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DEPARTMENT OF MINES AND RESOURCES

BUREAU OF MINES

CANADA

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Ottawa, July 8, 1946.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 2072.

Investigation of Defects in Hot-Rolled Round.

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(Copy No. 4.)

Bureau of Mines
Division of Metallic
Minerals
-
Physical Metallurgy
Research Laboratories

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DEPARTMENT
OF
MINES AND RESOURCES
Mines and Geology Branch

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Origin of Material:

On June 3, 1946, three transverse sections of 2¾" round were received from the Canadian Tube and Steel Products Limited, Montreal, Quebec. An accompanying letter, dated May 28, 1946, supplied the following information: The round had been rolled from a 316-pound ingot, No. 4A. Scrap on this shop order amounted to 36 per cent. The finished rounds had been rejected due to surface defects, which were thought to be caused by brick particles rolled into the ingot. Such particles may have come from fouled moulds or as a result of roof spalling in the reheating furnace.

In the letter, specific request was made for "a microscopic examination of the sections for inclusions and also a photograph of a macroetched section."

Object of Investigation:

To examine the round sections for defects and to determine the causes of such defects.

PROCEDURE:

1. Visual Examination:

Figure 1 is a photograph of the sections from the 2¾" round, as received. Note the surface defects. Several such defects were visible and could be described as laps, folds or seams. The round was rolled from a 317-pound ingot, No. 4A. This ingot measured 46 inches in length with 5" and 5-7/8" square ends.

2. Chemical Analysis:

Representative drillings were taken from one of the sections for chemical analysis, the results of which are listed below. Attention is drawn to the manganese, sulphur and phosphorus contents.

		Per Cent
Carbon	-	0.11
Manganese	-	0.80
Silicon	-	0.27
Sulphur	-	0.065
Phosphorus	-	0.062
Nickel	-	Trace.
Chromium	-	0.05
Molybdenum	-	Trace.

3. Macro-Examination:

A face of one section was ground to a smooth finish and the sample immersed in a 50 per cent HCl solution at 160° F. for 45 minutes. This treatment is used to reveal the presence of blowholes, cracks, porosity, or other evidence of internal unsoundness of the metal. Figure 2 is a photograph of the section after the hot HCl etch. With the exception of the surface lap noted, the round was sound, with no evidence of any unusual internal defects.

If an ordinary sensitized photographic paper is soaked in a 2 per cent solution of sulphuric acid, and the emulsion side applied to a smooth clean surface of a specimen for 90 seconds, a brown pattern appears which indicates the

(Procedure, cont'd) -

relative distribution of the sulphides. The darker and heavier the marks, the more sulphur is present. A sulphur print was taken of the cross-section of the round and was photographed (see Figure 3).

4. Micro-Examination:

Specimens were cut, both transversely and longitudinally to the direction of rolling, polished, and etched for microscopic examination. The microstructure was found to be normal. The following table lists the photomicrographs appearing at the end of the report:

Figure 4. - Normal structure parallel to the direction of rolling. Typical banded structure of ferrite and pearlite. Note the inclusions in ferrite bands.

Figure 5. - Unetched longitudinal area showing manganese sulphide inclusions.

Figure 6. - Area transverse to the direction of rolling. Note the oxide inclusions.

Figure 7. - Unwelded lap at the surface. Note the decarburization and the presence of iron oxide in the lap.

Figure 8. - Termination of an unwelded fold or lap. Note the decarburization and oxide inclusions.

Figure 9. - Small blowhole at the surface.

Discussion of Results:

The chemical analysis reveals that the phosphorus and sulphur contents are on the high side of the permissible range.

The phosphorus content is not considered serious. However, if the carbon content remains unchanged while the phosphorus content is allowed to rise far above 0.05 per cent, ductility is reduced and hardness increased. The segregation

(Discussion of Results, cont'd) -

of phosphorus during the solidification of the ingot increases the likelihood of a product of non-uniform properties.

The high sulphur content is counteracted by a high manganese content which reduces the sulphur to its least harmful form, manganese sulphide. Figures 3, 4, 5 and 6 substantiate this, while the photograph of the sulphur print, Figure 3, shows that there is uniform distribution of the sulphide inclusions. The sulphide inclusions with their lower melting point behave in the same manner as phosphorus, in solidifying later towards the centre of the ingot and acting as nuclei in the formation of ferrite. This explains the banded structure of ferrite and pearlite in the rolled product (see Figure 4). Ductility and impact resistance, compared with a more uniform structure, is decreased by this banding. The sulphide inclusions are distributed uniformly and would improve the machinability of the s teel. However, their influence as stress raisers is well known and, under certain service conditions, this should be considered. In addition, if welding is used during industrial fabrication, these sulphide inclusions may act as a source of difficulty in producing porosity-free welds, particularly if the concentration of sulphur is high or if there is undue segregation.

