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Metallurgy of steel castings

Earl Joesting McNely

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METALLURGY OF STEEL CASTINGS

BY

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A

Thesis

submitted to the faculty of the

School of Mines and Metallurgy of the University of Missouri

in partial fulfillment of the work required

for the

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Approved by _Chas.Y.Clayton_ ,

Associate Professor of Metallurgy and Ore Dressing.

23041

INDEX

TABLE OF CONTENTS

TABLE OF CONTENTS- Continued

INTRODUCTION

This Thesis is in the form of a report of the observations of the author while working in the American Steel Foundries plants in various departments. The parts of the report dealing with Moulding and Inspection of castings were written while in the Indiana Harbor Indiana plant. The parts dealing with the Laboratory and Furnace Operation were written while in the Granite City, Illinois plant. The company owns and operates six other plants but the material covered in this report will, in a general way cover the operations in these plants, also, in which foundry work is carried on.

METALLURGY OF STEEL CASTINGS

BASIC OPEN HEARTH STEEL FURNACE PRACTICE

OPEN HEARTH PRACTICE

At first glance, one not acquainted with the situation, might at once say that the whole Foundry depends mostly upon the production of steel. As important a part as the furnaces play, their importance is merely relative and their successful operation depends upon the co-operation of all other departments connected with casting and steel production. In actual production, it is difficult to say whether the furnace man or the molder comes first in importance. Opinions differ.

The best definition of furnace operation can be summed up as hard and hot work. Outside of the melter, highly skilled labor is not an essential.

Y A R D

Upon the Yard stocking boss and his crew, depends the satisfactory loading, assembling and delivery of heats to the furnace floor. To accomplish this in good form and with sufficient ease, the heats are made up in boxes on buggies. Enough buggies are used to have about three heats and a half in the cycle at a time, i.e., one heat on the platform; one on scales; and one in process of loading. To facilitate easy loading, the ground space in the yard is divided up into numbered sections. Between sections, tracks are laid so that material in any section can easily be loaded into the boxes.

The charge varies with the conditions of the heats, but at this particular time (January) 1917 the yard stock for a heat consisted of the following material.

```
Pig Iron-
     Mississippi Valley-              14500 lbs.
     Pickands-Brown or Algoma-         8000 lbs.
     Rails-                           10500 lbs.
     Lime-                             3750 lbs.
     Own & Co-                        14500 lbs.
     Miscellaneous-                    5500 lbs.
```

The lime is as a rule, loaded into the boxes
directly from the car, thus saving double handling and
storage. Pig Iron and miscellaneous are also thus
loaded when possible. The rails are cut into suitable
lengths and are loaded as far as possible as broken.
The Own & Company consists of heads, gates, ingots and
heads, scrap castings, wheels, skulls and drop steel.
The heads and gates are picked up from the Foundry.
The skulls, drop steel and scrap castings are a bug-
bear and must be loaded with the crane. This
material must be handled on the floor, but it is both
cumbersome and dangerous work.

About three hours are required to spot
buggies, load, weigh and put same on platform.

OPEN HEARTH OPERATION

It is possible to differentiate the duties of first, second, third helpers and melter. But to show how they work together, a heat will be followed through, both in mechanical working and chemical analysis.

We will assume, that the furnace, the construction of which will be mentioned, has been running, was empty at the time of this operation, the heat on the floor, and ready to charge. The third helper took his place at the door opening apparatus and the charging began. Since the bottom of the furnace was in good condition, anything except the pig iron could have been charged first, depending on what the first helper wished to use. In this instance, four boxes of miscellaneous were charged, followed by the limestone and manganese ore. The manganese ore is added to help make a good slag. It is assumed that it is used to help eliminate the sulphur and make a liquid slag. The quantity is small and outside of helping to make the slag an oxidizing one, it does not play a very important part. In fact, heats run without the ore, are quite as good as those run with it, apparently experience has taught the men that the heats can be run without, as they all consider it so much dump material. The balance of the heat was added as shown by log of heat, but any order would have been O.K.

The oil was left off after the bottom and walls were made up so that it would chill. If the heat is charged too soon, or on a hot bottom, there is danger that the bottom will come up with the lime. As soon as the charger began, the first helper turned on the oil, the burners were raised so that the flame could pass over the piled scrap and a copious flame was sent over it to cut it down sufficiently to allow the addition of the pig. Within an hour, the pig was added. It is not wise to allow the scrap to melt down too far, because upon the addition of the pig in the molten mass, the impurities are violently attacked as the pig melts, causing a forming heat. Such a heat is hard to handle and will inevitably run out of the door. As the metal cut down, the burners were lowered gradually until the bath was level. The oil was reversed during this melting period about every half hour until the lime came up. From then on, it was reversed every 15 minutes, since the metal is covered with a heavy slag and lime coating and the heat is radiated to the walls and roof of the furnace. The air was cut down and the furnace walls watched very closely to keep them from burning. With a little experience, one can judge the correct or safe temperature, by referring the color of the walls to the color

12

of the flame.   The flame at this point is quite white.
The walls should be _red_ in comparison.   The flame was
cut down so that it passed to the edge of the metal and
slope.   More is not necessary- only a waste.

During this period, the second and third helpers
did their work.   The second helper wheeled up mud and wood
for his runner and the additions for the bath- 80% ferro
manganese, spiegeleisen, 50% ferro silicon, aluminum,
titanium, coal and 10% ferro silicon, the quantities of
which are elsewhere mentioned.

The mud was made up very soft; the slag and
steel cut from the runner and the runner remudded.   The
runner was set and the joint between the short spout and
runner made with dry alum and mud to make it smooth.   A
wood fire was started in the runner to dry the joint and
mudded runner.   The runner and joint must be dry.   In addi-
tion to the work on his own furnace, the second helper must
help tap out, take care of tapping holes and do sundry jobs
on the other furnaces.

The third helper hauled up fluorspar, bottom mater-
ial and iron ore; swept the floor, took care of the rabbles
and bleeders, opened the doors when necessary and helped on
the other furnaces, especially while tapping out and making
up walls and heats.

During this melting period, the flame had been busy

oxidizing, impurities, sulphur and phosphorus and also
the manganese, silicon and carbon. Almost all the
silicon and about as much of the phosphorus and magan-
ese as could be oxidized were oxidized and eliminated,
while the carbon and sulphur depend on their elimination
to a larger extent upon iron ore (hematite) additions.
An examination of curves and data sheets will bear out
these remarks.

As soon as all the lime was up, the heat was in
condition to work. The first helper poured a spoon test
into a test block and the second helper cooled and broke
for fracture. From the fracture, the melter and first
helper approximated the amount of ore to be added. A
large quantity was not needed, so was added all at once.
Should a larger quantity be required it should be added
in two parts, otherwise the reaction will be so great
that the heat will foam out of the doors. Unless the
carbon is over 50% at this point, no ore is added. It is
not absolutely necessary to use ore to obtain a good heat.

The iron ore, besides oxidizing the sulphur,
manganese, phosphorus, silicon and carbon, also cuts up
the unmelted lime and forms slag.

The reaction between the iron ore and carbon,
is in its simplest form thus:

$$3C + Fe_2 O_3 = 3CO + 2 Fe$$

and is an end othermic reaction.

After the reaction subsided, say 15 or 20
minutes, another test was taken, cooled and fractured
as before. This test about .50 or 0.60 carbon was
sent to the laboratory for a preliminary test on
phosphorus. In case about .02% to .03% phosphorus
appears, more lime is added. The whistle was blown
for the ladle stopper. The heat was working nicely and
the slag began to open up. The bath was boiling or
taking the heat and the slag had a creamy appearance. A
few shovels of "spar" were added to faciliate the opening.
It is not known just what the action of the spar is, but
many conjecture. I believe Mr. Hamilton has a theory
which is plausible. In general, a basic slag is fluid.
The spar thins the slag. Some assume that the slag is
more basic on account of this addition.

The first helper knows about how to judge his
heat. Another test was taken and treated as before. A
piece was sent to the laboratory for preliminary carbon,
which was about 26%. Another test was immediately taken,

15

.the whistle blown for the ladle and the 10% ferro silicon,
previously broken up, by the second helper, was thrown in.

The Ferro Silicon has about 3-5% carbon content
and holds the heat at the carbon content of the last test
taken. It holds the heat until the test can be run, the
80% ferro manganese added, the ladle set and the tapping
hole dug out. It checks the reduction of carbon by tak-
ing the oxygen for its own use as later shown. It also
adds heat to the bath as the reaction is exothermic.
Tests show that no silicon is gained by the steel from
this addition. Carbon can be gained, depending on the
length of time the heat is allowed to stand before   .
tapping.

Four minutes after adding the 10% Ferro
Silicon, the 80% Ferro manganese was added. Just
about the time the manganese was added, two second
helpers dug out the tapping hole enough to make it
easy and safe to knock out from the front with a
bleeder. Eight minutes after addition of manganese,
the heat was tapped. It went out on about .25 carbon.
As soon as the metal began to run, the melter went back
of the furnace and put in ladle additions. The ladle
additions are all figured on a .28% to .26% carbon bath
content. That is, the manganese and silicon at that

carbon content, are as a rule the same and the additions are figured on that basis. The carbon on the last test was about .25%. The heats are supposed to be somewhere in the neighborhood of .28% carbon. Coal is added to bring this up. A bag of small nut hard coal weighing about 30 lbs. will bring up the steel .04% carbon or 4 points. Twenty pounds of coal were added when about a foot of metal covered the bottom of the ladle.

The shute additions were gradually added in the runner, and must all be in before the slag commences to come because the 50% ferro silicon attacks the basic slag and releases the phosphorus which has been eliminated and puts it back into the metal. The functions of the silicon and manganese additions are later explained. As the ladle filled, a large part of the slag ran over the lip of the ladle into the slag pit. About six inches of slag should remain in the ladle to act as a blanket to hold the heat in the metal. If there is not any slag on the metal, it should be covered with dolomite. As soon as the ladle was full, the craneman removed it and pouring proceeded.

The second helpers took off the runner. The first helpers began to work on the bottom. The first and most important task is to see that the tapping hole is open and stays open. The heat was clean with very little slag and lime in the bottom. A rabble was put into the middle door

and the bottom rabbled from end to end to locate any

holes. There were no puddle holes. The little remain-

ing slag that would not drain was dried up with bottom

material. A rabble was placed in front of the tapping

hole, the oil shut off and the front of and tapping hole,

dried out by both first and second helpers in their

respective places. The hole was shut up immediately with

dolomite and an alum plug put in to hold it. The second

helper is now ready to do his work for another heat.

While the second helpers were doing the above,

closing the hole from the back, the first helper rammed

the front of the hole and faced it with slag and

syndolag. All the first helpers helped make up the

back walls, breasts and bottom. The back walls and

breasts were made up with shovels of material. But

the breasts and slopes along the slag line were made

upwith the spoon, the third helpers carrying the

material to the spoon. The slag always cuts the walls,

slopes and breasts and it is necessary to repair them

after each heat. The furnace is now ready to recharge

as before outlined.

Understand that conditions on this particular

heat approached the ideal, and are not always thus. At

times the carbon refuses to come down, or comes down too

fast and it is necessary to add pig iron or spiegel to
hold or raise the carbon. It is easier to raise and
hold the carbon when it is about .30% than when it is
.18 or .20%.

The slags at times refuse to cut up and lays
in lumps; the bottom comes up with the lime leaving
large puddle holes to be rabbled out and repaired; the
tapping hole gets stopped up or is so large it must be
piped by the second helpers; the short spout gets filled
up, and troubles too many to mention.

One of the most serious troubles is a "boil".
It is liable to occur at any place in the bottom, breasts,
back walls, slope or tapping hole. If it occurs early
in the heat, it is hard to handle and the heat may be lost.
I recall seeing a heat boil out of a tapping hole a half
hour before time to tap. Suppose a boil should occur on
the breast about a half hour before tapping time. Ten
percent Ferro Silicon is shoveled into the spot that is
boiling to stop it for a time, until the 10% Ferro Silicon
melts. As soon as it starts again, more is added until
the heat is tapped. Just the other night a heat boiled
out through the breasts on #6 furnace. There are other
cases worse, but this gives an idea about how such might
be handled.

19

Of the bottom materials used on the floor, the men
differ in their opinion as to which they like the best.
Next to the magnesite, they like syndolag. The price
varies for the material used and it is needless to quote,
but will put the materials down in the order in which the
price ascends as follows: Raw dolomite, double burned
dolomite, magnebrent, syndolag, magdolite, magnesite and
kendymag, magnesite. Of course, these materials are all
basic in reaction.

HISTORY OF HEAT NO. 40415

The heat was melted in the furnace, May 1917. The furnace was about at its maximum efficiency, as it had 352 heats on the slag pits and 149 on the second roof and back walls. The heat was melted and finished in about the average time allowed for the same. Two tests were taken at each period; one was water cooled for a fracture test; the other was allowed to cool slowly in air so that it would be soft enough to drill for chemical analysis. The slag was taken from the test spoon for slag analysis. The following is data covering the heat, including charge, additions, chemical analysis, etc.

C H A R G E

TIME	STOCK	QUANTITY	
6:05 A.M.	Miscellaneous	10,500 lbs.	
6:15 A.M.	)Lime	3,850 lbs.	
	)Manganese Ore	500 lbs.	
6:25 A.M.	Bolsters	6,300 lbs.	
7:00 A.M.	Rails	5,000 lbs.	
7:05 A.M.	Own & Co.	7,700 lbs.	
7:55 A.M.	Pig Iron	23,500 lbs.	(Chicago 8000 (Pickands (Brown-15500

The miscellaneous stock consists of most everything-parts of plows, pipe, rail plates, scrap plate, structural

steel, etc., and is usually high sulphur and phosphorus material. Bolsters and Own & Company are steel scrap. Rails are high in carbon. Pig Iron is the bulk of the material which must be purified or refined to make the steel. It runs about O 4-5% carbon, 0.7%-1.00% silicon; 0.19% - 0.50% sulphur; and 0.15% - 0.25% phosphorus.

The heat was melted at the time of the first test 10;15 A.M.. It melted somewhat earlier than usual-in about four hours. It usually takes about 5 hours. Some of the recorded tests were taken independent of the test which the melter took for his fracture tests in order to get them spaced at suitable time intervals.

LOG OF HEAT.

Started charging-	6.05 AM
Finished charging-	8.05 AM
Melted at-	10:15 AM
#1 Test Taken	10:15 AM
#2 Test Taken-	11:15 AM
#3 Test Taken-	12:15 PM
200 lbs. Iron Ore added at-	12:45 PM
Whistle for stopper	1:00 PM
#4 Test Taken-	1:05 PM
100 lbs. shop scrap added after	
#4 test was taken-	1:05 PM
75 lbs. spar added-	1:12 PM
Whistle for ladle-	1:25 PM
Test for preliminary carbon-	1:28 PM
60 lbs. spar added-	1:25 PM
500 lbs. 10% Ferro Silicon added-	1:31 PM
Test #5 taken before adding-	
10% Ferro Silicon-	1:30 PM
260 lbs. 80% Ferro Manganese added-	1:35 PM
75 lbs. spar added-	1:38 PM
Tapped at-	1:42 PM

LADLE ADDITIONS

400 lbs. 50% Ferro Silicon

125 lbs. 80% Ferro Manganese

 48 lbs. Aluminum- and titanium

 20 lbs. coal

     Bottom material used to make up bottom

     after tapping.

       Raw dolomite-   400 lbs.

       Magnebrent-   2500 lbs.

The following photographs show the fracture
tests. The fracture depends entirely upon the carbon
content. When the carbon is high, the structure is
fine grained and dull gray in appearance. As the
carbon content decreases the granular structure
becomes larger and more metalic in appearance. With
some experience one can exactly predict the carbon
content by a fracture test.
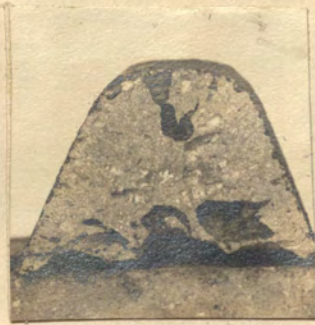
Test No. 1   Time Taken- 10:15 A.M.

