Case 35

LYNCHBURG FOUNDRY REVISITED

The materials manager for Lynchburg Foundry was faced with the decision of whether it was economically desirable to ship ductile iron return[1] from the casting plants at Lynchburg and Archer Creek to the pipe-making plant at Radford, Virginia. If so, he needed to figure out how to implement his decision, including the establishment of an appropriate transfer price or prices.

Founded in 1896 as the Lynchburg Plow Company, manufacturing gray iron plows and plow replacement parts, the company grew quickly and began to diversify. With the addition of cast iron pipe production in the early 1900s, the company changed its name to the Lynchburg Foundry Company. With the 1948 discovery of ductile iron, a new form of cast iron with properties similar to steel, the company became a major producer of gray and ductile iron precision castings and pipe. The precision castings were produced for cars, trucks, construction equipment, and farm equipment. The pipe was produced primarily for municipal water systems. The company employed over 4,000 employees at manufacturing facilities in three locations in Virginia.

LYNCHBURG AND ARCHER CREEK CASTING PLANTS

The Casting Process

A casting was made by pouring molten metal into a sand mold of the desired shape. Once the metal cooled and solidified, the sand mold was shaken and knocked away from the metal, leaving a casting. There were four steps in making a casting: melting and alloying the metal, making molds and cores, pouring iron into the molds, and finishing or cleaning the casting.

---

[1] *Ductile iron return* was a by-product of the casting process due to the low yield (approximately 50 percent) of good finished castings that resulted when molten iron was poured into a sand mold. Its chemical composition was the same as the finished casting, and thus it could be "returned" to the melting facility and remelted to produce more good castings.

Melting and Alloying

The raw materials were received by rail car in the iron yard behind the plant. The raw materials included coke for melting fuel, limestone to promote the coagulation of slag or impurities, pig iron for carbon and silicon, and steel scrap for the iron content. A mixture of these raw materials and ductile iron return, a process by-product, was prepared in the required proportions, making a "charge" to be melted. Exhibits 35-1 and 35-2 illustrate typical charges for the Lynchburg and Archer Creek plants.

The molten iron was received in refractory lined ladles at approximately 2800°F. The slag, or impurities, was removed, and various alloys were added to produce the different types of iron. Samples of the iron for laboratory analysis and other quality control checks were made, and the iron was then ready to be poured into sand molds.

Core and Mold-Making

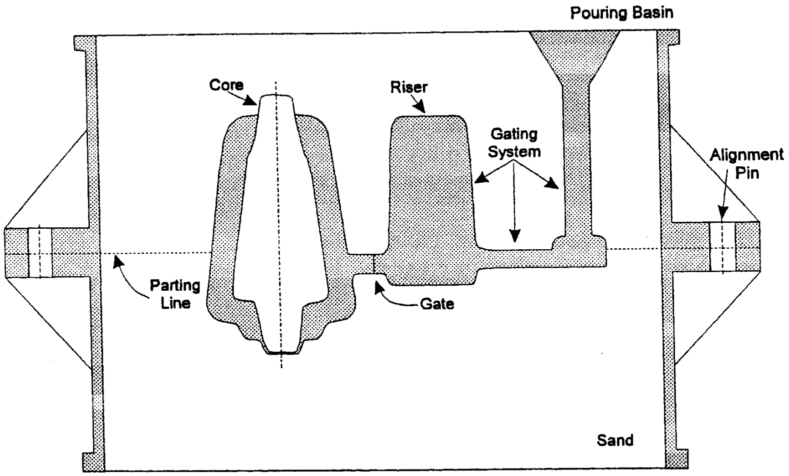
The mold was formed by packing a moist mixture of sand and certain hardening ingredients around the desired pattern. The pattern was then drawn away, leaving the two mold halves that formed the casting cavity.

The final step in mold-making was mold assembly. Cores were placed into recesses in the mold, and the halves of the mold were joined and clamped, making a complete casting cavity ready to receive the molten iron.

FIGURE 35-1

LYNCHBURG FOUNDRY REVISITED

Cross-Section of a Sand Mold



Pouring the Iron

The metal entered the top of the mold through a pouring basin. This basin was only part of a carefully designed network of internal channels called the gating system. It was a system of openings, or gates, that were shaped and located to control the rate and direction of the molten metal as it entered the casting cavity.

As the metal cooled and changed from a liquid to a solid, there was an accompanying decrease in volume that could cause voids and make a casting unsound. This problem was avoided through the use of a molten metal reservoir or "riser" in the gating system that supplied additional metal to the casting as contraction occurred. Figure 35-1 illustrates a typical cross-section of a mold with a casting cavity and gating system. Both the gating system and riser were filled and remained full of metal, making a good casting. The amount of metal required to fill this system was often equal to the amount of metal in the casting. After solidification of the casting, the gating system became excess material that, along with some scrap castings, was the source for the "ductile iron return." The ductile iron return was available for remelting in the cupola.

