The Furnace: An Evolution and Explanation as Applied to Those of the Longdale Mining Complex

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The heart and soul of the Longdale Mining Community, as in other mining communities of the period, lie within the walls of the furnace. In the mainstream of technological advancement since before the Industrial Revolution, the furnace underwent countless alterations to eventually arrive at the modernity of the Lucy Selina and Australia units, which served Longdale from the mid to late nineteenth century. The furnace of this time period was one of constant innovation and improvement in regards to the physical plant, process of iron refinement, and fuels used.

Modern iron refinement “may properly be said to have begun with the achievement of the blast furnace and the resulting making of cast iron.” (Smith 23) The blast furnace “developed gradually from the early hearths in which chiefly wrought iron was produced. The development consisted in gradually increasing the height of the furnace, introducing the charge at intervals through the top, and providing an adequate blast of air.” (Lankford et al. 7) Most industry changes, prior to the twentieth century, came from Great Britain, as well as other European nations. (Singer et al. 99) In the latter part of the Middle Ages, Germans, in the lower Rhine Valley, improved upon the ancient Catalan furnace, a primitive, open-hearth furnace in which iron ore was melted and worked by manpower. By building upon this basic design, those responsible created the “stuckofen”, or “wolf oven.” This advancement increased the height of the Catalan forge to around sixteen feet and constituted the final form of the Catalan design in Europe. (Smith 24) In Belgium, around 1340, the stuckofen furnace, itself, was enlarged and enhanced. The refinement allowed greater air passage to the flame of the furnace, thus increasing and strengthening the fire. By emitting more heat, the invigorated flame melted the iron more completely to and let it flow freely into casts, thereby easing the retrieval and shaping
of the metal. (Smith 24) This innovation, called the "flussofen," constituted the first, most basic "blast furnace." The flussofen was intended to produce molten, high-carbon iron, only, but actually provided the world with an early look of the future of iron refinement. (Lankford et al. 8) The blast furnace continued to grow in stature, however, as improvements were made and new techniques employed. In 1680, a blast furnace in the Forest of Dean, England, was "described as being thirty feet in height, operating continuously for months, and making cast iron ..." (Smith 25) These higher furnaces, dissimilar to the Catalan design, were labeled shaft furnaces. (Lankford et al. 7)

With the Industrial Revolution came a new assortment of innovations to Great Britain. In 1701, Edward Wright of London invented a new type of furnace, which he called the "cupola." By keeping the iron from immediate contact with the fuel, Wright's remelting furnace was able to deliver iron with far less impurities than before. (Singer et al. 101) Around 1750, the "beehive" oven was introduced, spawning a wider adoption of foundry furnaces for remelting the crude, impure iron. Remelting the iron allowed for improved homogeneity and purity. (Singer et al. 101) Possibly the greatest discovery of the time, however, was made by Abraham Darby at his Coalbrookdale Works in Shropshire, Great Britain. In 1709, Darby became the first to successfully smelt iron with charred coal, or coke. (Singer et al. 99) Because the use of charcoal resulted in the destruction of countless acres of forests, a more efficient, and less detrimental, fuel was sought. Coal, which was very plentiful as well as conveniently located, proved to be the answer. After Darby's revelation, English furnaces ceased using charcoal for fuel, replacing it with the more appropriate coke. (Smith 42) The existence of coke furnaces rose dramatically in England, from 17 in 1760, to 31 in 1775, to 81 in 1790.
(Singer et al. 104-5) Outside Great Britain, however, the use of coke caught on much more slowly. France was first to adopt the new fuel in 1785. Prussia, Belgium, and the Czech and Slovak regions of the Austrian Empire followed in 1792, 1823, and 1828, respectively.

