

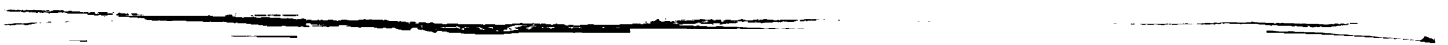
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HEAT BALANCE ON THE FOUNDRY CUPOLA

AT

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By

F. H. Prescott

H. E. Spurr

R. E. Decker

R. E. Olin.

Candidates for the Degree

of

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THESIS

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HEAT BALANCE ON FOUNDRY CUPOLA.

The object of this thesis is to show the sources of heat and the heat distribution in the foundry cupola; also the amount of loss and gain in the constituent elements of the iron from the charging door to the spout. Our tests, which were made upon the College Cupola, have shown that about twenty percent of the available heat goes to melt the iron, the largest of the remainder going into the stack gases. It was also determined that the elements in the charged irons all decreased more than the iron itself, except sulfur which showed an increase due to the high percentage of sulfur in the coke used.

The apparatus and methods used in determining these results were rather simple. See illustration. The results of the tests were secured by measuring the following quantities as indicated.

Charging Floor:- Weighing of iron and coke charged by platform scales.

Analysis of stack gases at charging door. The gases were drawn through a set of pipes by means of an aspirator and were later analyzed in an Orsat apparatus. The method of analyzing the gas used on the first tests was to draw the gas directly into the Orsat apparatus and analyze at once. The results were very unsatisfactory due to trouble in getting a good sample, and the time necessary to analyze the gas.

A new method was then devised as follows: A bottle with a two hole stopper, in which two glass tubes, one short and one long, had been inserted, was filled with water and connected with an aspirator suction and the sample pipe. The suction draws the gas from the stack into the bottle, displacing the water. The samples can then be analyzed as convenient, which makes a satisfactory method.

The temperature of the gases at the charging door was measured by a pyrometer. The photograph shows the arrangement of the apparatus.

Blast and Blower:- The velocity and pressure of the blast was measured in the blast pipe by means of a pitot tube. From this data, the weight of air used during the test was calculated. The humidity was measured by a whirling hygrometer, the temperature of the entering air was also measured, and the horse-power required to drive the fan was measured by means of a voltmeter and ammeter. The R. P. M. of the motor was taken and from it the R. P. M. of the fan was calculated.

In the first two tests, the fan was set close to the cupola and the short length of pipe made it impossible to get good reliable readings of the pitot tube without making a traverse. To correct this condition, the fan was moved back from the cupola and a longer piece of pipe used, the pitot tube being fastened in permanently. The result was a more satisfactory set of readings.

At the cupola spout, it was necessary to weigh the iron and determine its temperature. The weighing was first done on a platform scale, the iron being lifted in the bull-ladle each time and set upon the scale to be weighed by means of the crane. The tare weight of the ladle was also taken. The time taken by the method made it very objectionable to the proper handling of the cupola iron, and a spring scale, which was suspended from the crane, was substituted and eliminated any necessity for changing the position of the bull-ladle. In this scale, the spring elongation was connected by a wire so as to turn a pointer on a circular scale. The apparatus was found to weigh within one or two pounds of correct weight, and its capacity was about 2,000 pounds.

The measurement of the temperature of the molten iron was to have been accomplished by means of a special pyrometer, having a platinum rhodium couple. The main difficulty in the use of this pyrometer was the fact that it took about fifteen minutes to heat through the fire clay tube, which surrounded the couple, and this made the readings somewhat doubtful. Again, the clay tube was broken twice and when the pyrometer was first used the instrument had a short circuit and the readings of the voltmeter were too low. The readings, which the instrument registered, were also hard to use because of the fact that the specific heat of the molten iron was not accurately known, and could not be determined by the apparatus at hand.

Analysis: In the analysis of the various iron of the coke and stack gas, the work was done in the Chemistry Building, under the direction of Mr. W. F. Wood, As at first planned, the analysis of the irons used was to have been made for each test, but the difficulties encountered made it impossible to analyze more than four samples of iron in the time given. The results, which were finally secured, were only fair as to accuracy and would never have been gotten except for the kind assistance of Mr. Yonker, the Chemist of the Reo Motor Car Company. Some trouble was also encountered, due to poor chemicals, and it was necessary to secure some chemicals at the Reo Motor Car Company. In making determinations, the methods employed were substantially those employed by the U. S. Steel Corporation, as described in the "Transactions of the American Institute of Mining Engineers".

Determinations of Total Carbon. (See illustration). This was done by direct combustion in a current of oxygen at 1000°C, the carbon-dioxide being absorbed in a special soda lime and the change in weight being taken as due to the carbon-dioxide absorbed. The combustion takes place in a fused quartz tube, 24 inches long, which is heated by a Hoskins Electric Furnace. The tube used was only one-half inch in diameter, which is rather small, a 7/8 inch tube being recommended. The sample was placed in a porcelain boat about 1/4 inch wide by 2 1/2 inches long. This size of ^{boat} was

rather small for a one grain sample, and the result of using it was frequent trouble with spilling of the oxide and breaking of the boat. The oxygen was sent through the train from a gasometer at the rate of about 500 cc. per minute. The oxygen was first purified of CO_2 and moisture by passing through KOH , Ca Cl_2 and Soda lime, (Na OH ; CaO). It then passed through a Mercury seal and over the sample. The products of combustion then passed through metallic zinc and phosphoric anhydride, (P_2O_5), which were for the purpose of removing any acids or moisture present after combustion. Thence the gases passed to the absorption apparatus which consisted of a number of layers of a preparation of Na OH , Ca(OH)_2 and H_2O from the J. T. Baker Chemical Company. In the same tube, (as used at the Ree Motor Car Company), was placed some P_2O_5 to absorb any moisture which might be formed upon the absorption of CO_2 . The absorption tube was weighed before and after each combustion.

The gas was next passed through a wash bottle filled with KOH , which gave a means of telling how fast the oxygen was passing over, and whether any leaks were present. The actual combustion was found to take about two or three minutes, and the oxygen was passed for about five minutes before and about ten minutes after combustion. It can be seen that once this apparatus has been set up it ought to be possible to run all the determinations wanted in about one afternoon. Nevertheless, it took about 140 hours of

work to make four determinations and to get them to check. This was due to the necessity of making substantial changes in the set-up in order to secure a larger supply of oxygen and the operation of the furnace at too low a temperature, when it was impossible to get the iron to burn properly.

Determinations of manganese and sulphur were made as outlined by the U. S. Steel Corporation in the "Transaction of the A. I. E. E.". All other determinations were made as outlined in Blair's "Chemical Analysis of Iron and Steel".

The following references were used as preliminary reading and were constantly referred to in making calculations:

"Chemical Analysis of Iron and Steel". A. A. Blair.

"Methods of the U. S. Steel Corporation for the Sampling and Analysis of Pig Iron". J. L. Camp. A. I. E. E.

"Metallurgical Calculations". Parts I and II.

J. W. Richards.

"Fuel Efficiency in the Cupola Furnace".

J. J. Porter, A. I. E. E.

"Foundry Cupola Gases and Temperatures". Bul. 54,

U. S. Bureau of Mines.

"Metallurgy of Iron and Steel". B. Stoughton.

"Melting Iron in Cupola Furnace."

Dr. R. Moldenke, A. I. E. E.

"Transactions of American Foundrymen's Association -
1908.

**"Transactions of American Institute of Mining
Engineers". Vol. 36, Page 454.**

"Principles of Metallurgy". C. H. Fulton.

METHODS OF CALCULATION.

