NATIONAL BUREAU OF STANDARDS REPORT

9858

EXAMINATION OF FAILURE OF

PRINTING PLATE, NO. 29812

To

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

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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PRINTING PLATE, NO. 29812

By

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To

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Examination of Failure of Printing Plate, No. 29812

Introduction: A 0.179" x 3" x 11" section removed from Roosevelt six-cent plate no. 29812 that failed in service was submitted for an examination to determine the cause of failure of the plate. As was the case in a previous failure (plate no. 29724, NBS Report 9838), failure occurred because of cracking adjacent to the gripper slots machined into the plate. The failure of plate no. 29724 was attributed to faults stemming from fabrications, fit of the plate on the drum and heat treatment. Because of the apparent similarity in the failure mode, plate no. 29812 was subjected to the same type of examination as was plate no. 29724.

Visual Examination: Figure 1 shows the reverse face of the plate section. Tight cracks propagating from the corners of all eight of the gripper slots on the reverse face were observed. Figure 2 is an enlarged view showing cracks propagating from the corners of two of the slots. The plate section was chafed adjacent to the slots, a, Figure 2. The slot edges shown in this view are quite sharp; sharper than those found in the examination of plate no. 29724. However, the tool marks in the slots of the subject plate were not as deep.

Measurements made of the spacing between gripper slots, the base length of the slots and the thickness in slotted sections of both the subject plate sample and of a Lincoln plate sample are presented below for comparison. The Lincoln plate which was also used for comparisons in NBS Report 9838 did not crack at the slot corners.

	Roosevelt Plate No. 29812	Lincoln Plate
Intended separation of slots (between indices), inch	0.519	0.517
Intended base length of slots (between indices), inch	0.809	0.810
Actual separation of slots, inch	0.532	0.543
Actual base length of slots, inch	0.794	0.782
Overall thickness of plate, inch	0.179	0.182
Minimum thickness in slotted section, inch	0.070	0.088

These dimensions show appreciable deviations from intended slot separation and from intended slot base length in both the Roosevelt and Lincoln plates. As a result of these deviations and because the Roosevelt plate no. 29812 is thinner, the net material section area between slot corners is approximately 4 per cent less in the Roosevelt plate than it is in the Lincoln plate. The Roosevelt plate is also approximately 20 per cent thinner in the slot areas.

Figure 3 is a view of a typical fracture surface. This surface was revealed when a cracked section was opened. The bright fracture surface area resulted from completion of the fracture in the laboratory. The arrows in Figure 3 point to two apparent crack origins which are located at points where there is a change in section thickness that could cause severe stress concentration. The cracks propagated laterally from their individual origins and nearly merged. 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.

Hardness Measurements: The results of a hardness traverse across the thickness of a section adjacent to the crack are tabulated below:

Reading No.	Distance from obverse surface	Hardness		
		KHN 500 g load	Equivalent approximate R_B	R_C
	Inch			
1	0.0020	402		40
2	.0044	312		30
3	.0068	271		24
4	.0092	247	99	
5	.0116	226	95	
6	.0140	224	95	
7	.0164	223	94	
8	.0188	220	94	
9	.0212	208	91	
10	.0236	206	91	
11	.0336	199	90	
12	.0436	196	89	
13	.0536	189	87	
14	.0636	194	89	
15	.0736	196	89	
16	.0836	194	89	
17	.0936	194	89	
18	.1036	198	89	
19	.1136	195	89	
20	.1236	203	90	

Reading No.	Distance from obverse surface	Hardness KHN 500 g load	Hardness Equivalent approximate R_B	Hardness Equivalent approximate R_C
	Inch			
21	0.1336	201	90	
22	.1436	205	91	
23	.1536	218	93	
24	.1636	213	92	
25	.1660	231	96	
26	.1684	234	97	
27	.1708	265		23
28	.1732	300		28
29	.1756	359		36
Reverse surface	.1780			

The hardness traverse indicated the presence of a case approximately 0.007 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.