With the exception of the surface defects noted, the hot HCl test revealed a normal sound internal structure (Figure 2) with no evidence of internal cracks, porosity or blowholes.

The most serious defects noted were the laps, folds and seams on the surface of the round. (See Figures 7, 8 and 9. Decarburization and oxide inclusions, which are characteristic of such defects, are clearly evident.) These defects were the cause of the rejection of the round. Their origin can be either in the mould or in the rolling mill. There was no

(Discussion of Results, cont'd) -

evidence of dirt inclusion or rolled-in brick in the samples examined. If the ingots are being fouled through roof spalling of the reheating furnace, steps should be taken to eliminate this source of contamination. Fouling of the mould or the molten steel can be readily eliminated by greater care in these particular steps.

Cavities and cracks will form on the interior surface of the mould from continuous use, due to the erosive action of the molten steel on teeming the ingot and the alternate expansion and contraction of the mould caused by temperature changes. These cavities and cracks would restrict the normal contraction of the solidifying metal and would cause the appearance of surface irregularities and increase the possibility of internal cracks. Chipping with a pneumatic chisel, flame gouging, scarfing, or scalping should be employed to remove such irregularities on the surface of the ingot prior to rolling. If attention is not paid to surface preparation, the appearance of seams in the finished product is likely.

With a cleaned ingot, further difficulties might be encountered on rolling, because of a poorly designed pass and/or misalignment of the rolls. Too rapid a reduction for a section entering a pass would cause a folding or lap on the surface which would remain unwelded during rolling.

<u>Conclusions</u>:

1. The microstructure and chemical analysis of the round are considered normal, with the sulphur and phosphorus contents on the upper limit of the permissible range.

2. The manganese content is adequate in reducing the sulphur to its least harmful form, manganese sulphide.

3. The manganese sulphide inclusions are of uniform

(Conclusions, cont'd) -

size and distribution and, if not desirable to improve machinability, are at least innocuous. Their importance can be better evaluated by subsequent service conditions.

4. No evidence of internal cracks or porosity was found. The round is considered internally sound.

5. Serious surface defects were found, such as laps, folds or seams.

6. These laps or folds may be due to either or both of the following:

(a) An improperly cleaned ingot.
(b) A poorly designed pass or misalignment of the rolls.

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(Figures 1 to 9 follow,)
(on Pages 7 to 9.)

Figure 1.

SECTIONS OF THE $2\frac{3}{4}$" ROUND AS RECEIVED.

Note the visible surface defects.

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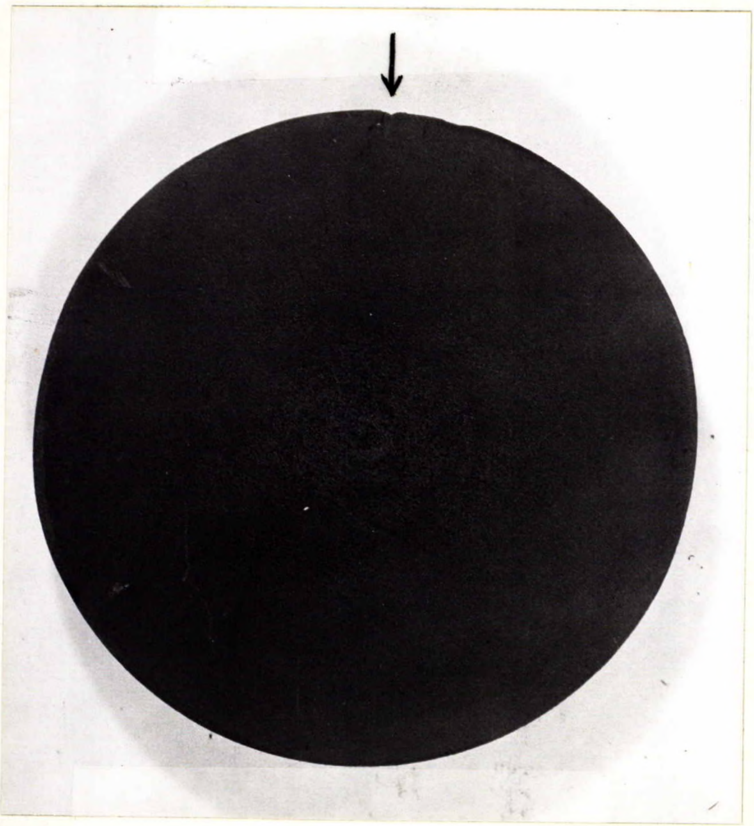
Figure 2.



TRANSVERSE SECTION OF ROUND AFTER ETCHING IN 50 PER CENT HCl AT 160° F. FOR 45 MINUTES.