The first step in calculating the heat balance is to make a materials balance. This is done first by computing the weight of each element charged per thousand pounds of iron charged. The analysis of iron, coke and the humidity of the blast are used to determine this. The iron delivered at the spout per one thousand pounds charged is calculated and from its analysis the elements delivered here are determined. The weight going into the blast and slag is determined by difference, all Fe, Si and Mn charged which does not go into the molten iron is assumed to go into the slag as oxides, and the S and P, and ash in the coke into the stack gases.

The percent of carbon burned to CO_2 and the percent burned to CO is determined by the analysis of the stack gases, and from it the weight of CO and CO_2 is determined.

From the materials balance sheet the sources of heat, and the heat used and lost are determined. The same sources of heat are sensible heat in the materials charged, the heat ^{of} formation of iron, slag, etc., and the heat of combustion of fuel charged.

The sensible heat of a substance is the heat which is necessary to raise it from zero degrees F, to the temperature at which it is charged.

The heat of formation ^a of substance is the heat which is liberated by oxidization.

The heat of combustion of fuel is taken heat which is liberated when the fuel is completely burned.

The heat used and lost is the sum of the heat used in melting the iron, the heat used in melting slag, the heat necessary to heat up cupola lining, and the heat lost in the stack gases in unburned CO, in superheating moisture, and in radiation.

The heat used in melting iron and slag is calculated in three parts: (1) the heat to heat iron to melting point; (2) the heat of fusion, and (3) the heat used to heat the liquid.

The heat to heat up the cupola lining is determined from the weight, specific heat, and mean temperature of the lining.

The heat lost in the sensible heat in the stack gases is determined from the weight of stack gases, and their specific heat and temperature.

The potential heat in unburned CO is determined from the weight of CO gas and the potential heat per pound .

The heat necessary to superheat moisture is determined from the temperature and the mean specific heat.

**Table of values of heat in computations in B. t. u. per
pound.**

Heat of fusion of slag.....	160.0
Heat of fusion of iron.....	41.4
Heat of burning iron.....	2112.0
Heat of burning silicon.....	12000.0
Heat of burning manganese.....	2375.0
Heat of burning coke.....	12130.0
Heat of burning wood.....	7200.0
Heat of burning CO.....	4370.0

Table of Specific Heats.

Coke.....	0.16
Iron (solid).....	0.12
Iron (molten).....	0.24
Blasht.....	0.237
Cases.....	0.272

TEST NO. 1. Balance Sheet per 1000 lb. of iron charged.

Charges		Castings	Slag	Gases
Total Pig Iron	458.500:			
Fe	423.526:			
Si	9.640:			
Mn	3.620:			
Total C	19.250:			
P	2.390:			SO ₂ 4.220:
S	0.074:			CO ₂ 374.000:
Scrap Iron	541.500:	Fe 882.784	FeO 60.20:	CO 65.100:
Fe	506.130:	C 33.400		O 121.460:
Si	9.920:	Si 15.800:	SiO ₂ 7.96:	
Mn	2.540:	Mn 3.670	MnO 3.21:	
Total C	19.300:	P 4.650		
P	3.200:	S 0.696		
S	0.410:			
Coke	151.400:			
C	124.767:			
S	2.330:			
Ash	22.700:			Ash 22.700:
H ₂ O	1.603:			H ₂ O 1.603:
Blast	1970.000:			
O ₂	450.000:			
N ₂	1510.000:			N ₂ 1510.000:
H ₂ O	10.000:			H ₂ O 10.000:
Total	3121.400:	941.000	71.37:	2109.083:

TEST NO. 2. Balance Sheet per 1000 lbs. of iron charged.

Charges		Castings		Slag		Gases	
Total Pig:	455.50						
Fe	420.89						
Si	9.56						
Mn	3.60						
C	19.10						
P	2.28						
S	0.07					SO ₂	4.54
Scrap	544.50	Fe	208.40	FeO	60.38	CO ₂	307.00
Fe	508.92	C	34.65			CO	60.20
Si	9.97	Si	17.38	SiO ₂	4.36		225.40
Mn	2.56	Mn	3.71	MnO	3.16		
C	19.42	P	4.68				
P	3.22	S	0.70				
S	0.41						
Coke	161.30						
C	133.20						
S	2.49						
H ₂ O	1.71					H ₂ O	1.71
Ash	24.20					Ash	24.20
Blast	2065.00						
H ₂ O	8.00					H ₂ O	8.00
O ₂	473.00						
U ₂	1583.00					U ₂	1583.00
Total	3226.30		949.5		67.90		2214.05

TEST NO. 3. Balance sheet per 1000 lb. of iron charged.

40067 charged.									
Charges		Castings		Slug		Gases			
Total									
Pig Iron	235.000								
Fe	217.101								
Si	4.941								
Mn	1.860								
C	9.830								
P	1.830								
S	0.038						SO ₂	5.300	
Scrap Iron	765.000	Fe	893.066	FeO	50.250	CO ₂	382.000		
Fe	715.118	C	31.000	SiO ₂	12.700	CO	97.800		
Si	14.000	Si	13.000	PnO	2.750	O	95.425		
Mn	3.600	Mn	3.320						
C	27.200	P	4.180						
P	4.500	S	0.630						
S	0.582								
Coke	173.000								
C	139.900								
S	2.660								
Ash	28.600					Ash	28.600		
H2O	1.840					H2O	1.840		
Blas	1960.000								
H2O	13.100					H2O	13.100		
O2	449.000								
H2	1497.900					H2	1497.900		
Total	3133.000		945.196		165.700		12121.965		

TEST NO. 4. Balance sheet per 1000 lb. of iron charged.

Charges	Charges	Castings	Slag	Gases
Total Pig 119.00	Coke 167.70			
Fe 110.00	C 138.20			
Si 2.40	S 2.58			
Mn 0.94	H2O 1.92			H2O 1.78
C 4.99	Ash 25.15			Ash 25.15
P 0.60	Blas 1803.00			
S 0.02	H2O 26.00			H2O 26.00
Spec. Pig 63.90	O2 409.00			
Fe 59.90	N2 1368.00			N2 1368.00
Si 0.83		Fe 890.00	FeO 56.10	
Mn 0.57		Si 15.93	SiO2 4.77	
C 2.48		Mn 3.70	MnO 2.13	
P 0.09		C 34.60	CaS 1.50	
S 0.01		P 4.65		SO2 3.60
Scrap 817.10		S 0.70		CO2 289.90
Fe 763.70				CO 72.00
Si 14.95				O 162.50
Mn 3.84				
C 29.10				
P 4.82				
S 0.62				
Flux 2.15				
CO2 0.90				CO2 0.90
CaO 1.25				
Total	2972.90	949.5	64.5	1948.50

TEST NO. 5. Balance sheet per 1000 lb. of iron charged.

Charges	Charges	Castings	Slag	Gases
Total Pig: 181.10	Coke : 187.00			
Fe : 167.30	C : 154.14			
Si : 3.80	S : 2.88			
Mn : 1.43	H ₂ O : 1.98			H ₂ O : 1.98
C : 7.60	Ash : 28.00			Ash : 28.00
P : 0.96	Blast : 2285.00			
S : .03	H ₂ O : 28.60			H ₂ O : 28.60
Spec. Pig: 78.40	O ₂ : 526.00			
Fe : 73.15	N ₂ : 1730.40			N ₂ : 1730.40
Si : 1.02		Fe: 880.00	FeO : 67.00	
Mn : 0.70		Si : 15.80	SiO ₂ : 5.40	
C : 3.40		Mn : 3.70	MnO : 2.50	
P : 0.12		C : 34.30	CaS : 1.90	
S : 0.03		P : 4.60		SO ₂ : 4.00
Scrap : 740.00		S : 0.70		CO ₂ : 253.50
Fe : 691.70				CO : 145.20
Si : 13.53				O : 264.00
Mn : 3.48				
C : 26.40				
P : 4.36				
S : 0.56				
Flux : 2.60				
CaO : 1.46				
CO ₂ : 1.14				CO ₂ : 1.14
Total	3474.10	939.10	76.80	2456.84

TEST NO. 6. Balance sheet per 1000 lb. of iron charged.