The hardness of the case on the reverse face of the plate in an area of full plate thickness averaged 75 Rockwell 15N. The hardness of the reverse face adjacent to the crack examined averaged 78 R_{15N}. The hardness of the adjacent thin slotted section averaged 81 R_{15N}. Since the steel under the gripper slots is substantially thinner, the cooling rate during a quench from 1550° F would be greater in this section and produce a slightly higher hardness. The thickness of the slotted section is markedly less than that in the Lincoln plate which has served as a basis of comparison. Like plate no. 29724, less available material to resist cyclic bending and higher hardness at the notch corners of plate no. 29812 could produce an unfavorable combination that would accelerate the formation of fatigue cracks.

Metallographic Examination: The plate sample contained mixed stringer and globular inclusions. These are shown in Figure 4a. The inclusion rating using ASTM Designation E-45 as a reference is A-2 - A-3. The steel is not as clean as desired for this application. The inclusions acted as paths for crack propagation and probably accelerated the rate of crack growth, Figure 4b. Cleaner material (inclusion rating A-1 - A-2) would be more desirable.

No evidence of ferrite banding was observed in a longitudinal section of a core area, Figure 5. The fine-grained structure exhibited has a grain size rating of 8 using ASTM designation E-112 as a reference. Figure 6 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 0.003 inch deep. The core is composed of partially spheroidized carbides (dark) in a ferrite matrix (white).

Discussion and Conclusions: Detrimental conditions that were considered to have contributed to the failure of plate no. 29724 were also found in the present plate investigation. These conditions included the following:

1. The plate was chafed adjacent to the cracks (Figures 1 and 2) indicating that cyclic stressing 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 sharp corners of the gripper slots are heterogeneities creating stress concentration and could be sites for crack initiation and/or propagation.

3. 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. This condition weakened the plate by increasing the unit stress in the area between slots under the loading imposed.

As in the case of plate no. 29724, cracking of plate no. 29812 resulted from fatigue fractures initiated at the slot corners which are in effect stress concentration notches. It is believed that the sharp slot corners locally harder than adjoining areas created a particularly notch sensitive condition that was an immediate factor in crack initiation. Cyclic bending occurring from repeated loading and unloading of the plate during printing put the reverse face of the plate in tension and provided tensile stresses of sufficient magnitude to initiate the cracks. It appears that inclusions in the material contributed to crack propagation. Darkening of the fatigue fracture surface indicated that corrosive oxidation also occurred.

Remedial Suggestions:

It is believed that faults stemming from fabrication and from fit of the plate on the drum are mainly responsible for this plate failure. The Bureau of Engraving and Printing has reported that an improvement in the service life of plates has resulted from introducing fillets at the base of gripper slots and feathering edges of the gripper slots all-around. It is suggested that adherence to these and the other remedial suggestions for printing plates listed in NBS Report 9838 be continued.