CHEMICAL ANALYSIS

S L A G

SiO_2	FeO	MnO	P_2O_5	Al_2O_3	CaO	MgO	S
25.68%	12.60%	12.41%	1.71%	1.01%	38.40%	7.78%	0.014%

S T E E L   A N A L Y S I S

C	Mn	Si	S	P
1.28%	0.34%	0.031%	0.038%	0.052%

Test No 2   Time Taken- 11:15 A.M.

CHEMICAL ANALYSIS

S L A G

SiO$_2$	FeO	MnO	P$_2$O$_5$	Al$_2$O$_3$	CaO	MnO	S
15.78%	20.21%	10.11%	2.17%	0.89%	46.10%	6.05%	0.021%

M E T A L

C	Mn	Si	S	P
1.20%	0.36%	0.022%	0.035%	0.028%

Test No. 3   Time Taken-   12:15 P.M.

CHEMICAL ANALYSIS

S L A G

SiO$_2$	FeO	MnO	P$_2$O$_5$	Al$_2$O$_3$	CaO	MgO	S
11.00%	19.70%	10.60%	1.79%	0.82%	49.30%	7.32%	0.022%

M E T A L

C	Mn	Si	S	P
0.84%	0.30%	0.022%	0.032%	0.014%
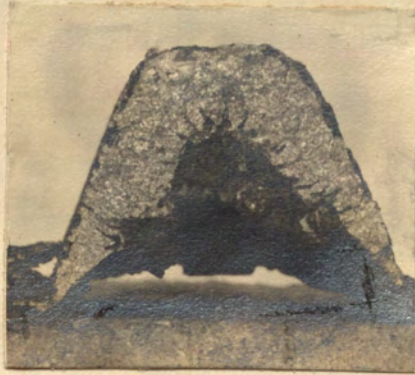
Test No. 4   Time Taken- 1:05 P.M.

CHEMICAL ANALYSIS

SLAG

SiO_2	FeO	MnO	P_2O_5	Al_2O_3	CaO	MgO	S
15.00%	15.99%	11.01%	1.82%	0.98%	47.30%	7.10%	0.038%

STEEL

C	Mn	Si	S	P
0.38%	0.28%	0.024%	0.025%	0.008%

Test No. 5   Time Taken-   1:30 P.M.

CHEMICAL ANALYSIS

SLAG

SiO2	FeO	MnO	P2O5	Al2O3	CaO	MgO	S
15.00%	17.04%	8.64%	1.49%	1.04%	48.71%	7.24%	0.041%

METAL

C	Mn	Si	S	P
0.22%	0.28%	0.022%	0.026%	0.009%

PLATE I

Carbon Time Curve - Steel
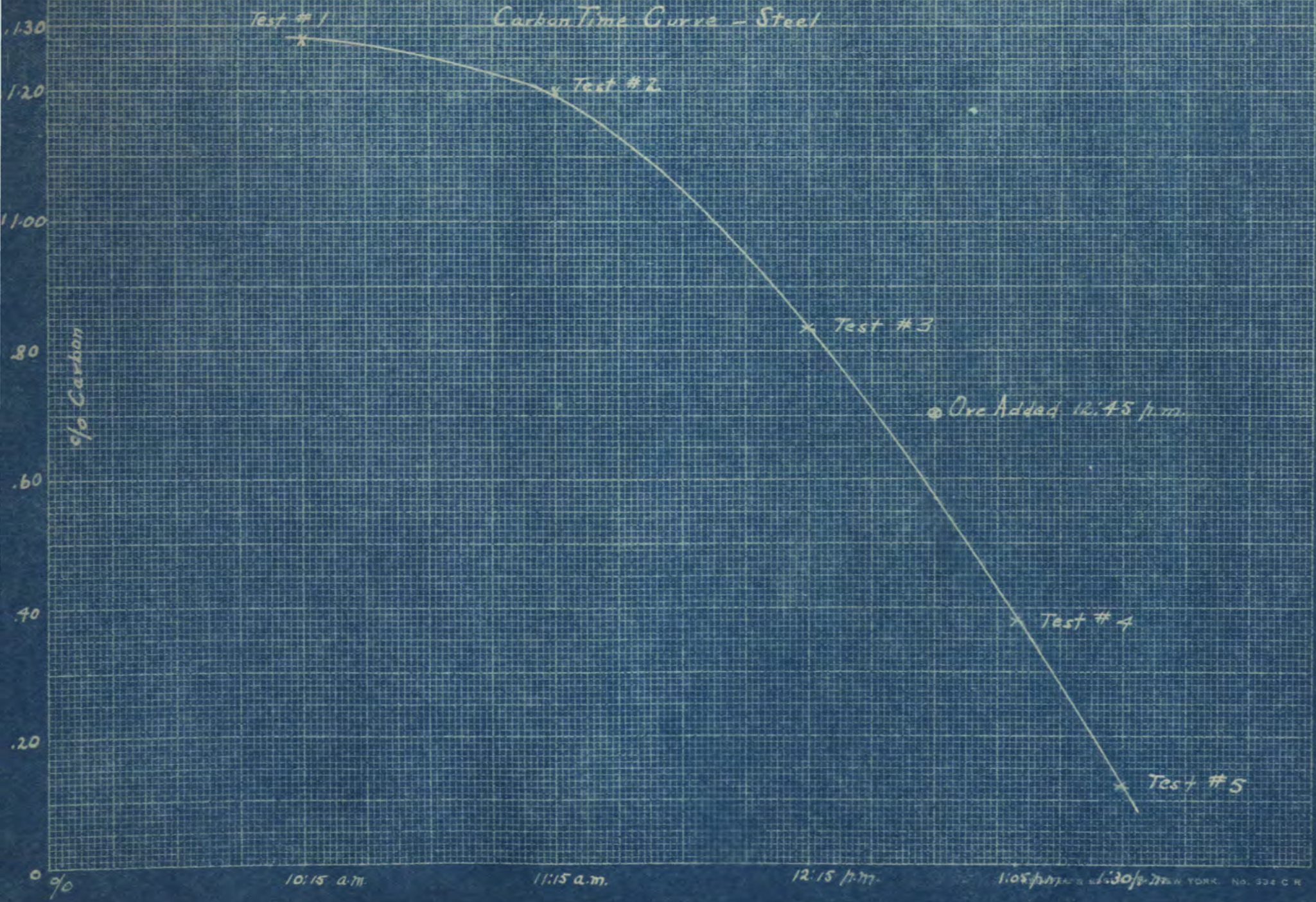
PLATE II

Sulphur Time Curve — Slag
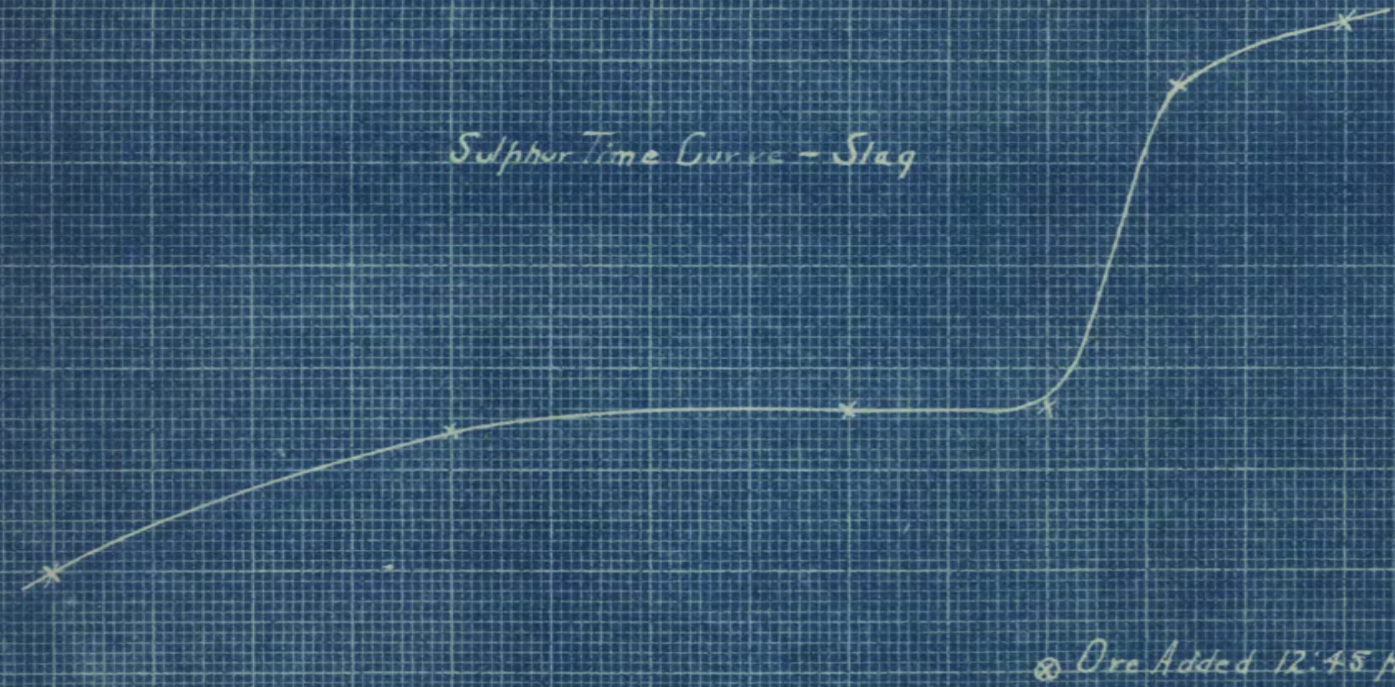
⊗ Ore Added 12:45 p.m.

Sulphur Time Curve — Steel

Test #1
Test #2
Test #3
Test #4
Test #5

% Sulphur Content
% Sulphur Content

044
039
034
029
024
019
014
038
35
032
029
026
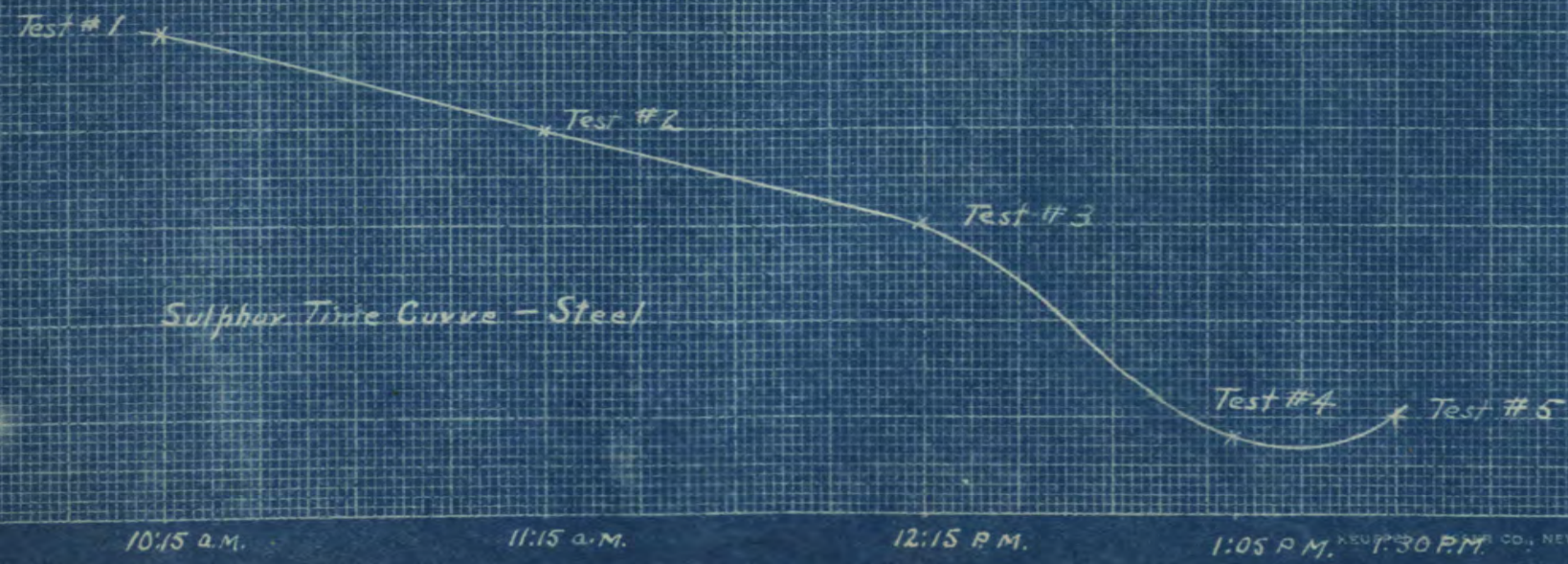
10:15 a.m.   11:15 a.m.   12:15 P.M.   1:05 P.M.   1:30 P.M.

PLATE III

Phosphorous Time Curve – Slag

% Phosphorous

.095

.085

.75

.665

Iron Ore Added 11.45 p.m.

Test #1

.5050

.4240

.030

.020

.1010

Test #2

Test #3

Test #4

Test #5

Phosphorous Time Curve – Steel

% Phosphorous

10:15 a.m.   11:15 a.m.   12:15 p.m.   1.05 p.m.   1.30 p.m.   YORK. No. 334 C B

PLATE IV

Manganese Oxide Curve – Slag

%/o Manganese Oxide

2.64

1.64

0.64

9.64

7.64

⊗ Iron Ore Added 12:45 p.m.

36

%/o Manganese

32

Test #1   Test #2

Test #3

Test #4   Test #5

Manganese Time Curve – Steel

10:15 a.m.   11:15 a.m.   12:15 p.m.   1:05 p.m.   1:30 p.m.

ESSEX BLUE PRINT WORK. No. 334 C P.
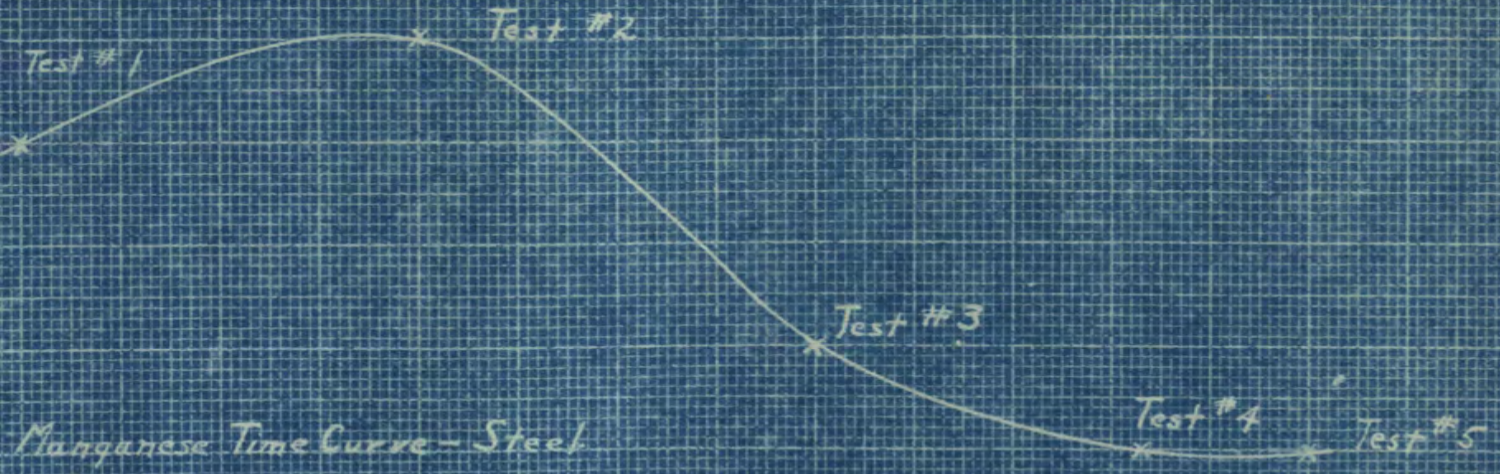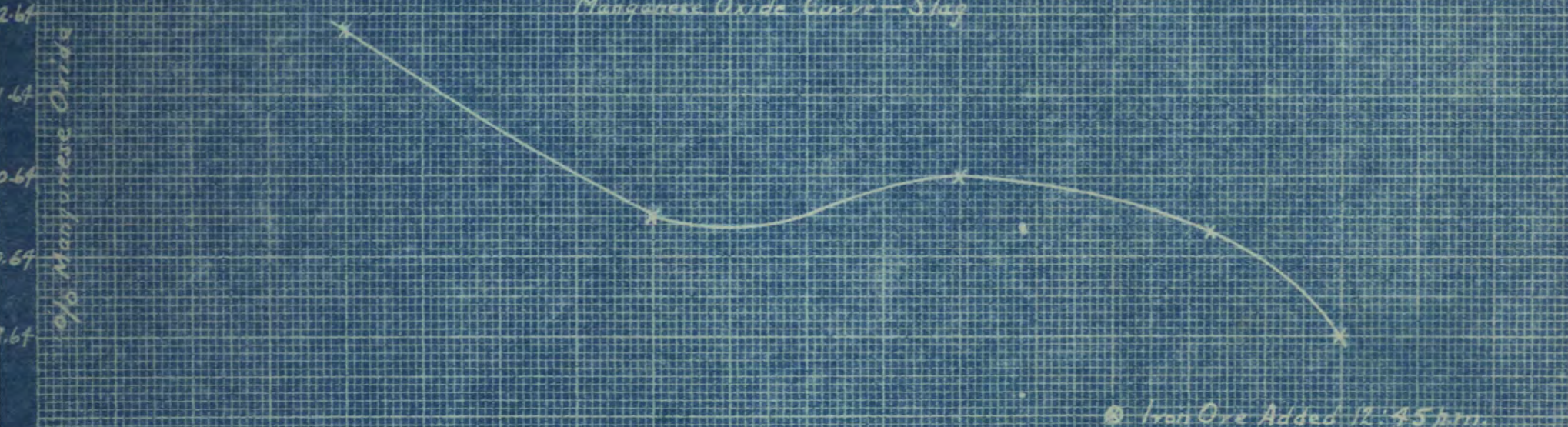
PLATE V