3850% Charged.

Charges	Charges	Castings	Slag	Gases
Tot. Pig	246.000	Coke 187.00	Fe 871.532	
Fe	227.325	C 154.14	Si 15.600	
Si	5.166	S 2.88	C 34.000	
Mn	1.940	Ash 29.00	Mn 3.630	Ash 28.00
C	10.300	H2O 1.98	P 4.550	H2O 1.980
P	1.230	Blast 2010.00	S 0.688	
S	0.039	H2O 23.00		H2O 23.000
Spec. Pig	78.500	O2 458.00		
Fe	73.406	N2 1529.00		N2 1529.000
Si	1.200			
Mn	0.700			SO2 3.886
C	3.050		FeO 77.5	CO2 317.000
P	0.118		SiO2 6.70	CO 89.900
S	0.026		FeO 12.96	O 153.955
Scrap	675.500		CaS 1.87	
Fe	631.204			
Si	12.400			
Mn	3.280			
C	24.000			
P	4.000			
S	0.516			
Flux	2.600			
CO2	1.140			CO2 1.140
CaO	1.460			
Total		3199.60	930.000	89.03
				2147.861

Heat Balance for Test No. 6.

1. Heat of combustion of fuel. - Total heat evolved =
12130 x lb. of coke burned + 7,200 x lb. of wood burned.

Hence B. t. u. per pound of iron charged =

$$12130 \times 0.187 + 7,200 \times 0.0215 = 2424.$$

2. Oxidation of iron to FeO . - Melting loss in iron =
6.04%. Then B. t. u. per pound of iron charged =

$$0.0604 \times 2112 = 127.0.$$

3. Oxidation of silicon to SiO_2 . - Melting loss in
silicon = 0.316%. Then B. t. u. per lb. of iron charged =

$$0.00316 \times 12600 = 40.0$$

4. Oxidation of manganese to MnO . - Melting loss in
manganese = 0.229%. Then B. t. u. per lb. of iron charged =

$$0.00229 \times 2975 = 6.8.$$

5. Sensible heat in coke. - B. t. u. per lb. of iron
charged = $0.187 \times 68 \times 0.16$ per lb. of iron charged = 2.03

6. Sensible heat in iron. - B. t. u. per lb. of iron
charged = $1 \times 68 \times 0.12 = 8.16.$

7. Sensible heat in blast. -

$$V = 66.2 \, h_v^{\frac{1}{2}} \left(\frac{460 + t}{520} \right)^{\frac{1}{2}} 0.92$$

V = velocity of air in feet per second.

h_v = velocity head in inches of water.

t = temperature of entering air.

$$\text{Then } V = 66.2 (1.63)^{\frac{1}{2}} \left(\frac{460 + 68}{520} \right)^{\frac{1}{2}} 0.92.$$

$$= 66.2 \times 1.28 \times 1.005 \times 0.92 = 78.4.$$

Area of pipe = 48.7 sq. inches.

$$\text{Volume} = \frac{78.4 \times 48.7 \times 12 \times 60}{1728} = 1590 \text{ cu. feet per minute.}$$

Time of test - 64 minutes.

$$1590 \times 64 = 102,000 \text{ cubic feet of air used during test.}$$

Relative humidity = 80.6

Pounds of moisture per cubic feet of air equals 0.00086.

$$\text{Total weight of air used} = \frac{144 \times 14.85 \times 102,000}{53.34 \times 528} = 7720 \text{ lbs.}$$

$$\text{Weight of moisture in air} = 0.00086 \times 102,000 = 88 \text{ lbs.}$$

$$\text{Weight of dry air used} = 7720 - 88 = 7632 \text{ lbs.}$$

B. t. u. per lb. of iron charged =

$$7632 \div 3856 \times 68 \times 0.237 = 32.0$$

8. Sensible heat in moisture of blast. - Pounds of moisture per lb. of iron charged = 0.023.

$$\text{Total heat} = 1089.4 \text{ B. t. u. per lb.}$$

Then B. t. u. per lb. of iron charged =

$$0.023 \times 1089.4 = 25.0$$

9. Heat and formation of slag. - This is a matter of some uncertainty, but is of minor importance. The heat of formation of $\text{CaO} + \text{SiO}_2$ is 278 B. t. u. per lb., and if $\text{FeO} + \text{SiO}_2$ is B. t. u. per lb. and if we assume that the slag consists of equal parts of each and that we have 0.089 lb. of slag made per lb. of iron charged, then the heat of formation of the slag is in B. t. u. per lb. of iron

charged $0.089 \times 200 = 17.8$.

1a. Heat in molten iron. - Specific heat of solid cast iron = 0.12

Specific heat of molten iron = 0.24.

Melting point 1950°F.

Temperature of iron issuing from spout 2138°F.

B. t. u. per lb. of iron charged =

$$0.93 (1950 \times 0.12 + 41.4 + 188 \times 0.24) = 298.$$

2a. Heat in molten slag. - B. t. u. per lb. of slag = $1 \times [t \times (0.17 + 0.0000t) + \text{latent heat of fusion} + (t' - t) 0.35]$, where t = melting point of slag or say 2000°F., and t' = the temperature at which it issues from the cupola, or say 2250°F.

Hence B. t. u. per lb. of iron charged =

$$0.089 (2000 \times 0.25 + 160 + 250 \times 0.35) = 0.089 \times 747.5 = 66.5$$

3a. Heat to evaporate moisture in coke. - B. t. u. per lb. of iron charged = $0.187 \times 0.0106 \times 970 = 1.92$.

4a. Heat stored up in lining. - The weight of the lining below the charging door figures out to approximately 5410 lbs. Estimating its average temperature to be 1000°F., the B. t. u. per lb. of iron charged = $\frac{5410}{3850} \times 1000 \times$

$$(0.193 + 0.000043 \times 1000) = \frac{5410}{3850} \times 1000 \times 0.234 = 329.0.$$

5a. Heat to superheat steam in the moisture. B. t. u. per lb. of iron charged = $25.0 + (0.49 \times 1764 \times 0.023) =$

$$25.0 + 19.9 = 44.9$$

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6a. Heat sensible in gases. - Average specific heat =
 $0.23 + 0.000023t = 0.23 + (0.000023 \times 1822) = 0.23 + 0.042 =$
 0.272. Then B. t. u. per lb. of iron charged =

$$2.1478 \times 1822 \times 0.272 = 1065.0.$$

7a. Heat potential in gases. - B. t. u. per lb. of iron
 charged = $0.0899 \times 4370 = 393.0.$

8a. Radiation and error. - This amount is found by dif-
 ference to be B. t. u. per lb. of iron charged.

Summarizing these items, we get the following heat
 balance express in B. t. u. per lb. of iron charged:

Sources of heat		Heat Used and Lost.	
1. Combustion of fuel	2424.00	1a. In molten iron	298.00
2. Oxidation of iron	127.00	2a. " " slag	66.50
3. " " Si	40.00	3a. To evaporate moisture	1.92
4. " " Mn	6.80	4a. To heat up lining	329.00
5. Sensible in coke	2.03	5a. To superheat vapor	44.90
6. " " Fe	8.16	6a. Sensible in gases	1065.00
7. " " blast	32.00	7a. Potential " "	393.00
8. " " moisture	25.00	8a. Radiation and error	484.47
9. Formation of slag	<u>17.80</u>		
	2682.79		<u>2682.79</u>

TEST NO. 1.

Heat Balance Per Pound of Iron Charged.

