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METALLURGICAL EXAMINATION OF COINING DIES

by

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PHYSICAL METALLURGY DIVISION

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D.A. Munro[*] and R.F. Knight[**]

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SUMMARY OF RESULTS

Hardening in a "neutral" hardening salt had resulted in extensive decarburization on coining dies. The addition of small amounts of cyanide prevented decarburization, but this improvement was only temporary.

Satisfactory results were obtained by rectifying the bath with graphite and perliton, but control by this method is difficult to maintain, and considerable perliton is consumed. A number of changes in the heat treating procedure are recommended.

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INTRODUCTION

In a letter dated April 28, 1965, Mr. N.A. Parker, Master of the Royal Canadian Mint requested a metallurgical examination of a number of coining dies to try to eliminate difficulties encountered with their newly acquired salt bath heat treating facility. Background details of their difficulties were obtained through liaison with Mr. R. Parisien and Mr. G. Pajot, Chief and Assistant Chief of the Assay Division, respectively, and through consultation with Mr. C. Allen of the engineering staff.

It was stated that past practice, involving the use of a gas atmosphere austenitizing furnace (Vapocarb) had produced good quality dies giving adequate service life. Initial attempts, using an unrectified "neutral" salt bath for hardening resulted in early roughening of the chrome plate (matting) followed by collapse of the die face. This failure was believed to be due to decarburization, and the addition of cyanide to rectify the bath was prescribed.

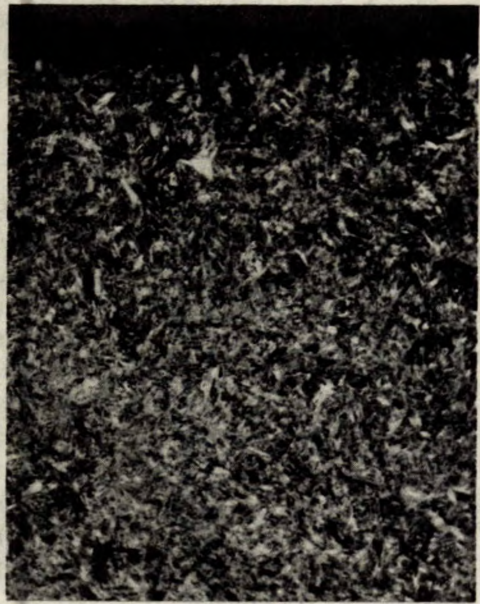
The original enquiry requested the examination of seven coining dies reportedly representing the three processes, i.e., hardening in a gas atmosphere furnace, hardening in a furnace containing "neutral" hardening salt, and hardening in the same salt with various quantities of cyanide added. As will be discussed, the original samples did not satisfactorily simulate the condition of the dies treated in the salt bath. Most of the discussion of this report will, therefore, concern other samples obtained, and conditions observed, on later visits to the Mint.

EXAMINATION OF SAMPLES

Samples Treated in Gas-Atmosphere Process

Samples "F" (W-2 type tool steel) and "G" (W-1 type) were submitted as representative of dies produced using the gas-atmosphere process. Such dies reportedly give satisfactory service life, although no figures for die life were available for these particular samples. The microstructures (Figure 1) and hardness level (Rc 57) were consistent with the hardening treatment reported. This consisted of holding at 1500°F for two hours, quenching in brine (6% NaCl at 68°F), and tempering at 500°F for four hours. (The suitability of this treatment will be commented upon in a later section).

Die "F" - W-2 Type



Die "G" - W-1 Type

(X500); Etched in 2% Nital

Figure 1. Microstructure at the surface of die samples austenitized for hardening in a gas atmosphere, brine quenched, and tempered at 500°F. Both samples gave Rc 57 hardness values.

Samples Treated in Salt Bath

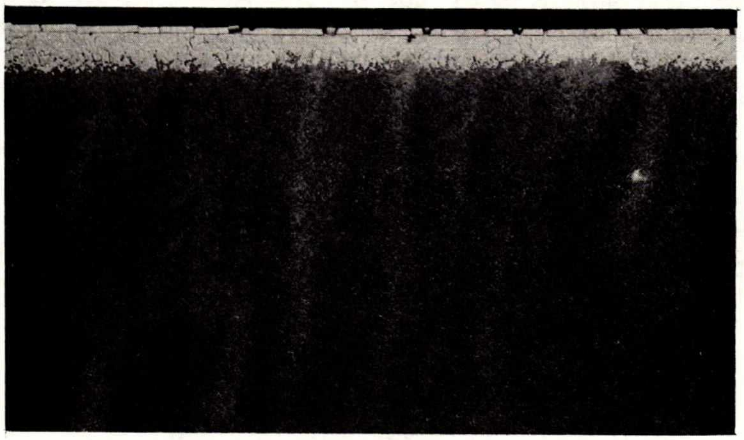
Five initial samples were submitted as being representative of dies treated in the "neutral" salt and in the salt with varying amounts of added cyanide. Some of these were blanks that had been given a treatment intended to simulate the conditions involved rather than actual dies. There was no record of the service life for those which were dies. Hardness values higher than Rc 65 were obtained on two of the samples, which indicated that these had never been tempered, and raised some question concerning the validity of the data for the other samples. Further samples of actual dies were subsequently obtained as more valid illustrations of the conditions involved. The following observations are limited to these latter samples.