Analysis
Summary

Slags

Test	#1	#2	#3	#4	#5
SiO_2	23.68 %	15.78 %	11.00 %	16.00 %	15.00 %
FeO	12.60	20.21	19.70	15.99	17.04
MnO	12.41	10.11	10.60	11.01	8.64
P_2O_5	1.71	2.17	1.79	1.82	1.49
Al_2O_3	1.01	0.89	0.82	0.98	1.04
CaO	38.40	46.10	49.30	47.30	48.71
MgO	7.78	6.05	7.32	7.10	7.24
S	0.014	0.021	0.022	0.038	0.041

Metal

	#1	#2	#3	#4	#5
C.	1.28	1.20	0.84	0.38	0.22
Mn	0.34	0.36	0.30	0.28	0.28
Si	0.031	0.022	0.022	0.024	0.022
S	0.038	0.036	0.032	0.025	0.026
P	0.052	0.028	0.014	0.008	0.009

Metal as Poured

	C.	Mn.	Si.	S.	P.
Heat Test	.27	.60	.358	.028	.020
Gate Test	—	—	—	—	.038

DISCUSSION OF CURVES

Carbon is removed from the metal both by the oxygen in the air, oil, slag and iron ore, and the CO generated by the limestone where used. On this particular heat, the carbon was almost reduced by the air and oil. In fact, by the time the ore was added, the carbon was leaving the bath at a rate which was not apparently hastened by the addition of the ore. Note Plate 1.

The carbon enters the bath in the rails, scrap and especially the pig. It leaves the bath in the form of CO_2.

$$C + O_2 = CO_2$$

$$2CO + O_2 = 2 CO_2$$
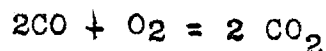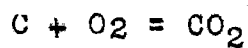
The reaction is exothermic and as a consequence gives heat to the bath. It is customary to reduce the carbon to a point just at the carbon content wanted or just below and then bring back by adding coal. It is assumed that by bringing the carbon low, it gives the impurities a better chance to become oxidized, since the carbon is then almost removed and less active. However, a glance at the analysis shows that anywhere between 0.84% and 0.22% carbon, the manganese, silicon, phosphorus and sulphur are practically as low as they go. Other data taken on another heat shows that

.between 0.66% and 0.18% carbon, the silicon and manganese
about at their lowest limits and phosphorus and sulphur
relatively low. (0.010% - 0.005% phos.; 0.035% - 0.030%
Sulphur). What would be against tapping out ingot heats
at the desired carbon content? A number of tests could be
made to determine how uniform the heats are in that region.
More titanium could be used for a deoxidizer to replace the
manganese used from the Spiegeleisen and the 1950 lbs. of
spiegeleisen saved. The usual run of sand heats are about
0.28% carbon and give the desired tensile, strength, elastic
limit, elongation and reduction of area.

S U L P H U R

Referring to Plate 2, some idea may be obtained
as to how the sulphur is eliminated. Apparently it is
removed after the bath is within an hour of tapping and
after ore has been added. There is a corresponding elimin-
ation from the metal and increase in sulphur content of slag.
It is understood that sulphur elimination is very erratic;
but there is nothing to indicate it in the data obtained,
except that it is evidently mostly removed at the time
there is an excess of oxygen present in the bath, due to
the iron ore. As the ore causes the bath to boil very
violently, it brings the metal more in contact with the
flame and air. This additional surface exposed may be

another reason for its elimination at this point.

The sulphur enters the bath in the pig iron (0.015% - 0.04%). in the scrap which is relatively low except in cast iron scrap which contains about 0.08% - 0.1%.

In some instances, it is held that sulphur enters from the flame. It is quite probably, but forces are at work in the furnace which oppose this. The sulphur to remain in stable form should enter the slag as CaS. But before it takes this form, it combines with the manganese for which it has a greater affinity and forms MnS. MnS in turn is soluble in the slag and metal, but in both slag and metal, there exists free oxygen, and MnS in contact with free O_2, has the property to give off SO_2 and SO_2 is volatile. Evidently this is not the only consideration we have to deal with as the sulphur content of the slag increases as the percentage in the metal decreases. Some of the sulphur remains in the slag as CaS.

Another place from which sulphur may come, is the bottom material. It is known that iron reduces calcium sulphate:

$$CaSO_4 + 4 Fe = FeS + CaO + 3 FeO.$$

Hence, should any calcium sulphate be present in the bottom materials with which the slag line is repaired, it is reasonable to expect that sulphur will

38

enter the bath. The fact of the matter is that several carloads of magnebrent were received and used. The sulphur began to run high in the heats. The bottom materials were analyzed and magnebrent was found to contain 1.% sulphur. Whether this existed as $CaSO_4$ or CaS was not determined, but no doubt it did as $CaSO_4$ for tests seemed to prove that the material increased the sulphur in the metal.

P H O S P H O R U S

Reference to Plate 3, will give some idea how phosphorus is eliminated from the metal. It is rapidly removed at first and then slowly toward the end of the heat. At Test #2 a corresponding decrease in the phosphorus in the metal and increase in the slag takes place. From this point on, both metal and slag decrease in phosphorus content. Two explanations may be given, one that the phosphorus is being carried away by the hot gases passing over the slag and that the bulk of slag has increased- more lime, iron ore, silica and spar have gone into solution to form slag. The percentage of phosphorus is so small that the additional slag decreased the percentage.

Phosphorus enters the bath mostly from the pig iron (0.15% - 0.25%), as all steel scrap is low in that impurity. Although the lime assists in eliminating the

sulphur, it is an essential to reduce the phosphorus.
Phosphorus exists in the metal as Fe_3P. In the
presence of metallic oxides, the phosphorus is oxidized
to P_2O_5. The phosphide passes to the slag where it is
converted to calcium phosphate, provided, however, that
the slag is basic with CaO. Otherwise the acid present
in the slag will reduce the phosphate and the phosphorus
will return to the metal. The oxidizing reactions of
Phosphorus to P_2O_5 and the phosphide to a calcium phos-
phate are exothermic.

There is always a difference in the phosphorus
and silicon content between the first mold and last mold.
The phosphorus increases and the silicon decreases. The
increase in phosphorus is due to the reduction of the
calcium phosphate by silica. The decrease in silicon is
due to the deoxidizing action the silicon has on the
metal, forming silica which in turn passes to the slag
and reduces the calcium phosphate.

The phosphorus content of the metal should not
run above 0.05% on riser test, otherwise the steel may
be cold short due to large crystals which the phosphorus
produces in the cooling steel.

M A N G A N E S E

According to Dickman, when the ratios between

.the iron oxide and manganese oxide in the slag is such t

that the manganese oxide percentage is greater, manganese

passes from the slag to the metal and vice versa. But

curves on plate 4 and results on Plate 5 do not bear out

his theory. However, it is not permissible to draw a

conclusion against him with but one result at hand. In

every instance, the iron oxide was greater than the

manganese oxide. Both metal and slag show a decrease.

However, this is quite probably due to the increased

bulk of slag as before stated.

The manganese enters the bath in the scrap and

pig. It is considered advisable to have the manganese

content of the bath about 1% when about melted. The

charge used runs about 0.82% before melting. The man-

ganese is oxidized and used by the sulphur in its

elimination. The manganese exists in the steel as MnS

and Mn_3C. The American Steel Foundries run about 0.70%

in manganese and in this percentage, improves the

quality of the steel.

D E O X I D I Z E R S

Oxygen enters the steel from the highly oxidizing slag. It also is present in the form of iron oxide due to the addition of iron ore which does not always have sufficient time allowed it to completely work its way out of the metal. This gas makes the steel wild and must be removed before it can be successfully poured into castings. This operation is known as deoxidization.

Manganese is one of the best deoxidizers. It possesses greater affinity for oxygen and sulphur than iron. A small percentage of manganese in the metal improves it. In determining tensile strength 0.10% mn is equal to 0.010% carbon. The reactions are exothermic,

$$2 Mn + O_2 = 2 MnO \; ; \; Mn + S = MnS$$
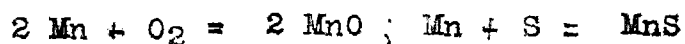
H. H. Campbell found that about 1.00% manganese must be added to gain 0.60% manganese in metal or 40% for deoxidization. A smaller percentage gave only 0.20% for deoxidization.

Manganese is added as 80% Ferro Manganese and in the American Steel Foundries additions are about 70% efficient toward raising the manganese content of the steel, thus, the total charge is 53000 lbs. metal.

42

Allowing 10% furnace loss, brings the available metal at end of heat to 47,700 lbs. 260 lbs. Ferro Manganese is added in the furnace and 125 lbs in the ladle, making a total addition of 385 lbs. or 308 manganese. 308 - 47,700 gives 0.62% manganese if all went to metal. On the average, the manganese in the bath before additions is about 0.28% and the steel finishes at 0.070%. 0.70%- 0.28% gives 0.42% due to the addition which enters the metal. 0.42 - 0.62 x 100 gives 70% approximate efficiency and 30% used for oxidization.

50% Ferro Silicon is also used. It has a much feebler action than manganese and if used in excess is deterimental to the steel. The reaction is exothermic.

$$Si - O_2 = SiO_2$$
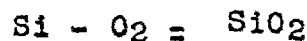
Using the same figuring as for manganese, the 50% ferro-silicon is 80% efficient in adding silicon to the metal and 20% for oxidization.

Both aluminum and silicon posses a property which manganese does not. They both hold gases dissolved in metal in solution, so that these are retained in solidification.

Eight pounds aluminum are added. The reaction is exothermic and is as follows:

$$4 AL - 3 O_2 = 2 Al_2O_3$$
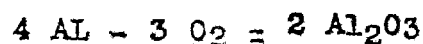
The alumina formed is light in weight and should

.rise to the slag, but as in all other deoxidizers,
some is included in the metal.

Ferro-Aluminum-titanium is considered one
of the best deoxidizers since this titanium eliminates
the nitrogen which heretofore has been considered of no
especial detriment ot the steel. 48 lbs. are added
instead of aluminum in ingot heats and in sand heats
when no aluminum is on hand. The alloy runs about
10- 14% Al. and 6 - 8% titanium.

Per pound of material used, aluminum takes
care of more oxygen.

If the iron ore added is given the proper
length of time to work through the heat, and the slag
is of the proper consistency in oxygen, etc., the metal
should not need very much of any of the materials
mentioned. In addition to adding deoxidizers to the ladle,
aluminum is added to each mold as the steel is poured.
It insures a sound casting and prevents a wild heat from
coming back.

CONSTRUCTION AND REPAIR

The open hearth furnace used by the American Steel Foundries is a Siemens-Martin type. Its construction is familar and detailed construction and size will not be entered into, except to mention the principal parts, i.e.:

Chimney, sewers, steel work, butterfly valve for air and discharge gases, flues, checkers, slag pits, ports for oil and discharge gases, monkeys, slopes, breasts, doors, walls, tapping hole, short spout, runner, and oil burners.

The checkers are built of fire clay brick. The balance of the furnace is built of good grade of silica fire brick with the exception of the bottom and slag line. Fire clay brick is used on the bottom over which is laid chrome or neutral brick. On the back and front walls along the slag line, a little above and below and all around the tapping hole, neutral brick is used on account of the basic steel process. The slag is basic. If the walls about the slag line or the bottom were silica brick, it would be but a matter of time until the walls could be cut through.

Upon completion of the brick work, a slow wood fire is built on the hearth and one at the base of the

stack to induce a draft. After 24 to 36 hours, a slow
oil fire is started and gradually increased. As soon as
the furnace is hot, the bottom is built up. The first
bottom is usually madeout of the best material; magnesite.
When the bottom is built up to the necessary height, a
long six inch pipe is tamped in place in the tapping hole
with magnesite and tar. Some use chrome ore, but it is
not as satisfactory as tarred magnesite. When the furnace
is hot enough, within a week or ten days, the tapping
hole is closed and the furnace charged as elsewhere
described.

The slag pockets are good for 600 to 800 heats;
the walls and roof from 100 to 250 and are torn out and
repaired two or three times before it becomes necessary
to close a campaign on a furnace for complete repair
of checkers, slag pockets, walls and roof. The bottom
lasts for several years without being rebuilt. When
the walls and roof are rebuilt, the bottom is given a
good washing by running several cinder heats, cleaning
out the old lime and slag. The bottom slope, back walls
and breasts are put in good shape. Within four to six
days the furnace is running again. Small holes in roof
or walls, back or side walls and arches are repaired
without shutting down the furnace.

So far as construction is concerned, the
acid and basic furnaces are the same with exception
of the bottom material. On the acid bottom silica sand
is used and put on the same as on the basic bottom.
The acid furnace does not eliminate the detrimental
impurities— phosphorus and sulphur. Hence to make
acid steel, it is necessary to make the charge up with
scrap and pig of low phosphorus and sulphur content. It
only requires about four hours to complete an acid heat.

L A D L E S

A ladle is in reality a large sheet steel
bucket. The essential parts are the bail, trunnions,
lip, slide, nozzle, dogs, feet and lining. The ladle is
lined first with a layer of fire clay brick laid on the
4" side. Another layer is laid over this on the 2" side;
the first layer extends the full depth of the ladle.
The second layer within a foot and a half from the top
or just above the metal line.

A mix consisting of fire clay brick dust and
fire clay was used for a coating over the brick. Out
of such a mix only 12 - 24 heats were poured before it
became necessary to rebrick the ladle. With some
experimenting the present mix used, consisting of
graphite and special clay in definite proportions, 3
clay, 1 graphite, on side and 6 clay, 1 graphite, on

bottom, better results have been secured. A greater
number of hears are poured, from 50 to 60 per lining,
with occasional patching. The skull, so pronounced
with old lining has practically disappeared. The
graphite in the lining has no effect on carbon content
of the steel.

The collar holding the nozzle is first placed
in position in the bottom of the ladle; about five or
six inches of bottom mix rammed in so that it tapers
toward the nozzle; and, the sides are mudded and smooth wi
with a brush. In a new ladle a wood fire is kept burning
for about 12 hours before placing in an oil fire. The
fire should be kept in long enough to heat the ladle well.
When the melter blows the first whistle, the stopper is
set. It consists of a rod, stopper head made of graphite,
stopper pin, lower and upper sleeve made of fire clay,
washer, and couple of nuts to fasten on the sleeves and goose
neck. The stopper is raised over the ladle with a jib crane,
lowered into position and fastened in the slide. The slide
is set so that the stopper hits the back of the nozzle and
slides into rest. This method of setting is considered
best. The stopper is held tightly in place and tightened
to hold it while the ladle is being filled with the heat.

48

A little sand is thrown around the nozzle, and if any goes through, is caught on a shovel previously placed under it. If none goes through the stopper is properly set. At the second whistle the crane takes the ladle and puts it in position under the furnace runner.