Sources of Heat		Heat Used and Lost.	
1. Combustion of fuel	2180.00	1a. In molten iron	426.00
2. Oxidation of iron	98.60	2a. " " slag	53.30
3. " of Silicon	47.50	3a. To exaporate H2O	1.55
4. " " Ln	7.40	4a. To heat up lining	380.00
5. Sensible in coke	1.12	5a. To superheat vapor	16.60
6. " " iron	5.56	6a. Sensible in gases	682.00
7. " " blast	21.50	7a. Potential in gases	285.00
8. " " moisture	10.79	8a. Radiation and error	<u>496.65</u>
9. Formation of slag	<u>8.63</u>		
	2341.10		2341.10

TEST NO. 2.

Heat Balance Per Pound of Iron Charged.

Sources of Heat		Heat Used and Lost.	
1. Combustion of fuel	2221.60	1a. In molten iron	427.00
2. Oxidation of iron	87.50	2a. " " slag	50.80
3. " of Si	26.00	3a. To evâporate H2O	1.90
4. " " Ln	7.30	4a. To heat up lining	460.00
5. Sensible in coke	1.10	5a. To superheat vapor	13.90
6. " " iron	5.20	6a. Sensible in gases	634.00
7. " " blast	21.40	7a. Potential in gases	263.00
8. " " moisture	8.60	8a. Radiation and error	<u>536.30</u>
9. Formation of slag	<u>8.20</u>		
	2386.90		2386.90

TEST NO. 3.

Heat Balance Per Pound of Iron Charged.

Sources of Heat			Heat Used and Lost	
1. Combustion of fuel	2198.80	1a. In molten iron	427.00	
2. Oxidation " iron	88.60	2a. " " slag	49.10	
3. " " Si	75.00	3a. To evaporate H2O	1.79	
4. " " Mn	6.36	4a. To heat up lining	281.00	
5. Sensible in coke	1.64	5a. To superheat vapor	22.80	
6. " " iron	7.08	6a. Sensible in gases	780.00	
7. " " blast	27.20	7a. Potential in gases	428.00	
8. " " moisture	14.20	8a. Radiation and error	437.13	
9. Formation of slag	<u>7.94</u>			
	2426.82			2426.82

TEST NO. 4.

Heat Balance Per Pound of Iron Charged

Sources of Heat			Heat Used and Lost	
1. Combustion of fuel	2183.20	1a. In molten iron	527.50	
2. Oxidation of iron	92.00	2a. " " slag	48.30	
3. " " Si	28.40	3a. To evaporate H2O	2.00	
4. " " Mn	4.80	4a. To heat up lining	272.00	
5. Sensible in coke	2.10	5a. To superheat vapor	46.50	
6. " " iron	9.47	6a. Sensible in gases	715.00	
7. " " blast	33.20	7a. Potential in "	314.00	
8. " " moisture	28.40	8a. Radiation and error	564.10	
9. Formation of slag	<u>7.80</u>			
	2389.40			2389.40

TEST NO. 5.

Heat Balance Per Pound of Iron Charged.

Sources of Heat		Heat Used and Lost	
1. Combustion of fuel	2377.00	1a. In molten iron	425.00
2. Oxidation of iron	110.00	2a. " " slag	57.50
3. " " Si	32.20	3a. To evaporate H2O	2.30
4. " " Mn	5.80	4a. To heat up lining	329.00
5. Sensible in coke	2.20	5a. To superheat vapor	53.20
6. " " iron	9.00	6a. Sensible in gases	942.00
7. " " blast	39.40	7a. Potential " "	635.00
8. " " moisture	32.20	8a. Radiation and error	173.10
9. Formation of slag	<u>9.30</u>		
	2617.10		2617.10

TEST NO. 6.

Heat Balance Per Pound of Iron Charged.

Sources of Heat		Heat Used and Lost	
1. Combustion of fuel	2424.00	1a. In molten iron	298.00
2. Oxidation of iron	127.00	2a. " " slag	66.50
3. " of Silicon	40.00	3a. To evaporate H2O	1.92
4. " " Mn	6.80	4a. To heat up lining	329.00
5. Sensible in coke	2.03	5a. To superheat vapor	44.90
6. " " iron	8.16	6a. Sensible in gases	1065.00
7. " " blast	32.00	7a. Potential in gases	393.00
8. " " moisture	25.00	8a. Radiation and error	484.47
9. Formation of slag	<u>17.80</u>		
	2682.79		2682.79

General Data on M. A. C. Cupola.

1. Diameter of cupola, inside	24"
2. Diameter of cupola, outside	36"
3. Height of tuyeres, above bottom	10"
4. Height of charging door above tuyeres	93"
5. Ratio - $4 \div 1$	3.88
6. Number of tuyeres	6
7. Size of tuyeres - Vertical X horizontal	6" x 5"
8. Area of tuyeres	180 sq. in.
9. Ratio of cupola area to tuyeres area	2.5
10. Diameter of blast pipe	7.87"
11. Area of blast pipe	48.7 sq.in.
12. Fan type and speed - Sturtevant Blower Fan	2800 R. P. M.
13. Class of work done - Job castings	
14. Kind of fuel used - Coke.	

CUPOLA TEST DATA - M. A. C. CUPOLA

1. Test number	1	2	3	4	5	6
2. Blast pressure in cupola				6.75	7	6.75
3. Cu.ft. air input min.	1283	1302	1620	1512	1565	1590
4. Avg. humidity of air	78	70	62	66	66	80
5. Temp. of entering air F.	46	43	59	79	75	68
6. Temp. gases at charging door F.	1250	1100	1400	1110	1472	1238
7. H. P. M. of fan	2440	2440	2760	2690	2690	2630
8. Horse-power input, fan.	5.72	5.45	6.87	5.82	5.62	6.00
9. Wt. fuel on bed-lbs.	300	300	360	360	360	360
10. Wt. of iron on bed lbs	562	555	654	650	550	550
11. Wt. of flux				10	10	10
12. Wt. of fuel in charge subsequent to beds	60	60	60	60	60	60
13. Wt. iron in charges subsequent to beds	550	550	550	550	550	550
14. Total wt. of fuel -lbs.	600	590	780	780	720	720
15. Total wt. of iron-lbs.	3323	2755	4506	4650	3850	3850
16. Ratio of fuel to iron bed	1:1.87	1:1.85	1:1.81	1:1.81	1:1.15	1:1.5
17. Ratio of fuel to iron	1:5.5	1:5.1	1:5.78	1:5.95	1:5.35	1:5.35

Cupola Test Data - Continued.

18. Time before iron comes after blast is on	15	15	18	18	21	23
19. Lbs. iron melted per minute	60.4	65.8	71	77.6	66.9	67.4
20. Lbs. iron melt- ed per min. per sq. ft. cupola area	19.2	21	22.6	24.7	21.3	21.4
21. Temp. of iron at spout	?	?	?	?	?	2138

Chemical Changes of Iron Charged.

Test number	1	2	3	4	5	6
Per cent loss in Fe	5.04	4.45	4.19	4.68	5.6	6.48
Per cent loss in Si	19.2	11	31.4	12.2	13.9	16.8
Per cent loss in Mn	40.3	39.7	39.2	30.8	34	38.6
Per cent loss in C	13.4	10	16.2	5.4	8.3	9.2
Per cent loss in P	16.8	14.9	27	15.6	15.4	14.9
Percent gain in S	43.8	45.8	1.6	7.7	12.9	18.4

CONCLUSIONS

In good cupola practice, the first iron should come from seven to ten minutes after the blast is put on. The average time for the first iron in our tests was eighteen minutes. This leads us to believe that too much coke is put on the bed. Examples of modern cupola practice confirms this statement. Our iron melted per pound of coke is less than in comparative cupola practice. This makes our heat loss by radiation and error high.

Standard practice states that about one thousand cubic feet of air should be used per minute. We used about 1800 cubic feet per minute. By reducing the bed, we could reduce the amount of air used.