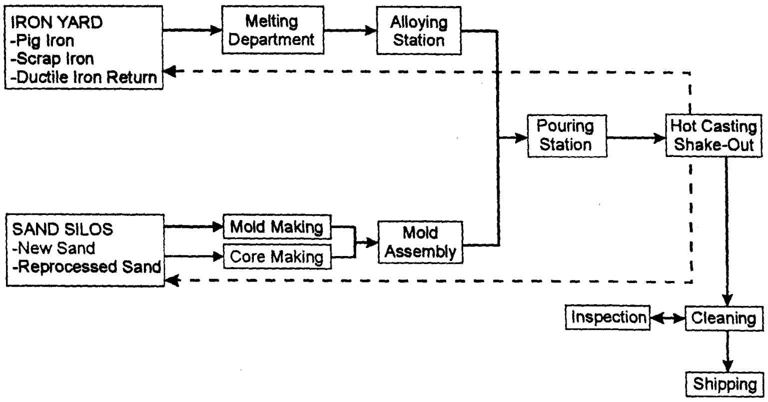
Finishing or Cleaning

After the iron in the mold solidified, the mold was shaken off and the sand reclaimed. The gating system, which also solidified while attached to the casting, was removed and returned to the iron yard area. The remaining sand was blasted off the casting, and the rough edges were ground, yielding a smooth, clean casting. Figure 35-2 contains a diagram of the steps in the total casting process.

FIGURE 35-2

LYNCHBURG FOUNDRY REVISITED

Production Flow Diagram



THE RADFORD PIPE PLANT

The Pipe-Making Process

Pipe was produced in a somewhat different manner than castings. The iron melting and alloying was done in the same manner as castings. However, the raw materials charge was not the same for pipe-making. A typical pipe charge is shown in Exhibit 35-3. Pipe charges were different from castings charges (see Exhibits 35-1 and 35-2) for two basic reasons. The chemical composition of ductile iron pipe was different from ductile iron castings, and the pipe-making process had a higher yield (over 80 percent vs. 50 percent to 60 percent) than the casting process, thus leaving less ductile iron return available for remelting.

Permanent Mold Pipe-Making

A permanent mold for pipe-making was made of special high alloy steel for high temperature performance and long life. The mold was a long cylindrical tube with its interior surface the desired shape and dimensions of the exterior of the desired ductile iron pipe size. The mold was completely enclosed in a large mold spinning machine with a water jacket that covered the length of the mold. The entire machine sat on a slightly inclined track that allowed the molten metal to flow down the length of the mold. With the mold spinning rapidly, a measured amount of molten iron was injected into one end of the mold. The spinning caused centrifugal force on the molten iron to form the walls of the pipe with a uniform thickness. The water jacket surrounding the mold quickly absorbed the heat from the molten iron through the mold wall and solidified the pipe in less than two minutes.

The ductile iron return from the pipe-making process came from scrap pipe, excess metal in the permanent mold injection system, and spillage and excess during ladle transfers. This process typically yielded 80 percent to 90 percent good pipe, leaving the rest for ductile iron return.

USES OF DUCTILE IRON RETURN

As part of the deliberations regarding whether or not to transfer ductile iron return from the Lynchburg and Archer Creek casting plants to the Radford pipe-making plant, the materials manager reviewed how the ductile iron return was typically used.

Because the Lynchburg and Archer Creek plants' yields were in the 50 percent to 60 percent range, there was 40 percent to 50 percent return available to use in subsequent charges. If it were available, these plants could have used a charge containing 50 percent to 60 percent return, but because not enough was produced internally, and it was seldom available on the metals market, various amounts of pig iron and scrap steel had to be purchased instead.

The minimum ductile iron return content in a casting charge was determined by the cost and melting efficiency of the substitute materials. As ductile iron return was removed from the casting charge, it had to be replaced by pig iron, steel scrap, or a combination of these two materials.[2] The disadvantages of adding these two materials were that pig iron was the most expensive raw material, and steel scrap required more heat to melt, thus reducing the melting rate of the plant. Through past experience with different casting charges, the melting supervisors at the Lynchburg and Archer Creek casting plants had determined that 40 percent ductile iron return was the minimum amount a casting charge must have to meet the demand for molten iron. Thus, the materials manager attempted to work within this constraint when considering material transfers.