Sample 20 x 2N had been treated in the salt bath with the negligible quantity of 0.05% CN present, and after it had struck only ten pieces of coinage the flaw referred to as "matting" appeared and the die was withdrawn from service. A magnified view of the "matting" shows it to be extensive cracking of the chromium plating.

(X100); As-received

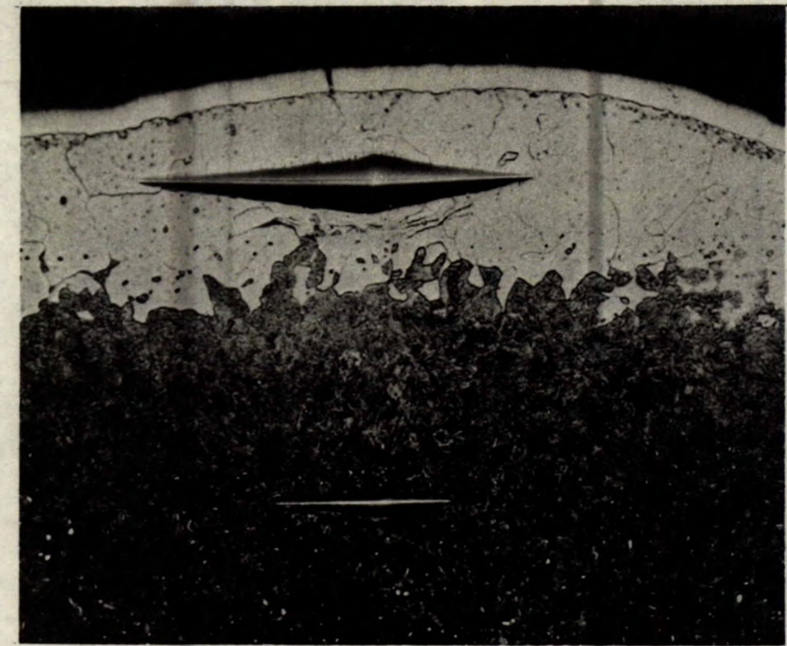
Figure 2. Magnified view of "matting" at the striking face of Die 20 X 2N.

Figures 3 and 4 show the microstructure of a section taken through the "matted" area, illustrating the cracked layer of chromium and deep decarburized layer observed.



(X100); Etched in 2% Nital

Figure 3. Microstructure through "matting" defect, illustrating layers of cracked chromium plating and of ferrite formed by decarburization.

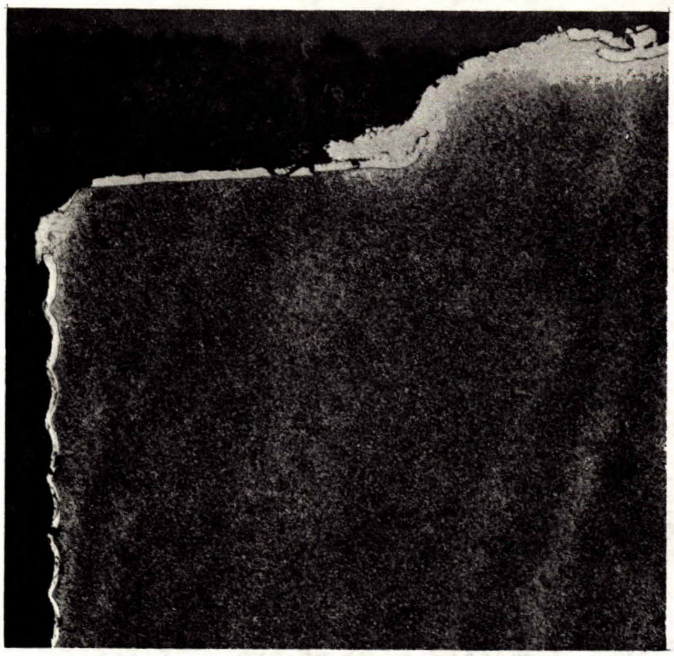


(X500); Etched in 2% Nital

Figure 4. Shows a field similar to Figure 3. but at higher magnification. The difference in hardness between the decarburized layer (Rb 61) and the tempered martensite core (Rc 59) is readily seen.