REMARKS AND SUGGESTIONS

In making up back walls, slag line and breasts, it is an essential to have a binder for the bottom material used. Slag is such a binder. Once in a great while, a little slag is ground and sent to the furnace floor. About 1/3 to 1/4 slag should be mixed with this bottom material. It not only makes a stronger slag line, but saves bottom material. It is only a question of grinding the slag and sending it to the furnace platform. Figure out the amount of dollars saved, if 1/3 or 1/4 of the bottom material used were slag. It is an item worth looking into.

The overflow slag runs into the furnace pit and necessitates a gang of men to clean it out. Why not use the slag pots provided for catching the slag as it runs over the ladle lip? The slag could be easily dumped out of the pot with one handling. Of course men would be needed to clean the pit just the same but not so many men. Dollars saved.

The burners badly need a mechanical device to hold them in place. At present, bricks, rods and wire are the only means and this method is cumbersome and unsatis-factory.

The 50% Ferro Silicon is ground up in a grinding

machine. The machine is set at one end of the
Foundry in such a way that the ground material
falls below the furnace platform. The 50% Ferro
Silicon comes in barrels and is unloaded at the
other end of the platform. Two men are employed
to wheel the material from one end of the platform
to the mill, grind it, go down into the Foundry and
wheel the ground material up onto the center of the
platform. More time is actually spent in wheeling
than in grinding, due to the way the material and
mill are located. Why not at least put the ground
material box and unground material near the mill?
It ought then only take one man to do the work.
The second helpers ought to be able to grind the
material if they had a small gyratory or Dodge crush-
ing machine on the floor.

When it is necessary to pig steel, a large
hole is made in the sand floor and the steel poured
in. It is either necessary to break the pig with the
drop, or if not broken, is cumbersome to handle on the
floor as skeleton. Why not have a specific spot in
which to pour the steel and have suitable holes already
dug similar to pig iron runs? It appears that it would
be as advisable.   51

METALLURGY OF STEEL CASTINGS

LABORATORY PRACTICE

The Laboratory plays an important part in the Foundry, especially in the production and final analysis of the steel. In fact, a large amount of the analysis is on material, such as lime, spiegeleisen, pig iron, manganese ore, iron ore, 30%, 50%, and 80% Ferro-manganese, 10% and 50% Ferro-silicon; dolomite, fluorspar, fire clay, Al-Ti, oil, etc., which has some part to play in the steel manufacture, rather than on the final product. It is from this stock analysis that the charge for the furnace is calculated and some idea is obtained as to what the steel will contain in the product condition. However, the anlaysis of the product is of as much importance, because the results obtained determine whether the steel falls within the purchasing company's specification.

Metallographic anlaysis is auxiliary to chemical and is employed in the determination of the proper heat treatment to produce a steel of proper ductility, high strength and elastic limit, all of which properties depend on the proper steel structure. At the time this report was written no metallographic analysis was being done in the Granite City laboratory.

No attempt will be made to give every method

employed in the Granite City Laboratory, since any of them can be copied from books on the subject. Enough will be included to indicate a speaking acquaintance with the American Steel Foundries' methods.

SAMPLES

Samples are made on all stock material which comes in.

On pig iron, 50% and 80% Ferro manganese and spiegeleisen, two pieces are taken from each end of a carloard. On manganese ore, iron ore and lime, two pieces in each end of a carload are broken up and the center pieces taken. A grab sample is made from ten different places in cars of Dolomite, magdolite, fluorspar, syndolite, magnobrent, fire clay and sand; and from ten sacks of flour and aluminum-titanium. Samples are taken from the top, middle and bottom of four barrels of 50% Ferro-silicon, etc. All these samples are only rough ones, but are quite satisfactory for the nature of the analysis. They are reduced to a small fraction of the whole, pulverized where necessary and put through a 100-mesh sieve, except the clay and sand, to make an assay sample.

A few years ago, standard ladle tests were adopted. At present they are not strictly adhered to, but a statement of them will give an idea about what is being done:

54

1.   The test ingot should be of a designated size.

2.   Three tests per melt should be taken on all melts of various sizes.

3.   Drillings from each ingot analyzed separately.   When consumer desires report of analysis, the ingot taken from the center of the heat should be used.

4.   Ingot tests should be taken as follows:

1.   After 5th mold, or when about 2000 pounds of steel has been poured.

2.   After half the heat has been poured.

3.   At the last of the heat and if more than 2000# is poured, the gate on the last mold is taken for a test instead of the third ingot.

4.   The drill hole should be bored at the centre of the bottom of the ingot.

5.   A half inch drill should be used.

6.   The drillings for 1/4" should be rejected.

7.   The depth of drill in ingot representing drillings taken for analysis should be 1-3/4".

Tests on the ingot heats are taken where wanted and analysis made per instructions, which vary for different heats, being on the first, middle or last of the heat. On sand heats the complete analysis is made on the center of the heat and only a phosphorus determination made of the last part.

The test ingots on the ingot heats are allowed to cool in the atmosphere until cool enough to be handled, or about two hours. Not so much care is taken with the sand heat test ingots.

STEEL ANALYSIS

The steel analysis consists of a determination of the carbon, phosphorous, manganese, silicon and

lphur content. Outside of a small percentage of

ldized impurities, such as oxides, sulphides, and

licates of iron and gaseous impurities such as

Drogen, nitrogen and carbon monoxide, the balance of

e steel is iron. The first five elements mentioned run

a rule about as follows: C .24% - .30%: Mn .60% to .80%;

.2% - .4%; Phos.015%- .05%; S.025% - .045%. So the largest

rt of the steel is iron. The oxidized or gaseous impuri-

es in commercial work are seldom determined since their

fects are about nil on the physical properties of steel.

Occasionally an alloy or a high carbon steel is

le but as a rule, the steels fall within the soft and

lium high carbon. The carbon exists in the steel as

on and manganese carbides $Fe_3 C$ and Mn_3C. It is upon

e carbon content which the annealing or any subsequent

it treatment depends and the heat treatment, upon the

idition in which the steel is wanted- whether soft and

tile or high strength and elastic limit with fair

tility.

It is not definitely known whether the silicon

lsts merely in solution in the steel or as an iron

licide, FeSi. In which-ever form it may exist, it is

own that up to several tenths of one per cent, silicon

s does not materially affect the properties of steel.

Steel of satisfactory quality contains from a trace to 0.1 per cent of phosphorus. It is held in solution in the iron as an iron phosphide, Fe_3P. Phosphorus above the percentage mentioned makes steel very brittle. This brittleness is due to the enlargement of the grains of the steel and possibly to the fact that the phosphide is segregated.

Steel of a satisfactory commercial quality may contain from a mere trace to 0.1 per cent sulphur, but specifications usually call for 0.05 per cent or less. It exists as manganese sulphide, MnS, or as an iron manganese sulphide $Fe_3 Mn_2S_5$. It is a well known fact that manganese and sulphur when brought together at a high temperature, have a very great affinity for each other and combine readily to form MnS. The MnS as such or MnS and FeS in $Fe_3 Mn_2 S_5$ are present in the steel as mechanical inclusions. If sufficient manganese is not present to take care of the sulphur, which is seldom if ever the case, an iron sulphide is formed which causes the steel to become weak and brittle.

Whatever manganese is left, after the sulphur is taken care of, goes to form a manganese carbide, Mn_3C. It is associated with the iron carbide in forming cementite.

58

In the small percentage in which the manganese exists
it improved the quality of the steel. The higher percent-
ages, say from 2% to 6%, manganese steel is very brittle
unless properly heat treated.

Having the chemical analysis of a steel and
knowing how the elements act which have been mentioned,
with the aid of atomic weights, the probable chemical
composition of a steel can be estimated. Using a steel
of about an average chemical analysis, say 0.25 per cent
carbon, 0.70 per cent manganese, 0.045 per cent sulphur,
0.05 per cent phosphorus and 0.03 per cent silicon, the
following chemical composition may be expected:

C - .25% -	Fe_3C- 3.08%
Mn-- .70% -	Mn_3C- 0.67%
S- .045%	Mn S - 0.12%
P- .05%	Fe_3P- 0.30%
Si- .30% -	Fe Si-0.90%
Fe (by diff)	94.93%
	100.00%

About a half hour before a heat is tapped, a
preliminary test is sent into the laboratory for a phos-
phorus determination.

A 1½ gram sample is taken and put into a
250 c.c. Elermeyer flask and 35 c.c. (5) of nitric acid
added. After violent action is over caused by addition
of acid, the flask is placed on the hot plate until the
steel is entirely digested. About 2 c.c. of chromic
acid (10) are added to completely oxidize the phosphorus
to P_2O_5. The solution is put into a Goetz tube in which
about 30 c.c. of molybdic acid solution has been poured.
The tube is placed in a centrifugal settler and run for a
few minutes. If any phosphorus is present, it will appear
as a yellow precipitate in the bottom of the graduated
stem of the bulb where it can be roughly calculated in
hundredth of a per cent. If more than a trace is present,
it is reported to the melter.

As the heat nears completion, tests are sent in
for perliminary carbon determinations. These tests are
conducted in about the same manner as the regular carbon
determination, so will be explained with it.

PHOSPHORUS

2 grams drillings are dissolved in 35 c.c.
nitric acid (5) in a 250 c.c. Elermeyer flask. After
violent action is over due to addition of acid, the
flask is placed on a hot plate at a gentle heat until
the steel is digested. 3 c.c.KMnO4 solution (6) are
added to complete the oxidation of the phosphorus to
P_2O_5 and the excess reduced with tartaric acid (7).
When the solution becomes clear, it is removed from the
hot plate and allowed to cool until the solution is about
85 degrees C. 60 c.c. Ammonimum Molydate (8) is added
and the phosphorus comes down as ammonium phosphododeca
molybdate. A good many conditions accompany this deter-
mination and it must be carefully done. The ppt. is
allowed to settle, filtered, washed well with cold water
until acid free, and ppt. and filter placed in the same
flask in which it was ppted. 10 c. c. more or less of
potassium hydroxide solution (9) are added from a burette,
or sufficient to dissolve the ppt. The paper is thoroughly
masticated 30-50 c.c. of neutral CO2 free water and 3 drops
of phenolphthalein (12) added and the excess potassium
hydroxide titrated against a nitric acid solution (11)

COMBUSTION CARBON APPARATUS
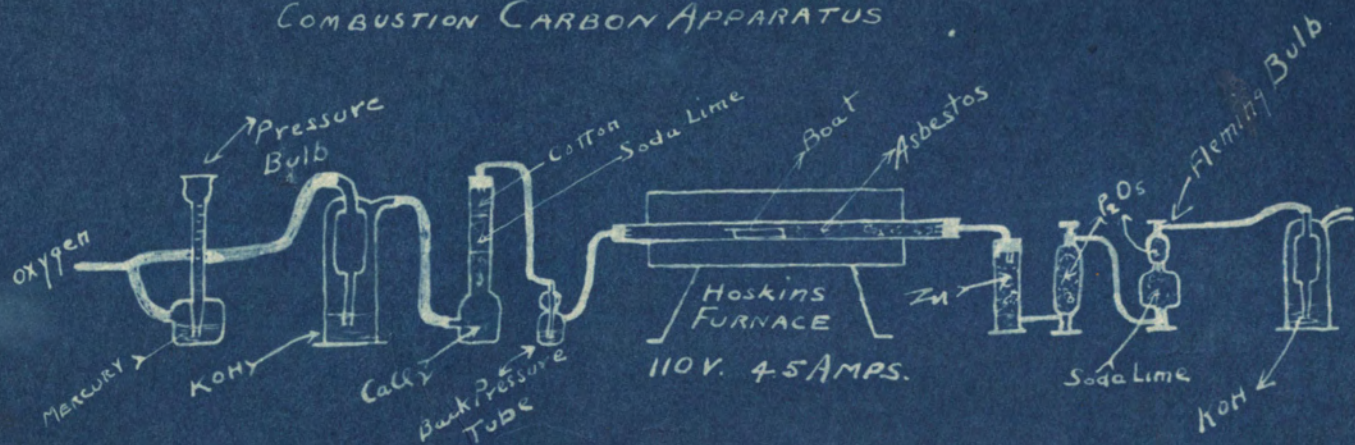
which exactly matches the potassium hydroxide. The
difference between the number of c.c. of hydroxide added
and the number of c.c. of acid used X factor if any, gives
percentage of Phosphorus in 0.01th%.

CARBON

Carbon on sand heats is determined by color;
on ingot and high carbon heats, by combustion. The color
method depends upon the fact that combined carbon imparts
a characteristic brown color to nitric acid.

A standard steel of the same kind and same heat
treatment and within 3 or 4 points on either side of the
steel to be compared, is necessary. A 0.26% carbon
standard is used in the Granite City Plant. Nickel,
Chromium and manganese in any appreciable amount affect
the test. Since the test is on combined carbon, to get a
correct comparison, it is necessary that the steels being
compared have the same heat treatment.

On preliminary tests 0.2 gram samples and on finial
determinations 0.3 gram samples are uesd. The other differ-
ence is that the preliminary is hastened on a sand bath
while the final is completed on a hot water bath and given
more time. A preliminary test must be made within three to
five minutes. A sample of both a standard and steel under
test are weighed and placed in separate 30-50 c.c. test tubes

and 5 c.c. of nitric acid (.5) added to each; after

ciolent action in over, if a preliminary, it is placed

on a sand bath and a final in a hot water bath. As soon

as the steel is digested, the tubes are cooled and the

solutions transferred to graduated comparison tubes and

the color compared by means of a colorimeter.

The standars is diluted to 13 C.C. making

each c.c. equal to two points carbon. The carbon

solution under test is gradually diluted until the

colors are matched by means of a colori-meter. The carbon

contents are proportional to the volumes. Hence each c.c.

of carbon solution under test is equal to two points carbon.

Carbon by combustion depends upon the fact that

at a high temperature, about 960^0C and above, carbon in

an atmosphere of oxygen burns to (CO_2) carbon dioxide.

Carbon dioxide can be caught in various ways, two of

the most practical being in potassium hydroxide solution

and powdered soda lime. Soda lime is here used.

The apparatus consists of a train in which a

pressure tube a KOH tube for catching any CO_2 in the

oxygen before entering a $CaCl_2$ calcium chloride tube to take

up any moisture and a mercury back pressure tube, precede

the Heskin's Electric Furnace heating chamber and following

the furnace, a zinc tube to catch any sulphur which might

63

pass over, a P_2O_5 tower to take up any moisture,
the Fleming Tube which contains the soda lime to
catch the CO_2; and P_2O_5 to keep the weight of the
tube constant by catching any moisture which might
leave the soda lime, and a KOH tube following the
Fleming tube to prevent any CO_2 entering the tube
from the air. About 2 - 3% moisture is supposed
to be present in the soda lime. But it has been
used with just a little more success with about 5%
moisture. In the delivery end of the combustion
tube, a mat of asbestes is placed to insure the
complete combustion of (CO) carbon monoxide to
(CO_2) carbon dioxide. Some consider this unncessary.

A factor weight 2.73 grams, of steel drill-
ings is used and placed in a nickel boat previously
burned to constant weight. The drillings must be fine
and in small pieces. The bottom of the boat is covered
with a thin layer of alumdum and the drillings finally
covered with it to protect the boat. The boat is
placed in the furnace, proper connections made, and
enough oxygen is passed through to slowly burn the
carbon. It takes about 20 minutes to make a determina-
tion. The Fleming bulb is weighed and the difference
between that weight and the weight previous to starting

64

the comnustion gives the carbon content direct in percentage. A blank is usually run on the bulb to determine whether it is picking up weight from any other source except the CO_2.

The oxygen comes under about 2000 lbs. pressure and is reduced to 30# or 40# and used at about 3 lbs. It is practically free from any injurious impurities.

SILICON

A factor weight, 2.35 grams of drillings is put into a 250 c.c. casserole and digested in 35 c.c. of silicon mixture (1). It is evaporated to dryness and baked until SO_3 fumes are given off to insure complete oxidation of Si to SiO_2 and total reduction of H_2SiO_3. About 35 c.c. of water and 35 c.c. HCL (2) are added after cooling, to put residue in solution. The solution is filtered hot and the ppt. is washed with hot HCl (2) to dissolve any iron salts remaining on filter paper. After washing with hot water until free from acid, the filter and ppt. is placed in a platinum crucible and ignited. Each 10.0 milligram SiO_2 represents 0.10 x 2% Si.