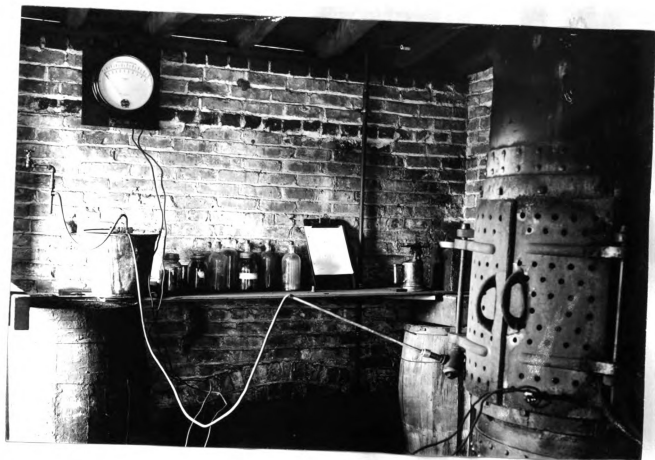
From our total heat balance, it is evident that the great source of wasted heat in the cupola is in the escaping gases. The temperature of the top gases depends on the amount of heat absorbed by the stack in proportion to the total amount generated. More heat is generated when C is burned to CO_2 .

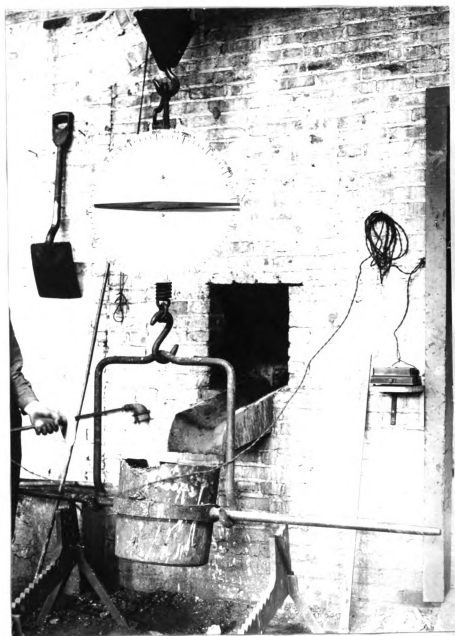
The rapid rate of blowing that was necessary to the formation of CO_2 increases the velocity of the gases and gives less opportunity for the absorption of heat by the stack.

As a final conclusion, we suggest that the fuel bed be cut down, and consequently the blast pressure. The peck-holes should be repaired so as to be air tight. If this is done, the fan can be run slower. We also suggest that in

charging, the cupola should be kept full to the charging door. This will eliminate a large part of the waste heat in top gases. Since a high sulfur coke is used, more limestone should be charged to reduce the sulfur in the castings.







MECHANICAL ENGINEERING LABORATORY
MICHIGAN AGRICULTURAL COLLEGE

Running Log of Heat Balance On Cupola - College Test No. 4

In Charge

Assistants

Observers

F. H. PRESCOTT

Date May 3 1945

NO.	Time	By Volume		By Vol.	
		% CO ₂	% O ₂	% CO	% O ₂
1	2.55	14.8	1.6	3.8	
2	3.07	12.4	1.8	5.7	
3	3.15	7.	12.4	0.7	
4	3.22	10.9	4.6	4.6	
5	3.25	11.4	6.2	2.7	
6	3.33	13.5	0.4	7.7	
7	3.38	12.3	3.9	3.7	
8	3.45	12.5	3.7	4.0	
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

Remarks:

MECHANICAL ENGINEERING LABORATORY
MICHIGAN AGRICULTURAL COLLEGE

Running Log of Heat Balance on Foundry Cupola.
Test No. 4.

In Charge

Assistants

Observers

F. H. Prescott

Date Apr 28, 1915

No.	Tappings	Time	Gross Wt. Iron + Scales.	Tare Wt. Scales.	Net Wt. Iron.	Wt. of Slag.	Wt. of Droppings.	Wt. of Iron in Slag.
1		2.53	463	257	206			
2		2.55	460	310	150			
3		2.57	480	310	170			
4		3.01	495	360	135			
5		3.02	540	470	70			
6		3.03	575	530	45			
7		3.08	605	282	323			
8		3.10	660	275	385			
9		3.15	610	275	335			
10		3.20	587	275	312			
11		3.23	600	354	246			
12		3.25	650	340	310			
13		3.29	625	312	313			
14		3.32	635	327	308			
15		3.37	615	264	351			
16		3.40	595	275	320			
17		3.45	595	280	315			
18		3.50	505	370	135			
19					4429			
20								

Remarks:

Blast on 2.34
First Iron 2.48

10# on floor.

MECHANICAL ENGINEERING LABORATORY
MICHIGAN AGRICULTURAL COLLEGE

Running Log of Heat Balance on Foundry Cupola.
Test No. 2.

In Charge

Assistants

Observers

F. H. Prescott

W. D. Thompson

Date Mar. 2 19 15

No. Tappings	Time	Temperature of Iron C.	Gross Wt. Iron + slag.	Tare Wt. Ladle.	Net Wt. Iron	Wt. of slag	Wt. of droppings	Wt. of Iron in slag	Wt. of unburned coke
1	1.55	970	566	230	330	70	298	181	95
2	2.02	1000	601	291	310				
3	2.06	1000	590	268	322				
4	2.10	1000	584	332	252				
5	2.15	900	600	333	267				
6	2.20	870	592	299	293				
7	2.25	950	640	312	328				
8	2.32		454	355	99				
9					100				
10					129				
11					2430				
12									
13									
14									
15									
16									
17									
18									
19									
20									

Remarks: 100# in small ladles at No. 7. Tap.
129# on floor at No. 7. Tap.

MECHANICAL ENGINEERING LABORATORY

MICHIGAN AGRICULTURAL COLLEGE

Running Log of *Heat Balance on Cypolast Test No. 2*

In Charge

Assistants

Observers

*R. E. Decker*Date *March 1913*

NO.	Pilot Tube								
	Time in min.	Pressure Head, H ₂ O	Difference	R.P.M. of Motor	Volts	Temp.	Wet Bulb	Dry Bulb	Temp.
Blast on									
1	1:40	7.6	2.1	1300	200	18.5	41.5	44.5	44
2	1:50	8.5	2.0	1230	200	18.5	39	43	43
3	1:55	8.1	2.15	1230	200	19.	37.5	42	43
4	2:00	8.6	2.	1300	201	18.5	37.5	42	43
5	2:05	9.2	1.95	1300	202	18.5	37.	41	43
6	2:10	8.95	2.0	1310	201	18.5	36.5	41.5	42
7	2:15	8.9	2.05	1300	201	19.	37.5	42.5	42.5
8	2:20	9.25	2.25	1310	200	20.5	37.5	41.5	42.5
9	2:30	5.5	3.25	1300	200	23.5	37.5	41.5	43
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									

Remarks:

MECHANICAL ENGINEERING LABORATORY

MICHIGAN AGRICULTURAL COLLEGE

Running Log of *Heat Balance on Cypolite - Test No. 4*

In Charge

Assistants

Observers

*R. C. Decker*Date *Feb. 28, 1915*

NO.	<i>Pitch Tube</i>									
	<i>Time in minutes</i>	<i>Pressure Head "H₂O"</i>	<i>Difference</i>	<i>R.P.M. of Motor</i>	<i>Volts</i>	<i>Amperes</i>	<i>Wet Bulb</i>	<i>Dry Bulb</i>	<i>Temp.</i>	<i>Cypolite Flow - g</i>
<i>Blast on</i> 1	<i>2:35</i>	<i>4</i>	<i>.5</i>	<i>1430</i>	<i>212</i>	<i>11</i>	<i>72</i>	<i>80</i>	<i>81</i>	<i>2.75</i>
2	<i>2:40</i>	<i>7</i>	<i>.3</i>	<i>1430</i>	<i>212</i>	<i>15</i>	<i>73</i>	<i>79</i>	<i>80</i>	<i>1.5</i>
3	<i>2:45</i>	<i>31</i>	<i>1.45</i>	<i>1425</i>	<i>212</i>	<i>19.5</i>			<i>80</i>	<i>6.5</i>
4	<i>2:50</i>	<i>36</i>	<i>1.9</i>	<i>1430</i>	<i>211</i>	<i>20</i>	<i>70</i>	<i>78</i>	<i>80</i>	<i>6.75</i>
5	<i>2:55</i>	<i>10.4</i>	<i>1.55</i>	<i>1430</i>	<i>209</i>	<i>19.5</i>			<i>80</i>	<i>6.75</i>
6	<i>3:00</i>	<i>10.6</i>	<i>1.75</i>	<i>1430</i>	<i>210</i>	<i>20</i>	<i>70</i>	<i>79</i>	<i>80</i>	<i>7</i>
7	<i>3:05</i>	<i>10.05</i>	<i>1.45</i>	<i>1430</i>	<i>211</i>	<i>20</i>			<i>80</i>	<i>7</i>
8	<i>3:10</i>	<i>11.2</i>	<i>1.9</i>	<i>1435</i>	<i>211</i>	<i>20</i>			<i>80</i>	<i>7.2</i>
9	<i>3:15</i>	<i>10.6</i>	<i>1.6</i>	<i>1440</i>	<i>212</i>	<i>21</i>			<i>80</i>	<i>6.75</i>
10	<i>3:20</i>	<i>11.35</i>	<i>1.9</i>	<i>1445</i>	<i>211</i>	<i>20.5</i>	<i>67</i>	<i>77</i>	<i>80</i>	<i>7</i>
11	<i>3:25</i>	<i>10.3</i>	<i>1.5</i>	<i>1440</i>	<i>212</i>	<i>21</i>			<i>80</i>	<i>6.8</i>
12	<i>3:30</i>	<i>11.3</i>	<i>1.9</i>	<i>1445</i>	<i>212</i>	<i>21</i>	<i>70</i>	<i>79</i>	<i>80</i>	<i>7.1</i>
13	<i>3:35</i>	<i>11.3</i>	<i>1.9</i>	<i>1445</i>	<i>212</i>	<i>21</i>			<i>80</i>	<i>7.2</i>
14	<i>3:40</i>	<i>11.2</i>	<i>1.91</i>	<i>1445</i>	<i>212</i>	<i>21</i>			<i>80</i>	<i>7</i>
15	<i>3:45</i>	<i>11</i>	<i>1.5</i>	<i>1445</i>	<i>212</i>	<i>21</i>			<i>80</i>	<i>6.75</i>
16	<i>3:50</i>	<i>10.3</i>	<i>1.5</i>	<i>1445</i>	<i>212</i>	<i>21</i>	<i>70</i>	<i>78</i>	<i>80</i>	<i>6.4</i>
17										
18										
19										
20										

Remarks:

MECHANICAL ENGINEERING LABORATORY

MICHIGAN AGRICULTURAL COLLEGE

Running Log of Test on Foundry Fan Connected
To Induction Motor

In Charge

Assistants

Observers

F. S. Spur
R. S. Decker

R. E. Olin
F. H. Prescott, Date Mar. 31, 1915

NO.	Pressure Head In. of H ₂ O	Vel. Head In. of H ₂ O	Amperes K = 5	Volts	Speed of Fan	Int. open or diameter.
1	14.3	0.75	1.50	212.5	2726	closed
2	12.5	1.30	2.75	211	2590	2"
3	6.1	2.45	4.20		2600	4"
4	1.15	3.00	5.50	200	2440	6"
5				232		open
6	12.9	0.65	1.30	235	2590	closed
7	12.0	1.10	2.00	237	2620	2"
8	6.3	2.40	3.05	238	2616	4"
9	1.3	3.40	3.73	237	2440	6"
10	-2.7	4.30	4.20	236	2432	open
11	10.15	0.45	1.15	232	2440	closed
12	9.6	0.82	1.58	232	2270	2"
13	5.2	1.95	2.30	230	2146	4"
14	1.1	2.75	2.70	228	2010	6"
15	-2.25	3.55	2.95	230	2150	open
16	7.4	0.30	1.20	228	1860	closed
17	7.1	0.60	1.42	228	1900	2"
18	3.9	1.45	1.78	226	1880	4"
19	0.9	2.10	2.00	225	1836	6"
20	-1.7	2.70	2.13	223	1810	open

Remarks:

MECHANICAL ENGINEERING LABORATORY

MICHIGAN AGRICULTURAL COLLEGE

Running Log of Heat Balance on Foundry Cupola
Test No. 4

In Charge

Assistants

Observers

R. E. Olson
H. Spurr

Date Dec. 28, 1915

	No. of charge	Weight of Fuel	Weight of Pig (T)	Weight of Pig (S)	Weight of Scrap	Total weight of Iron in charge	Time	Temperature of Gas, °C.	Number of Core Sample	Weight of Wind	Weight of Tails
<u>Bed</u>	1	360	186	104	350	650	2.50	610	1	8	10
	2	60	205	97	350	650	3.07	675	2	95	
	3	60	134	96	350	600	3.15	650	3	93	
	4	60			550	550	3.22		4		
	5	60			550	550	3.25		5		
	6	60			550	550	3.33	590	6		
	7	60			550	550	3.38	680	7		
	8	60			550	550	3.45	920	8		
<u>Total</u>	9	780	553	380	3800	4650	3.50	1000			
	10										
	11										
	12										
	13										
	14										
	15										
	16										
	17										
	18										
	19										
	20										

Remarks:

MECHANICAL ENGINEERING LABORATORY

MICHIGAN AGRICULTURAL COLLEGE

Running Log of Heat Balance on Foundry Cupola.
Test No. 2.

Observers { In Charge R. E. Olin. { Assistants
H. Spurr. { Date Mar. 2 1915.

	NO. of Charge.	Weight of Fuel.	Weight of Fuel.	Weight of Pig.	Weight of Scrap.	Total weight of Iron in Charge.	Per cent of C ₀₂ .	Per cent of CO.	Per cent of O.	Temperature of Gas. °C.
Bed.	1	300		255	300	555	14	5	0	510
	2	60		250	300	550	16	5	0	580
	3	60		250	300	550	6	3	0	475
	4	60		250	300	550				560
	5	60	No. 3 cup.	250	300	550				665
Total.	6	540		1255	1500	2755				805
	7									
	8									
	9									
	10									
	11									
	12									
	13									
	14									
	15									
	16									
	17									
	18									
	19									
	20									

Remarks:

MECHANICAL ENGINEERING LABORATORY MICHIGAN AGRICULTURAL COLLEGE

Running Log of *Heat Balance on Foundry Copola -*
Gas Analysis *College Test No 3.*

In Charge

Assistants

Observers

*R. E. Olin.*Date *Apr. 15* 19 *16*

NO.	Time	<i>% CO₂ By Volume</i>	<i>% O₂ By Volume</i>	<i>% CO By Volume</i>
		<i>%</i>	<i>%</i>	<i>%</i>
1	<i>9:30</i>	<i>6.</i>	<i>7.</i>	<i>6.7</i>
2	<i>9:40</i>	<i>12.4</i>	<i>2.4</i>	<i>5.</i>
3	<i>9:50</i>	<i>10.2</i>	<i>6.6</i>	<i>2.2</i>
4	<i>10:00</i>	<i>9.0</i>	<i>4.8</i>	<i>6.0</i>
5	<i>10:10</i>	<i>8.0</i>	<i>3.0</i>	<i>7.2</i>
6	<i>10:20</i>	<i>9.3</i>	<i>1.3</i>	<i>8.0</i>
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

Remarks:

MECHANICAL ENGINEERING LABORATORY

MICHIGAN AGRICULTURAL COLLEGE

Running Log of Heat Balance on Foundry Cypok-
Gas Analysis College Test No 6

In Charge

Assistant

Observers

H. SpurrDate June 2, 1915

NO.	Time.		
	% CO ₂	O	CO.
1	13.	3.	6.
2	11.3	5.2	8.
3	7.	6.	9.
4	11.	4.3	7.
5	16.	2.	5.7
6	12.	2.5	6.2
7	13.	2.	5.
8	10.	5.	6.
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			

Remarks:

MECHANICAL ENGINEERING LABORATORY
 MICHIGAN AGRICULTURAL COLLEGE

Running Log of

Heat Balance on Foundry Cupola
Test No. 1.

