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OTTAWA November 19, 1945.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1964.

(Subsequent to Report of)
(Investigation No. 1957,)
(dated November 3, 1945.)

Investigation of the Cause of "Burn-in" on Steel Castings.

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(Copy No. 10.)

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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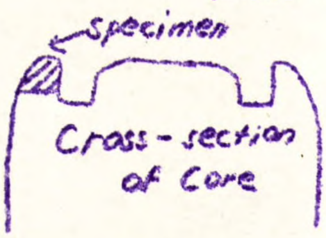
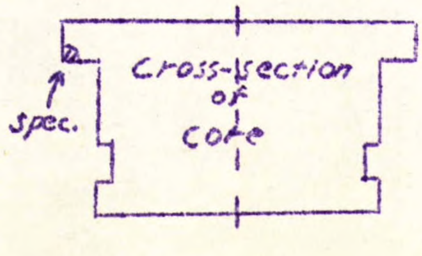
Origin of Request and Object of Investigation:

On November 3, 1945, Investigation Report No. 1957, dealing with burn-in on steel castings, was forwarded to the Hull Iron and Steel Foundries Limited, Hull, Quebec. On November 12, 1945, ten further sand samples were submitted, to determine whether they would throw any further light on this phenomenon.

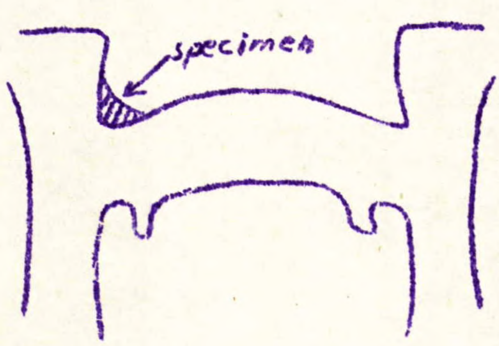
Description of Samples:

The samples were described as follows:

Specimen No.	Patt. No.	Sand Mixture	Detail of Specimen
3	V.P. 333	OIL SAND FOR CENTRE FLOOR 50 gal. #57 sand 50 lb. silica flour 4 gal. bentonite 1½ gal. cereal 1¼ gal. oil	Readily peeling sand from outside of rounded part of casting. Specimen showed a dark layer about 1/8"
4	A.P.35	OIL CORE SAND FOR HEAVY SECTION 50 gal. #57 sand 150 lb. silica flour 5 gal. bentonite 2 gal. No Vein 1½ gal. cereal 2½ gal. oil	Core cleaned out readily except for a couple of areas where there was mossy penetration to about ¼". This is a sample of this penetration. It was chipped off, part of the steel casting coming with it.
6	V.P.333	OIL CORE SAND FOR HEAVY SECTION (same as No. 4) 	Major penetration from locality as indicated. Most of core came out readily except for this promontory of sand. Penetration here was about 1".
7	A.P.43	OIL CORE SAND FOR HEAVY SECTION (same as No. 4)	Perfectly peeling sand from large central core
8	G.P.36	OIL CORE SAND FOR BENCH 50 gal. #57 sand 1 gal. bentonite 2½ gal. cereal 1¼ gal. oil	Major penetration in reduced end of core (where metal section is heavier). Poor sample. Could not chip out to sand-metal interface.
9	G.P.36	OIL CORE SAND FOR HEAVY SECTION (same as No. 4) 	Major penetration in fillets. Core felt soft green.

(Description of Samples, cont'd) -

Specimen No.	Patt. No.	Sand Mixture	Detail of Specimen
10	G.P.36	OIL SAND FOR C.F. (same as No. 3)	Fair peel but penetrated, adhering sand 3/8" thick. Silica wash layer seemed separate.
11	V.P.124	OIL CORE SAND FOR HEAVY SECTION 50 gal. #57 sand 150 lb. silica flour 2 gal. No Vein 4 gal. bentonite 1½ gal. cereal 2 gal. oil	Very good peel. This core formed part of the outside of the casting and was adjacent to No. 12. Core was hand rammed.
12	V.P.124	OIL SAND FOR C.F. (same as No. 3)	Very good peel. This is from mould forming almost same part of casting as core specimen No. 11. Mould was pneumatic-hammer rammed.
17	M.P.1019	OIL SAND FOR C.F. (HEAVY SECTION) 50 gal. #57 sand 150 lb. silica flour 4 gal. bentonite 1½ gal. cereal 2¼ gal. oil.	Major penetration 1" deep. Specimen from part of mould that left its own core.