In case of an accurate assay, SiO_2 should be purified by putting a drop of H_2SO_4 and 3 or 4 c.c. of HF on the SiO_2 in the platinum crucible and Si driven off as SiF. The difference of weight of crucible after purifying and before, gives the true weight of the SiO_2.

MANGANESE

0.1 gram of drillings are dissolved in a 1"x12" test tube with 10 c.c. of nitric acid (5). The tube is placed in a hot water bath until the steel is digested. 10 c.c. silver nitrate (13) which simply acts as a catalizer and 5 grams (14) of ammonium persulphate are added

and the tube replaced in the hot water bath. The

persulphate reduces the manganese nitrate to per-

manganic acid which imparts a pink color to the

solution. When the persulphate is about gone, the

test tube is placed in an ice cold water bath and

allowed to cool. The solution is transferred to a

150 c.c. extraction flask and titrated to a pea green

end point with an arsenite solution (15). Each cc

arsenite solution used is equal to 0.1 of one per cent

manganese. The manganese solution should be titrated

while cold and quite rapidly because the end point is a

returning one.

SULPHUR

5 grams of drilling are placed in a 250 c.c.

Johnson flask fitted with thistle tube and discharge

tube. The delivery tube is led into a 500 c.c. jar

containing about 250 c.c. of water and 15 c.c. of $(CdCl_2)$

Cadmium Chloride Solution (4) About 85 c.c. of HCl (2)

are added to the flask by means of the thistle tube,

the flask placed on the hot plate, and the jar at a

convenient distance from same, to keep the Cd Cl_2

solution from becoming hot. This solution should be

cold, otherwise the standard iodine solution against which

it is titrated volatilizes, giving high sulphur

results. The sulphur present passes over as H_2S

and is converted into CdS in the jar. When the steel

is completely digested, the apparatus is disconnected,

100 c.c. HCl (2) added to the jar and the resultant H_2S

titrated immediately against the standard iodine solution

(3) to a distinct blue end point. The number of c.c. s x

the factor of the solution, if any, gives the percentage

of sulphur in hundredths of one per cent. (o.01)

S O L U T I O N S

1. **SILICON MIXTURE:**

>   385 c.c.s Nitric Acid (1.4) sp.
>
>   gravity
>
>   250 c.c.s Sulphuric Acid
>
>   1150 c.c.s Water

2. **HYDROGEN CHLORIDE:** 1 part strong acid, 1 part

>   water.

3. **IODINE SOLUTION:**

>   Iodine 9.15 grams
>
>   Potassium Iodide 20.6 grams (Put in
>   (solution
>   (in 30 c.c.
>   (of water.
>
>   2000 c.c. water.

Solution is standarized against a standard

steel of known sulphur content and the factor

estimated.

4. **CADMIUM CHLORIDE SOLUTION:**

>   Cadmium Chloride- 50 grams dissolved
>
>   in 500 c.c. water
>
>   Ammonium Hydroxide- 2500 c.c.
>
>   Water 800 c.c.
>
>   Starch- 12 grams

A paste if made of the starch and added to

200   200 c.c. of boiling water and it to the

solution.

5. NITRIC ACID: 1.2 sp. gravity:

        4200 c.c. water

        3000 c.c. Nitric Acid, 1.42

        sp. gravity

6. POTASSIUM PERMANGANATE- $KMnO_4$

        10% Solution.

7. TARTARIC ACID:

        10% Solution

8. AMMONIUM MOLYBDATE:

        Molybdic Acid- 225 grams

        Ammonium Hydroxide- 500 c.c.

        Water- 500 c.c.

The above mix added slowly to 2500 c.c. of

Nitric Acid (1.2 sp. gravity) stirred and

cooled during operation. Add 3 c.c. of a

10% solution of microscopic salt, allow to

settle and filter.

9. POTASSIUM HYDROXIDE SOLUTION:

        10% Solution

10. CHROMIC ACID:

        CrO_3 - 125 grams

        Water - 75 c.c.s

11. NITRIC ACID:

        10% Solution

        No. 9 and 11 are matched and standatized

        against a steel of a known phosphorus

        content and the factor estimated.

12. PHENOLPHTHALEIN:

        1 gram

        100 c.c. grain alcohol

13. SILVER NITRATE:

        Silver Nitrate Crystals C.P.

        33.25 grams) stock
) solution
) Water- 500 c.c.

        20 c.c. Stock Solution) Desk
) solution
) 1000 c.c.
) water

14. PERSULPHATE:

        Crystals C.P.

15. ARSENITE SOLUTION:

        Sodium Carbonate- 36 grams (Boil and
        Arsenious Acid-   10 grams) filter
        Water-   1000 c.c

        Stock Solution-   68 c.c.)
) Desk
        Water-   2000 c.c.) solution

Solution is standarize against a steel of
known Manganese content and the factor
estimated.

16.   RECLAMATION OF MOLYBDIC ACID FROM PHOSPHORUS
      DETERMINATION FILTRATE:

Add to 2 liters of filtrate, **45**
grams of Sodium biphosphate. Stir and allow to settle.
Decant and wash ppt. by decantation three or four times.
Dry and store.

Preparation of Solution

175 grams yellow ppt. added to 500 c.c.
water and after shaking well add 750 c.c. strong ammonium
hydroxide and 30 grams Magnesium Nitrate in 100 c.c. of
water. Filter and add filtrate slowly to 1200 c.c. of
strong nitric acid add 700 c.c. water.

Beside the above solutions for heat work, other
standards are kept on hand for general work.

17.   TENTH NORMAL SOLUTION OF POTASSIUM PERMANGANATE:

3.16 grams C.P. KMnO4 crystals

1000 c.c. water.

Standardized against Ferrous Ammonimum Sulphate.
Used for iron, antimony, chromium, and manganese
determinations.

72

18. TENTH NORMAL POTASSIUM DICHROMATE:

    4.9 grams C.P. Potassium Dichromate crystals

    1000 c.c. Water.

Standardize against iron wire and Ferrous Ammonium

Sulphate. Used for iron determinations.

19. TENTH NORMAL IODINE SOLUTION:

    12.9 grams Iodine C.P. Crystals

    25 grams C.P. Potassium Iodine crystals)30 c.c.
)water
    1000 c.c. water.

Standardized against a standard dichromate solution

along with a Thiosulphate standard. Used on tin

determinations.

20. TENTH NORMAL THIOSULPHATE SOLUTION:

    16.0 grams C.P. Thiosulphate crystals

    1000 c.c. water.

Standardized as indicated in 19. Used on copper

determinations.

21. SILICON SOLUTION FOR 10% FERRO SILICON:

    Water-   725 c.c.

    Nitric Acid-325 c.c.

    Sulphuric Acid-125 c.c.

    Hydrochloric Acid-50 c.c.

STOCK ANALYSIS

Under the head of stock analysis will be included, beside stock material, pig iron, coal, coke and fuel oil. A number of the determinations on stock material are similar with some variations to steel. For instance, pig iron, with a few differences in assay sample weights and minor points in method. Determinations only will be indicated on the following:

Pig Iron- sulphur, silicon, phosphorus and manganese. Pig is bought from several companies and buying specifications call for about the following alalysis: S- 0.05% or under; Mn- 1.0% or over; Si- 1.3- 1.% or under; Phos- 0.5% or under.

Spiegeleisen- manganese, which should fall between 18. and 22.0%; silicon between 1. - 4.% and Phos. .1-.5%. Some grades run up as high as 60% Mn.

Sand- fineness which should run about 35.

Clay-   "   "   "   "   "   60.

Flour- Ash running about 1.2 to 2.0%.

Al-Ti- Aluminum 12-15%; Titanium 4-8%; and the balance iron.

10% Ferro Silicon- Silicon approximately 10%.

50% Ferro Silicon- Silicon between 48 -50%, depending on what grade it is.

Iron Ore- Fe falling between 55% to 76%;
Silica 1 to 5%; Phos. up to 0.5%. A complete analysis
is not madw which would be more extensive. The iron
ore is either Hematite or Magnetite.

Manganese Ore-Mn falling between 28% to 51%;
Silica 1% to 5%; Phos. up to 0.5%. The most common
ores of manganese are pyrolusite and brawnite.

Ferro-Manganese- Mn various percentages up to
80%, depending upon the grade.

Lime- Loss on ignition; Silica; R_2O_3 consisting
of Al_2O_3, P_2O_5, FeO and any other oxides of this group;
MgO and CaO of which lime contains a very large per cent,
say between 77% and 93%, depending upon the quality of
the material.

Slag- FeO; P_2O_5; MnO; CaO; SiO_2; Al_2O_3; MgO.
A slag analysis is only run for slag control in case it
is running bad. It is very essential that the slag
contain a large excess of CaO or lime to take care of
the excess phosphorus or rather to eliminate it from
the steel bath.

Magnebrent- R_2O_3; CaO; MgO; SiO_2; loss on
ignition.

STOCK ANLAYSIS   (Continued)

Dolomite, magdolite, syndolite- Loss on ignition; SiO2.

Coal and coke analysis is seldom made, but when so, only an approximate analysis. On coal, it consists in the determination of moisture, volatile matter, fixed carbon and ash; on coke, ash and porosity.

On Fuel Oil the Baum' or specific gravity is taken. To be of the proper quality it should run about 27.00 Baume' at 60°C. Modern conditions demand that any fuels should be bought on B.T.U. basis rather than on a tonnage basis, for coal and coke,and gallon or barrel basis for oil.

Some analyses are only occasionally done and will be simply mentioned as follows:

Babbit metals, solder, aluminum in steel, fluorspar, impurities in aluminum, linseed oil, nickel in steel, bauxite, and some which have already been alluded to. For any of these just mentioned or any of the analyses, flow sheets are available.

Most stock is bought under specifications, as has been already indicated and the analysis on such is made to determine if it falls within the limits or is up to standard. As a rule, material "comes in", but occasionally something must be rejected.

A N N E A L I N G

Steel when melted in the open hearth attains
a temperature approximating 1800-2000° C.   Upon being
poured into a mould, the metal next the sand is cooled
to the solid condition at once, while the inner and
larger mass of metal remains moulten for varying lengths
of time, depending on the size of the casting.

On account of the outside shell cooling quickly,
the crystals, making up the structure are smaller than
those which form in the interior of the casting, owing
to the difference in time allowed for growth from the
liquid state.   These crystals grow under peculiar
conditions.   The metal while in the liquid state has
increased in volume from the solid. With the formation
of the shell on the outside at once, and the moulten mass
in the center, the shell will be relatively larger than
the total shrinkage of the hot metal to solid. Making
due allowance for the head to feed metal to the interior
forming crystals, nevertheless, there will be a tendency
for the crystals to pull upon each other as the center
becomes solid, causing internal strains.

Besides the time allowed for the growth of
crystals, the metal cools from a high temperature through
a range in which large crystals are pronounced, with a
resultant brittleness and hardness.   Some idea of how

brittle the metal is, may be gained from flogging floor practice. On small heads and gates it is only necessary to nick and strike them a hard blow to remove them from the casting, leaving an almost true surface with but little grinding.

To reduce the internal strains, brittleness and extreme hardness, is the purpose of annealing. Annealing operating consists of three distinct steps: (1) heating the metal, (2) keeping its temperature constantly at the annealing temperature and (3) cooling from the annealing to atmospheric temperature.

It will not be necessary to go into detail of the annealing from a physical chemistry standpoint, except to say that every different "C" content steel has a different temperature to which it should be heated. The proper temperature to which it should be heated is that temperature or critical point at which there is a change in the steel, completely changing the previous structure from coarse grained, brittle and hard steel, to fine grained, ductile and soft steel. A few critical temperatures are as follows:

"C" Content	Temperature - Critical
.12 - .25	1544^0 - 1598^0 F.
.50 - .49	1499^0 - 1544^0 F.
.50 - 1.00	1454^0 - 1499^0 F.

78

The usual run of steel in the foundry,
except on special heats lies between .25 - .50 "C"
content, and should be heated to the temperature
indicated.

In case of cast steel it has been found that
it is necessary to heat slightly above the critical
temperature or there will be no desired annealing
effect.

To obtain the proper results the furnace
charge should be brought to the proper temperature
slowly, allowing all castings to become heated
evenly throughout. The time to accomplish this
varies with the size of the casting. If castings
of any magnitude are heated too rapidly, the struct-
ural changes will be so uneven that the resulting
casting will be warped and cracked. After the steel
has been brought to the desired temperature it is
necessary to hold it at that point at least an hour
or more varying with the size of the piece.

The rate of cooling depends upon the nature
of the effect desired. If softness and ductility are
wanted (for ease in machining) at the sacrifice of
strength and elasticity, the cooling should be slow
and in the furnace in which heated. If hardness for

79

wearing power, strength and elasticity at the sacrifice of ductility, the cooling should be in air or in a quenching agent such as oil, brine, or even water.

The castings should be racked in such a way that they do not rest upon each other. The furnace should be constructed so that the hot gases pass through and about the castings freely and not have all the flame buck up against one side of the racked material, resulting in too rapid and over heated castings on one side and under heated on the other.

Since heating and cooling has much to do with the proper annealing result, small castings and large castings should be racked separately and annealed separately. The different size pieces need entirely different heat treatment. Should they be annealed together, the result is apparent.

If the fuel used is oxidizing in its effect upon the casting surface, the castings should be placed in pits and packed so that the gases cannot attack the metal because the oxides formed upon the castings tend to decarburize the steel.

The ideal appearance of a casting, after

being annealed, is a reddish hue. If blue, it has
been over-oxidized.

T E S T I N G

Following are a few of the most important
A. S. T. M. standard specifications for steel castings.

	Hard # per sq. in.	Medium # per sq. in.	Soft # per sq. in.
Tensile	80000	70000	60000
Elastic Limit	36000	31500	27000
Elongation in 2"	15 %	18 %	22 %
Red. of Area	20 %	25 %	30 %
Bend Test	none	90°	120°

CHEMICAL ANALYSIS

P	.05	.05	.05
S	.05	.05	.05
C		Not Specified	

Process must be the open hearth.

Analysis shall be taken from ladle.

Yield point shall be determined by drop beam.

Fracture must be silky or fine granular.

Bend specimens shall be 1" x $\frac{1}{2}$" in section.

Tension specimens shall be $2\frac{1}{2}$" x $\frac{1}{2}$" in section

The purpose in giving the foregoing, is because most companies have their own specifications, all of which are governed by the A. S. T. M. standard, and approximate, as a fair average, the standard. Some have adopted the standard: H. Y. C. All companies specify the chemical analysis and a corresponding physical test.

The average run of the American Steel Foundry steel is about,

Physical,

Tensile	El. Limit	Elongation	Red. of Area
70200	37600	28.8	45.4

Chemical,

C.	Mn.	Si	P.	S.
.285	.633	.28	.0396	.0323

On all castings requiring a test, a test coupon is cast on the casting unless too small and then a test block of the same heat is made. The coupon is put through the same heat treatment as the casting so that it will approximate the steel under test. Before the coupon is knocked off the casting, it is numbered and the corresponding number painted on the casting. The numbers are consecutive in the filling schems, and are independent of any of the company marks. Any necessary information, such as name of customer, date cast, pattern number, nature of casting, is filed with the number so that it is easily identified. After the bars are tested, the remaining part which has not been machined is matched on the casting to assure the foreign inspector that the bar in question belongs to the casting. The machine used in pulling tests is a Riehle' Bros. 300,000# capacity and operated upon laboratory principles.

METALLURGY OF STEEL CASTINGS

MOULDING PRACTICE

DRY FLOOR MOULDING

It would be an endless task to give the names of all the castings, the moulds of which are made in any department, but on the dry floor, large work is mostly handled such as wheel-centers, rolls, driving boxes and bridge blocks all sizes, ladle trunions, cylinders, cylinder heads, deck plates, annealing vats and trays, blank gears, spur wheels and bevel gears all sizes, motor and engine frames, globe valves, elbows, all sizes, riding rings, coupling boxes, ladles, hammer blocks, hammer arms, forge dies, and others too numerous to mention.