In Charge

Assistant

Observers

F. H. Prescott

Date Feb 15, 1915

No. Tappings	Time	Temperature of Iron P.	Crown Wt. Iron + Scales	Tare Wt. Ladle	Net Wt. Iron	Wt. of Slag
1	9.16	2200	463	267	196	141
2	9.25	2250	502	273	229	
3	9.30	2250	575	257	318	
4	9.35	2300	575	228	347	
5	9.40	2350	598	227	371	
6	9.45	2400	575	259	316	
7	9.50	2350	579	305	274	
8	9.55	2375	582	288	294	
9	10.00	2300	578	375	203	
10	10.05	2300	587	395	192	
11	10.11	2200	552	233	319	
12					3059	
13					75	
14					Total	3134 #

Remarks:

 Temperature readings are approximate.
 75 # of Iron unfouled.
 Total wt. of castings and sprues = 3119 #

MECHANICAL ENGINEERING LABORATORY

MICHIGAN AGRICULTURAL COLLEGE

Running Log of Heat Balance on Foundry Cupola.
Test No. 3.

In Charge

Assistants

Observers

F. H. Prescott.Date Apr. 15 1915

No.	Tappings	Time	Temp. of Iron C.	Gross Wt. Iron & Ladle	Tare Wt. of Ladle	Net Wt. of Iron	Wt. of Slag	Wt. of unskirted coke	Wt. of droppings	Wt. of Iron in Slag
1				280	150					
2		9.28		415						
3		9.32	1200	440	218					
4		9.35	1250	480	212					
5		9.40	1250	500	200					
6		9.45	1250	550	200					
7		9.48	1250	550	250					
8		9.51	1200	550	250					
9		9.53½	1200	450	250					
10		9.56	1200	400	250					
11		9.58	1220	450	200					
12		10.00								
13										
14										
15										
16										
17										
18										
19										
20										

Wts. were assumed.

Remarks:

CHECK BOOK

MECHANICAL ENGINEERING LABORATORY MICHIGAN AGRICULTURAL COLLEGE

Running Log of *Heat Balance on Cupola - Test No. 1*

In Charge

Assistants

Observers

*R. E. Decker*Date *Feb. 15 1915*

NO.	Time in minutes	Temp. of entering air	<u>Pitot Tube</u>		R. P. M. of motor	Volts	Amperes	Wet Bulb	Dry Bulb
			Pressure head "Hg	Velocity head					
<i>Heat on</i>									
2	20	40	93	18	1363	125	18.5		
3	45	46	1045	16	1375	126	19		
4	60	45	65	3.0	1378	126	24		
5	65		47	2.5					
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									

Remarks: *Relative Humidity - 75% - U.S. Weather Bureau*
Making of Instrumental Read.
Jewel Standard Ammeter
Weston Direct Reading Voltmeter
Schaeffer and Budenberg Psychrometer
Schwaner and Lindholm

MECHANICAL ENGINEERING LABORATORY
MICHIGAN AGRICULTURAL COLLEGERunning Log of Heat Balance on Foundry Cufol
Test No. 6.

In Charge

Assistants

Observers

F. H. Prescott

Date May 24, 1914

No.	Tappings	Time	Temp of Iron 10 C.	Gross wt. Iron + ladle	Temp wt. ladle.	Net wt. Iron
1	3.01	1050	445	170	275	
2	3.06	1120	550	320	230	
3	3.15		510	302	210	
4	3.20		400	193	207	
5	3.27		800	233	567	
6	3.32		532	285	247	
7	3.35		570	275	295	
8	3.39	1170	600	290	310	
9	3.45	1170	700	307	393	
10	3.50		595	255	340	
11	3.54		440	202	238	

245 # on floor

20 # in small ladles

Total 3577

Remarks:

First Iron 2.59
Blast broke at 3.10
" again at 3.16

MECHANICAL ENGINEERING LABORATORY

MICHIGAN AGRICULTURAL COLLEGE

Running Log of *Heat Balance on Cypole-Test No. 3.*

In Charge

Assistants

Observers

*R. S. Decker*Date *Apr. 15, 1915*

No.	Time in min.	Best Time		Difference	R.P.M. of Motor	Volts	Amps.	Wet Bulb	Dry Bulb	Temp.	Cypole Barometer
		Revolve	Heat "100								
21	9:10										
2	9:15	9.8	.55		1465	207	19.			57	
3	9:20	5.0	.8		1470	206	16.	51	56	58	35
4	9:30	10.3	1.3		1460	203	20.			57	
5	9:35	11.5	1.7		1450	201	23.5	51	57	58	
6	9:40	11.9	1.75		1460	203	24.5	52	59	59	
7	9:45	11.9	1.8		1460	202	25.			59	
8	9:50	9.3	1.6		1470	203	24	51.5	58.5	59	
9	9:55	11.8	1.3		1465	202	25.	52.	59	59	
10	10:00	11.0	1.75		1470	205	24.			60	
11	10:05	11.1	1.85		1470	203	25.	52.5	60	61	
12	10:10	12.4	1.8		1470	202	25.			61	
13	10:15	11.5	2.0		1470	205	26.	53	60	62	
14	10:20	9.9	2.2		1470	206	26.				
15											
16											
17											
18											
19											
20											

Remarks:

MECHANICAL ENGINEERING LABORATORY

MICHIGAN AGRICULTURAL COLLEGE

Running Log of Heat Balance on Foundry Cupola.
Test No. 1

In Charge

Assistants

Observers

R. E. Olin
H. Spurr

Date Feb. 15 1915

NO. of charge	Weight of Fuel.	Weight of Flux.	Weight of Pig.	Weight of Scrap.	Total Weight of Iron in Charge.	Percent of CO_2 .	Percent of O.	Percent of CO.	Temperature of Gases. °F.
<u>Bed</u> 1	300		262	300	562	8	0	4	980
2	60		255	300	555				1690
3	60		250	300	550				1080
4	60		261	300	561				
5	60		238	300	538				
6	60	No Flux.	257	300	557				
<u>Total</u>	<u>600</u>		<u>1523</u>	<u>1800</u>	<u>3323</u>				

Remarks:

MECHANICAL ENGINEERING LABORATORY

MICHIGAN AGRICULTURAL COLLEGE

Running Log of Heat Balance on Capolar-Test No. 6

In Charge

Assistants

Observers

R. E. DickellDate May 27, 1915Test Table

NO.	Time in minutes	Baromet. Readings	Diff. Press.	RPM of Motor	Volts	Amps.	Wet Bulb	Dry Bulb	Temp.	Exhaust Temp. °C.
<u>Blast on</u>										
1	0:30									
2	2:40	33	3	1410	211	9			68	2
3	2:45	32	4	1410	212	9	69	68	68	2.1
4	2:50	32	5	1420	215	12			68	3.5
5	2:55	10.7	9	1700	217	13	62.5	66.5	68	6.75
6	3:00	10.5	62	1400	217	20			68	6.75
7	3:05	10.8	45	1400	212	20			68	6.8
8	3:20	10.5	135	1336	213	19			68	6.75
9	3:25	10.6	17	1400	214	20			68	6.75
10	3:30	10.4	175	1410	212	20			68	6.7
11	3:35	10.5	15	1700	212	20	67.5	68	68	6.7
12	3:40	3.3	165	1700	213	21			68	6.7
13	3:45	3.5	175	1710	213	21			68	6
14	3:50	7.2	23	1700	213	24			68	7.8
15										
16										
17										
18										
19										
20										