The extreme softness of the decarburized layer makes it obvious why the heavy cracking of the chromium plating occurs, and why, when this condition exists, the dies ultimately fail by "sinking" of the crown, that is, by collapse and outward flow of the soft material under pressure.

Hardness testing of the heat treated die should have made it clear that such a condition existed and that the use of this die in service would be nonproductive. Removal of the decarburized layer at the collar before chromium plating (see Figure 5) will not in any way improve conditions at the die face.

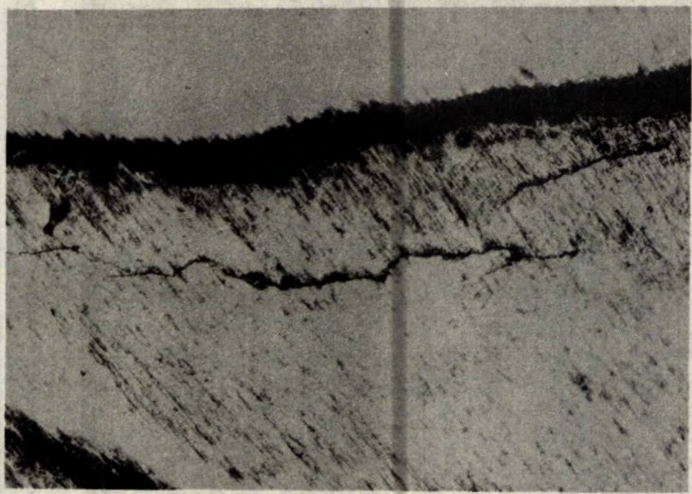


(X100); Etched in 2% Nital

Figure 5. Shows where decarburized metal has been removed on the collar, but remains at the face.

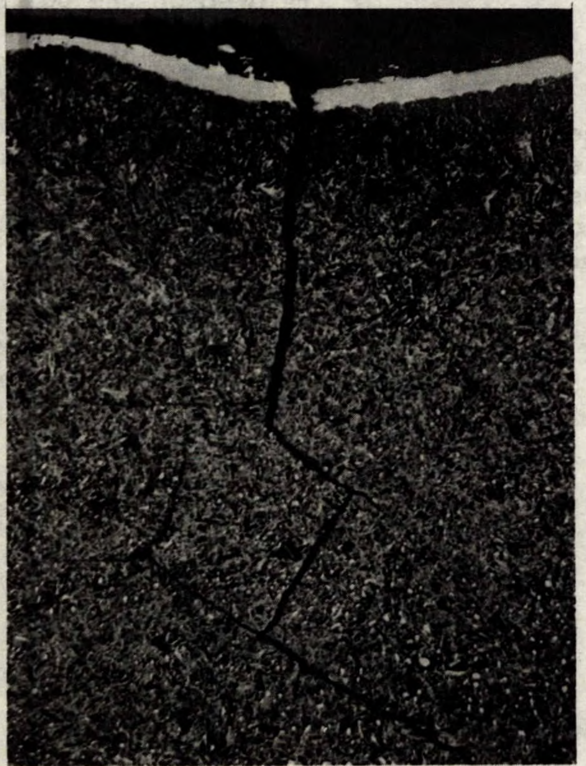
Sample CVX 10-2C was one of three experimental dies that had been treated immediately after addition of 1.75% CN to the salt. These dies were immersed at 1500°F for periods of 5, 10 and 15 minutes, respectively, before quenching, and the die lives were 102,000, 137,000 and 186,000 pieces. Sample CVX 10-2C was the experimental die exhibiting the longest service life.

Figure 6 shows a view of the crack, which resulted in rejection of the die, and Figure 7 shows sections through the crack. No decarburization is evident. Figure 8 shows another crack that occurred between the neck and collar of the die.



(X100); as-received

Figure 6. Magnified view of crack at the striking face of Die CVX.10-2C.



(X100); as-polished (X500); Etched in 2% Nital

(X100); Etched in 2% Nital

Figure 8. Shows crack at relatively sharp angle between the neck and collar of Die CVX. 10-2C

DISCUSSION

The conclusions to be drawn from the examination of the samples provided, and others subsequently obtained, are relatively straightforward and for the most part confirm what was previously suspected. A number of observations and recommendations that have been made of the heat treating practice involved, while outside the scope of this limited investigation, are included here for the record.

Most of the difficulties encountered have been in the larger austenitizing furnace which contained "neutral" hardening salt 168. This salt would appear to be an unfortunate choice in the first place, since it is a highly corrosive binary salt and is most difficult to keep rectified. The major difficulty arose due to confusion about the "neutral" terminology. This salt when not rectified is far from neutral to 1% carbon steel, and as can be seen from the preceding results will result in extensive decarburization.