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MICROSCOPIC EXAMINATION:

General -

The samples were examined in direct and in oblique illumination. In direct illumination the metal appears bright and the sand grains are grey. In oblique illumination the sand grains are light and the metal black.

Photomicrographs of some of these specimens are shown in Figures 1 to 9.

Four general types of penetration were found in the samples:

(a) The specimens of sand which peeled readily (Nos. 3, 7, 11, and 12) all showed similar characteristics. They were a dense, partly sintered mixture of silica flour and silica (see Figure 1).

(b) The "mossy" type of penetration (Spec. No. 4, Figure 2) is less severe than the other types studied. The metal evidently has not permeated the sand sufficiently to entrap the grains, and these are removed in the sand blast. The remaining permeable metal has a mossy appearance.

(c) Separate layer of silica wash. Sample No. 10 (Figure 3) appears to be a special type of penetration. Possibly this occurred as a result of the mould wash separating from the sand. The sand in this specimen was sintered.

(d) Severe penetration in depth. These specimens (Nos. 6, 8, 9 and 17, Figures 4 to 9) appear to be similar to the samples studied in Investigation Report No. 1957. The metal in these specimens had penetrated the sand to a depth of from 1 to 6 inches.

Examination of Penetrated Sand from Severe "Burn-in" Specimens -

In oblique illumination the sand grains stand out in relief. The sand grains in Specimen No. 6 were fused (Figure 4), but those in Specimens Nos. 8, 9 and 17 (Figure 5) were scarcely

(Microscopic Examination, cont'd) -

altered. This indicates that the core from which Specimen No. 6 was taken had been subjected to greater heat, either from a larger mass of metal or from a higher pouring temperature.

Examination of Penetrated Metal from "Burn-in" Specimens -

An indication of the degree of ramming and the fluidity of the metal may be obtained from examination under direct illumination. Approximately the same sand mixture was used in making the cores from which Specimens Nos. 6 and 9 were taken, and the mould for Specimen No. 17. However, there is a great difference in the size of the metal patches. Assuming that the voids are filled with metal, the size of the metal patches is proportional to the degree of ramming. If this is so, the specimens in order of increasing hardness of ramming are: Nos. 8, 9, 17, and 6. (See Figures 6, 7, 8 and 9.)

The specimens which contain the finest metal stringers evidently had the most fluid metal. The samples in increasing order of fluidity are, thus, Nos. 8, 9, 17 and 6, or in the same order as for increasing hardness. Note the fine stringers of metal penetrating through the mould wash of Specimen No. 6 (Figure 9). This metal was evidently very fluid when penetration occurred.

Discussion:

Undoubtedly there are several factors which influence metal penetration. Three of the most important of these are:

1. Density of the sand.

2. Fluidity of the metal, and length of time the metal is fluid.

3. Sintering point of the sand.

(Discussion, cont'd) -

1. Density of the Sand -

This may be affected by:

(a) Degree of Ramming.

The fact that projections of the sand, which are the most difficult to ram, experience the most severe burn-in emphasizes the importance of ramming.

(b) Flowability of the Sand.

Flowability is the property which allows sand grains to flow over each other. If the sand is too stiff the grains will not slide and this tends to leave voids in the sand. Under these conditions, even hard ramming will not fill all the voids, and metal can enter. Bentonite and cereal lessen flowability; hence, only enough of these should be used to obtain sufficient green bond for moulding. Note the high content of cereal flour in Mixture No. 8 and compare with Figure 6, which evidences very open sand.

(c) Permeability.

The finest sand will offer the greatest resistance to the flow of the metal, and decrease penetration. This fact is made use of by the addition of silica flour to the sand, to fill up the voids.

2. Fluidity of the Metal -

Factors which influence the fluidity of the metal and length of time it is fluid are:

(a) Composition of the metal.

(b) Pouring temperature.

(c) Size of casting.

(d) The amount of baking a core receives may influence the fluidity of the metal. As core baking is an oxidizing action, a baked core will give off a gas

(Discussion, cont'd) -

with a higher oxygen content than will a partly baked core. These gases are hydrocarbons, and may have a carburizing effect on the metal. This would give the outside layer enough fluidity to lead it into the sand. The less oxygen the core gas contained the greater would be the carburizing effect. Experts insist that properly baked cores give less penetration than improperly baked ones. The explanation may lie in the effect of the carburizing gases.

