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OTTAWA October 8, 1946.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 2113.

Metallurgical Examination of a Cyanided Steel Engraving Plate Which Had Cracked Prematurely in Service.

(Copy No. 3.)

Bureau of Mines
Division of Metallic
Minerals

Physical Metallurgy
Research Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

OTTAWA October 8, 1946.

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Origin of Material and Object of Investigation:

On August 12, 1946, the Canadian Bank Note Company Limited, 224 Wellington Street, Ottawa, Ontario, per Mr. J. E. Gooddie, submitted by hand an engraved steel plate, for printing postage stamps, which had cracked prematurely in service. A small sample of the plate in the cracked area was cut from the plate and the remaining portion was returned. It was requested that a metallurgical examination be made to determine the cause of the failure.

At our suggestion, three pieces of blank steel plate, 6" x 11" x 3/16", were submitted to the Laboratories for experimental purposes on August 14, 1946.

These plates had been case-hardened in sodium cyanide and then bent over a drum 94 inches in circumference, in accordance with the usual plant procedure.

PROCEDURE:

1. Chemical Examination.

The results of chemical analyses made on the cracked plate and on one of the plates submitted for experimental purposes are as follows:

TABLE I.

		Cracked Cyanided Plate	Cyanided Plate Submitted for Experiment
		- Per Cent -	
Carbon	-	0.36	0.35
Manganese	-	0.38	0.39
Silicon	-	0.42	0.42
Sulphur	-	0.016	0.013
Phosphorus	-	0.012	0.009
Nickel	-	Nil.	Nil.
Chromium	-	Nil.	0.08
Molybdenum	-	Trace.	Trace.

2. Heat Treating Experiments and Hardness Tests.

One of the bent, cyanided, engraving plates was subjected to three different tempering temperatures, 300°, 350° and 400° F., for a period of 10 hours at each temperature in a Homo tempering furnace.

Measurements of the height (maximum perpendicular from the chord to the circumference) of the plate were made before and after each tempering operation in order to detect the amount of movement resulting from each heat treatment.

Hardness tests by means of a Scleroscope were also made after each draw. In addition, the surface condition as regards scaling and discolouration was also noted.

A second plate was then tempered at 350° F. for 10 hours and measurements taken in order to confirm the first experiments. The results are contained in the

(Procedure, cont'd) -

following tables:

Tempering Temp. (°F.)		Hardness, (Scleroscope)	Maximum Movement (inches)
0	-	46½	0.0000
300	-	-	+0.0057
350	-	47	+0.0071
400	-	49½@	-0.0004

@ Note: Increased hardness may be due to inaccuracies in the readings.

3. Microscopic Examination.

Figures 1, 2, 3 and 4 are all taken from the cracked cyanide-hardened engraving plate, whereas Figure 5 was taken from one of the cyanided plates used for the tempering experiments.

Figure 1, taken at X8 magnification, shows that the crack extends completely through the plate.

Figures 2 and 3, taken at X100 magnification, show the appearance of the crack at both surfaces.

Figure 4, taken at X500 magnification, in intended to show the extent of the cyanide case. The white layer is chromium plating.

Figure 5, taken at X500 magnification, shows the extent of the cyanide case in the plate used for the tempering experiments.

Discussion:

The results of this examination indicated that the steel was metallurgically sound. The microscopic examination and chemical analysis failed to reveal anything but a normal steel relatively free from impurities.

The normal plant procedure in handling the engraving plates is as follows:

(Discussion, cont'd) -

The plates are engraved in the softened condition. A very thin cyanide case is then applied by heating the plates in a sodium cyanide bath at 1525° F. for ~~40~~ 10 minutes. (The bath is made up of 50 per cent NaCN and 50 per cent Na_2CO_3). The plate is then quenched in oil for 10 seconds, followed by immersion in water at room temperature. The hardened plate is next bent around a drum 94 inches in circumference, and then chromium-plated in order to furnish a very hard surface. The object of the cyanide treatment is to produce a case hard enough to prevent wrinkling on bending and soft enough to prevent cracking. This may be achieved by aiming for a Scleroscope hardness of 45 to 46.

The above heat treatment does not provide any tempering operation for the removal of internal stresses set up by the hardening operation, and it is our opinion that this would account for cracking in service. Accordingly, tempering experiments were suggested in order to determine the optimum temperature which would result in complete removal of stresses without sacrificing hardness and without causing scaling. This was determined by heating the cyanided plate at 300°, 350° and 400° F. successively in a Homo tempering furnace and measuring the height of the plate before and after each heat treatment. The results of these experiments showed no movement between 350° and 400° F. There was very little scaling evident and no decrease in hardness, even at 400° F. Consequently, the temperature of 350° F. was selected as being the optimum temperature for the job.