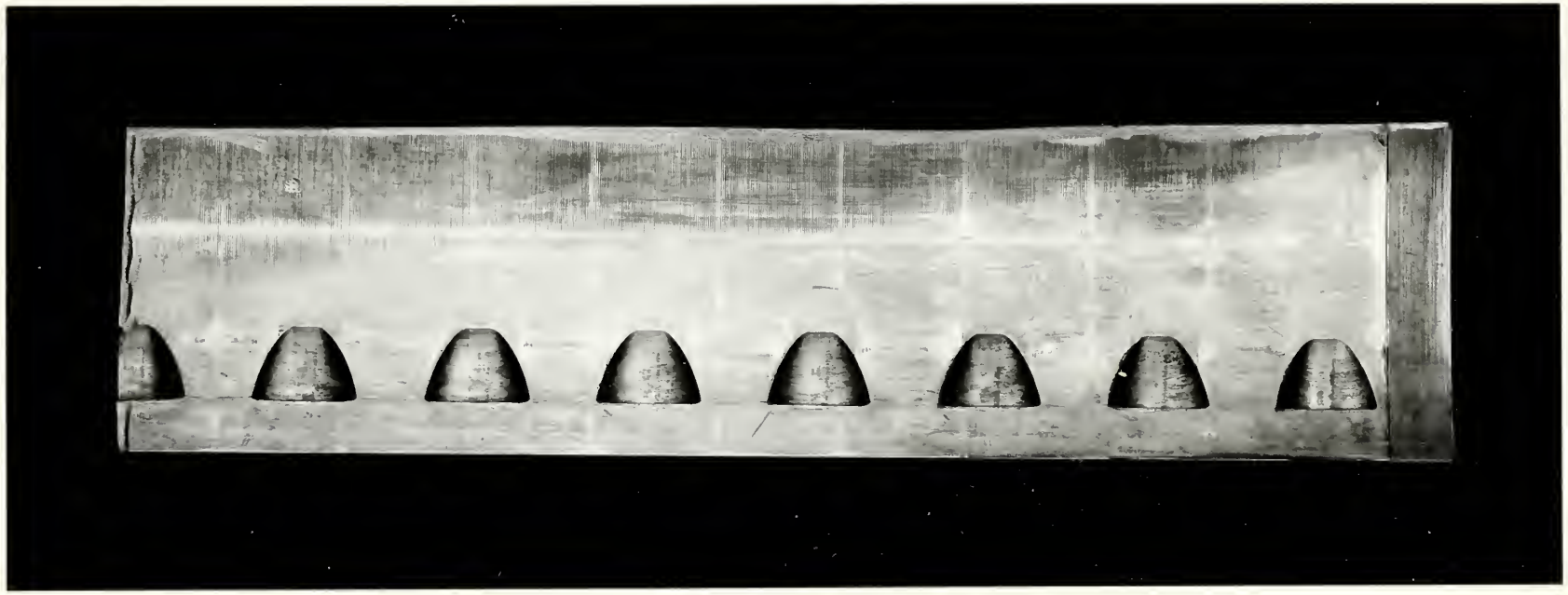


Figure 1. Reverse of section cut from plate no. 29812. X 1

