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CUPOLA OPERATION AT STITTSVILLE FOUNDRY LIMITED

by

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PHYSICAL METALLURGY DIVISION

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SUMMARY OF RESULTS

Several heats of cast iron produced in a cupola were observed and data was obtained from six of the heats in order to improve the cupola operation and upgrade the quality and strength of the iron produced. Several changes were made in the operation so that a Class 30 iron could be produced, and the necessary steps, which should be maintained, were outlined so that consistent production of good quality iron could be realized.

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INTRODUCTION

A letter was received requesting assistance and advice in regard to the cupola operation at the Stittsville Foundry. This is a relatively new foundry and the personnel involved were not familiar with techniques used to produce high quality cast iron. In particular, they were interested in producing a Class 30 iron. The writer observed several heats being made at the foundry and took certain measurements and certain modifications to the melting procedure were made. This report outlines the details of these visits and the changes either made or recommended.

GENERAL

The cupola is a Whiting No. 6, lined down to an internal diameter of 36 inches. Rear slagging is employed in the operation. Some other pertinent data on the cupola is given below.

Height	- bottom to bottom of tuyeres		- 15 in.
Height	- top of tuyeres to charging door		- 18 ft.
Tuyere dimensions	- 5 - 11 in. x 6 in.		
	1 - 9 in. x 6 1/2 in.		
Total tuyere area	- 388 sq. in.		
Bed height used	- approx. 48 in.		
Charge -	M-225 pig*	- 150 lb.	
	Returns	- 100	
	Cast iron scrap	- 250 lb.	
		500 lb.	
	1 Silicon briquette per charge (2 lb Si)		
	Coke - approx. 50 lb.		

* M 225 pig - T.C. - 3.60% min.
Si - 2.25/2.49%
Mn - 0.7/1.00%

The data obtained on the heats observed are given below. A total of six heats was observed.

Heat No. 1

This heat was made using normal practice. The only change made was to reduce the amount of silicon added to one-half of a briquette for the first half of the heat and none to the remainder. This would allow the determination of both reduced silicon content and silicon recovery in the cast iron. Melting rate was 3.4 tons per hour and the maximum metal temperature was about 2600°F.

Heat No. 2

The charge weight was increased to 800 lb so that 80-lb coke splits could be used and still maintain a 10:1 metal to coke ratio; 80 lb of coke is the minimum suggested for a 36-inch cupola. In addition, 15 lb limestone was added with each charge. No silicon was added. The bed height was lowered to 36 inches. A mercury manometer was used to measure the windbox pressure. This reading was 1 1/4 in. to 1 3/8 in. mercury during the heat. The maximum temperature recorded was 2580°F and the melting rate was 3.6 tons per hour.

Heat No. 3

The charge make-up was altered by adding 50 lb of steel scrap, replacing 50 lb pig iron, i.e.,

Pig	190 lb
Steel	50 lb
Scrap iron plus returns	560 lb
	800 lb

Limestone was increased to 18 lb as the slag was somewhat thick in heat No. 2. A one-half briquette of silicon was added to compensate for that lost when the pig was reduced. The bed height was 36 inches. Also the tuyere area was reduced from 388 sq.in. to 252 sq.in. by inserting a wedge in the middle of each tuyere. The windbox pressure was 1-1/4 inches mercury. It was thought that a higher windbox pressure would have been obtained because of the smaller tuyere area. Unfortunately, a new shipment of coke was used, which was too large. The lumps were about 5 inches to 7 inches instead of 3 inches to 4 inches. Melting rate was 4.25 tons per hour and the maximum temperature recorded was about 2625°F.

Heat No. 4

The bed height was raised to 42 in. from 36 inches for heat 4. The windbox pressure was up slightly to 1 3/8 inches mercury. Melting rate was 4.25 tons per hour and the temperature was 2610°F.

Heat No. 5

The bed height was raised to 48 inches and 3/4 of a silicon briquette were added to each charge. Difficulties were encountered with closing the tap hole and so no other details of the heat were recorded.

Heat No. 6

The bed height was reduced to 42 inches as a very high carbon content was obtained on heat 5. Windbox pressure was about 1-1/4 inches mercury, and the maximum temperature recorded was about 2560°F. Melting rate was 4 tons per hour.

Two 1.2 inch diameter arbitration bars were poured during each heat except for heat 5. These were broken in a transverse test (18 inch centres) and then a tensile bar was machined from a broken half. In all cases, bar "A" was poured early in the heat and bar "B" late in the heat. The Brinell hardness number was obtained from a sample also cut from the transverse test bar. The carbon equivalent was calculated assuming a phosphorus content of 0.25%. This figure was found to be typical of the metal produced, although phosphorus analyses were not taken on each heat. The chemical composition and mechanical properties obtained are tabulated in Table 1.