The investigation revealed apparent success in rectifying this bath, and thus preventing decarburization, by the addition of cyanide. Such an approach is only a temporary expedient in this case, however, since the cyanide rapidly decomposes, forming a sludge which collects on the thermocouples and results in worse conditions than before any cyanide was added.

In most cases the selection in the first place of a ternary, high-cyanide liquid carburizing salt would be better than making cyanide additions to a binary salt. However, the particular conditions present at the Mint militate against any use of cyanide. The close proximity of acids for the chromium plating process makes the use of cyanide hazardous.

It was demonstrated that good results could still be achieved with this salt when it was rectified with graphite and perliton. Regular additions of perliton are required, far more than would be required with many other salts.

Some experimental hardening was being carried out in a smaller furnace containing a barium-base neutral ternary salt (K3). This salt is much easier to keep rectified with graphite and perliton, and good results were demonstrated using single samples. However, this furnace was apparently installed as a pre-heat furnace, and the quench tank is too far away to allow an efficient quench.

It was noted that a fixture was available to allow the treatment of approximately 36 dies at one time. For several reasons, this is far too many. The large bulk of the samples themselves, as well as the fixture required to hold them, cause too large temperature fluctuations of the baths. The temperature of the salt bath might not recover, and the dies themselves might not reach the hardening temperature in the short holding times that are being used. The large number of samples would also result in an inefficient quench. The desired agitation would not be possible, and the quench tank is far too small to maintain temperature control of the brine when quenching such a large number of samples. Far more satisfactory results would be obtained using a light fixture holding from 5 to 10 dies.

The process controls required some improvement. It was pointed out that a hardness check after quenching using the Rockwell Superficial Hardness Tester would reveal any extensive decarburization before any further expense is devoted to the dies, and would indicate that remedial action is required. Control of temperature should also be checked at regular intervals. It was demonstrated that while the control temperature indicated 1500°F, the actual temperature was only 1410°F. It should be pointed out that the 1500°F target was too high for this steel. The maximum hardening temperature recommended is usually about 1450°F.

The tempering temperature of 500°F would seem to be an unfortunate choice since this is the temperature corresponding to the greatest degree of tempered martensite brittleness. One would expect equal or better ductility and superior hardness on a draw at a lower temperature.

CONCLUSIONS

On the basis of the samples examined and inspection of the heat treating facility the following conclusions may be drawn:

1. The binary "neutral" hardening salt (168) is strongly decarburizing in the unrectified state.

2. Small additions of cyanide will prevent the decarburization, but the protection is only temporary.

3. The use of cyanide is too hazardous because of the proximity of acids.

4. Both the K3 salt and the 168 salt were successfully employed for hardening after rectifying with graphite and perliton. The latter salt is far harder to keep under control, however, and much more perliton is consumed.

5. The heat treating cycle and the controls involved need revision to assure satisfactory results.

RECOMMENDATIONS

General

1. In the high temperature furnaces use a ternary neutral hardening salt such as the barium-base K3 salt, or 1145 salt. These salts must be kept rectified by constant contact with a graphite rod and the regular addition of perliton.

2. The neutrality of the bath can be checked by the rapid treatment of high carbon strips (such as razor blades). The quenched strip should snap; if it bends the bath is decarburizing.

3. Temperature control should be checked regularly.

4. Hardness testing with the Rockwell Superficial Hardness Tester should be carried out after quenching as a further check for decarburization.

5. Treat the dies in batches of from five to ten only to minimize temperature fluctuations and to give more satisfactory hardening.

Recommended Process

1. Stamp the dies.

2. Preheat at 1300°F in the smaller furnace. Hold at temperature for 30 minutes per inch of section.

3. Transfer to larger furnace and hold at temperature of 1425 to 1450°F for 10 minutes per inch of section.

4. Quench directly, and rapidly, into brine maintained at room temperature. Agitate within the tank and do not remove until the dies can be held comfortably in the hand.

5. Rinse in hot water, or preferably a hot alkali rinse solution (10% caustic at 180°F) to remove any residual traces of chloride which will cause pitting on subsequent tempering.

6. Dry and check hardness with Superficial Hardness Tester. A number of readings which do not convert to approximately Rc 67, are indicative of decarburization.

7. Temper in oven at 300°F or in salt at approximately 350°F. Holding times are 60 minutes per inch of section in the oven and 30 minutes per inch of section in salt.

8. Proceed with cleaning preparatory to chromium plating.

ACKNOWLEDGEMENTS

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DAM/RFK/cg