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O T T A W A March 28, 1946.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 2027.

Metallurgical Examination of Defects
in Hot-Rolled Sections.

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(Copy No. 5.)

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

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
Mines and Geology Branch

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Origin of Material and Object of Investigation:

On March 2, 1946, a portion cut from an ingot (see Figure 1) and two rolled sections (see Figures 2 and 3) were submitted for metallurgical examination by the Canadian Tube and Steel Products Limited, Montreal, Quebec, per T. C. Hirst, Metallurgist.

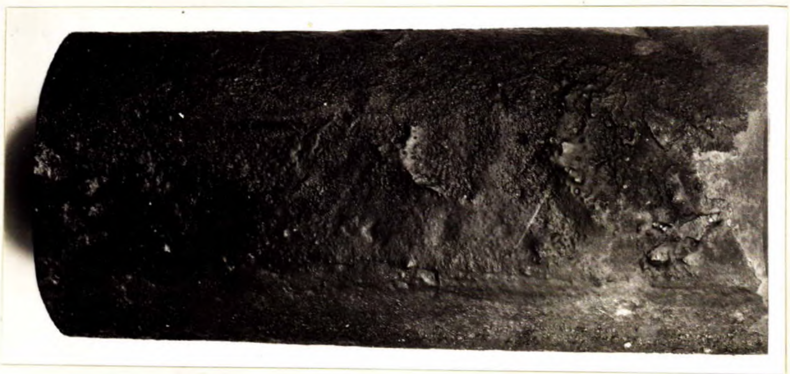
The covering letter, dated February 28, 1946, stated that the ingot portion submitted was representative of several ingots which gave poor rolling properties, especially when rolled into the larger-sized angles. The rolled sections submitted illustrated the types of defects encountered (see Figures

(Origin of Material and Object of Investigation, cont'd) -

2 and 3). It was further stated that the cracks in the rolled sections appeared usually in the first or second pass and frequently were sealed up under subsequent rolling. Such defects were said to appear from time to time for no apparent reason.

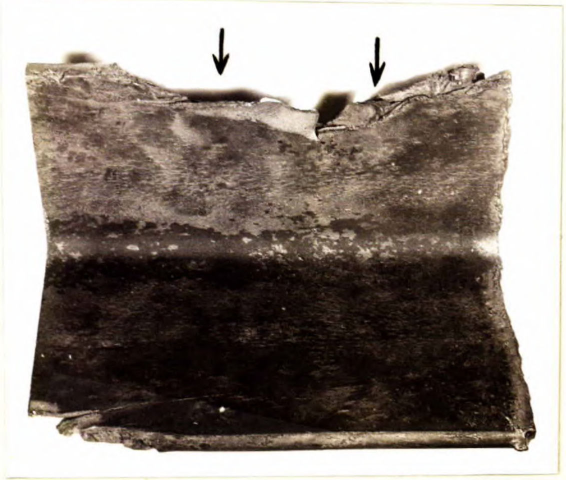
The dimensions of the ingots involved are: 46 in. in length by 5-7/8 in. square at the top and 5 in. at the bottom. The ingot section submitted had been cut 12 in. from the bottom.

Figure 1.



INGOT SECTION SHOWING SCALING.
(Approximately 1/3 actual size).

Figure 2.



ANGLE IRON (4" x 4" x 3/10").
Showing defects encountered in rolling.

Figure 3.

ROLLED SECTION.
Showing cavity defect encountered in rolling.

Procedure:

(1) Visual Examination:

Visual examination of the ingot revealed considerable scale adhering to the surface.

Visual examination of the angle iron indicated the presence of a great many laps, seams, and folded metal.

(2) Macro Examination:

A section of the ingot was etched in 50 per cent HCl at 160° F. for 1/2 hour. Examination of the etched surface revealed a normal dendritic structure typical of a cast ingot.

Figure 4, taken at X9 magnification, is a macrophotograph of the transverse section of the angle iron at the defective area, showing the unwelded folds in the metal.

Figure 5, taken at X18 magnification, is a macrophotograph made on the transverse section of the angle iron, showing a lap.

(3) Chemical Analysis:

The results of the chemical analysis are given in the following table:

TABLE I.

		Ingot	Angle Iron	Rolled Section
		- Per	Cent -	
Carbon	-	0.15	0.15	0.16
Manganese	-	0.34	0.39	0.45
Silicon	-	0.03	0.07	0.21
Sulphur	-	0.053	0.044	0.058
Phosphorus	-	0.010	0.005	0.021
Nickel	-	Trace.	Trace.	Trace.
Chromium	-	"	"	"
Molybdenum	-	"	"	"

(4) Microscopic Examination:

Figures 6 and 7, taken at X100 magnification, show the microstructure of the lap in the angle iron shown in Figure 5. Figure 6 reveals the microstructure of the lap at

(Procedure, cont'd) -

the surface, whereas Figure 7 shows the microstructure in the centre of the metal. Note evidence of decarburization in Figure 6.