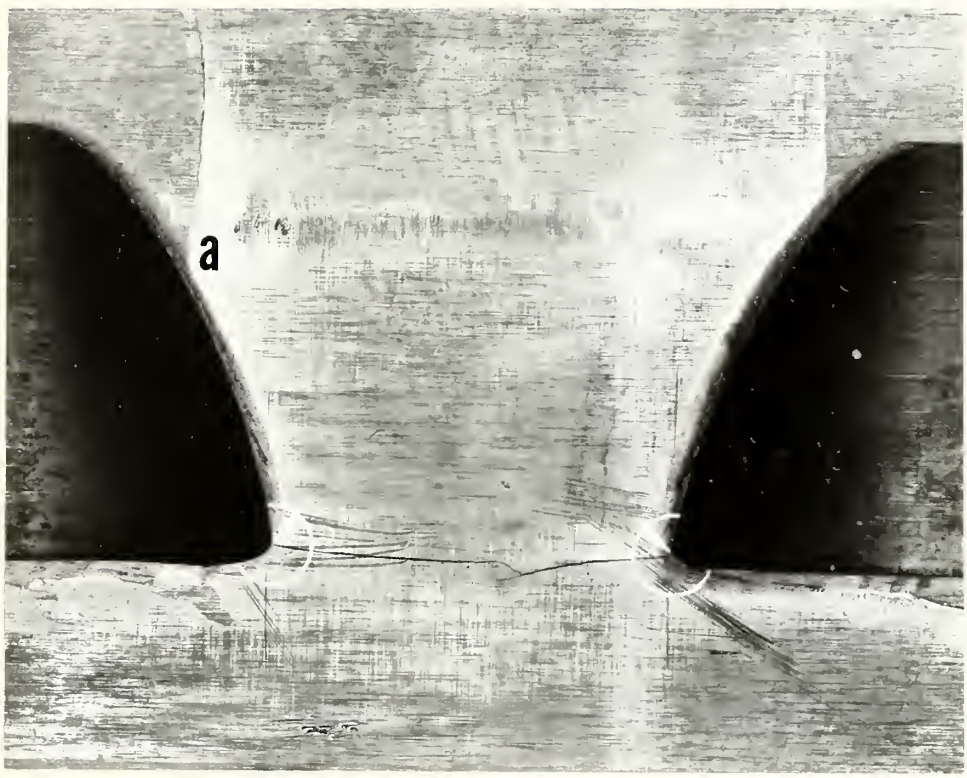
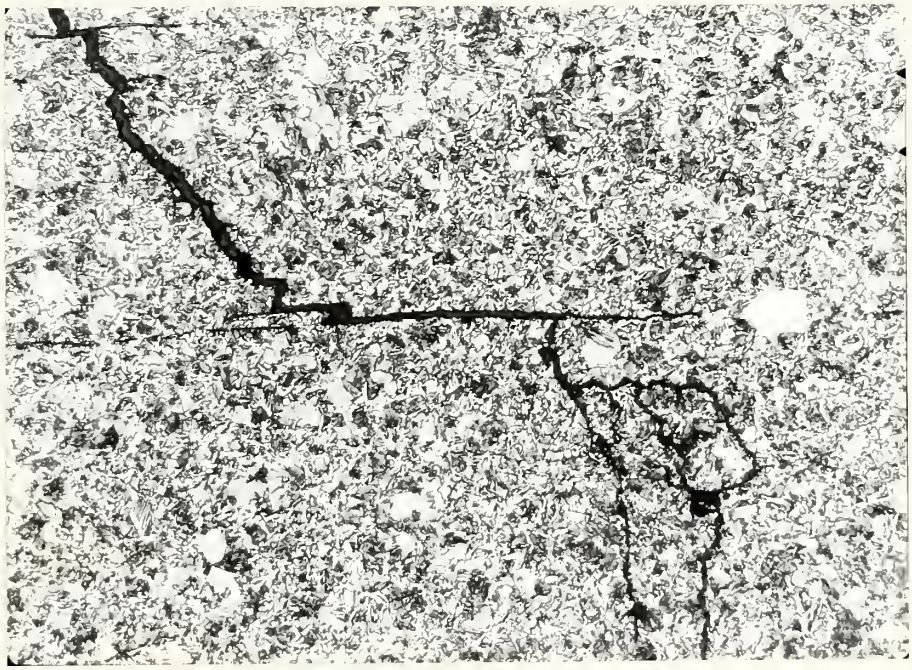