(Singer et al. 105) In America, coke was slow to catch on because charcoal was plentiful and inexpensive. It was not until years later that the United States opened up to the use of coal as a fuel. (Smith 42) To sustain the necessary flame, the coke furnaces needed a stronger blast of air than that from a water wheel. In 1762, John Smeaton “introduced his blowing cylinders which ensured a more complete combustion.” James Watt’s steam engine was eventually applied to Smeaton’s blowing cylinders, ensuring the victory of coke over charcoal. (Singer et al. 103)

As furnace technology reached America, innovators realized that a cold air blast was not sufficient to keep the new, more powerful furnaces in blast. The furnace needed a “hot-blast” of air to adequately fuel the flame. (Smith 48) “The first idea that a higher temperature in the furnace could be achieved by heating the blast before its entrance through the tuyeres was due to James Beaumont Neilson, manager of the Glasgow Gas-Works” in 1828. (Singer et al. 109) After 1840, hot-blast furnaces became extremely popular. Outdated water wheels were replaced with engines to power the air pumps. With this change began the age of anthracite as a fuel. (Smith 50) Because anthracite and charcoal were so abundant and inexpensive in America, coke was unable to infiltrate their stranglehold until much later. (Singer et al. 111) Although coke had been used exclusively in Britain for years, “it was not until 1850 that coke was used on a large scale in the United States.” (Singer et al. 111) With the advent of the railroad, however, coke commenced its journey to popularity. Between the years of 1865 and 1880, the use of coal grew twenty-fold. (Smith 56) In 1875, coke overtook anthracite as the most used fuel in the
United States. (Smith 55) After 1875, the geographic base of iron refinement slipped across the Appalachian into the drainage basin of the Ohio River. Pittsburgh, because of its proximity to resources as well as routes of transportation, i.e. the famous “Three Rivers,” arose as the new capital of iron. (Smith 60-1) One reason for Pittsburgh’s success was a small town 40 miles upstream called Connellsville. This Pennsylvania town became famous for its production of coke, the finest in the world. (Smith 58)

The blast furnaces which served Longdale, the Lucy Selina and the Australia, resembled the final product of the preceding evolution. The Lucy Selina, in blast from 1827 to 1852 and 1863 to 1865 as a cold blast furnace, was fitted in 1874 with the new hot-blast technology. The Australia began hot-blast operation in 1854 and ran through 1865. (Russ, McDaniel, and Upchurch 2) A blast furnace in 1855 was typically eight to 19 feet in internal diameter and 20 to 60 feet in height. (Truran 19) The bottom of the furnace was constructed of fire brick. Upon this foundation, the hearth was built of stone or brick. (Truran 20-1) “In the base of the furnace, four arches [were] left; the back and the sides [were] called ‘tuyere-houses,’ the front is known as the ‘cinder fall.’” (Truran 20) The cinder fall, a plate measuring six feet by three feet by three inches, was built into the brickwork of the hearth. Near the center of the plate, two openings were left for “tapping.” The lower opening was for the molten iron to run into a specified bed or ladle. Slag, because it was less dense and floated on the molten iron, was drained through the upper hole into a slag ladle or tank of water known as a granulating pit. The upper edge was serrated to allow burning cinders to pass. (Truran 22) The tuyeres, on the sides and back of the hearth, are built up with brickwork to around two feet high. Above the bricks, cast or wrought iron tuyeres are placed with points flush to the wall. The remainder of the space is filled with
brick. (Truran 22) The furnaces were built with space to accommodate separate stoves placed in front of each tuyere. Metal pipes would take hot air through the tuyere and into the furnace. The air blast would enter the stove at 50 degrees Fahrenheit and leave at 600 degrees, thereby creating the heat necessary to sustain the required flame. (Truran 27) Above the tuyeres was a region called the “bosh.” The bosh “can be described as the frustum of an inverted cone that connects the tuyere region breast to the level of maximum diameter of the stack.” (Lankford et al. 550) “The boshes commence at the top of the hearth; their interior diameter increasing with their height until they meet the inner lining of the brickwork . . .” (Truran 21) The chimney began just above the boshes. It was 10 to 12 feet in height and served to release the smoke created by the flame, as well as inject the charge into the furnace. Holes were left in the brickwork for workers to dump barrows full of iron and flux into the furnace. Metal doors were installed at each hole to protect the men. (Backert 77)

