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# METALLURGICAL EXAMINATION OF THREE BOILER GRATE BARS WHICH WARPED IN SERVICE.



by

R. K. BUHR

PHYSICAL METALLURGY DIVISION



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## SUMMARY OF RESULTS

The warpage of the grate bars is considered to be mainly due to differential heating, exaggerated in the present case by the design of the casting. An alternative composition is recommended which should extend the service life of the bars, as a result of the increased oxidation resistance, and may at the same time, because of its inherently higher strength, reduce the amount of warpage.

* Scientific Officer, Physical Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada.

## ORIGIN OF MATERIAL AND OBJECT OF INVESTIGATION

On January 23, 1958, three samples of grate bars, designated "No. 3 Boiler Grate Bars", were received at the Physical Metallurgy Division, Mines Branch, Ottawa, for examination and report, from the Plant Engineering Services, Montreal Road Laboratories, National Research Council of Canada, Ottawa 2, Ontario. In an accompanying request letter, File M6-27-13, Mr. A. E. Toole, P. Eng., Supervision Engineer (Power), stated that trouble was being encountered with excessive warpage, causing the bars to bend and eventually break off. His letter asked these questions:

1) Is there something wrong with the grate bar so that it warps with low temperatures?

2) Is there something wrong with our operation? With the type of coal we are burning?

3) Should we plan on changing all the grate bars this Summer? Cost $11,000.

The bars were stated to be similar to the composition for Taylorite 11 (which is given in Table 1 on page 2).

## CHEMICAL ANALYSIS

Drillings were obtained from each sample for chemical analysis. These analyses are given in Table 1.

TABLE 1. - Analyses of Grate Bars.

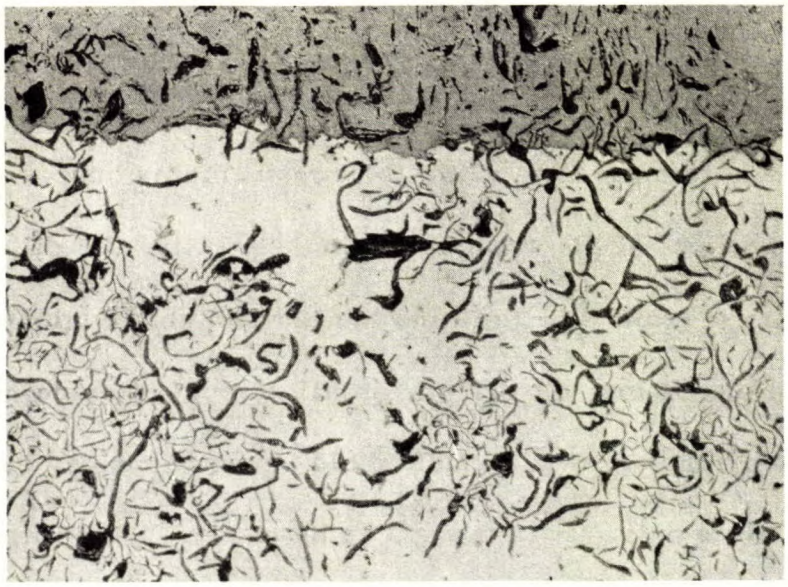
| Element | Sample A % | Sample B % | Sample C % | Taylorite 11 Spec. % |
|---|---|---|---|---|
| C | 3.49 | 3.59 | 3.53 | 3.3-3.5 |
| Mn | 0.58 | 0.55 | 0.69 | 0.6-0.7 |
| Si | 2.97 | 3.21 | 2.62 | 2.0-2.2 |
| S | 0.088 | 0.081 | 0.108 | 0.10 max. |
| P | 0.24 | 0.26 | 0.24 | 0.30 max. |
| Cr | 0.06 | 0.05 | 0.08 | 0.50-0.75 |
| Ni | 0.06 | 0.05 | 0.05 | 0.20-0.60 |

## HARDNESS TESTS

Brinell hardness readings, using a 3000-kg load and a 10-mm-diameter ball, were obtained on all three samples. The hardness was 140 Brinell in each sample.

