

CONNECTICUT STATE DEPARTMENT OF EDUCATION
Division of Instruction
Hartford

SHOP THEORY FOR THE MACHINE TRADES

SUBJECT: Metallurgy of Iron and Steel

SESSION 2.

OBJECT: Methods of Manufacture

A. Furnaces and Crucibles

REFERENCES: Johnson, Metallurgy
Palmer, Tool Steel Simplified
Machinery's Handbook

METHOD: Reading lesson; test, and discussion

I. The Blast Furnace (Johnson, p. 67)

1. Reduces iron ore to pig iron
 - a. Takes away oxygen (O)
 - b. Adds 3.5% to 4% carbon and varying amounts of silicon
 - c. Some impurities remain (sulphur and phosphorous)
2. Charge
 - a. Iron ore
 - b. Coke—supplies necessary heat—provides carbon—reduces ore
 - c. Limestone—acts as flux—melts and unites with impurities to form slag
 - d. Hot air blast—starts combustion
3. Product
 - a. Makes pig iron, either as cast into pigs for storing and shipping or taken to another furnace in molten state
 - b. Composition is 3.5% to 4% carbon, 92% to 93% iron, and balance impurities

II. The Puddling Furnace (Johnson, pp. 79,80. Palmer, p. 16)

1. Second stage in making W.I.
 - a. Pig iron is reduced to pure iron
 - b. 2% to 3% slag is added
2. Charge
 - a. Cold pig iron
 - b. Iron oxide lining to furnace (ore or mill scale)
 - c. Continuous hot air blast

SHOP THEORY FOR THE MACHINE TRADES, Session 2 -- (Continued)

3. Working--third stage in making W.I.
 - a. Mixed with slag in the furnace by "puddling"
 - b. "Bloom" is squeezed and rolled into rough bars
 - c. Bars are stacked, reheated, and rolled again and again to secure uniform distribution of the slag fibres. Fibres are lengthways of the bar and may run 200,000 to the square inch of cross section. If W.I. is remelted, this fibrous structure is destroyed
4. Product
 - a. Wrought Iron
 - b. Composition is pure iron plus 2% to 3% slag in mechanical mixture

III. The Foundry Cupola (Johnson, pp. 81,82.)

1. Converts pig iron into cast iron
2. Charge
 - a. Pig iron
 - b. Coke--supplies heat
 - c. Other ingredients for special purposes
 - d. Hot air blast - starts combustion
3. Products
 - a. Grey cast iron--contains carbon in the form of black graphite flakes--produced by pouring into sand molds
 - b. White cast iron--contains carbon in the form of white granules--produced by quick cooling when poured into iron of steel molds
 - c. Malleable castings--white cast iron made malleable by long heating and very slow cooling (process takes several days)
 - d. Alloys of cast iron--copper and molybdenum are sometimes added to give special properties
 - e. Cupola method is crude and hard to control when exact composition is necessary. For very accurate compositions, an electric furnace is sometimes used

SHOP THEORY FOR THE MACHINE TRADES, Session 2 - (Continued)

IV. The Open Hearth (Johnson, pp. 72-5. Palmer, p.18)

1. Mixes pig iron and steel scrap and reduces mixture to low carbon steel
2. Charge
 - a. Steel scrap-up to 50%
 - b. Iron ore
 - c. Dolomite lining (calcium magnesium carbonate)
 - d. Limestone (calcium carbonate)
 - e. Molten pig iron
 - f. Continuous air blast
3. Operation
 - a. Furnace is cleaned of traces of steel
 - b. Dolomite is applied to bottom and side walls
 - c. Limestone is laid on bottom of furnace
 - d. Ore is placed on top of limestone
 - e. Steel scrap on top of ore
 - f. Iron ore is added after melting starts
 - g. Carbon content is controlled, after a quick analysis, by adding ore to reduce, or pig iron to increase
4. Product
 - a. Basic high grade carbon steels
 - b. Acid steel-produced by using no limestone and tapping metal out of the furnace without any carburizing or decarburizing
5. Uses
 - a. Plates and sheets
 - b. Wire stock
 - c. Rails
 - d. Structural steel
 - e. 90% of all steel used in U.S. is basic open hearth steel

SHOP THEORY FOR MACHINE TRADES, Session 2 - (Continued)

V. The Bessemer Converter (Johnson, pp. 70,71)

1. Reduces molten pig iron to pure iron and adds certain other ingredients
2. Charge
 - a. Silica lining for acid steel
 - b. Dolomite lining for basic steel
 - c. Molten pig iron
 - d. Carbon, manganese, and silicon to suit specifications
 - e. Air blast, introduced at bottom of the converter
3. Operation
 - a. Renew lining of converter
 - b. Pour in molten pig iron
 - c. Start air blast to burn out metaloids (impurities)
 - d. Add other ingredients to meet specifications, when "blowing" to pure iron has ceased
4. Product
 - a. Acid Bessemer steel (in U.S.)
 - b. Basic Bessemer steel (in Europe)
5. Uses
 - a. Low grade sheets and wire stock
 - b. Steel pipe
 - c. Automatic screw machine stock

VI. The Crucible Furnace (Johnson, p. 76, Palmer, pp. 20-3.)

1. Mixes pig iron and good scrap and certain alloying elements in graphite crucibles to make a high quality of toolsteel
2. Charge
 - a. W.I. or scrap
 - b. High grade pig iron
 - c. Alloying metals, as desired
 - d. Apply heat of furnace
3. Operation
 - a. Graphite crucible is charged and placed in furnace
 - b. Slag is removed from top with a cold iron bar
 - c. Residue (about 100lb.) of fine steel is poured into ingot

SHOP THEORY FOR THE MACHINE TRADES, Session 2 - (Continued)

4. Product

- a. High grade carbon and alloy steels

5. Uses

- a. High grade tools and instruments
- b. Process is now nearly obsolete-is replaced by Electric furnace

VII. The Electric Furnace (Johnson, pp.76-8. Palmer, pp.23-5)

- a. Same mixing process as in making crucible steel-same quality of steel-same uses
- b. Has advantage of much greater capacity (up to 10 tons)
- c. Arc type furnace
- d. Coreless induction furnace

VIII. Cementation Steel

- a. Obsolete - of historical interest only
- b. Made by heating for a long time at red heat or hotter, W.I. in the presence of an excess of carbon (coal, wood, twigs, or leaves). The iron slowly soaks up carbon (carburizes) to form carbon steel. Similar to pack hardening process.

STUDENT ASSIGNMENT

- I. Carefully follow this outline and read the references indicated.
- II. Answer briefly the questions for Session 2.
- III. Conference and grading of answer papers.

CONNECTICUT STATE DEPARTMENT OF EDUCATION

Division of Instruction

Hartford

Name of Student _____ Date _____

Instructor _____ Grade _____

Questions - Metallurgy of Iron and Steel
Session 2, Methods of Manufacture

1. What is the furnace called that is ordinarily used to make W.I.?
2. How is combustion started in the blast furnace?
3. What three desirable results are obtained by adding coke to the charge of the blast furnace?
4. What are the two reasons for "squeezing" a W.I. bloom?
5. Name four types of steel making furnaces.
6. What two factors cut the costs of making Bessemer steel?
7. What percentage of steel scrap can be used in making steel?
8. Name two types of electric furnace.
9. What was the first process of making steel?
10. Give two reasons why the electric furnace has largely supplanted the crucible process of making steel.