3. Sintering Point of the Sand -

The samples of good peel (Figure 1) show that the sand has partly sintered, presenting an impervious face to the metal. This seems to be a prerequisite of good peel. It is evident, however, that control of the sintering is not alone an answer. If the mould is lightly rammed, or the metal is too fluid for a long time, penetration will occur whatever sand mixture is used.

Conclusions:

1. Some of the burn-in specimens indicate soft ramming.

2. Other specimens indicate that the metal was very fluid.

Suggestions:

Improvement of casting finish may be obtained by paying close attention to the following details of foundry operation:

1. Hardness of green cores as rammed.
2. Amount of bentonite and cereal in core mixes.
3. Pouring castings at as low a temperature as possible.
4. Length of baking time.

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(Figures 1 to 9 follow,)
(on Pages 8 to 12.)

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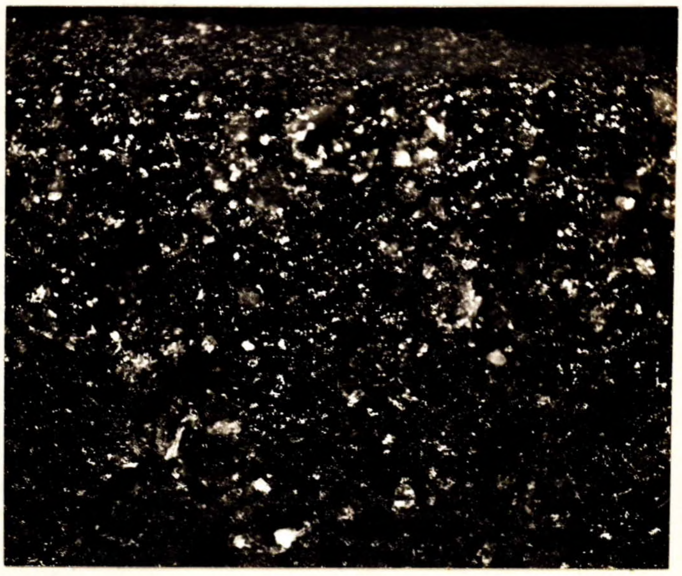
Figure 1.



X20.

SAMPLE OF GOOD PEEL (SPECIMEN NO. 7.).

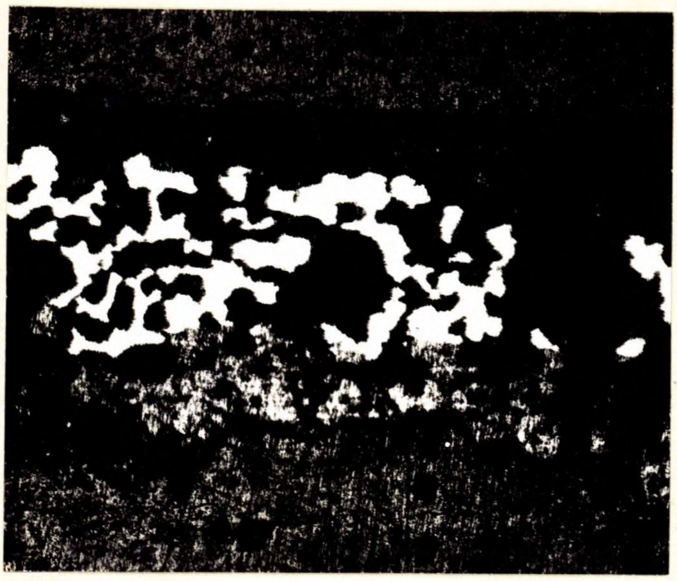
Figure 2.

X20, nital etch.

"MOSSY" PENETRATION (SPECIMEN NO. 4).

Rough casting.

Figure 3.