The moulder's tools and materials are first essentials in moulding. A trowel, stick, hammer, lifter, hand and air rammer and shovel are necessary tools. The wood or metal frames containing the mould are called flasks. The mould is made up of two parts, and sometimes three or more called cope, cheek and drag. The cope consists of the top flasks, the cheek any center, and the drag the bottom flasks. Other materials are follow boards, gaggers, rods, clamps, wedges, nails, paste, plates, bars, heads, burnt and facing sand, molasses and silica wash.

The moulding of a particular elbow for a blast

furnace will first be considered. The pattern is split and has a number of loose pieces called draw-outs attached with dowel pins. The pattern, if new, and sometimes even though old, is first oiled with kerosene oil. The oil keeps the facing sand from sticking to the new or old pattern, but is not used to any great extent.

In a symmetrical pattern like a pipe, it is immaterial which part of the pattern, as far as the draft is concerned, is placed in a four foot drag, with the exception that the half containing the joining dowel pins is left for the cope. The drag half of the pattern is placed on a follow board, joint down. A gate consisting of a piece of $2\frac{1}{2}$ inch pipe is set in place so that a bottom gate can be cut. Facing sand, about an inch and a half thick is carefully placed about the pattern. About ten inches of burnt sand is thrown on, and after kneading with the hand rammer, the air rammer is used. About one ramming will bring the sand up to the loose pieces. These are carefully put in their places and facing rammed by hand about them. The dowel pins which extend through the parts are withdrawn. The burnt sand which has been forced about the pattern is cleaned away and more facing and burnt sand added. This ramming brings the sand high enough to give more attention to the gate.

Gates are of various kinds. The most
important are bottom gates, side gates, end gates and
swirl gates. Whatever kind, it is necessary to make
a gate so that it will break the onrush of the ingoing
metal and save the mould. By much experimenting, it
has been found that a shallow wide gate, with a slight
indentation where the metal first hits the bottom is
best. In placing gates, they should be set with refer-
ence to the risers. The metal should find its way
through the mould before finding the head.

In this particular case, a bottom gate is
used. A piece of 1" x 3" board is set vertical on one of
the flanges and facing about 3 inches thick rammed about
it. The facing is leveled off and both stick and pipe
are withdrawn. A channel about 1" x 2" is cut from the
opening left by the stick to the opening left by the pipe.
The channel is washed with silica wash, covered with
slab cores or fire clay brick, another flask is added and
the ramming proceeds until the whole pattern is covered
and the sand is level with the bottom of the flask. The
sand is smoothed off, a plate is set in place, and both
it and the follow board are clamped on.

With the assistance of a crane, the drag is
rolled over. The follow board is taken off and the mould's

surface smoothed down. The other half of the pattern
is set, a flask put on and set to the pin holes. Bars
are placed on the flask about and free from the pattern,
leaving places for risers about 5" x 9" on the flanges.
Parting sand is thrown over the drag to keep the facing
of the drag and the facing in the cope from sticking.

The gate pipe is put in its place. A thin
layer of facing about an inch, is scattered over the
pattern and mould. Gaggers are then pasted with mud
and set so that they set firmly against the bars and
joint. The ramming process goes on as before, first
kneading well with the hand rammer. The sand is rammed
some harder than in the drag to insure a good lift.
There is such a thing as ramming solid but not too hard.
If too hard, the pattern will not draw clean; if not hard
enough, the sand may fall out. After the first ram, the
bars are pasted and another flask added. Since the
pattern extends into the cope and the heads are placed
on the flanges, they are not set until the ramming brings
the sand up to about where they are placed. Small risers
called pop heads are set on the projections on the cope
side to take care of any gas which might keep the metal
from rising into the cavity. Two rammings fill the
flasks. The gate and heads are withdrawn, a little

88

facing placed in the head hole and rammed down. The
risers and gate are washed with silica wash. The two
cope flasks are clamped together and if pins have not
been used at the joint two or three chisel marks
extending over the joint edge of the drag and cope
are cut at equal intervals on the flasks to facilitate
correct closing.

The cope is lifted and turned over. Molasses
water is sprinkled around the edge of the pattern. The
pattern is rapped with a block of wood and hammer to
loosen it from the sand. It is withdrawn with the aid
of woodscrews and is sometimes rapped as it is being
withdrawn. Some care must be exercised in drawing the
draw-outs. The facing is cut out of the opening or neck
to the heads and made eliptical in shape tapering toward
the top of the head. The heads
are cut this shape to give ease in
removing the head metal.

The metal when hot has
increased in volume and will de-
crease when it becomes cold. The
cooling takes place slowly from
the outside, which becomes a shell
almost immediately, to the center.

Should a casting be poured without a riser, when it cools it would be scrap because of the shrink holes in it. The head is made large enough to carry a mass of hot molten metal to fed the gradually cooling casting. The neck of the head is made correspondingly large, so that it will stay open as long as the casting.

Fillets are put on any sharp edges to cause the metal to lay against the mould better. The edge of the mould is finished off smoothly and any breaks patched. Ten penny nails and finishing nails are tacked all over the surface of the cope. In the drag finishing nails are large enough and a large number are placed at the gate entrance to keep the ingoing metal from cutting the mould. These nails answer two purposes: one to give a clean casting; and two, to help keep the sand from the cope from being drawn down by the hot metal.

Brackets are cut between the flange and pipe. A bracket is simply a small slit about $\frac{1}{4}$" wide, various lengths, cut into the mould. When the metal flows into it, it cools at once.

Brackets are used very much and it is easier to explain their purpose by referring to a wheel hub. Note figure.

Where the spokes join the hub, there is a
greater mass of metal than in any one spoke alone.
Hence the spoke cools faster and consequently shrinks
faster than the hub. Any cracking usually takes place
when the metal is in its transformation stage between
the liquid and solid when it is more like paste. The
spoke passes this point before the hub and is stronger,
and since it is shrinking faster, tends to pull on the
pasty mass which gives readily.
Here the bracket plays its part.
It is strong metal before either
hub or spoke and keeps the stronger
from destroying the weaker. This
explanation will hold true for most
any bracket.
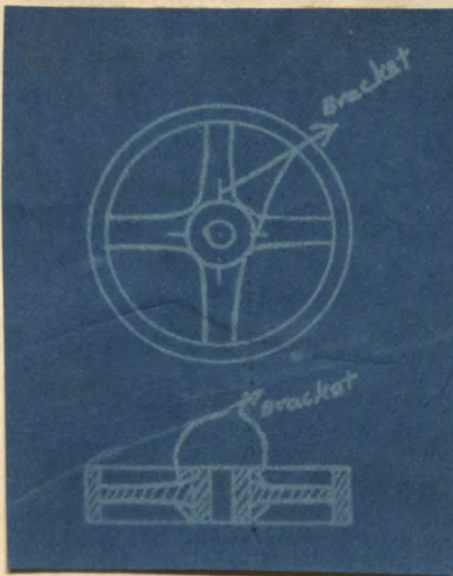
The dirt is cleaned out of
the mould and molasses water sprink-
led over it to act, when it dries,
as a binder. The mould is washed
with a silica wash, consisting of
silica, salt, molasses and water. The wash when dry gives
a smooth surface for the metal to lie on and tends to
produce a cleaner casting.

91

The mould is now ready for the oven. It is placed on iron carts and pulled into the drying oven. The temperature is gradually brought up to between 600 degrees Fahr. and 700 degrees Fahr. and the mould is left there about 8 or 12 hours, depending on the size of the mould. From the oven it is pulled out to the dry floor.

Before passing to the dry floor a few more types of moulds will be considered.

Some patterns are not so easily placed on the follow board as the one first described; for instance, a bevel gear large enough to require a four foot flask.

BEVEL GEAR

Cross Section

Experience has taught that it is best to put the tooth section in the drag. It is apparent from the rough sketch that to do this it would be necessary to turn the spoke side down on the follow board. But the spoke side is constructed so that it would not be advantageous to do so unless a special follow board was made.

92

There are various ways to overcome this, one of which would be to fill a flask with burnt sand and ram up about the shape of the spoke side. Add enough loose sand to permit the pattern to be "batted" in so that the base of the teeth would be even with the top edge of the flask. Another flask is added.

A special facing, made for gears of all kinds, and large flat surfaces and pockets is placed about the teeth. This facing is made stronger and gives a cleaner casting. Nails are placed between the teeth to strengthen them. In modern practice, nails are being discarded to some extent. Roll facing is placed about the balance of the pattern, a bottom gate cut, feeding through the hub on each side of the core, more burnt sand added until ramming is finished, follow plate put on and clamped, and the flasks clamped together. The flasks are rolled over and the follow flask removed including the burnt sand. The spoke side is now up and the operations of adding cope flasks, facing, gaggers and heads are similar to what has been explained. Three heads about 5" x 9" are placed on the rim of the gear and a larger one at the hub. On account of the head at the hub it is necessary to place a ring of soft iron about the core print to hold the core when the neck of the head is out. The

pattern is lifted with the cope with the assistance
of wood screws which are put through convenient places
in the cope and fastened. The usual finishing is done
and the mould is ready for the oven.

Rolls are made with a sweep pattern. The
pattern consists of a long 1½" board, cut the shape of
the roll. It is centered on a shaft and the shaft
centered in the mould on cross bars. The gate is made
of fire clay tile and enters the mould at the bottom
through the gate cavity. An enormous head is necessary.

The flask is filled with burnt sand
and facing and rammed even with the
joint edge of the flask. A cut is
made through the facing about the
width and length of the pattern.
The pattern is fixed in place and
by means of a handle is swung down
on the sand. An outline of the
pattern is thus made and more fac-
ing is cut out following the lines
of the pattern. The sweep is again
forced down and by this cut and try method, the facing
is gradually swept out to the shape of the mould. In
the cope side, rods, paste, nails and hemp rope are
used to hold the sand in place. The drag has only paste

94

and nails on the mould surface. After being smoothed
down with slick and trowel and the wabbler put in, the
usual finishing is done and the completed mould is placed
in the oven.

There are occasions when moulds are made from
a skeleton pattern. A large elbow, about 5 ft. inside
diameter and containing about $2\frac{1}{2}$ inches of surface metal,
flange on each end, was cast. The pattern was only an
outline of the casting. Instead of making a core box
for the core part, the core was made in the mould. A
large arbor to carry the weight of the core was first
made. It consisted of a frame of metal bars cast to
the shape of the elbow.

The drag was rammed up about the shape of the
pattern. The drag half of the pattern was placed in
and the drag completed, bringing the facing through the
skeleton even with the inner surface. A bottom gate in
the flange was used. Parting powder was sprinkled over
the surface of the mould, the arbor hung in place and
the drag half of the core made. The cope half of the
pattern was set and the core built up, bringing the
facing through even with the outside of the skeleton.
The cope was completed, using two large heads, one on
each flange, and lifted. The facing on the core part

was cut out to the inside of the skeleton and the cope
half of the pattern drawn. The finishing touches were
added to this part and the whole core lifted and the
other half finished and the whole dried by building a
fire under it. The facing in the drag was cut to the
outside of the pattern and the pattern drawn. Both cope
and drag were finished and dried with charcoal since the
mould was too large for the oven.

The necessary means for carrying off the gases
were provided. When the metal is poured into the moulds,
gases and also steam in green moulds are evolved. It is
essential that they be carried away or they will ruin the
casting by making blow holes in the hot metal. In large
moulds that are not put in the oven, and also in some
that are, a layer of cinders is first placed in the drag
to act as vents. In green sand, vents are put in the
cope with a vent rod. In dry sand the sand is practic-
ally free from moisture and permits the gases to escape
through the sand recesses. Since vents are placed in
the cores, vents to convey the gas from them must be
made in the mould. This is done on the dry floor.

There is no end of ways to do moulding.
These few methods were used to give some idea how it
is done. Just a few general remarks.

A large number of blank gears are made.
Some are cast vertical and some horizontal. The
arguments in favor of the vertical are that it
saves head metal and gives a more sound casting.
The head is cut as shown and shows to some extent
why a better casting is the result of this method.
The neck is free to contract with the casting,
doing away with any possibility of cracking due to
this cause. Each part above feeds the part below
which is another reason. If all heads could be cut
thus it would do away with
"digging out" heads.

In any pockets, nails,
if small, and gaggers, if
large, are used in the drag
to strengthen and in the cope,
to help lift.

In case there are a
number of ribs on a casting
causing deep large pockets, a
mixture of saw dust and sand
is used in them to insure give
in the mould when the metal cools and shrinks to keep
the casting from cracking. In the panels between the

spokes of wheel centers and large spur wheels and blank gears, the sand is dug out and loosened to some extent for the same purpose. A parting powder, made of bone ash is used instead of parting sand for parting purposes.

A large number of moulds are merely outlines of a casting, since the cores form the larger part. For instance in a certain deck plate mould there were 16 cores both large and small.

DRY FLOOR

The moulds are drawn out of the oven on the dry floor side and placed on the floor by means of cranes.

The elbow before mentioned is brushed out to loosen any dirt which may be sticking to the mould. The core is dressed down to cut away any rough corners and set in place and braced by chaplets.

Chaplets are of various kinds, the two most used are the perforated and spool shaped. They are made of tin-plated iron. The tin plate acts as a solder. The perforated ones can be bent to most any shape and are especially advantageous because the metal can run through the perforations.

Oil is sprayed over the surface of the cope
to act as an additional bond and make the mould surface
harder. The heads in most cases, are built up to insure
a large enough mass of metal to feed the casting.

The dirt is blown out of the mould and the
gate drained thoroughly. Flour is scattered around the
edge of the drag to make it possible to see where the
cope sets too hard on the drag. Clay balls are placed
on top of the elbow core to indicate the height of
chaplets on the cope side. The cope is set and then
lifted. A dry mould is always lifted to catch any
crushing. The crushed places, if any, are patched and
the high places filed down. Again the dirt is blown out.
Dough is rolled out in long strips and laid about the
edge of the pattern print in order to seal the mould
when the mould is closed. The clay balls are replaced
by chaplets. Several 20 penny nails are driven between
the cope and drag at equal intervals to keep the joint
from crushing when the mould is clamped. A cup is set
over the gate and the mould is ready to be poured.

The rough edges on all cores should be filed
off before they are set in place. Care should be
exercised to see that proper vents are provided to
carry the gases from the cores.

99

When there are any inside ribs in a mould, chill rods and nails should be set. An explanation of the chill rod would be similar to that of the bracket with the exception that the chill rod and nail perform their function within the casting, while the bracket without. The chill rod simply equalizes the rate of cooling in heavy and light parts of a casting thus preventing cracking, while the bracket holds together the parts cooling at a different rate.

In wheel centers, gears and blank gears or any casting having a hub core, it is essential to have the core centered. When possible, such cores should be tried in both cope and drag to keep them from crushing when the mould is closed. Any cores extending into the cope should be tapered some to allow for proper clearnace; otherwise both cope and core may be crushed.

Some moulds do not have any cores, for instance most rolls do not. They are closed as usual, the cope and drag bolted together, the joint luted up with mud and the mould set in a pit to facilitate pouring. A roll runs anywhere from 6 to 24 tons including head when cast. Other moulds are all core.

A casting free from cracks is sometimes due to the care used after the metal is cast. On large castings

the sand about the head is always dug out to keep
the heads from binding on the hard sand. The copes
on large flat castings and wheel centers are lifted
a few inches while the metal is quite hot, to take
the cope weight off.

GREEN SAND MOULDING

As far as actual operations are concerned, green sand moulding is like dry sand with some exceptions.

On small work, the cores, if any, are set and the moulds closed at once. Molasses water is used sparingly and only when the mould is skin dried. Dough is seldom used to seal the joint, but flour is used on skin dried moulds.

The flasks are made of wood; and nails used in the cope bars and short sticks instead of as many gaggers as are used on dry work.

Silica wash in not used and the facing called center plate is harder to work than roll facing.

Castings that do not require very much machining are cast in green sand. Small orders and intricate patterns are handled on the floor while large orders on castings such as rail joints, buffers, center plates, Studebaker hubs, spur wheels, locks, yokes, tooth racks and others too numerous to mention are made on machines.

The automatic machines used are called bumpers and are operated by compressed air. The pattern is fastened to a match board to which the flask fits exactly. Necessary gagers are set, facing and burnt sand added

102

and the air turned on. The bumping does the sand

ramming. The balance of the operation is similar

to other moulding.

Comparison Table for Green and Dry Sand Moulding.

	Green		Dry
1. Cost	low		high
2. Time in handling	short		long
3. Moulds lost	few		many
4. Gas in mould	much		little
5. Nature of work handled	little machining on casting		much machining on casting

Metal lays better in a dry mould than in a

green.

