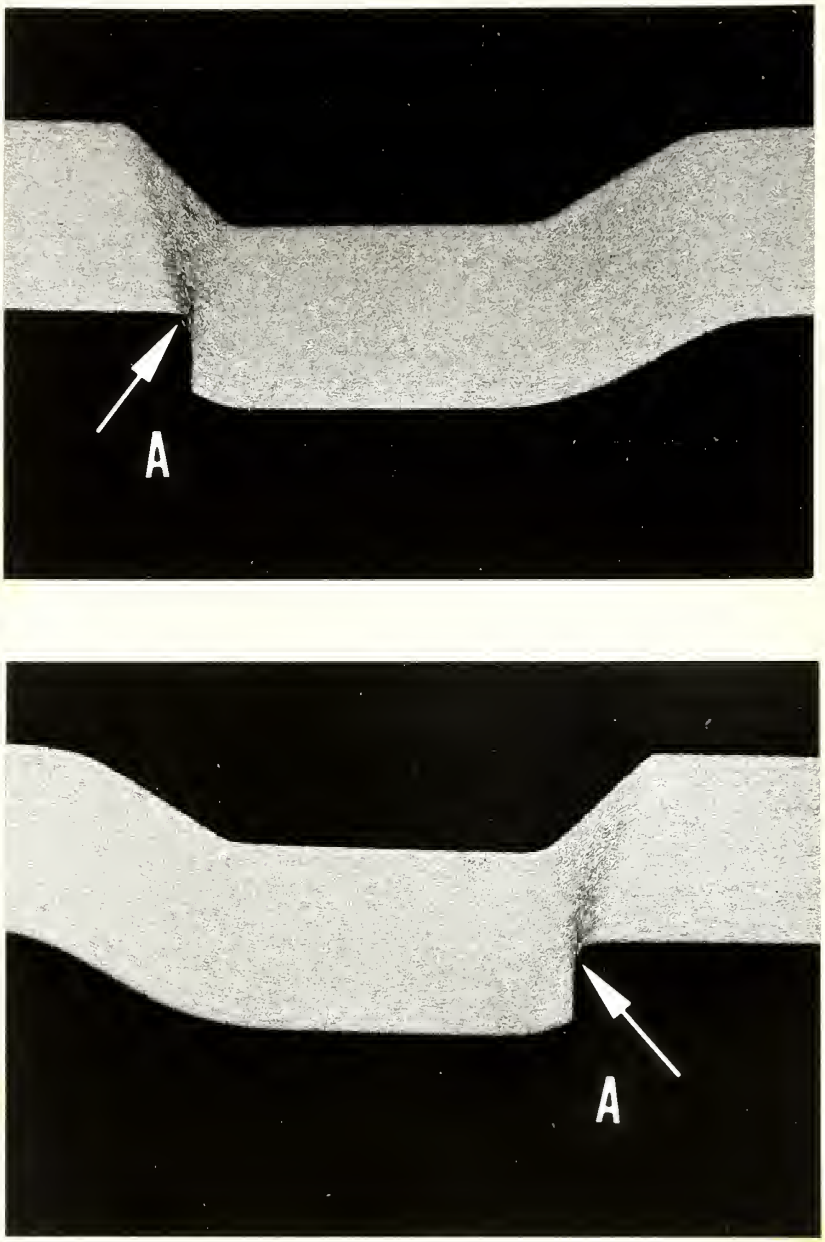

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Figure 5. Longitudinal sections of fuse sleeve type ΔHP, not tensile tested. Photograph (1) is of the fired condition, and (2) of the unfired condition. Arrow (A) indicates area through which failure occurred during tensile tests, and area of a crack and sharp radius. Etched, Keller's, X 12.

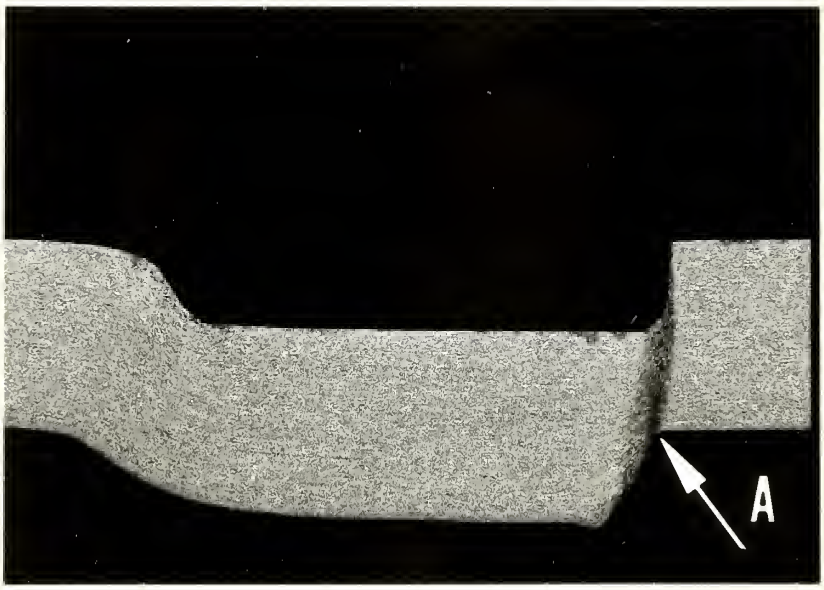
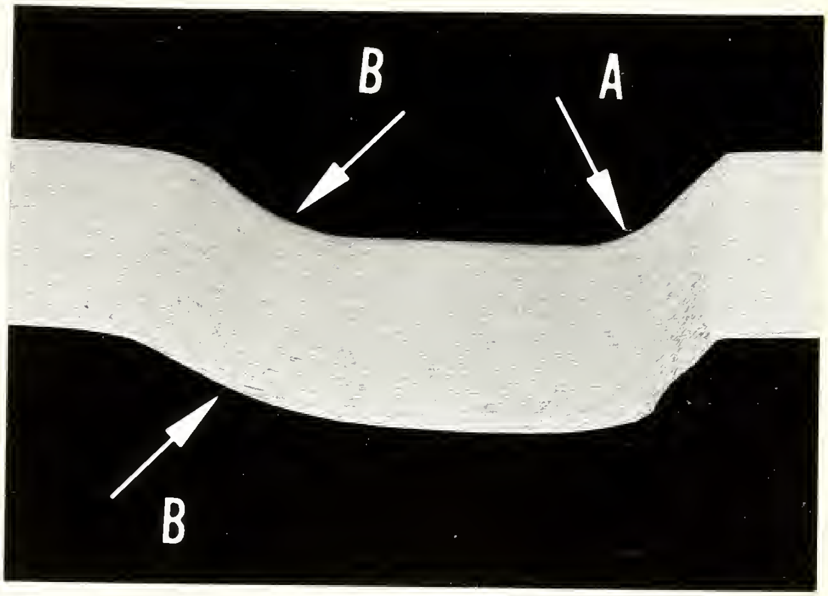