Another important factor in the prevention of cracking is the selection and standardization of the plate as regards carbon content. A plate having a comparatively

(Discussion, cont'd) -

low carbon content would require immersion in the cyanide bath for a longer time and at a higher temperature to produce the same surface hardness than one of higher carbon content. Hence it is suggested that the carbon content be specified to fall between a certain range, say 0.25 to 0.35 per cent. Records should be kept showing the analyses of the plates and also their performance in service.

Conclusions:

1. The cracked plate was found to be metallurgically sound, both as regards chemical content and microstructure.

2. Cracking most likely occurred as a result of failure to remove internal stresses incurred during the hardening heat treatment and bending operations.

Recommendations:

1. It is recommended that the engraved plates be tempered at 350° F. for 10 hours immediately after hardening.

Tempering after the bending operation is also recommended.

2. The carbon content of the steel used as engraving plates should be standardized at, say, 0.25 to 0.35 per cent.

3. Records should be maintained comparing the carbon content and the service life of each batch of steel used as engraving plates.

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(Figures 1 to 5 follow,)
(on Pages 6 to 8.)

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Figure 1.

X8 (unetched).

TRANSVERSE SECTION OF CYANIDE-HARDENED ENGRAVING PLATE WHICH CRACKED IN SERVICE, SHOWING THAT THE CRACK HAS PENETRATED COMPLETELY THROUGH THE STEEL.

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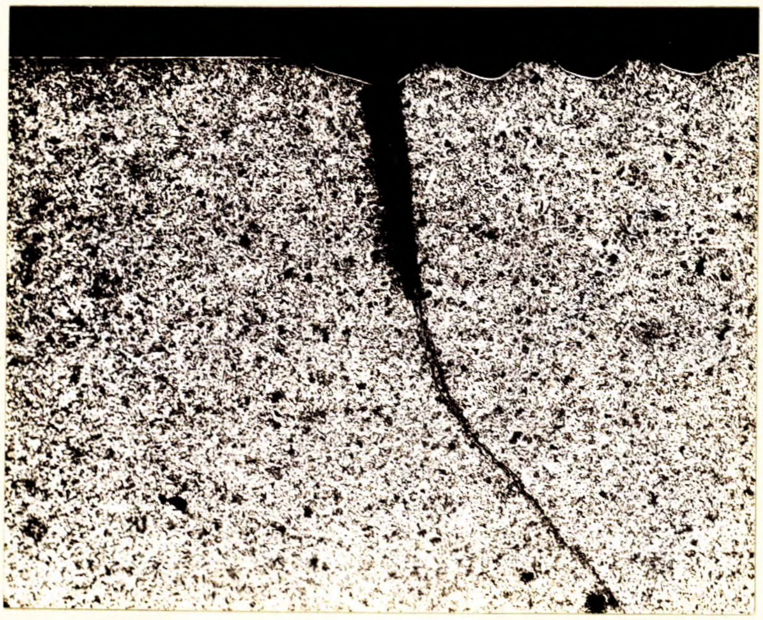
Figure 2.



X100. Nital etch.

TRANSVERSE SECTION OF CRACKED CYANIDE-HARDENED ENGRAVING PLATE, SHOWING APPEARANCE OF CRACK AT THE ENGRAVED SURFACE.