“It is the function of the blast furnace to remove the oxygen from the iron and to slag-off the impurities. Carbon in the form of coke is the usual deoxidizing agent and its combustion also furnishes the heat necessary to melt the resulting iron and slag. Limestone is added as a flux to render the slag more easily fusible.” (Backert 77) Firstly, five to six feet of dry timber is placed in the hearth, topped off by a layer of coke. Then, the fire is lit. Regular charges of calcinated ore and limestone are added to the coke until the materials reached the throat of the furnace. (Truran 29) “Top fillers” wheeled the materials to the charging position at the top of the chimney and dumped them into the furnace. (Lankford 10) This is the preparation of the furnace, and could take days to complete. With everything ready, air is let into the tuyeres and the furnace is “blown in.” (Truran 29) Air is forced into the furnace at eight to 16 pounds per
square inch and at 700 to 1400 degrees Fahrenheit. (Backert 77) Twelve to 24 hours after blowing, the hearth is cleared for the reception of cinders. (Truran 30) At regular intervals, about 10 hours after the cinders, the furnace would be tapped. “The molten iron that flowed out would either be ladled directly into casting (for stoves, pots, and so on) or be directed along channels in the sandy floor of the casting house to form three foot blocks of iron known as ‘pigs.’” (Heron 35-6) Pig iron gets its name from the shape it forms on the floor of the casting house. Lined up in parallel stalls connected to a central line to the furnace, they take on the appearance of infant swine in the process of feeding. (Smith 25) Three to three and a half tons of the pig iron would be collected in the first 60 hours after blowing. In another 18 hours, another casting of about two tons can be made. By the fourth week, the furnace should produce about 80 tons per week. At full blast, after 10 to 12 weeks, the typical furnace would average 110 tons per week. (Truran 30) The pig iron was then entered the next stage of purification. “This conversion process has always involved the application of heat to a mixture of iron ore, charcoal or coke, and limestone, with some draft to increase the heat.” (Heron 35) There were two predominant methods for purifying the iron after the furnace: the charcoal-hearth process and puddling. Both processes reduce the ore to pig iron, and purify the pig iron into wrought iron. (Lankford et al. 10-1) In the charcoal-hearth process, the pig iron is remelted by a charcoal fueled fire. The metal would be “desiliconized and decarbonized by the oxygen in the air blast, would collect as a pasty mass upon the bottom, being worked vigorously as it collected.” (Lankford et al. 11) In 1784, Henry Cort obtained a patent for turning pig iron into wrought iron by a process called “puddling.” (Singer et al. 106) The pig iron would be melted in a hearth while stirred and formed by a “puddler.” The stirring would allow the carbon to combine with
the oxygen in the atmosphere while separating it from the impure slag. (Lankford et al. 12)

While purifying the iron, this process also strengthened the metal by combining it with oxygen. Thus, the resulting iron could be sold at a much higher price.

"The fuel required for the smelting of iron must burn very easily, must furnish great heat, and must be physically hard as to bear the burden of the ore that lies upon it . . .” According to J. Russell Smith, charcoal is the perfect fuel, but destroys resources too quickly. (Smith 41) Therefore, as noted earlier, coal became the preferred fuel of most iron companies. Anthracite coal caught on first in America because of its purity, heat production, and ability to bear the weight of the iron ore. However, anthracite proved difficult to kindle. (Smith 47) Coke overtook anthracite because its chemical agents, carbon and carbon monoxide, proved more useful for reducing the iron ore. Coke also protected the iron from being reoxidized by oxygen in the air as long as the iron was surrounded by hot carbon. Coke could also be absorbed by the iron to form iron-carbon alloys of several types. (Lankford et al. 5) Even though coke had more impurities, created more ash, and was more phosphorus (which weakened the iron), it was cheaper, more easily obtained, and less friable (which allowed it to be used in larger furnaces.) (Singer et al. 100) These details decided the fate of the fuels. There was no distinct differences between anthracite and coke furnaces, but factors such as expense and availability settled the debate between the coals. Although iron made with charcoal was “unmistakenly better than a coke iron having a similar chemical composition,” coke was much more used because of the destruction caused by charcoal retrieval. (Beckert 90)

The other essential ingredient, besides iron ore and fuel, was the flux. “The major function of the fluxes, limestone and/or dolomite, [was] to combine with the ash in the coke and
the gangue in the ores to make a fluid slag that can be drained readily into the furnace hearth.”

(Lankford et al. 543)

The furnace became an integral part of the American economy, and, therefore, American society in the eighteenth and nineteenth centuries. Hundreds of towns in Pennsylvania, Virginia, and other eastern states, relied upon the local mining company to support the community. Longdale was no different. The furnace, of course, played a large part in this culture.
WORKS CITED