Figure 8 shows a surface defect caused by rolled-in scale. This defect secured in the angle iron. Note, also, decarburization.

Figure 9 shows the microstructure of the defective area of the rolled section. This defect is in the form of unwelded metal. Note extensive decarburization.

Figure 10 illustrates the microstructure of the ingot at X100 magnification. Note presence of huge inclusion.

Discussion and Conclusions:

The results of the chemical analysis reveal nothing unusual about the chemical content of the steel. The sulphur content is on the high side of the permissible range but cannot be considered serious.

Both chemical analysis and microscopic examination of the ingot reveal normal conditions. The large inclusion shown in Figure 10 is certainly undesirable in steel. However, the average size of the inclusions are considerably smaller than the one shown and can be considered normal for a medium quality steel.

Visual examination of the rolled sections reveals defects which may be described as laps, seams and folds. Their presence is substantiated by the macro- and microphotographs. Decarburization, which accompanies these defects, is clearly evident in Figures 6, 8 and 9.

A lap is caused by the folding of one part of metal past another. This is caused by too rapid reduction or when the section is too large for the pass it is entering. A

(Discussion and Conclusions, cont'd) -

typical lap is shown in Figures 5, 6 and 7.

Further visual examination of the ingot revealed considerable quantities of scale adhering to the surface. This condition, plus the evidence supplied by the microscopic examination, leads to the conclusion that the majority of the defects must have occurred during the rolling operations as a result of the rolling of improperly cleaned ingots. When the oxide scale is rolled into the metal several conditions may result:

(a) Formation of folds caused by the lack of welding. (See Figure 9).

(b) Defects as typified by Figure 8.

(c) Decarburization of the adjacent metal. (Figures 6 and 8).

(d) Formation of a defect in the form of unwelded oxidized metal. (See Figure 9).

A telephone conversation with Mr. Hirst, on March 29, revealed that no provision had been made for the cleaning of the ingot surfaces before rolling.

Summary of Conclusions:

1. The chemical composition and microstructure of the ingot are considered normal for medium quality steel.

2. Visual and microscopic examination revealed many laps, seams, folds, unwelded metal, rolled in scale, etc.

3. Considerable scale was found adhering to the ingot surface.

4. The defects are considered to have resulted from the rolling of scale into the metal as well as from faulty rolling technique.

I don't agree.
T.V.S.
Mar 28/47

(Continued on next page)

Recommendations:

In order to prevent such defects from recurring, standard precautions should be taken to remove scale from the ingot before rolling. The adoption of a more careful rolling procedure is also recommended, in order to prevent the formation of laps.

I don't agree.
T.V.S.
March 28/47

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AF:LB.

(Figures 4 to 10 follow,)
(on Pages 7 to 10.)

Figure 4.

X9, unetched.

TRANSVERSE SECTION OF ANGLE IRON
AT DEFECTIVE AREA.

Note unwelded folds resulting from rolling of scale into the metal.

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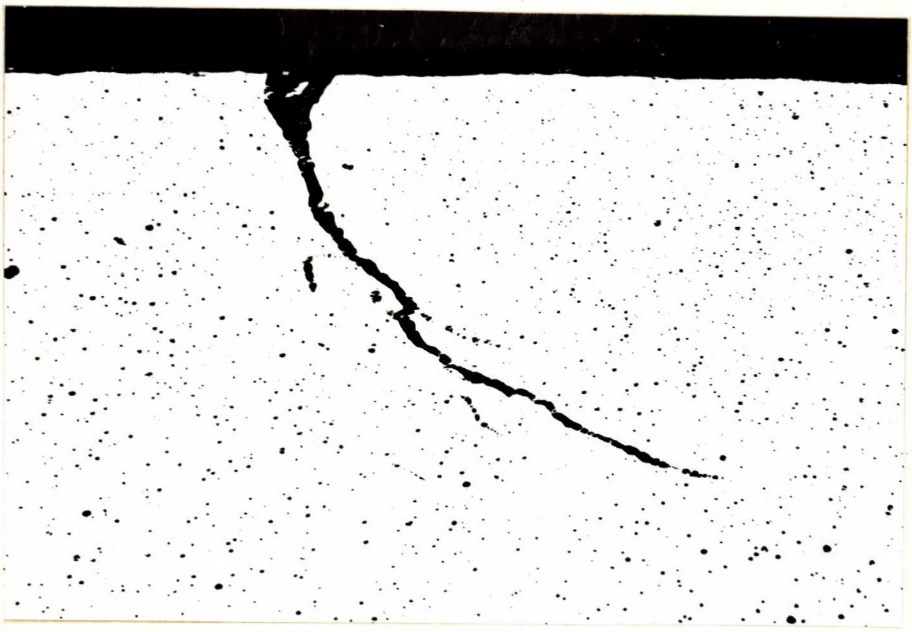
Figure 5.



