NATIONAL BUREAU OF STANDARDS REPORT

9838

EXAMINATION OF FAILURE OF PRINTING PLATE, NO. 29724

To

Electrolytic Section
Bureau of Engraving and Printing
Washington, D. C.

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D. C., 20234.

[2] Located at Boulder, Colorado, 80302.

[3] Located at 5285 Port Royal Road, Springfield, Virginia 22151.

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EXAMINATION OF FAILURE OF
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By

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To

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These dimensions show appreciable deviations from intended slot separation and from intended slot base length in both plates. As a result of these deviations and because the Roosevelt plate is thinner, the net material section area between slot corners is approximately 8 per cent less in the Roosevelt plate. The Roosevelt plate is also approximately 10 per cent thinner in the slot areas. Interestingly, the Lincoln plate did not crack at the slot corners as did the Roosevelt plate. Because the overall thickness of the Roosevelt plate is less than the Lincoln plate, and the steel under the gripper slots is substantially thinner, the cooling rate during a quench from 1550°F would be greater in the Roosevelt plate. This would produce a slightly higher hardness than previously observed in other plates, and in particular, the hardness in the vicinity of the gripper slots would be higher. Less available material to resist cyclic bending and higher hardness at the notch corners could produce an unfavorable combination that would accelerate the formation of fatigue cracks.

Figure 4 is a view of a typical fracture surface. This surface was revealed when a cracked section was opened. The thin bright fracture surface area resulted from completion of the fracture in the laboratory. The arrow in Figure 4 points to the apparent crack origin which is located at a point where there is a change in section thickness that could cause severe stress concentration. The dark area has a smooth portion adjacent to the origin and appears to be a fatigue fracture surface. This surface was darkened by corrosion products.

<u>Hardness Measurements</u>: The hardness of the reverse face of a section adjacent to the crack examined averaged 84 Rockwell 15N (47 R_c). A surface hardness of 80-82 Rockwell 15N for this plate was reported by the Bureau of Engraving and Printing.

The results of a hardness traverse across the thickness of the section on which hardness impressions were made at intervals of from 0.0008 inch to 0.010 inch are tabulated below:

Reading No.	Distance from obverse surface	Hardness: KHN 500 g load	Hardness: Equivalent R_B	Hardness: Approximate R_c
	Inch			
1	0.0024	564		51
2	.0032	532		49
3	.0048	420		41
4	.0072	310		30
5	.0096	286		26
6	.0120	253		20
7	.0144	241	98	
8	.0168	241	98	
9	.0268	227	95	
10	.0368	226	95	
11	.0468	216	93	
12	.0568	223	94	
13	.0668	220	94	
14	.0768	217	93	
15	.0868	222	94	
16	.0968	221	94	
17	.1068	223	94	
18	.1168	221	94	
19	.1268	224	95	
20	.1368	223	94	
21	.1468	226	95	
22	.1568	231	96	
23	.1628	253		20
24	.1652	284		26
25	.1676	328		32
26	.1700	509		48
27	.1716	497		47
28	.1724	454		44
Reverse surface	.1740			

The hardness traverse indicated the presence of a case approximately 0.001 inch deep on both faces. It also indicated that the interior was uniformly hardened throughout inasmuch as there was no appreciable variation in hardness in the interior.

Metallographic Examination: Uniformly distributed thin inclusions, probably manganese sulfide, were found in the plate sample. These are shown in Figure 5. The inclusion rating using ASTM Designation E-45 as a reference is A-1 to A-2 which indicates a clean steel.

No evidence of ferrite banding was observed in a longitudinal section of a core area, Figure 6. The fine-grained structure exhibited has a grain size rating of 8 using ASTM Designation E 112 as a reference. Figure 7 shows the microstructure of a longitudinal section adjacent to the crack mouth. There are no indications of decarburization adjacent to the surface. The case shown is predominantly martensitic and is approximately 0.0015 inch deep. The core is composed of partially spheroidized carbides (dark) in a ferrite matrix (white).

