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O T T A W A November 20th, 1944.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1749.

Metallurgical Examination of Two Steel Pots
Used for Melting Magnesium.

(Copy No. 10.)

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Origin of Material and Object of Investigation:

On November 1st, 1944, Mr. D. J. McPhail, of Dominion Magnesium Limited, Haley, Ontario, submitted for examination pieces taken from two steel pots used for melting magnesium. An accompanying letter stated that one section showed a crack which was typical of the failures occurring in pots made by the Hull Iron and Steel Foundries Limited, Hull, Quebec. The crack nearly encircled the pot fifteen inches from the bottom. This particular pot had had 466 hours of operation. The other section was taken from a pot received from Allegheny-Ludlum Steel Co., Brackenridge, Pa., U.S.A. This pot had been in use for 1,426 hours. It was also reported that both pots received the same treatment at the Dominion Magnesium plant. They were fired by a single #781 Hauck Oil Burner but there was no direct impingement of flame. The melting is a batch process and there

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

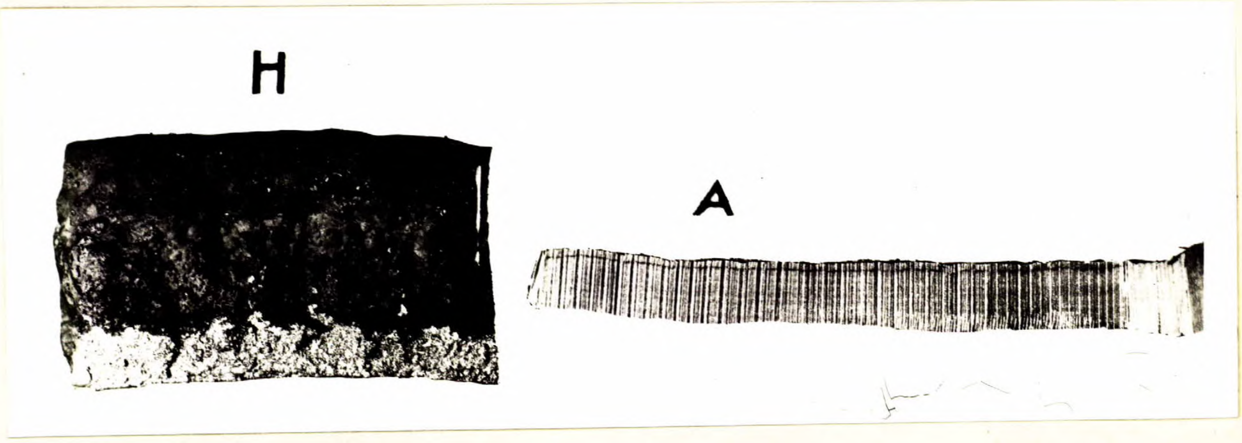
is a repeated cycle every $3\frac{1}{2}$ hours with a range of temperature of about 1600° - 2200° F. on the outside of the pot. A further letter received from Mr. McPhail, on Nov. 11th, stated that the two pieces were taken at approximately the same distance from the top of the pot. The section from the U.S. pot scaled off considerably and stretched, whereas the Hull pot cracked.

Macro-Examination:

The Hull pot section was $2\frac{1}{2}$ inches thick. A sledge hammer was used to break open the crack. Figure 1 shows the fractured surface (mark 'H'). The heating temperature was evidently high enough to cause some melting of the metal. This was seen on an unetched specimen under the microscope. The crack penetrated the wall of the pot for approximately 2 inches. The fracture gives evidence of porosity and suggests the possibility of a cold shut.

The Allegheny-Ludlum pot section (under 'A' in picture) was $\frac{1}{2}$ to $\frac{5}{8}$ inch thick.

Figure 1.



Note rippling characteristic of surface in the dark portion of the Hull section.

Chemical Analysis:

Drillings were taken for chemical analysis. The results were:

		Allegheny-Ludlum	Hull
		- Per Cent -	
Carbon	-	0.69	0.28
Silicon	-	0.32	0.36
Manganese	-	0.59	0.78
Phosphorus	-	0.038	0.044
Sulphur	-	0.029	0.026
Chromium	-	0.08	0.12
Nickel	-	Trace.	Trace.
Molybdenum	-	Trace.	0.01
Copper	-	Trace.	Trace.