Historically, company policy had encouraged each plant to consume its own ductile iron return, except for some very large scrap castings produced at the Lynchburg plant. These castings were shipped to the Radford plant because the melting facilities at Radford could accommodate these larger pieces of ductile iron return. Otherwise, the large scrap castings would require very costly cutting to enable them to be used at the Lynchburg plant.[3] This type of ductile casting scrap amounted to approximately 3500 tons per year and allowed the Radford plant enough material for about 200 pounds, or 4 percent, of each 5000 pound charge. This 4 percent was added to the 12 percent (600 pounds per charge) of ductile iron return generated by the pipe-making process. The result was 16 percent ductile iron return available per pipe-making charge as compared to 40 percent to 50 percent ductile iron return available per casting charge. Because of the high required melt rate in pipe-making, the charge could not contain more than the present 38 percent of steel scrap. The remaining 62 percent could be either pig iron or ductile iron return. According to the metallurgist at the pipe-making plant, each additional pound of ductile iron return from the casting plants could be substituted for pig iron on a one for one basis.

In order to reach a decision, the materials manager gathered data on the cost of producing ductile iron return. He then reasoned that, because this material was readily available at the plants, and the other raw materials included freight costs in their price, he should subtract the average cost per ton for freight. Thus, as shown in Exhibit 35-4, he arrived at $110 per ton as the cost of the ductile iron return.

In calculating the ductile iron return cost, the materials manager included only the weighted average cost of the original raw materials. This cost was actually less than the true cost of making the ductile iron return because it did not include the fuel cost, the variable cost of labor and other supplies, the cost of facilities and equipment, or the cost of supervisory personnel.

The materials manager worked with the production manager and sales manager to determine the maximum amount of ductile iron return that would be available for shipment to the Radford plant. This amount was based on historic ductile casting and pipe production. The results of their calculations are shown in Exhibit 35-5. The materials manager had explicitly assumed, as he had been told, that the Lynchburg and Archer Creek plants could cut their consumption of ductile iron return to 40 percent of the charge mix. Shipping cost between the two castings plants and the Radford plant were assumed to remain at $6.75 per ton. There was no cost charged for loading and unloading the

---

[2] The ratio of steel scrap to pig iron had to remain the same, regardless of the percentage of ductile iron return in the charge.

[3] Although no attempt had ever been made to sell these large pieces of scrap, buyers could be found through the metals market. The net price per ton was estimated to be in the range of $70 to $75. Freight costs of $6.75 a ton were charged to the Radford plant and represented the only cost the Radford plant incurred for the large scrap castings.

material from the rail cars because the workers and equipment were already available at each plant.

THE RECOMMENDATION

There seemed to be at least three possible methods for valuing the ductile iron return. One method would treat it as a free by-product with no cost. Another method would use the market price, or at least $70 a ton. A third basic method would use production cost, either the method used by the materials manager or some variation thereof.

In the absence of a clear directive regarding the use of the excess ductile iron return, including the transfer price, the materials manager was concerned about the plant managers' motivations, as well as the effect on individual plant performances. The individual plants were cost centers, and the plant managers were evaluated on their ability to meet good ton shipment requirements efficiently and at minimum cost. If a transfer program were adopted, a transfer pricing system would need to credit the Archer Creek and Lynchburg plants with the transfer price of the ductile iron return transferred to Radford. The Radford plant would then be charged the same amount, or some other amount, in addition to the actual transportation cost.

The materials manager was also aware of the long-term trends in the product markets and the age of the individual facilities. The castings market was growing at a good rate, and many parts that were formerly made in steel or welded assemblies were being switched to ductile iron castings. Lynchburg Foundry was a leader in ductile iron castings and was one of the most respected independent foundries in the nation.

The pipe market was not as strong as the market for ductile castings, as it was closely linked to the general economy, particularly housing construction. There was also strong competition from substitute materials (such as plastic). Lynchburg Foundry was among the smaller pipe producers, and most of its equipment was old. Growth or even continuation of present operations would eventually require large amounts of capital. The materials manger was concerned about how the transfer of ductile iron return to Radford would affect the profitability of that operation. Changes in profitability might be large enough to affect future investment decisions.

The materials manager was to make a comprehensive presentation, including plans for implementation, to the company's chief operating officer within a week.

EXHIBIT 35-1

LYNCHBURG FOUNDRY REVISITED

Typical Raw Materials Charge and Ductile Iron Casting Cost

Lynchburg Plant (2000 lb. charge)

Material	*Percent of Charge*	*Weight per Charge*	*Material Cost per Ton*	*Cost per Charge*
Ductile Iron Return	45	900	$ 110	$ 49.50
Pig Iron	21	420	200	42.00
Steel Scrap:				
Shredded	17	340	80	13.60
Structural	17	340	88	14.96
	100	2000		120.06

Calculation of good casting cost:

Average casting yield = 55%
Good castings per charge = 1100 pounds
Ductile iron return generated = 900 pounds