Figure 6. Longitudinal sections of unfired fuse sleeve of type NB, not tensile tested. Arrow (A) indicates area through which failure occurred during tensile test and area of a crack and a sharp radius. Etched, Keller's, X 12.



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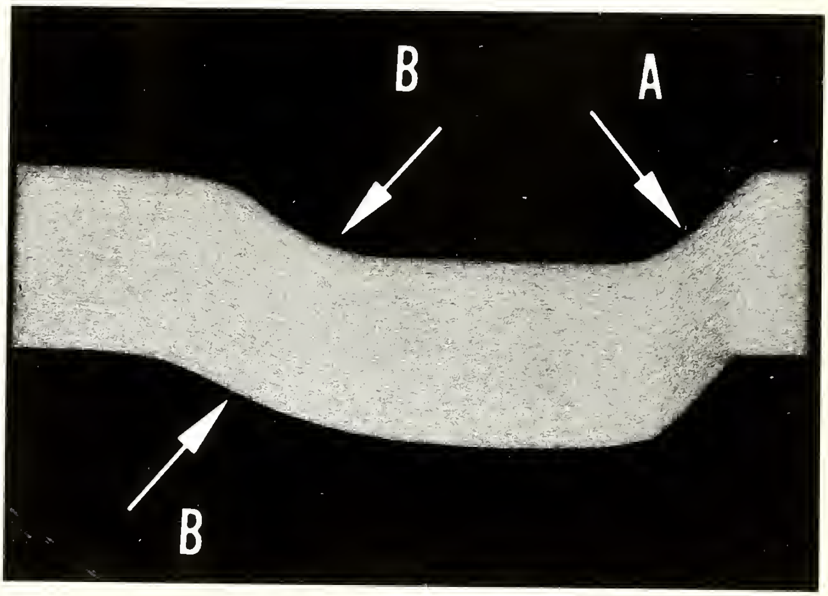

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Figure 7. Longitudinal sections of fuse sleeve type ZW, not tensile tested. Photograph (1) is of the fired condition and (2) of the unfired condition. Arrows (A) and (B) indicate areas of smooth radius. Arrow (A) also indicates area through which fracture occurred during tensile tests. Etched, Keller's, X 12.

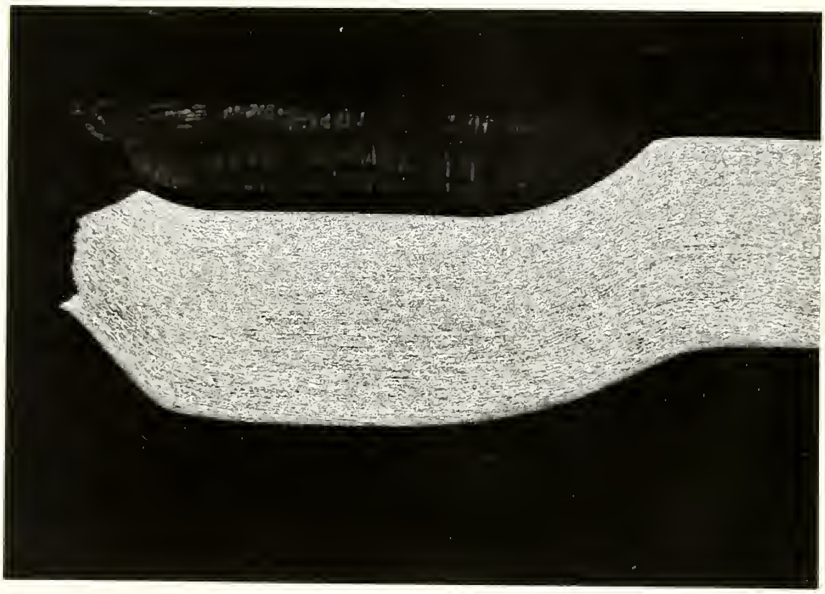

Figure 8. Longitudinal section of fuse sleeve of type ZW after the fuse sleeve was tensile tested. Note absence of cracks on both the top and underside of the semi-perforation. Etched, Keller's, X 12.

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