TABLE 1

Analyses and Mechanical Properties of Heats Tested

Heat No.	Analyses, %			Transverse Test		UTS psi	Brinell Hardness
	T.C.	Si	C.E.*	Break Load, lb	Deflection Inches		
1A	3.94	2.40	4.86	1575	0.231	22,200	187
1B	3.94	2.28	4.78	2175	0.150	31,500	207
2A	3.64	2.17	4.45	1300 (flaw)	0.165	24,400	179
2B	3.61	2.21	4.43	1800	0.200	24,800	192
3A	3.32	1.91	4.04	2150	0.290	30,900	197
3B	3.37	1.92	4.09	2250	0.250	35,900	217
4A	3.52	2.00	4.27	1800	0.207	29,700	207
4B	3.50	1.86	4.20	2300	0.263	37,000	217
5	4.02	2.12	4.80	-	-	-	207
6A	3.47	2.15	4.27	1700 (flaw)	0.215	25,100	185
6B	3.45	2.15	4.25	2150	0.310	31,800	197

* C.E. = carbon equivalent = $\% \text{T.C.} + \frac{(\% \text{Si} + \% \text{P})}{3}$

DISCUSSION

It is difficult to state, with the results obtained to date, what the best charge make-up and bed height should be to assure the production of Class 30 iron, since data are available from six heats only. Also, these heats have all been quite short, melting anywhere from under 2 tons to 3 1/2 tons of metal. There is not sufficient time in such small heats for operating conditions to become uniform. Examination of the results shown in Table 1 show that the test bars taken late in each heat are always of a higher strength, probably due to a combination of higher temperature and cleaner metal. In other words, a bigger heat would likely mean the production of higher quality metal, even if no other changes were made.

The total carbon content, although affected by alterations in the charge make-up, is also dependent on the bed height, as might be expected. The two highest carbon contents, Heats 1 and 5 coincided with the highest bed height tried (48 inches). The lowest total carbon resulted in Heat 3 where a bed height of 36 inches was used and steel was added to the charge.

It should be pointed out, however, that the bed height is not determined by the effect on carbon pick-up, as much as by the time required for melting to start after the wind is put on. A proper bed height should result in a continuous stream of metal in from 8 to 10 minutes. The time for a continuous stream in the heats examined here were all within this time, i.e., at a bed height of 36 inches, the first continuous stream started in 8 minutes, and for a 48-inch bed height it took 10 minutes. The 42-inch bed height resulted in a continuous stream after 9 minutes. These figures should change when a smaller size coke is used, so that it should be possible to determine the optimum bed height more precisely. Based on the time for a continuous stream and carbon pick-up, the bed height should be in the range of 39 to 42 inches, using the large coke. Use of smaller coke could reduce this figure.

The composition of the metal produced can be calculated with reasonable accuracy provided that the charges are accurately weighed. If care is not taken in weighing the raw materials, then the composition of the resulting metal will not be consistent. Calculations forHeat 3 are shown below in Table 2 to illustrate the technique employed. In normal practice, one can expect a 10% increase in the carbon over that charged, a 10% loss of silicon and about a 20% loss of manganese. The closeness of the actual and estimated analyses indicates the correctness of these gains and losses and also indicates the accuracy with which a given analysis can be produced if care is taken in weighing.

No information was available on the blower. It is a positive displacement type, but no name plate or other information could be found. Consequently, the amount of air being delivered to the cupola is not known. Based on the melting rate, iron to coke ratio, and temperature of the molten metal, it is probably of the order of 1500 cu ft/min. The melting rate and temperature could be readily increased by increasing the air volume.

Based on the data obtained from these six heats, Class 30 (i.e. 30,000 psi ultimate tensile strength) iron can be readily produced provided (1) that the first metal is not used to meet this specification (2) that the carbon equivalent is below 4.27 and, (3) that the hardness is above 200 BHN. In order to produce a readily machineable Class 30 iron, the carbon and silicon should be in the ranges of 3.30 to 3.50% and 1.90 to 2.30% respectively when pouring sections from 3/4 to 1-1/2 inches. Lower carbon equivalent irons should be used for heavier sections and higher carbon equivalent irons for lighter sections.

TABLE 2

<u>Charge Calculations for Heat 3</u>

Charge Material	Weight lb	Carbon %	Carbon Weight in lb	Silicon %	Silicon Weight in lb	Manganese %	Manganese Weight in lb %
Pig Iron	190	3.60	$\frac{190 \times 3.60}{100} = 6.85$	2.35	$\frac{190 \times 2.35}{100} = 4.46$	0.85	$\frac{190 \times 0.85}{100} = 1.62$
Steel	50	0.20	$\frac{50 \times 0.20}{100} = 0.10$	0.10	$\frac{50 \times .10}{100} = 0.05$	0.60	$\frac{50 \times 0.60}{100} = 0.30$
Scrap + Returns	560	3.10	$\frac{560 \times 3.10}{100} = 17.40$	2.25	$\frac{560 \times 2.25}{100} = 12.60$	0.50	$\frac{560 \times 0.50}{100} = 2.80$
Silicon	1/2 briquette				1.00		
Totals	800		24.35		18.11		4.62
% Charged			$\frac{24.35}{800} \times 100 = 3.04$		$\frac{18.11}{800} \times 100 = 2.26$		$\frac{4.62}{800} \times 100 = 0.58$
% Loss or Gain			3.04 x .10 = +.30		2.26 x -0.10 = -.23		0.58 x -.20 = -.12
Estimated Final Analysis			3.34		2.03		0.46
Actual Final Analysis			3.37		1.92		0.44

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