Charge cost	$120.06
less credit for ductile iron return (900 pounds @ $110/ton)	49.50
Cost of 1100 pounds good castings	$ 70.56

Convert to casting cost per ton:

$$\frac{2000 \text{ pounds}}{1100 \text{ pounds}} \times \$70.56 = \$128.29/\text{ton}$$

EXHIBIT 35-2

LYNCHBURG FOUNDRY REVISITED

Typical Raw Materials Charge and Ductile Iron Casting Cost

Archer Creek Plant (4000 lb. charge)

Material	*Percent of Charge*	*Weight per Charge*	*Material Cost per Ton*	*Cost per Charge*
Ductile Iron Return	46	1840	$ 110	$ 101.20
Pig Iron	19	760	200	76.00
Steel Scrap:				
Shredded	19	760	80	30.40
Structural	16	640	88	28.16
	100	4000		235.76

Calculation of good casting cost:

Average casting yield = 54%
Good castings per charge = 2160 pounds
Ductile iron return generated = 1840 pounds

Charge cost	$235.76
less credit for ductile iron return (1840 pounds @ $110/ton)	101.20
Cost of 2160 pounds good castings	$134.56

Convert to casting cost per ton:

$$\frac{2000 \text{ pounds}}{2160 \text{ pounds}} \times \$134.56 = \$124.59/\text{ton}$$

EXHIBIT 35-3

LYNCHBURG FOUNDRY REVISITED

Typical Raw Materials Charge and Ductile Iron Casting Cost

Radford Plant (5000 lb. charge)

Material	*Percent of Charge*	*Weight per Charge*	*Material Cost per Ton*	*Cost per Charge*
Ductile Iron Return:				
Scrap Pipe	12	600	$ 110	$ 33.00
Scrap Castings	4	200	110[4]	11.00
Pig Iron	46	2300	190[5]	218.50
Steel Scrap:				
Shredded	18	900	80	36.00
Structural	20	1000	88	44.00
	100	5000		342.50

Calculation of good pipe cost:

Average pipe yield = 88%
Good pipe per charge = 4400 pounds
Ductile iron return (pipe) generated = 600 pounds

Charge cost	$342.50
less credit for ductile iron return (600 pounds @ $110/ton)	33.00
Cost of 4400 pounds good castings	**$ 309.50**

Convert to casting cost per ton:

$$\frac{2000 \text{ pounds}}{4400 \text{ pounds}} \times \$309.50 = \$140.68/\text{ton}$$

---

[4] This $110 transfer cost does not include the $6.75 per ton freight charge.
[5] Pig iron for pipe making cost $190 per ton, compared with $200 per ton for castings.

EXHIBIT 35-4

LYNCHBURG FOUNDRY REVISITED

Material Manager's Valuation of Ductile Iron Return

1. Calculate the value of the raw material without ductile iron return (based on Lynchburg plant charge shown in Exhibit 1).

Material	*Weight per Charge*	*Material Cost per Ton*	*Cost per Charge*
Pig Iron	420	$ 200	$ 42.00
Steel Scrap:			
Shredded	340	80	13.60
Structural	340	88	14.96
	1100		70.56

2. If 1100 pounds cost $70.56, then 2000 lb. cost:

$$\frac{2000 \text{ pounds}}{1100 \text{ pounds}} \quad \times \quad \$70.56 = \$128.29/\text{ton}$$

3. Subtract a freight cost - 16.00/ton
$112.29/ton

4. Use *$110/ton* to recognize variations in charge mix and variations in raw materials prices.

EXHIBIT 35-5

LYNCHBURG FOUNDRY REVISITED

Projection of Maximum Available Ductile Iron Return (tons)

Plant	*Estimated Pouring Weight*	*Number of Charges*	*Yield*	*Good Castings*	*Ductile Iron Return*
Lynchburg	84,000	84,000	55%	46,200	37,800
Archer Creek	30,000	15,000	54%	16,200	13,800
Radford	87,500	35,000	88%	77,000	10,500
Total Available					61,800 tons

Lynchburg and Archer Creek ductile iron return requirements at 40 percent per charge:

Plant	*Tons Available*	*Required for 40% of Charge*	*Excess Available for Radford Plant*
Lynchburg	37,800	33,600	4,200[6]
Archer Creek	13,800	12,000	1,800
Total			6,000 tons

Affect on individual Radford pipe charge:

Number of charges required per year = 35,000 charges
Pounds of ductile iron return available per pipe charge:

From Lynchburg
4,200 tons ÷ 35,000 charges = .120 ton (240 lbs/charge)

From Archer Creek
1,800 tons ÷ 35,000 charges = .051 ton (103 lbs/charge)

Total = 343 lbs/charge

---

[6] This includes the 3500 tons of scrapped castings already being shipped to the Radford plant.