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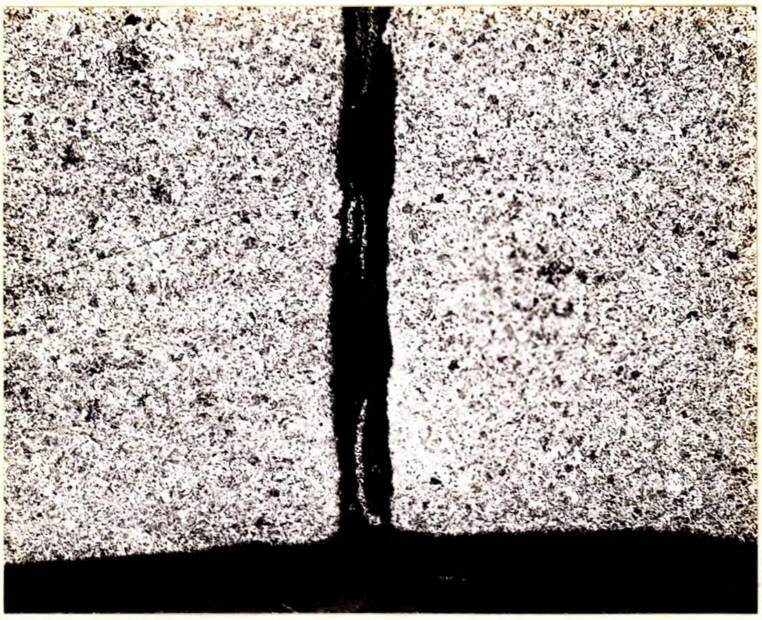
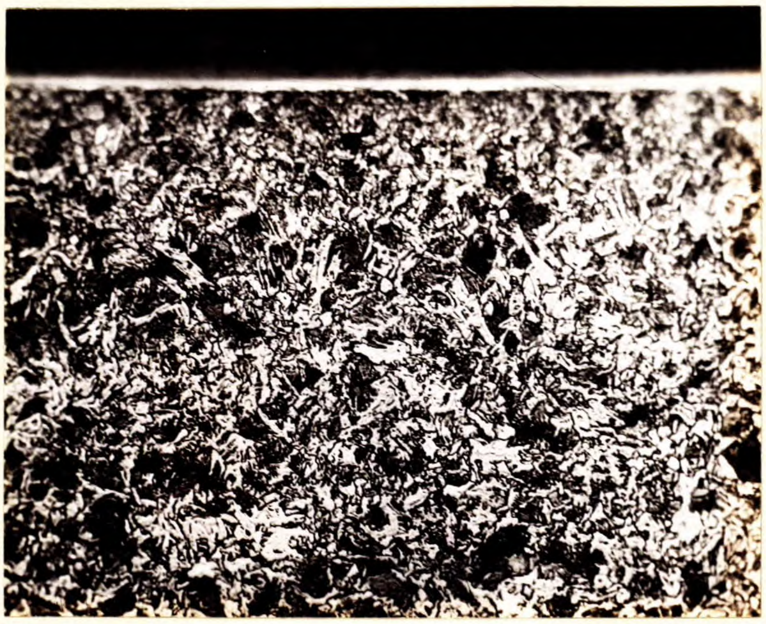
Figure 3.



X100. Nital etch.

TRANSVERSE SECTION OF CRACKED CYANIDE-HARDENED ENGRAVING PLATE, SHOWING APPEARANCE OF CRACK AT THE REVERSE SURFACE.

Figure 4.

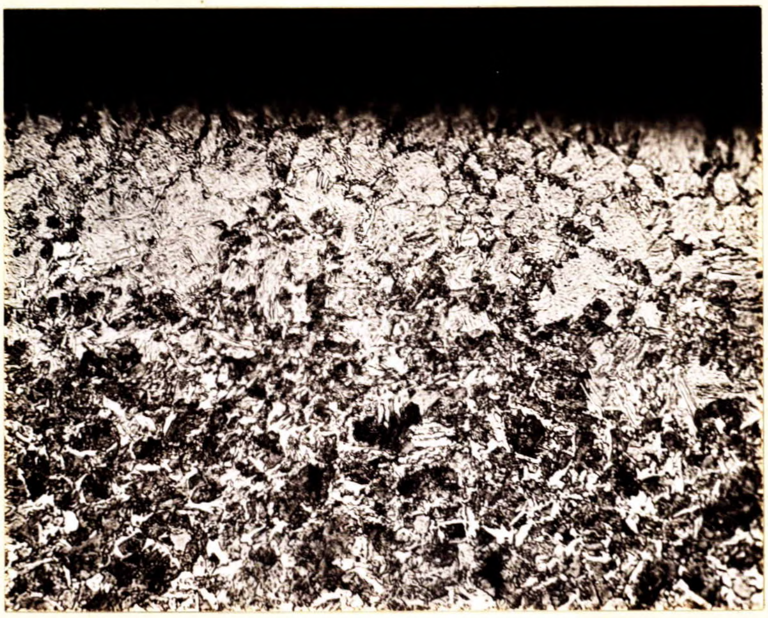


X500. Nital etch.

TRANSVERSE SECTION OF CRACKED CYANIDE-HARDENED ENGRAVING PLATE, SHOWING EXTENT OF CYANIDED CASE.

(White layer is chromium plating.)

Figure 5.



X500. Nital etch.

CYANIDE-HARDENED ENGRAVING PLATE USED IN THE TEMPERING EXPERIMENTS, SHOWING EXTENT OF CASE.

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