Hardness:

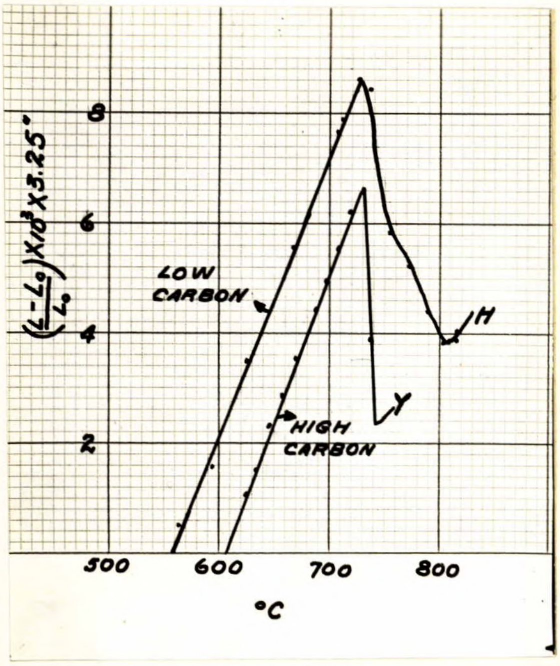
The Brinell hardness was taken on both pieces:

Hull	-	159
Allegheny	-	223

Dilatometric Curves:

Specimens, $3\frac{1}{4}$ in. x $\frac{1}{4}$ in. diameter, were cut from both sections and heated up to obtain the comparative expansion and contraction of the high carbon and low carbon steels. Figure 2 illustrates the curves obtained.

Figure 2.



L = Final length.
L_o = Original length, 3.25 inches.

Note: Divide the vertical ordinates by 3.25 to get to unit expansion in mils per inch.

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Microscopic Examination:

Specimens were cut from each section for microscopic examination. In the unetched condition the samples were fairly clean. Some sulphide and oxide inclusions were observed but these were well dispersed. The latter type were much more evident in the Hull specimen, where they were duplexed with the sulphides. The samples were etched in 2 per cent nital. Figure 3 (X250) shows the structure of the Hull section and Figure 4 (X250) that of the Allegheny pot. The Hull structure contains, as would be expected from the analysis, more ferrite. The pearlite is also somewhat coarser.

Figure 3.

X250, nital etch.

HULL POT.

Note ferrite (white constituent) and pearlite.

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(Continued on next page)

(Microscopic Examination, cont'd) -

Figure 4.

X250, nital etch.

ALLEGHENY-LUDLUM POT.

Note smaller amount of ferrite (white constituent) and finer pearlite.

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Discussion:

The problem on melting pots resolves itself into two phases:

(1) Wide variation in life obtained with Hull pots, i.e., 400 to 1100 hours, approximately.

(2) The difference between the Hull pots of 1100 hours' life and those of Allegheny-Ludlum which gave 1400.

It is felt that the solution of the first phase is an internal foundry problem. The lack of distortion in the Hull pot prior to failure suggests that the pot gave way at a point of weakness in the casting. The fractured surface of the crack indicates some porosity and suggests the possibility of a cold shut. The foundry technique should be thoroughly investigated. The gating, risering, chills, pouring, and the

(Discussion, cont'd) -

pattern condition are some of the factors that should be checked.

One factor which may account for the difference in the length of life of the Hull as compared with the Allegheny pot is shown by the chemical analysis. The latter has been poured from a high carbon (0.69%) steel whereas the former corresponds to the 0.25-0.35 carbon required by the blueprint. The dilatometer curves show the relative expansion and contraction of the two steels at different temperatures. It is interesting to note that if the pots are kept for any length of time in service at temperatures between 1373° - 1472° F. (745° - 800° C.) the low-carbon steel would be subjected to greater internal change. The volumetric change for the high-carbon steel would be merely due to thermal change whereas for the low-carbon pot it would be the sum total of thermal change plus change induced from being within the critical range 1341°-- 1472° F. (727° - 800° C.).* If this hypothesis is correct the high-carbon steel should be superior.

Another factor to be considered is the possibility that the pots are varying in the thickness of the section at the bottom. The thinner the section the less internal stress due to thermal change would be encountered. It is also felt that a greater life could be secured by heating up the pots more slowly. It is interesting to note that the outside of the pot is heated to the point of fusion. Evidence of burnt metal was seen under the microscope.

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* See Figure 2.

CONCLUSIONS:

1. The Hull pot is cast from 0.28 carbon steel and was not cast solidly.

2. The temperature of the Hull pot was over its point of fusion at the place where cracking occurred.

3. The Allegheny-Ludlum pot is cast from an 0.69 carbon steel.

4. The Hull pot has a hardness of 159 Brinell whereas the Allegheny pot is 223.

5. Differences in the thermal behaviour of the two steels may account for the difference in life of a well-cast Hull pot (1100 hours) and the American pot.

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Recommendations:

1. Hull should cast a pot from a higher carbon heat of steel and a careful record of its performance should be made.

2. The foundry should investigate their technique. Careful examination should be made of the condition of the casting at the line of failure approximately 15 inches from the bottom of the pot.

3. Care should be taken in heating up the pots.

4. Consideration should be given to the possibility of using somewhat thinner sections, having due regard, of course, to safety in service.

5. A close check should be made of the weights of pots going into service. A correlation of weight of pot to service life might prove useful.

6. Chemical analysis should be made of other Allegheny-Ludlum pots to establish whether they are always made of high-carbon steel.

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