Remarks: Blast off for 6 min. due to accident

MECHANICAL ENGINEERING LABORATORY

MICHIGAN AGRICULTURAL COLLEGE

Running Log of *Heat Balance on Foundry Cupola.**Test No. 3.*

In Charge

Assistant

Observers

R. E. Olin
*H. Spurr.*Date *Apr. 15 1915.*

	No. of Charge.	Weight of Fuel.	Weight of Fuel.	Weight of Pig.	Weight of Scrap.	Total weight of Bottom Charge.	Weight of Wood.	Time.	Temperature of Gas °C.	Number of Gas Sample.
Bed	1	360		304	350	654	62	9.30	590	1
	2	60		250	302	552		9.40	665	2
	3	60		250	300	550		9.50	765	3
	4	60		250	300	550		10.00	690	4
	5	60			550	550		10.06	860	5
	6	60			550	550		10.10	1000	6
	7	60			550	550		10.20	1000	7
	8	60			550	550				
Total	9	780		1054	3752	7506	62			

CHECK BOND

Remarks:

MECHANICAL ENGINEERING LABORATORY

MICHIGAN AGRICULTURAL COLLEGE

Running Log of Heat Balance on Cupola - Test No 5
Gas Analysis.

In Charge

Assistant

Observers

H. Spurr

Date May 23, 1915

NO.	Time	by volume		
		% CO ₂	% O	% CO
1	2:10	8.4	1.6	12.2
2	2:17	13.	1.	6.4
3	2:30	12.3	1.4	8.6
4	2:40	11.3	4.3	5.9
5	2:48	11.2	1.6	10.6
6	2:52	12.6	3.5	3.9
7	2:55	12.5	1.1	6.0
8	2:57	11.4	1.8	7.3
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

Remarks:

MECHANICAL ENGINEERING LABORATORY

MICHIGAN AGRICULTURAL COLLEGE

Running Log of *Heat Balance on Foundry Cylinder.*Test No. *6.*

In Charge

Assistants

Observers

R. E. Olson
*H. J. J. J.*Date *May 29 1915*

No. of charge	Weight of Fuel		Weight of Pig. (I)		Weight of Pig. (II)		Weight of Scrap		Total weight of Iron in Charge	Time	Temperature of Gas in °C.	Number of Gas Samples	Weight of Wood	Weight of Fuel
	1	2	3	4	5	6	7	8						
<i>Red</i>	1	360	160	90	300	550	3.00	680	1	83	10			
	2	60	148	102	300	550	3.05	520	2					
	3	60	140	110	300	550	3.18	640	3					
	4	60	250		300	550	3.23	450	4					
	5	60	250		300	550	3.27	550	5					
	6	60			550	550	3.35	730	6					
	7	60			550	550	3.38	780	7					
<i>Total</i>	8	720	448	302	2600	3850	3.41	1000	8					
	9													
	10													
	11													
	12													
	13													
	14													
	15													
	16													
	17													
	18													
	19													
	20													

Remarks:

MECHANICAL ENGINEERING LABORATORY
MICHIGAN AGRICULTURAL COLLEGERunning Log of *Heat Balance on Foundry Cupola.*
Test No. 5.

In Charge

Assistants

Observers

*F. H. Prescott.*Date *May 11, 1915.*

No. Tappings	Time	Gross Wt. Iron & Slag	Tare wt. Scales	Net wt. Iron	Wt. of Slag	Wt. of Drippings	Wt. of Iron in slag.
1	2.09	240	150	90			
2	2.11	330	260	70			
3	2.13	385	220	165			
4	2.16	478	190	288			
5	2.20	525	250	275			
6	2.25	600	297	303			
7	2.31	615	289	326			
8	2.37	635	235	400			
9	2.41	605	387	218			
10	2.45	593	230	363	Add 20 [#] = 383		
11	2.50	610	236	374			
12	2.55	565	220	345			
13	3.00	565	308	257			
14	3.03	372	250	122			
15				3596			
16				20			
17				3616			
18							
19							
20							

Remarks: *Blast on 1.48.*
First Iron 2.04.

MECHANICAL ENGINEERING LABORATORY

MICHIGAN AGRICULTURAL COLLEGE

Running Log of *Heat Balance on Cupola - Test No. 5*

In Charge

Assistants

Observers

*R. C. Decker*Date *May 11, 1912**Test Table*

NO.	Time in minutes	Barometric Head "Hg	Difference	R.P.M. of Motor	Voltage	Amps.	Wet Bulb	Dry Bulb	Temp.	Cupola Temp. - °C
<i>Blast on 1:40</i>										
2	1:50	2.5	34	1420						
3	1:55	4.2	55	1430	210	15			80	2.8
4	2:00	6.2	73	1480	210	20	69	75	81	4
5	2:05	9.5	1.5							
6	2:10	10.0	1.35	1430	210	20	66	74	73	6.5
7	2:15	10.0	1.95	1420	210	20			75	7
8	2:20	10.7	1.6	1430	210	21	66	74	75	6.75
9	2:25	11.6	1.35	1420	210	24			75	7.3
10	2:30	11.5	1.34	1430	210	20			73.5	7.85
11	2:35	11.55	1.34	1430	210	20	67.5	73	73.5	7.25
12	2:40	11.1	1.5	1430	210	20			74	7
13	2:45	10.6	1.55	1430	211	21			74	6.8
14	2:50	10.8	1.6	1430	210	21.5	67	73	73	6.8
15	2:55	10.5	1.8	1430	210	22			73	6.7
16	3:00	9.8	1.85	1440	212	24			74	6.5

*Blast off 3:03*18
19
20

Remarks:

MECHANICAL ENGINEERING LABORATORY

MICHIGAN AGRICULTURAL COLLEGE

Running Log of *Heat Balance on Foundry Copola.*Test No. *5*

In Charge

Assistants

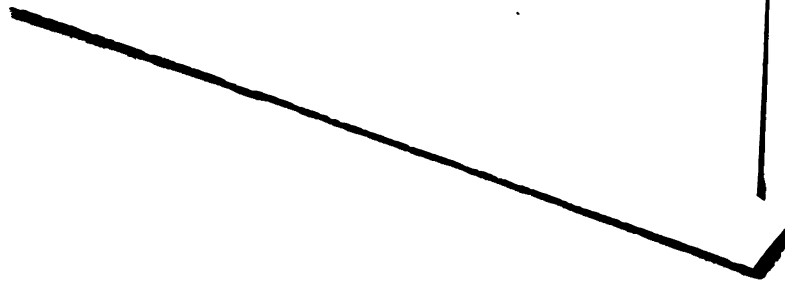
Observers

*A. E. Alin.**H. J. Gurn.*Date *May 11, 1915*

Bed	No. of Charge	Weight of				Total weight of Iron in charge	Time	Temperature of Gas, °C.	Number of Gas samples	Weight of Wood	Weight of Flue
		Fuel	Py. (T)	Weight of Py. (C)	Weight of Sags.						
1	360	165	85	300	550	2.10	570	1	59	10"	
2	60	130	120	300	550	2.17	750	2			
3	60	153	97	300	550	2.30	700	3			
4	60	250		300	550	2.40	665	4			
5	60			550	550	2.48	790	5			
6	60			550	550	2.52	880	6			
7	60			550	550	2.55	990	7			
Total	720	698	302	2850	3850	2.57	5040	8			

Remarks:

REC'D USE ONLY



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