BENCH MOULDING

Most all bench work, except small orders, is

done on match boards. Anyone who can ram sand and handle

a shovel can do it. The matchboard includes pattern,

gate and head runners. The work runs something like this:

a flask is fitted to the drag matchboard, necessary sands

are added and rammed up, mould rolled over, pattern drawn,

very little finishing done and cores set, mould set on

channel irons and in some cases skin dried. The cope

is finished in about the same hurry and the mould is

103

closed at once unless it is to be dried. The mould is
clamped and is ready for the metal.

GENERAL REMARKS

Leaky and worn out air valves in air rammers
and air line represent per hours - energy lost - Dollars.
New valves would save their cost in a short time. Plenty
leaky valves can be found in most foundries.

Air once compressed can be increased in motive
value by heating it. It is very apparent that there are
numerous places where large quantities of hear are being
dissipated.

Increase the temperature of the compressed
air 100 degrees Fahr. and you increase your energy 20%;
increase it 300 degrees Fahr. and your energy is increas-
ed 45%. Lubrication only limits the temperature. A 20 -
45% increase in energy in your air means a reduction of
20 - 45% in your electrical bill.- The proper
installation could only be used for the machines as the
men could not handle the air rammers. Even so, more air
is used by the machines than by the air rammers.

Wood flour is used as a plastic. Whether it
would serve the purpose that flour does now is only a
matter of experiment. At any rate it was quoted at about
$12 or $13 a ton not long ago against $29 a ton for flour.

A nail making equipment costs but about $100, quoted directly in an article in the American Machinist, as follows:

"A suitable moulding machine plate could be made for less than $100, whereby one moulder could easily produce 125,000 nails per day."

Silica wash is a mixture of silica and molasses and water.

There are not sufficient tools, such as shovels, hand and air rammers, heads, wedges, clamps and sledge hammers on the dry moulding floor. Much time is lost in looking for and waiting on such materials. In a short time more tools would pay for themselves in time saved.

SAND MILL

Facing Mixtures.

Roll Facing - Formula

A.

40	shovel	new sand
1/2	"	silica
3/4	"	flour
2-3½	"	clay

B.

30	shovel	new sand
10	"	old sand
2	"	silica
2½	"	clay
1	"	flour

Roll facing - now in use.

#1 fdry. Dry floor	#1 fdry. Green sand side
40 shovel new sand	16 shovel new sand
3 " silica	2 " silica
5 " clay	2 " clay
	2 quarts flour

#2 Foundry

40 shovel new sand

8 " silica

5 " clay

1 " flour

Center Plate - Formula

#1 Foundry	#2 Foundry
16 shovel new sand	18 shovel new sand
$\frac{3}{4}$-1$\frac{1}{2}$ " clay	$\frac{3}{4}$-1$\frac{1}{2}$ " clay
1 quart flour	1 " silica
	1 quart flour

Center Plate - now in use.

#1 Foundry - Dry Floor	#1 Foundry - Green sand side
40 shovel new sand	17 shovel new sand
2$\frac{1}{2}$ " clay	2 " clay
	1 quart flour

#2 Foundry

30 shovel new sand

10 " old sand

2$\frac{1}{2}$-5 " clay

1 " flour

Special Roll

40	shovel	new sand		45	shovel	new sand
8	"	silica		4	"	silica
1	"	flour		1½	"	flour
3	"	clay		3	"	clay
				molasses water.		

Roll, Wabbler, Dies and Gears

Wabbler

10 shovels new sand

5 " silica

2 quarts clay

3 pts. Linseed oil

Die Pocket

6 shovels silica

2 " graphite

Special Die

16 shovels new sand

1 " clay

1 " silica

1 quart flour

1 " salt

Pocket Facing

35 shovels new sand

1 " silica

1 " clay

Tooth Facing

5 shovel new sand

6 " silica

½ " clay

3 pts. Linseed oil

Half and Half

8 shovels new sand

8 " old sand

1 " clay

Dextrine Facing

25 shovels new sand

1 " clay

½ " dextrine

Only enough moisture should be used to hold the sands together.

The formulas vary, depending on the conditions of the sand and fire clay and upon the men who handle the scoop.

One of the main essentials of a good facing is that it should peel from the castings readily. The flour acts as a peeling agent.

The mills used for mixing the molding sands are chillian dry pan.

Cores.

Cores play an important part in moulding. Almost without exception cores of some kind or description are used in every mould.

They are all hand made and vary in size from a small pin core weighing a fraction of an ounce to larger cores weighing several hundred pounds.

Small cores are made by ramming core facings into core boxes, putting a few nails into them for strengthening them, a few vents to permit gases to escape and drying them in the oven. Larger cores require nails and rods of various lengths and paste to give them sufficient strength to permit handling.

All cores are sprayed with a glutrine or molasses water solution before being placed in the oven. The spray is supposed to act as a binder and give the cores a smooth surface. In order to determine the value of glutrine water spray a special investigation was carried on, the results of which follow after core discussion.

The cores are placed in an oven heated either by coal, coke or oil. The oil gives the best results as a more even temperature can be maintained and there is less trouble in handling. The oven is held at a temperature of about 600° F. Higher temperatures burn the cores

and fail to dry them. The length of time that cores stay in the oven varies with the size, running on average about ¾ hour.

After passing through the ovens the cores are stored in racks until needed. Large quantities of cores are lost in handling running sometimes as high as 50%. The cores are made by piece workers making $5 to $7 a day. Some idea can be gained as to the amount of dollars lost with such large per centage of breakage. Closer supervision in handling would eliminate a· large amount of this waste.

The core boxes are made of wood or metal, mostly aluminum.

MOISTURE ABSORPTION STUDY OF CORES IN GREEN SAND MOLDS.

Mr. Begley, Chief Chemist, Granite City Plant, had his attention called to the moisture absorption of a core mixture which he had suggested for use. Because the cores made from it, after standing in the closed molds for several hours, absorbed moisture, word came from the Core Department that the mixture was "no good". In order to find out if this mixture really absorbed more moisture than the other in use, Mr. Begley decided to try a simple comparison experiment. He took a 1½" x 7" pin core made out of the mixture in question and a similar core made out

of another mixture and placed the end of each one in
separate jars, partially filled with foundry facing and
sealed the jars. After standing several hours, the jars
were opened and the cores examined. Both core mixtures
had absorbed moisture. The question was raised whether
or not and to what extent, all the mixtures absorbed
moisture upon standing in closed molds. A description of
the work done to decide this question follows and numerical
results are tabulated.

Pin cores, $1\frac{1}{2}$" x 7" were made of six standard
Foundry core mixtures, the formulas of which are found
elsewhere. The mixtures were taken from the mill as made.
Samples were taken for moisture determination, the results
of which are found in table. The cores were sprayed with
glutrine water as in practice, and were placed in the same
core oven on the same shelf, and left in about a half hour.
Six brickets per mixture of the same mixture were also made.
Three of these sprayed with glutrine water and three were
not and were dried under the same conditions as the cores.

FIG #1
LOWER   UPPER
HALF   HALF
Cut Here

Fig #2
Cut Here   Here
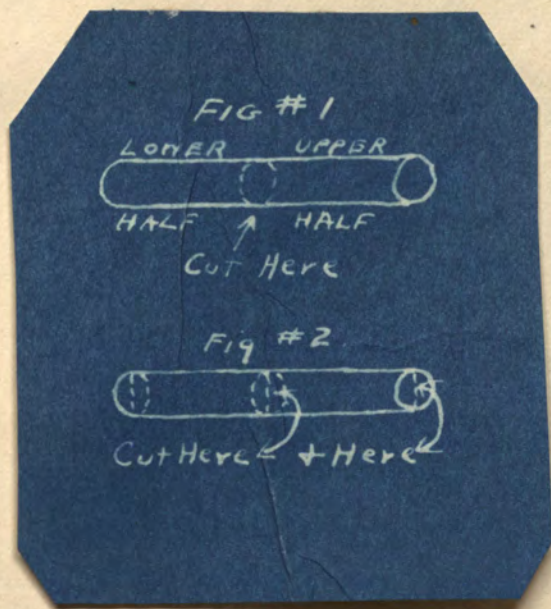
500 grams of Foundry facing were placed in a 64 ox. preservation jar and quickly sealed. Two sets of six each were made. In each jar a pin core was set horizontally to the depth of two inches, the facing tamped snugly about it and the jar sealed. Twelve pin cores were used, two from each mixture, making two sets. One set was set aside for 24 hours and the other for 48 hours. At the end of these periods, the cores were taken out cut in halves, (with one exception), designated the top half and lower half, the halves quickly crushed and placed in air tight sample bottles. The exception, the car wheel mixture core, was cut into four equal parts, as indicated in figure #2, samples quickly made and sealed in air tight sample bottles. Ten gram samples were run for moisture, the results of which are found in the table at end of discussion.

     Six cores, one from each mixture were broken and the centers run for moisture. The results are found in the table.

113

Twelve cores, two of each mixture, were placed on a stock shelf in the core room. One set of six was left for eight days and the other for sixteen days. The cores were broken up at the end of these periods and run for moisture. Results are found in the table.

The brickets were tested for their relative strength and results are tabulated. The results appear to be erratic. A second set of brickets were made and tested with but little difference in results.

DISCUSSION AND REMARKS

Since some parts of this work are supplementary to the real purpose indicated in this paper, they will be discussed in brief.

It is considered good practice to have about 3½% moisture in the core mixtures. By reference to the table, a moisture content of from 0.95% to 5.02% is indicated. The two lowest, 1.98% and 0.95% can be accounted for since the mixtures in question are both oil mixtures- the oil is part of the moisture when the sand is being mixed and is not driven off when the moisture test is made. The core from #3 Flour Mixture is the only one which shows any appreciable amount of moisture in its center. And at most, it is negligible in it and all other core centers. The cores placed in the Foundry do not show any absorption of moisture in either the eight-day or sixteen-day set, which would be of any consequence.

On the 24-hour and 48-hour test, the figures indicate that the lower half of the cores or that part which came in contact with the foundry facing absorbed more moisture than the upper half. To consider the figures only, one might get the impression that the cores did not take up much moisture. But the sample

115

taken for the moisture determination represents the
whole half, when in reality the moisture was very
pronounced only on the surface where the steel comes
in contact with the core.

In connection with this surface absorption,
more moisture was absorbed by the sand sprayed with
glutrine than without. Due to the method of spraying
the cores, with glutrine water, this discovery was made.
Only half of the pin cores, or the side up, receives any
glutrine water. In order to ascertain whether the
glutrine side really did absorb more than the dry side,
the car wheel mixture core, on both the 24-hour and 48-
hour test were cut as before indicated. The figures
indicate that the glutrine side absorbs the moisture.
To further substantiate these figures, a skin sample
was taken from the bottom half of the oil misture core,
run 48 hours from both the glutrine and dry side and the
moisture estimated. On the dry side 2.19% moisture was
absorbed while on the glutrine side 5.05%, which again
indicates that glutrine has a tendency to cause water
absorption and that to a great extent. These figures
further show how much moisture is absorbed by the
surface in comparison with the whole half, varying from
2.19, 5.19, 5.05% on the surface to 0.61%, 1.15% on the
116

whole half. In as much as the steel must come in contact with the surface of the core, this surface absorption might prove to be quite serious. Although most of the moisture appears to be on the surface of the cores, the whole core is affected, as indicated in the way that they crumbled when crushed.

It is contended that it is absolutely necessary to spray the cores with glutrine water to make them hold up. The brickets were made and tested to see what difference if any, the glutrine water made. A definite conclusion can hardly be drawn from the results obtained, but from all indications and figures too, the glutrine water effect is nil. The glutrine wet only one side and penetrated to a depth of but about 1/8".

In connection with this work, a study of the sand mill operations was carried on. As a result, a set of standard operation sheets have been compiled, one for each mixture, indicating the formula, how ingredients should be added and total time of milling.

Just a brief summary:

Cores placed in green sand mold and allowed to stand, absorb moisture sufficient to ruin the core. The amount of moisture absorbed, increasing with length of period of standing.

117

Most of the moisture is absorbed by the surface of the cores.

Glutrine water increases tendency to absorb moisture.

Glutrine water does not strengthen small cores as contended.

Cores standing in foundry on stock shelves show no moisture absorption.

CORE FACINGS

#1 and 3- Car wheel and Linseed Oil.

720 lbs. New Sand
8 lbs. Dextrin
7½ lbs. Fire Clay
7½ lbs. Linseed Oil

Tempered with glutrine water. #1 is mixed in large sand mill. #3 is mixed in oil sand mill. #3 used for hub cores for Davis wheels and on small cores where strength is required.

#2- Dextrin and rosin.
650 lbs. New Sand
500 lbs. Old Sand
7 lbs. Dextrin
14 lbs. Fire Clay
4 lbs. Rosin

Tempered with Glutrine water 1-20. Used on center and end cores on side frames.

#4- Rosin

650 lbs. New Sand
500 lbs. Heap Sand
14 lbs. Fire Clay
20 lbs. Rosin

Tempered with clear water. Used on Journal lug, and Brake Hanger Cores.

#5- #3 Flour

650 lbs. New Sand
500 lbs. Heap Sand
14 lbs. Fire Clay
20 lbs. Flour

Tempered with glutrine water 1-20. Used on Davis Wheel Cups.

#6- Core Compound

800 lbs. Old Cores
350 lbs. New Sand
14 lbs. Fire Clay
19 lbs. Core Compound

Tempered with Goulac water 1-20. Used for pouring cups on side frames and bolsters.

Foundry Facing.

400 lbs. New Sand
800 lbs. Old Sand
30 lbs. Clay

Tempered with clear water.

119

MOISTURE ABSORPTION TABLE

Sand Mixture	Moisture in Mix	Moisture in center Dry Core	Moisture after 24 hr. test		Moisture after 48 Hr. test		Moisture after standing in Foundry	
			Upper Half	Lower Half	Upper Half	Lower Half	8 Days	16 Days
Car Wheel #1	1.98%	0.18%	0.58 W 0.24 D	0.93 W 0.51 D	0.78% 0.38%	1.50% 0.77%	0.24%	0.18%
Dextrin & Rosin #2	3.75%	0.17%	0.54%	0.69%	0.78%	0.61%	0.20%	0.20%
Oil #3	0.95%	0.17%	0.54%	0.08%	0.61%	1.15%	0.24%	0.16%
Rosin #4	2.85%	0.10%	0.50%	1.18%	0.72%	1.30%	0.17%	0.16%
#3 Flour #5	5.02%	0.66%	0.99%	1.85%	0.74%	1.47%	0.39%	0.37%
Core Compound #6	4.20%	0.08%	0.49%	1.30%	1.54%	2.64%	0.20%	0.16%
Foundry Facing	3.49%	----	----	----	-----	-----	-----	-----

W- Wet with glutrine water.

D- As made

MOISTURE ABSORPTION TABLE

Sand Mixture	Test	Relative Strength Sand Check		Test
	Dry	Wet	Dry	Wet
Car Wheel #1	416	435	198	154
Dextrin & Rosin #2	101	126	90	108
Oil #3	195	172	69	51
Rosin #4	68	85	109	81
#3 Flour #5	196	213	95	115
Core Compound #6	75	112	86	91
Foundry Facing	--	--	--	--

W- Wet with glutrine water.

D- As made.

FLOW SHEET

SHOWING—BRIEFLY—MOULDING PROCESS FROM BLUE PRINT TO COMPLETED CASTING

Blue Print
↓
Pattern Shop
↓
Pattern To Storage for Record
↓
Pattern to Moulding Floor
↓
(Nails, Gagers, Rods, Molasses Water, Silica Wash.) → Pattern To Drag & Cope Flasks ← (Facing, Burnt, Parting Sands.)