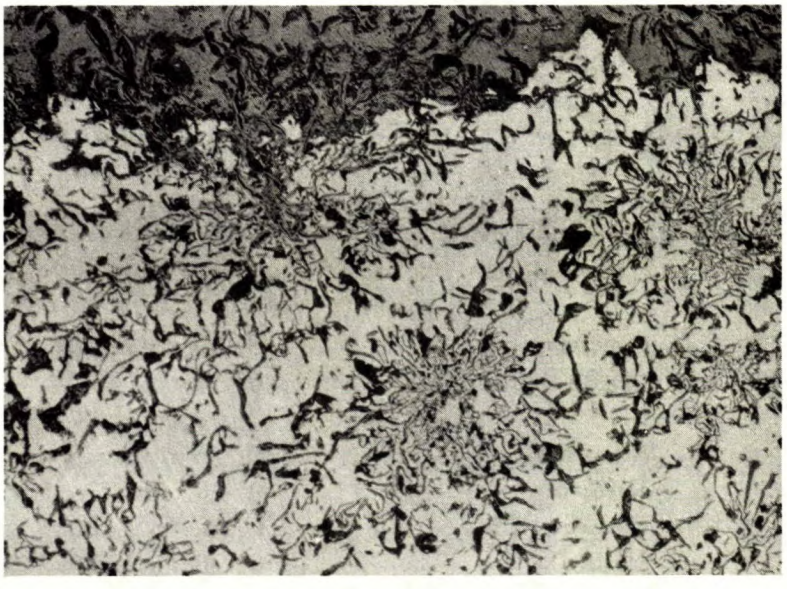
## MICROSCOPIC EXAMINATION

Samples were cut from the thin section of each grate bar and, after suitable preparation, were examined under a microscope. Varying thicknesses of oxide scale were observed on the exposed surfaces of the samples, but little penetration of the scale could be found. Figures 1 and 2 illustrate these remarks.



Mag. X100. Unetched.

Fig. 1. - Photomicrograph of surface of Sample B, showing lack of penetration of oxide scale.



Mag. X100. Unetched.

Fig. 2. - Photomicrograph of surface of Sample A, showing some penetration along the graphite flakes.

## DISCUSSION

The primary reason for warpage in the grate bars appears to be the design, rather than the metallurgy, of the castings. Part of the bar gets quite hot, while the rest remains conparatively cool, due to the effect of the air blast. Consequently, the difference in the amount of expansion between the hot and cold regions causes the warpage. It may be that the small amount of oxide penetration has caused some growth, which could cause warpage, but if this mechanism is active it is thought to be of secondary importance.

Despite the fact that only a small amount of oxide penetration was found in the grate bars, the surface of the castings is badly scaled as a result of the poor oxidation resistance of the composition used. The Taylorite 11 composition, because of its chromium and nickel contents, is certainly an improvement over that actually found. However, the following composition is thought to be a further improvement for this application:

| Element | | Per Cent |
|---|---|---|
| Carbon | - | 3.30 to 3.50 |
| Manganese | - | 0.50 to 0.70 |
| Silicon | - | 2.00 to 2.40 |
| Sulphur | - | 0.15 max. |
| Phosphorus | - | 0.30 max. |
| Chromium | - | 0.80 to 1.20 |
| Nickel | - | 0.90 to 1.10 |

A redesign of the grate bars to eliminate the warpage would be a major undertaking and would involve several changes in other

parts of the boiler. Consequently, if the above composition is chosen, it is probable that the warpage will be reduced, due to the increased oxidation resistance of the new composition together with its inherently higher strength.

It was learned that the grate bars cost $36.20 each, and weighed approximately 62 pounds. This means that these grey iron castings are costing the National Research Council just under 58 1/2¢ per pound. This is felt to be excessive, and it is recommended that quotations be obtained from several foundries for this casting made to the recommended analysis.

As for replacement of the grate bars this summer, this will depend entirely on the condition of the grate at this time. It is suggested, however, that sufficient castings of the recommended analysis be obtained and kept on hand to replace the existing grate when necessary.

## CONCLUSIONS

1. The major cause of warpage is the differential heating, exaggerated in this case by the design of the grate bar.

2. The analyses of the grate bars examined do not correspond with the Taylorite 11 analysis.

3. The grate bars had scaled, but oxide penetration had not occurred to any large degree. Therefore, growth, if any had occurred, was felt to be of secondary importance in causing the warpage.

4. It should be possible to obtain the new bars at a lower

price than is presently being paid.

5. Considerable improvement in service life should result if future grate bars are made to conform to either the Taylorite 11 composition or the composition recommended in the "Discussion".

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