X18, unetched.

TRANSVERSE SECTION OF ANGLE IRON,
SHOWING A LAP.

-

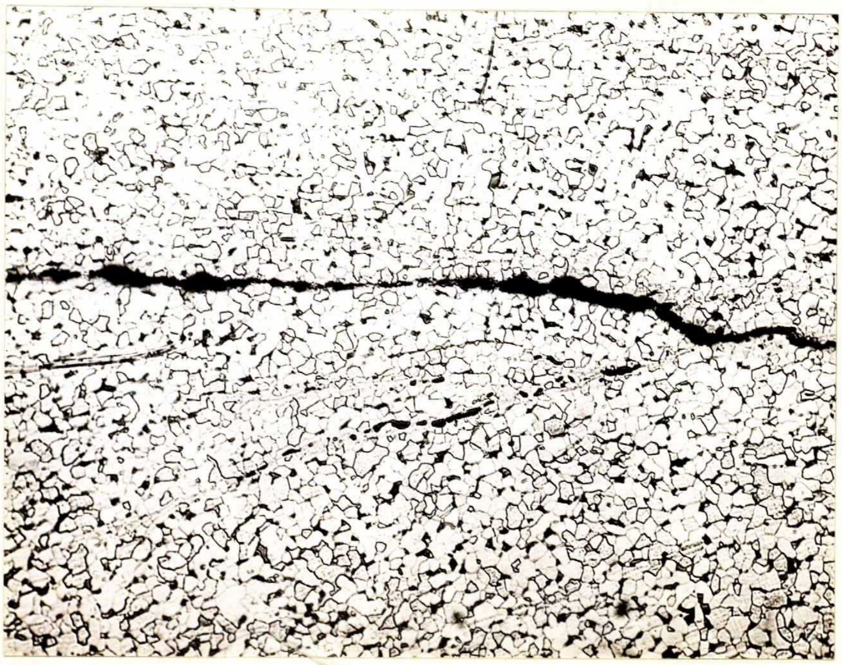
Figure 6.

X100, nital etch.

TRANSVERSE SECTION OF ANGLE IRON,
SHOWING LAP AT SURFACE.

Note decarburization. (See Figure 5).

Figure 7.



X100, nital etch

TRANSVERSE SECTION OF ANGLE IRON,
SHOWING LAP AT CENTRE OF METAL.

(See Figure 5).

Figure 8.

X100, nital etch.

TRANSVERSE SECTION OF ANGLE IRON, SHOWING ROLLED-IN SURFACE DEFECT.

Note decarburization.

-

Figure 9.

X100, nital etch.

TRANSVERSE SECTION OF ROLLED PRODUCT AT DEFECTIVE AREA (UNWELDED METAL).

Note surface decarburization.

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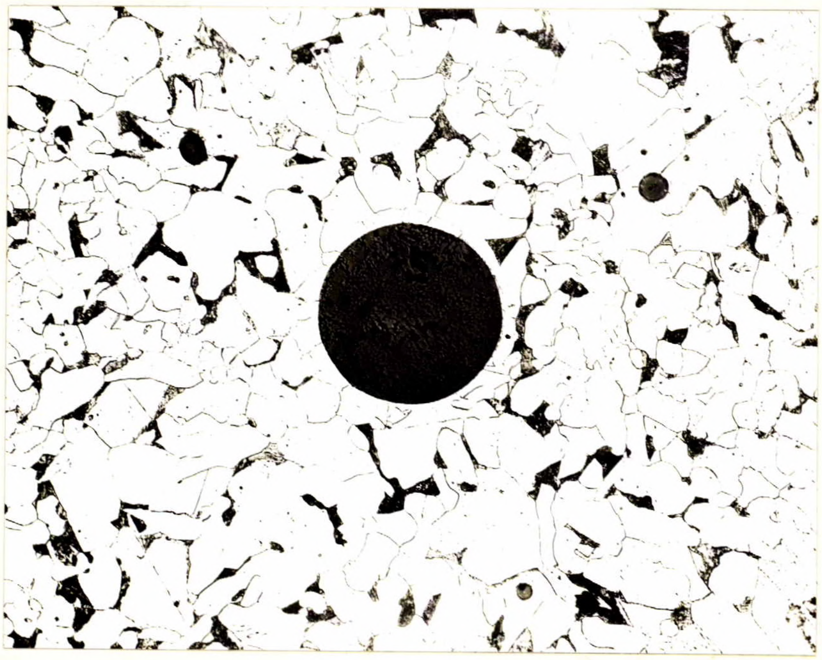
Figure 10.



X100, nital etch.

MICROSTRUCTURE OF INGOT, SHOWING
LARGE INCLUSION.

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