(Cope Lifted; Pattern Drawn; Mould Finished; Nailed; Brackets Cut; Proper Silica and Molasses Treatment

MOULDER
Does Most of His Work Here)
↓

MOULDS

Oven Dried — Green — Skin Dried
8-12 hrs. 600-700°F — — Few Min. with Oil
— — 1-4 hrs. with Charcoal
↓
Brackets Cut; Chill Rods & Nails; and Cores Set, using Nails, Chaplets and Paste
↓
MOULDS CLOSED

Dry Moulds — — Green Sand
Dry Lifted to Catch Crushing; — Closed—Clamped
Closed Again; Dough to — Cups Set
Seal Joints; Clamped.
Cups Set.
↓

METAL POURED

LARGE CASTINGS — — SMALL CASTINGS
Sand Loosened about Heads to
Permit Shrinkage
↓
SHAKE OUT FLOOR

Gagers, Nails, Clamps Picked up — SAND — FLASKS, PLATES
by Helpers, Kids, Moulders
To Moulding Floor — To Dump — Dump — Moulding Floor

CASTINGS
Cleaning Floor

LARGE CASTINGS — SCRAP — SMALL CASTINGS
Rolls, Wheel Centers — Machined
INSPECTION
Scrap
↓
ANNEALING PIT
INSPECTION

Scrap — — To SHIPPING FLOOR
To FURNACE — — To CUSTOMER

METALLURGY OF STEEL CASTINGS

INSPECTION OF CASTINGS

Inspection is the last word on castings
before they reach the shipping floor. The work con-
sists of surface inspection on castings which are
not machined and a more careful inspection on castings
to be machined.

It is almost impossible to find a perfect
casting: one which does not contain some of the
imperfections to be mentioned. The perfect casting
is an ideal toward which to work.

In surface inspection, sand drop, sand holes,
apparent gas and shrink holes, cold run, fins, core and
cope shift, crooked, dirty and scabby castings, cracks
and gage specification, (where necessary) are given
attention.

When machined castings are under considera-
tion, non-apparent gas and shrink holes are sought for
in addition to other defects mentioned.

Almost all these defects can be traced to
the moulding department. A sand drop is the result
of sand falling from the cope into the drag. The
casting has a hole where the sand fell and a chunk
of metal from where the sand fell. Sand holes are
caused by sand drop and dirty mould. Gas holes leave
holes of various sizes and are found when the mould is
not properly vented. These holes are more injurious to

123

small castings than to large, and to machined than those which are not machined. Shrink holes are due either to the condition of the metal when poured or to the use of too small heads. Cold run explains itself and leaves some part of the casting ragged and possibly causes it to be scrapped. Fins are produced when the joint is too wide and also by loose cores. Core and cope shift are caused by improper core setting and closing, and both leave the castings in bad condition. Badly shifted center cores on blank gears and spur wheels are quite frequently the cause of scrapping important and expensive castings. Dirty and poorly mailed moulds give scabby castings. Some cracks are due to the metal shrinking about cores or included parts of the mould, while others are caused in annealing and to different rates of cooling in the casting. Bent castings are the result of shrinking, warping in annealing, and handling while hot. The best example of using a gage is found in center plate inspection. All center plates must be gaged. The gages are made so that 1/16" is allowed over outside dimensions, and under inside dimensions while the height is made exact. The height can be 1/16" maximum or minimum size. The large majority of castings do not need to pass a gage.

Whenever any of these defect appear, all except a bad center core or cope shift can be remedied by the welder, grinder, chipper or pressman, depending upon their nature and extent. On large castings where welding is necessary and permissable, the casting should be re-annealed, especially if the weld is located in a vital part of the casting.

It is the duty of the welder to weld gas and shrink holes and serious cracks. The grinder takes down the rough surfaces made when gates and heads are flogged, sawed and burned off (in case of large heads) with oxy-acetylene burner. The chipper cuts off any fins, cleans any holes, cuts off brackets, in fact makes a good looking casting. The pressman straightens and opens or closes sprung and warped castings.

The large castings are usually checked for important dimensions. Where machining is necessary about ¼" metal is allowed over exact dimension.

All castings, whether they be R. E. J. Locks and small castings, center plates and other car castings and miscellaneous castings are covered in a general way by the above discussion.

SAMPLE CASTINGS

Not all castings are checked before they are run, but a large number require a check on a sample before the order is completed, even going so far as sending a sample to the customer to obtain his O. K. or corrections, if any.

When a new pattern is sent into the foundry, the casting of which requires a check, the pattern shop Foreman makes out a sample report sheet and sends it with the blue print to the general foundry foreman. The general foundry foreman supervises, as a rule, the work of making the mould. After the mould is made, the report is forwarded to the cleaning department. The cleaning department sends the completed casting with the report, to the checking inspector. The casting is checked with the blue print for all dimensions, the weight of the casting found, a report made and sent to the pattern foreman who makes any necessary changes. Usually the castings check O. K. in all except a few minor points or dimensions.

DAILY SAMPLES

On large orders which run for several days and weeks, a daily sample is submitted, upon which a report is made. These samples are put through the usual cleaning process and sent to the surface table, where gages are tried, dimensions checked, defects noted, and the necessary changes, if any, reported. It is quite often the case, that a pattern, after several days use will become loose or worn, and throw the casting off. Immediate attention is given such defects to keep any more casting coming through in this manner.

DEFECTIVE CASTINGS

Defective castings may fall under two heads; (1) those which are found so in the foundry, and (2) those which are shipped and returned. A casting is not considered defective unless it is so bad that it cannot be repaired to meet specifications.

The defects which send a casting to the scrap heap have been mentioned before in the first part of this report, and are the more serious forms of cold run, short run, miss run, slag, bad cope and center

core shift, bad and deep cracks, important dimensions
off on account of shrinkage (the last case rare) and
others.

Seldom does an unmachined casting return
unless it should be on account of dimensions or flaws
which the inspection department failed to catch, and
this is quite probable. A man who inspects castings
100% well is _rare_.

Most returned castings are machined ones.
Non-apparent gas and shrink holes, cope shift and
cracks are causes which send most machined castings
back; a large number of blank gears, at times after
the teeth have been almost completely cut; cylinders
on account of cracks. In some instances these defects
are not of any consequence or in a vital point and can
be (and it is quite permissible to do so) welded and
reshipped.

The chief foundry clerk makes a record of the
defective castings and sends a daily report to the
Superindendent and Main Office so that % good castings
can be figured. From 3% to 5% of the castings are
scrapped.

G A G E S

There are gages of various kinds and used

for various reasons, but those of most importance are

the contour and spacing. These are made of wood and

sheet metal, mostly of the latter on account of wear.

Both maximum and minimum templates are made but as a

rule only minimum are used, and any variations from

the minimum being left to the justment of the inspect-

ors in charge.

The method of making the most common contour

gage has been previously mentioned: center plate.

All gages, unless otherwise specified, are made so that

outside dimensions are 1/16" over and inside dimensions are

1/16" under size. In case of an exact dimension gage, it

is necessary to allow a 1/64" or 1/32" over, otherwise the

gage will not fit the dimension in question, as it is

impossible to put an exact dimension gage over an exact

dimension.

In course of time the gages become worn, and it

is necessary to recheck them for wear, and perhaps make a

new one, in case the old is off any appreciable amount.

A spacing gage is used to check hole centers

for correct measurement. Others are used for blast

furnace segments to measure arcs and angles; buffers;

exact dimensions: as Hercules Pedestals; French rail joints; center fillers and in fact, any casting have exact and important specifications.

Flow sheet #1 shows the ideal route of a casting from the Flogging Floor to customer. It is not possible to have all castings follow this route, but it is probable that the majority could.

Flow sheet #2 shows as near as possible how the castings do go. It is apparent that some of the steps following inspection might be eliminated. All castings should be sand blasted or rattled before they reach the chipper and inspectors, with a disappearance of step (1) one. A more rigid demand on grinders and chippers would cut #2 and #3 out entirely. It is not necessary to anneal all castings, but a number do find their way to the inspector and even to the shipping floor that should be annealed. More care in inspection and on the flogging floor would leave this step out. A large number of castings can be cast so that they will shrink straight rather than bent. A little more time and care could be used in handling castings while hot. Care in racking and handling in annealing would prevent warping and bending. The pattern on castings which flare could be

F L O W   S H E E T   #1
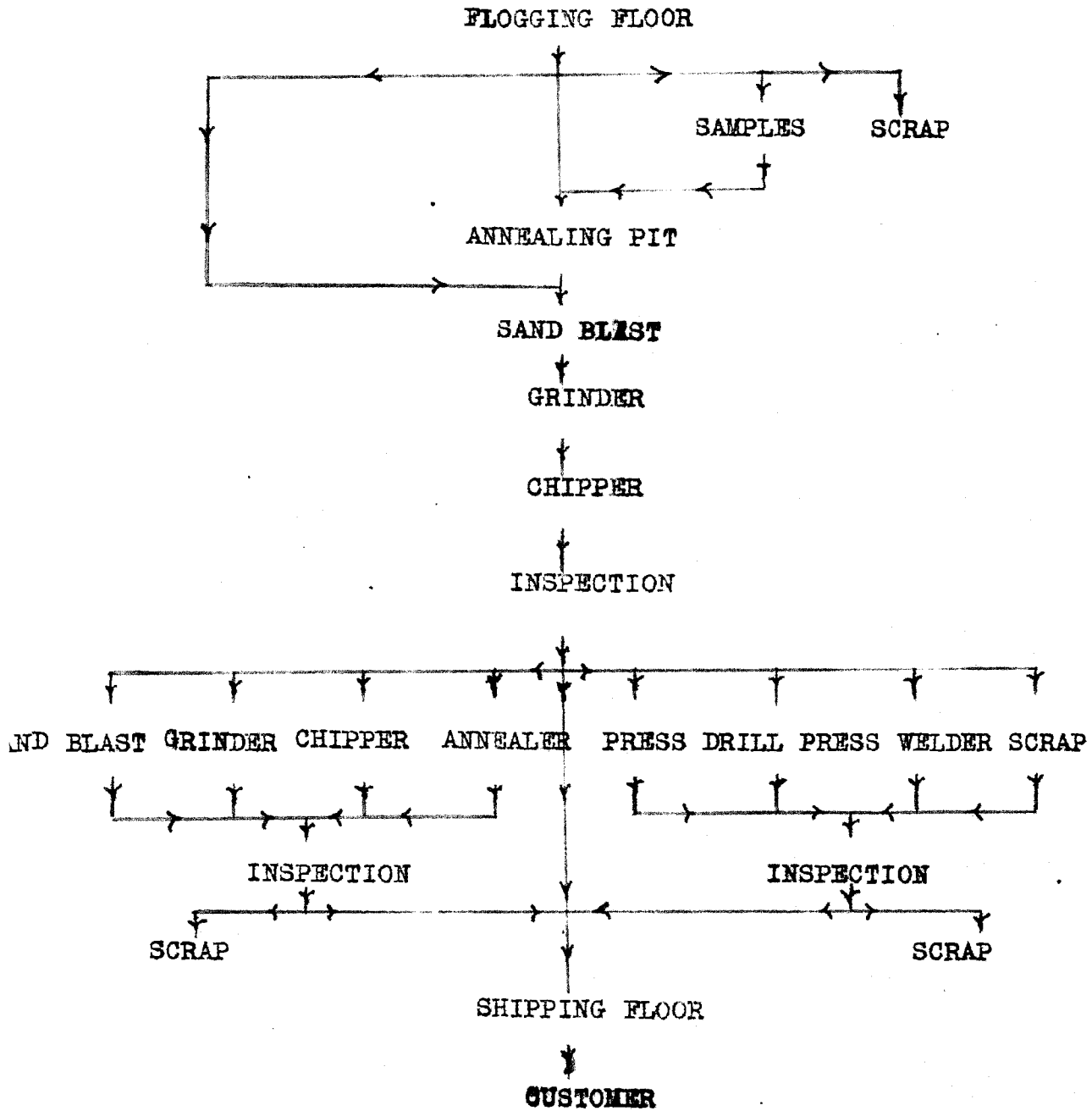
SHOWING IDEAL PATH OF CASTING FROM FLOGGING

FLOOR TO CUSTOMER

FLOGGING   FLOOR

ANNEALING PIT   SCRAP

SAND BLAST

GRINDER

CHIPPER

INSPECTION

SCRAP   SHIPPING FLOOR
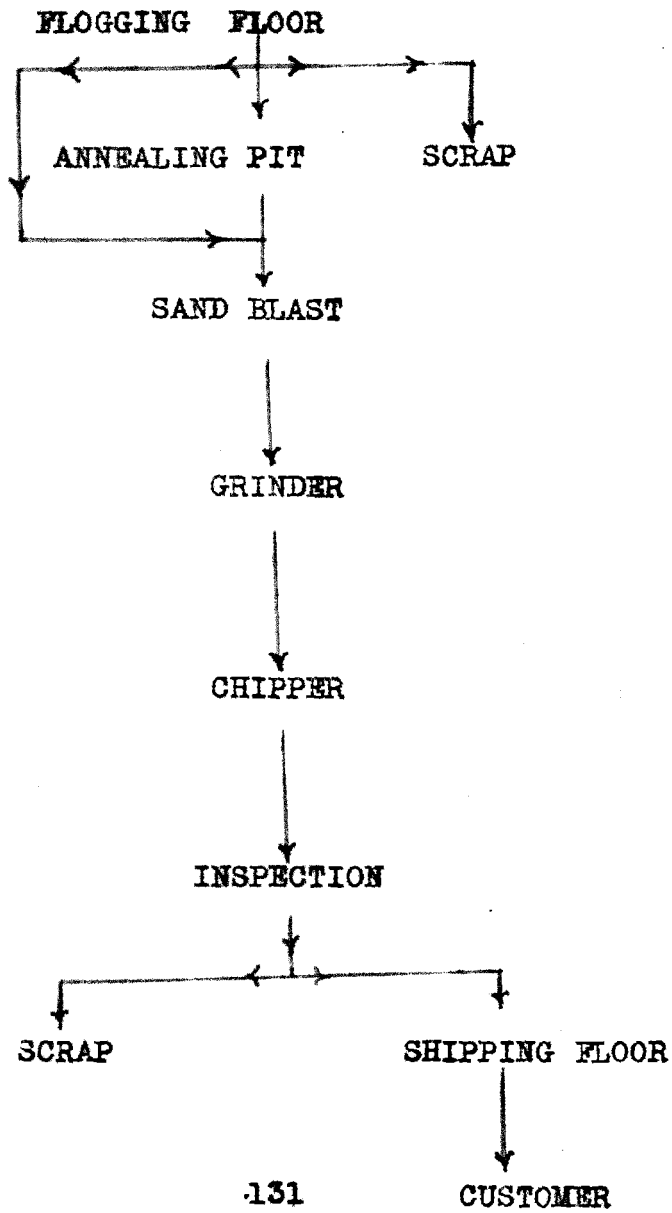
131   CUSTOMER

F L O W _ S H E E T _ #2._

SHOWING ACTUAL AND VARIOUS PATHS TAKEN BY CASTINGS
FROM FLOGGING FLOOR TO CUSTOMER.

FLOGGING FLOOR

SAMPLES   SCRAP

ANNEALING PIT

SAND BLAST

GRINDER

CHIPPER

INSPECTION

ND BLAST GRINDER CHIPPER ANNEALER   PRESS DRILL PRESS WELDER SCRAP

INSPECTION   INSPECTION

SCRAP   SCRAP

SHIPPING FLOOR

CUSTOMER

so made that the most of the flare could be taken out.
Presswork, the most of it, is due to some of the few
conditions mentioned. Drill press work is due to high
joints and poor hole cores and coring. It is quite hard
to get around welding, yet a large amount is necessary on
account of heads not being large enough causing shrink
holes under the heads and in other parts of the castings.

Where foreign inspection is necessary, it is
needless to say that a few castings will find their way
back through some one of these steps and possibly be
rejected.

The main point in question in this discussion,
besides those mentioned, is that all this repeated work
means additional handling of the same castings by the
truckers, where once after reaching the inspector, in
most cases, should be sufficient.

There are many kinds of castings,- castings
of every description passing through the foundry. In
order to give some idea in a small way of the variety, the
castings for one car are mentioned below:

Buffer; Draft, Rigging and Lugs; Yoke; Side
Wedge; Follow Block; Cam Block; Carriers;

Center Plates, Truck Columns; Journal Boxes; Wedges;
Knuckle; Locks; Links; Safety Hooks; Door Hinges;
Door Roller Bracket; Side Bearings; Center Filler;
Struts; Break Fulcrum; Break Wheel; Break Shoe;
Roping Iron; Pole Sockets and, no doubt, some few
which failed to catch my attention.

Suggestions from Philip E. Langworthy and
assistance of Frank James Assistant Chief Chemist at
Granite City Plant are acknowledged in work on Open
Hearth Practice.

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