Discussion and Conclusions: Examination of the sample removed from the cracked printing plate revealed a number of conditions that could have contributed to premature failure of the plate:

1. The chafing of the plate adjacent to the cracks (Figures 1 and 2) indicates cyclic stressing that could have been caused by improper seating of the plate on the drum in this area. The stressing involved repeated bending along a line parallel to the base of the gripper slots.

2. The deep tool marks in the gripper slots and the sharp corners of the gripper slots (Figures 1 and 2) are objectionable features. They are heterogeneities creating stress concentration and could be sites for crack initiation and/or propagation.

3. The hardness of the reverse surface of the plate (R_c 47) and of the case adjacent to the crack (R_c 44-48) are slightly high. This is based on a review of the hardness of previously examined plates that had a lower hardness and were satisfactory.

In comparison with a previously examined plate that did not fail in service, gripper slot separation in the subject plate was found to be closer and slot walls thinner. These conditions weakened the plate. The first condition increased the unit stress in the area between slots under the loading imposed. The second condition created an area that became excessively hard in heat treatment.

Cracking of the subject plate resulted from fatigue fractures apparently initiated at the slot corners which had a "built-in" notch. It appears that the hard case combined with the sharp corners of the slots was an immediate factor in crack initiation. It is well known that a hard case has low plastic properties and is particularly notch sensitive. Fatigue cracks were initiated in the case as the result of cyclic bending stresses that

put the reverse face of the plate in tension. These bending stresses resulted from repeated loading and unloading occurring in rotation of the plate during printing. It appears that the tool marks in the slots contributed to crack propagation. Darkening of the fatigue fracture surface is evidence that corrosive oxidation also occurred.

Remedial Suggestions:

It is considered that faults stemming from fabrication, fit of plate on the drum, and heat treatment are responsible for the plate failure. Adherence to the following practices should result in an improvement in the service life of the plates:

1. Gripper slot separation, size, and depth in future plates should be the same as that in plates that proved to be satisfactory.

2. Introduce fillets at the corners of the base of the gripper slots (encircled areas, Figure 2). These fillets may be made by first drilling 3/16 inch diameter holes to a depth of approximately 0.075 inch in the reverse face of the plates where the slot corners are to be located, or by other suitable techniques. All sharp edges resulting from drilling and subsequent machining of slots should be removed.

3. Feather edges of the gripper slots all-around and avoid leaving deep tool marks in the slots and on the over-all reverse face of the plates.

4. Ensure close fitting of the plate on the printing drum to reduce bending or cyclic stressing during rotation of the plate.

5. Equalize loads on the grippers.

6. Temper plate to obtain a hardness of 79.5 to 81.5 R_{15N} in the case, as measured on an area of full plate thickness.