Figure 2. Enlarged view of a section of the plate sample shows cracks propagating from slot corners. Area a, is a highly reflective surface resulting from chafing of the plate on the drum. Note the sharp edges of the slots adjacent to the cracks. Feathering of the slot edges all-around and grinding generous fillets in the encircled slot corners to reduce possibility of crack initiation at these points is recommended. X 4.

Figure 3. Fracture surface of failed printing plate. Arrows point to apparent crack origins. The surface is typical of that resulting from fatigue. The depth to which the crack propagated is bracketed. X 8

a



b

Figure 4a. Mixed stringer and globular inclusions found in longitudinal section of sample. Unetched. X 100.

Figure 4b. Part of fatigue crack showing the crack propagating through stringer of inclusions at arrow. Etched with 1% nital. X 200.

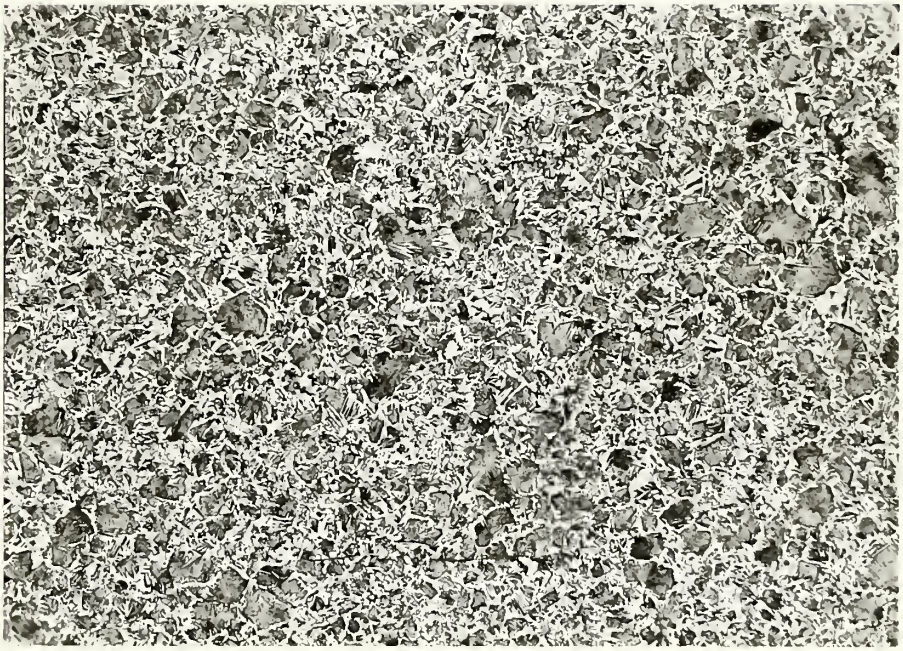


Figure 5. Microstructure of sample. Shows no evidence of ferrite banding in longitudinal section. Etched with 4% picral. X 200.

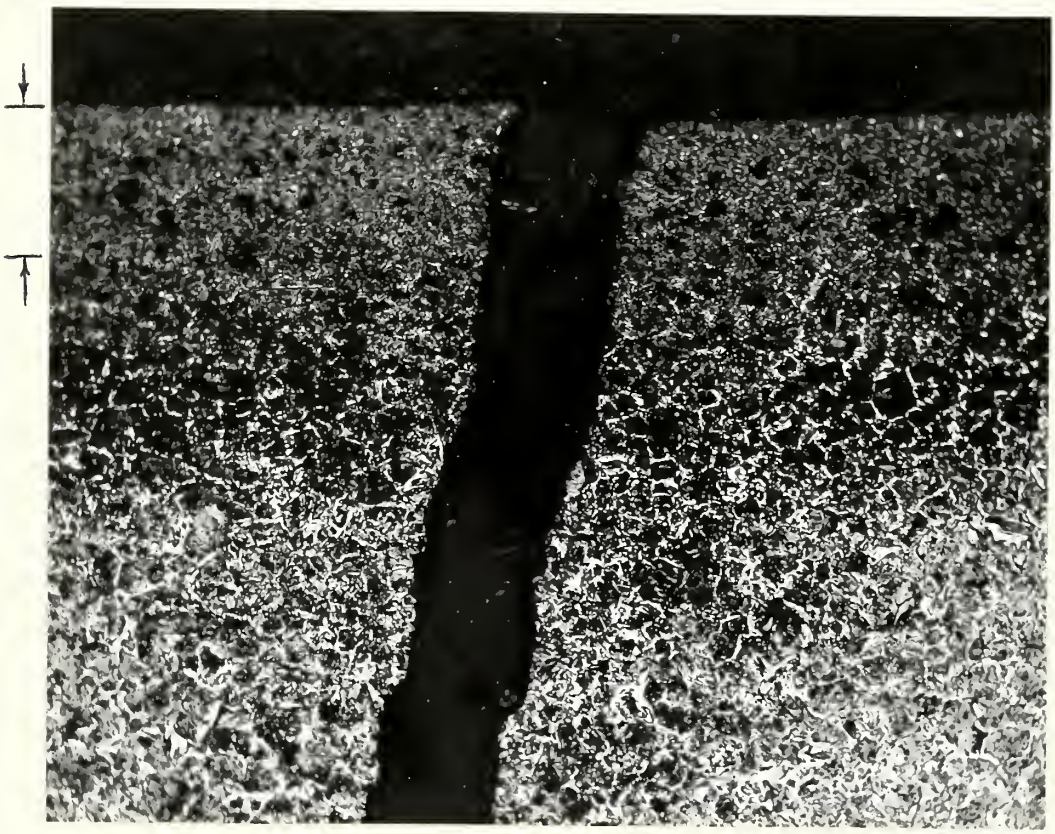


Figure 6. Structure of longitudinal section of plate sample adjacent to fracture origin. Martensitic case is approximately 0.003 inch deep. Core is composed of partially spheroidized carbides (dark) in a ferrite matrix (white). Etched with 4% picral. X 250.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