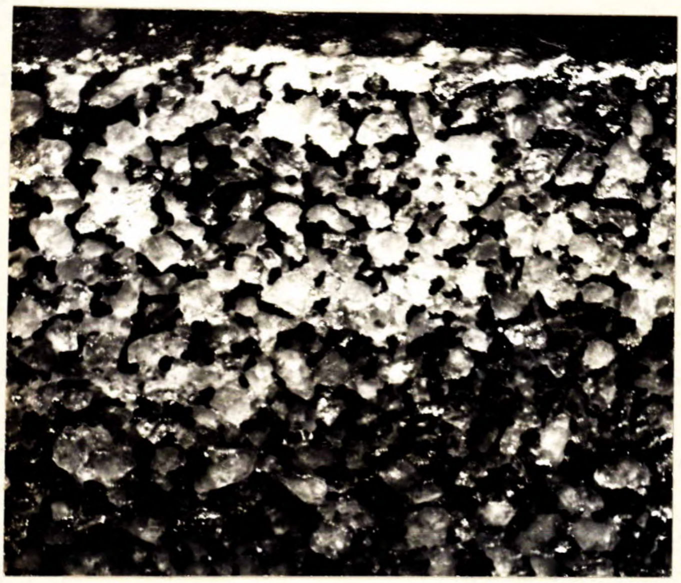


X20, direct illumination.

MODERATE PENETRATION (SPECIMEN NO. 10).

Mould wash shows as black layer above metal; fused sand (light grey), below metal. Grey edges are bakelite mount.

Figure 4.

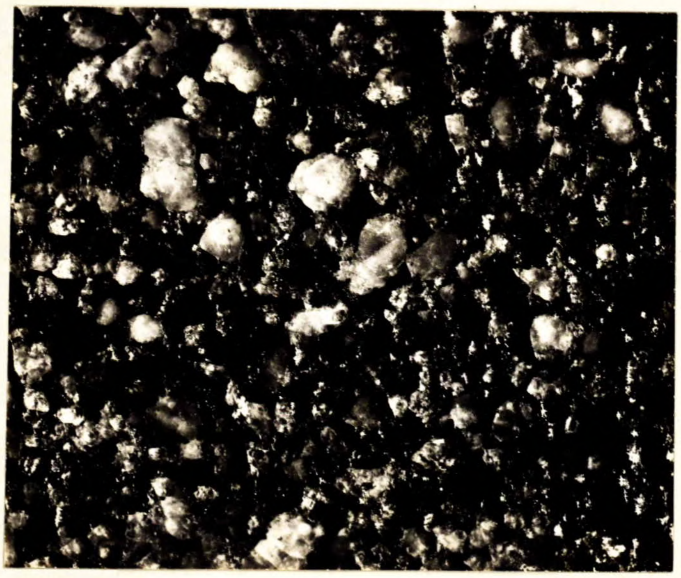


X20, oblique illumination.

SEVERE PENETRATION (SPECIMEN NO. 6; cf. Figure 9).

Note sintering of sand grains.

Figure 5.

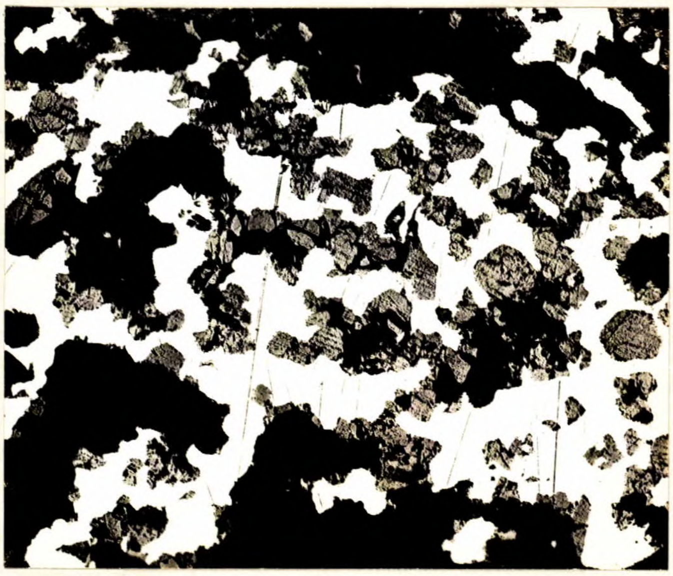


X20, oblique illumination.

SEVERE PENETRATION (SPECIMEN NO. 17; cf. Figure 8).

Note unfused sand grains.

Figure 6.