Figure 1. Reverse of plate section cut from plate no. 29724. X 1

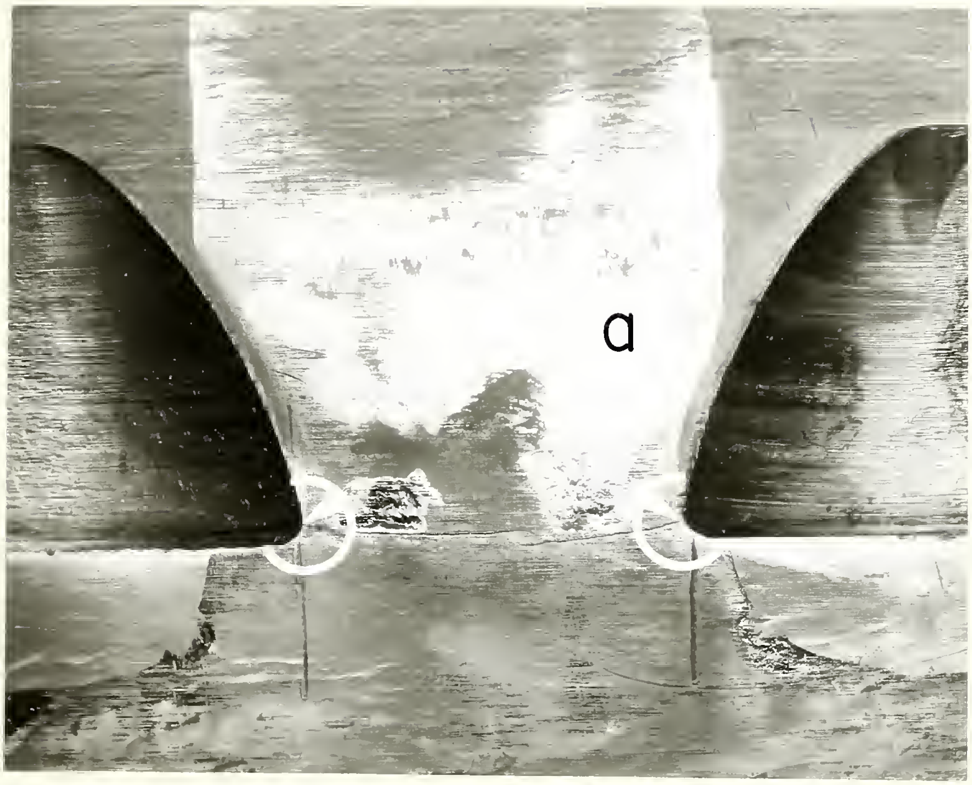

Figure 2. Enlarged view of a section of the plate sample shows cracks propagating from slot corners. Arrows point to probable crack origin. Area a, is a highly reflective surface resulting from chafing of the plate on the drum. Note the deep tool marks in the gripper slots and the sharp edges of the slots adjacent to the cracks. Grinding generous fillets in the encircled slot corners to reduce possibility of crack initiation at these points is recommended. X 4

a b

Figure 3, a Section cut from subject Roosevelt 6 cent plate.

Figure 3, b Section cut from Lincoln 4 cent plate that did not crack in gripper slot area.

Note that slot separation is less and that slot size and depth are greater in the Roosevelt plate. X 1

Figure 4. Fracture surface of failed printing plate. Arrow points to apparent origin of crack and direction of propagation. The surface is typical of that resulting from fatigue. The depth to which the crack propagated is bracketed. X 4

Figure 5. Thin inclusions, probably manganese sulfide, found in longitudinal section of sample. Unetched. X 100

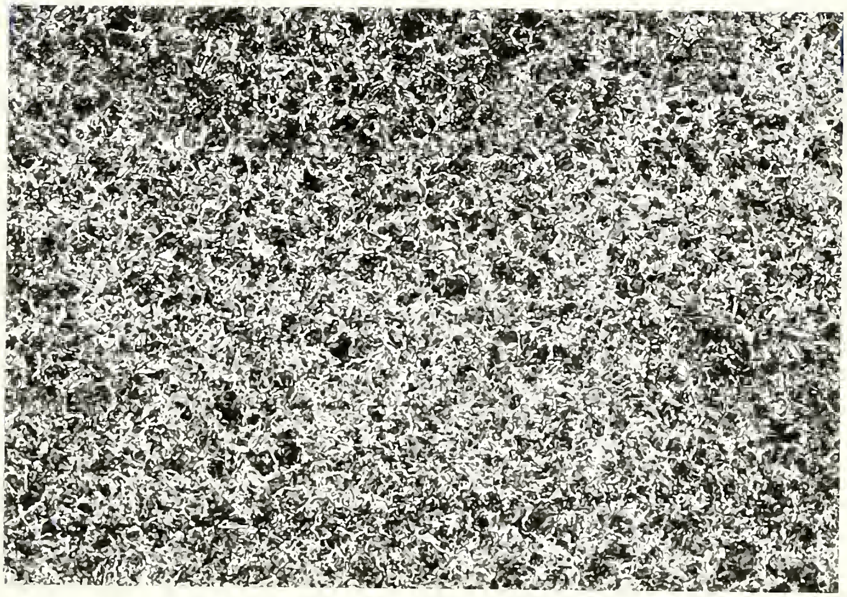

Figure 6. Microstructure of sample. Shows no evidence of ferrite banding in longitudinal section. Etched with 2% picral. X 200