Note the lap or fold.

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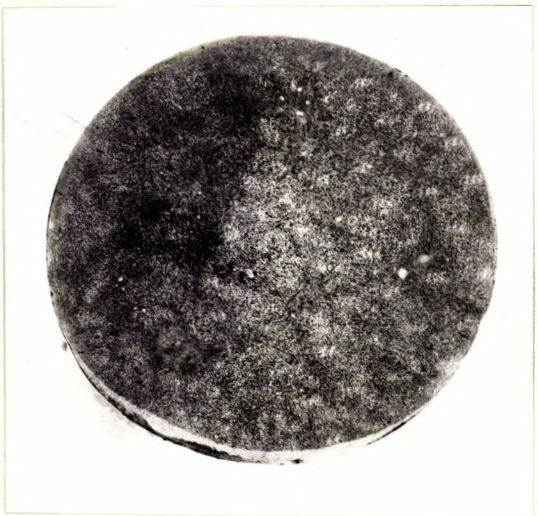
Figure 3.



PHOTOGRAPH OF SULPHUR PRINT.

Note the uniformity of distribution of the manganese sulphide inclusions.

Figure 4.

X100, nital etch.

TYPICAL LONGITUDINAL STRUCTURE.

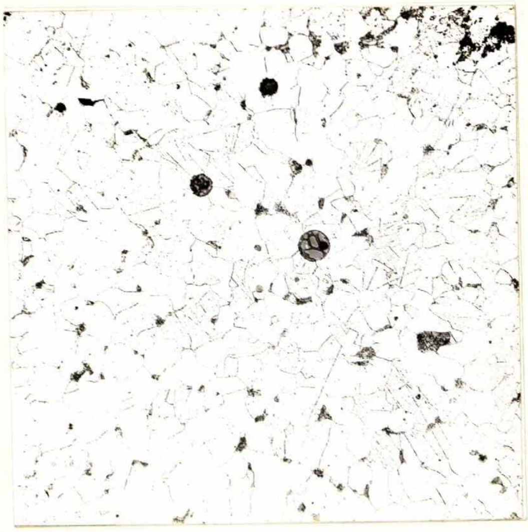
Normal banded ferrite and pearlite structure with inclusions in the ferrite bands.

Figure 5.

X100, Unetched.

MANGANESE SULPHIDE INCLUSIONS TYPICAL OF A LONGITUDINAL SECTION.

Figure 6.



X100, nital etch.
TRANSVERSE AREA.
Note the oxide inclusions.

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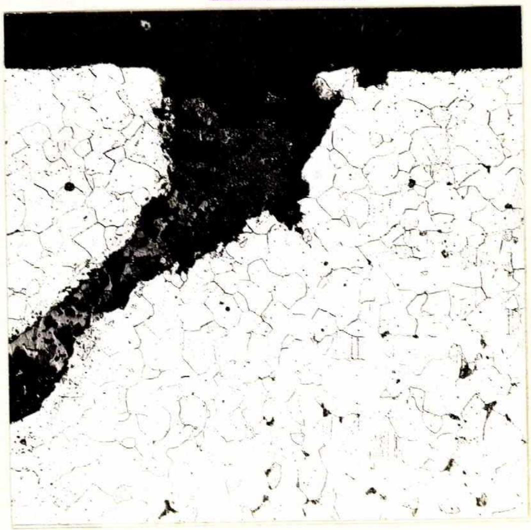
Figure 7.



X100, nital etch.
UNWELDED FOLD OR LAP AT THE SURFACE.
Note the decarburization.

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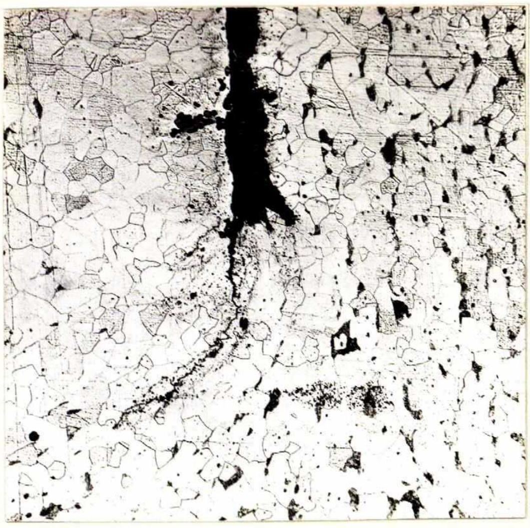
Figure 8.



X100, nital etch.

TERMINATION OF UNWELDED LAP OR FOLD.

Note decarburization and oxide inclusions.

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Figure 9.

X100, nital etch.

SMALL BLOWHOLE NEAR THE SURFACE.

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