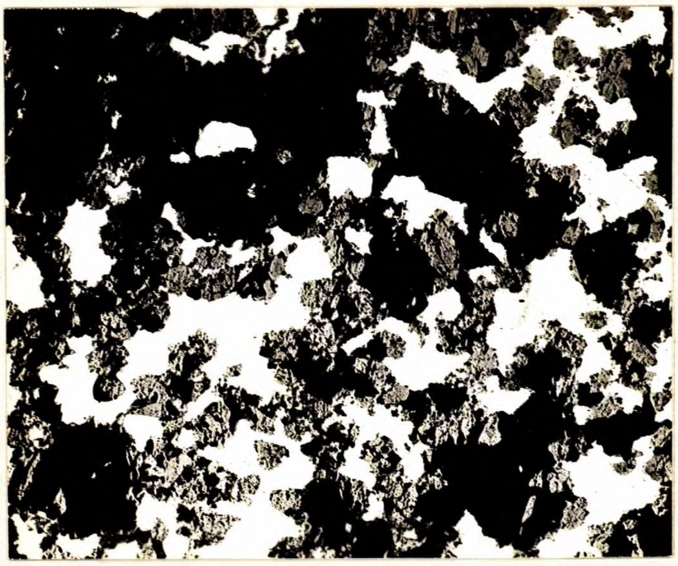


X20, direct illumination.

SEVERE PENETRATION (SPECIMEN NO. 8).

Large metal particles indicate light ramming.

Figure 7.



X20, direct illumination.

SEVERE PENETRATION (SPECIMEN NO. 9).

Large metal particles indicate light ramming.

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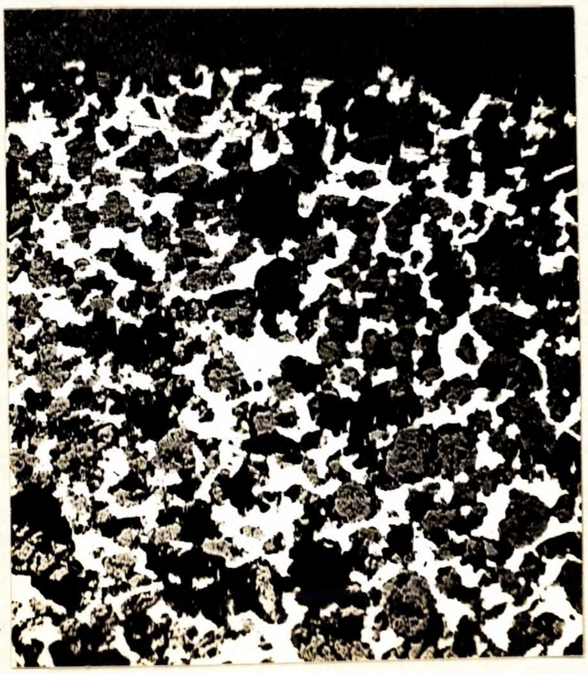
Figure 8.



X20, direct illumination.

SEVERE PENETRATION (SPECIMEN NO. 17; cf. Figure 5).

Evidence of fairly hard ramming, Metal was apparently quite fluid.

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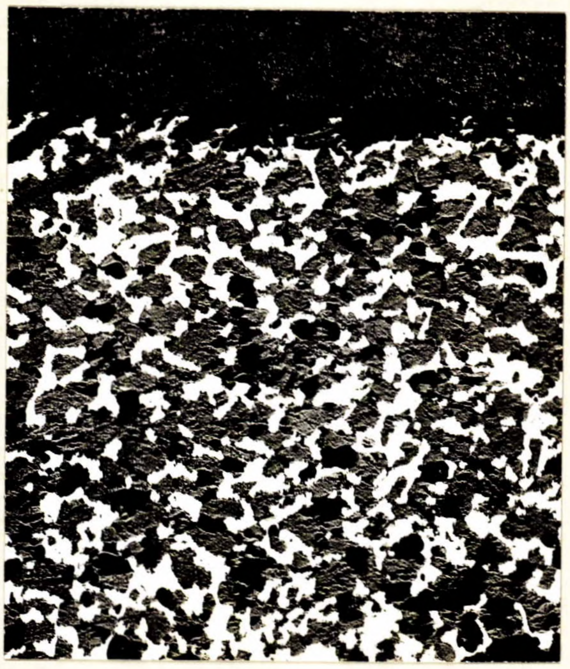
Figure 9.



X20, direct illumination.

SEVERE PENETRATION (SPECIMEN NO. 6; cf. Figure 4).

Note the fine stringers of metal through mould wash. Sand was densely rammed, metal very fluid.

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