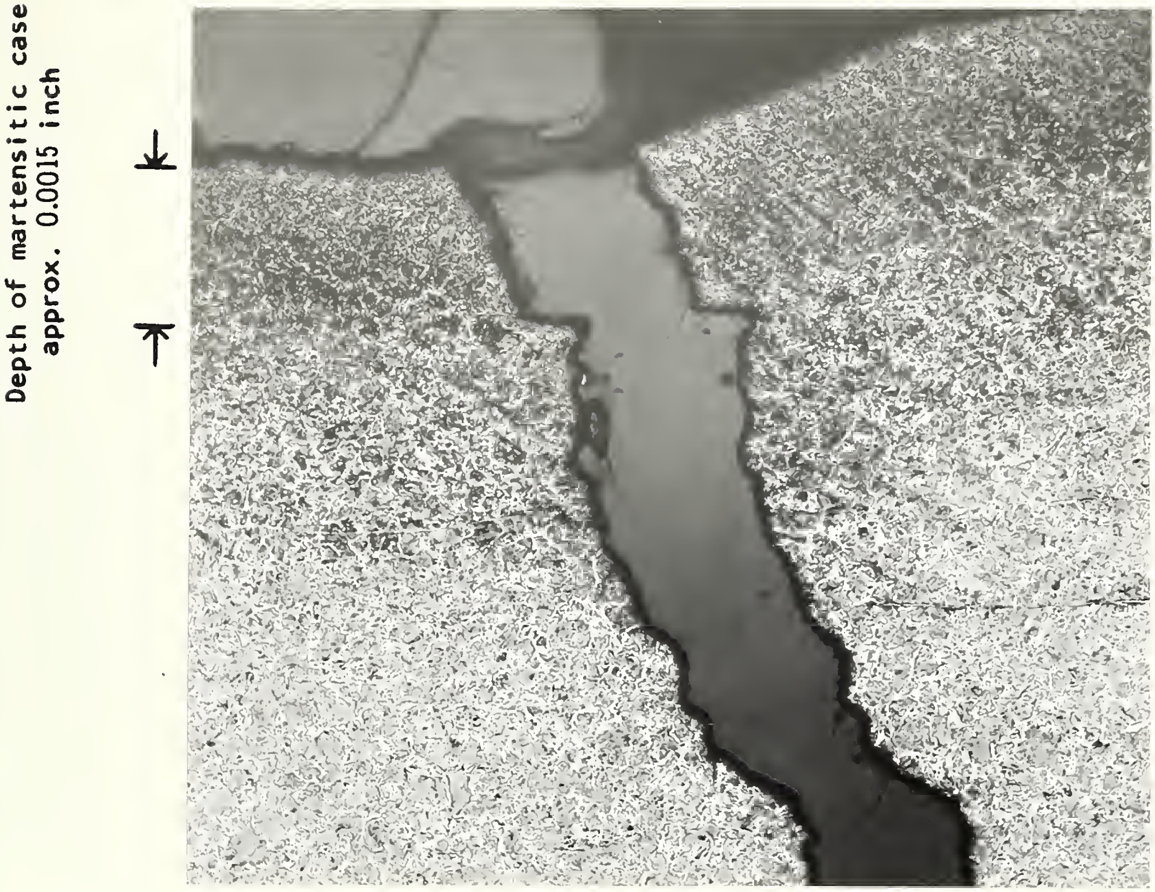

Figure 7. Structure of longidutinal section of plate sample adjacent to fracture origin. Show no decarburization at plate surface. Martensitic case is approximately 0.0015 inch deep. Core is composed of partially spheroidized carbides (dark) in a ferrite matrix (white). Etched with 2% picral. X 500

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