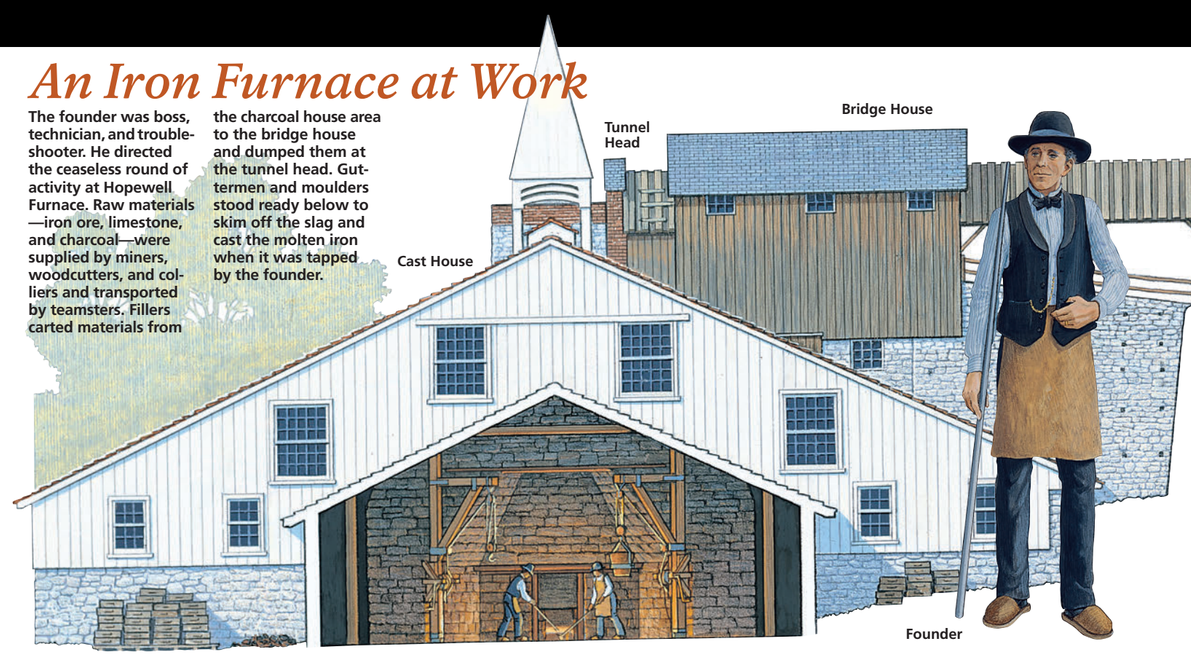
An Iron Furnace at Work

The founder was boss, technician, and troubleshooter. He directed the ceaseless round of activity at Hopewell Furnace. Raw materials—iron ore, limestone, and charcoal—were supplied by miners, woodcutters, and colliers and transported by teamsters. Fillers carted materials from the charcoal house area to the bridge house and dumped them at the tunnel head. Guttermen and moulders stood ready below to skim off the slag and cast the molten iron when it was tapped by the founder.



ILLUSTRATIONS NPS / L. KENNETH TOWNSEND

An ancient alchemy sustained Hopewell Furnace: transforming mineral into metal. Since 4,000 years ago, when humans learned how to free iron from ore, the basic process has not changed. Iron oxide is heated in an intense flame fed by a carbon fuel. Oxygen in the ore combines with carbon monoxide released from the fuel and is expelled as CO_2. What is left is iron. The blast furnace's height lets the rising gases preheat the ore and gives the iron more distance to descend as it softens—so it absorbs more carbon from the fuel. Because iron's melting point falls as its carbon content rises, the iron becomes fully molten. A calcium-based "flux," usually limestone, is added. The flux combines with the impurities in the ore and forms slag.

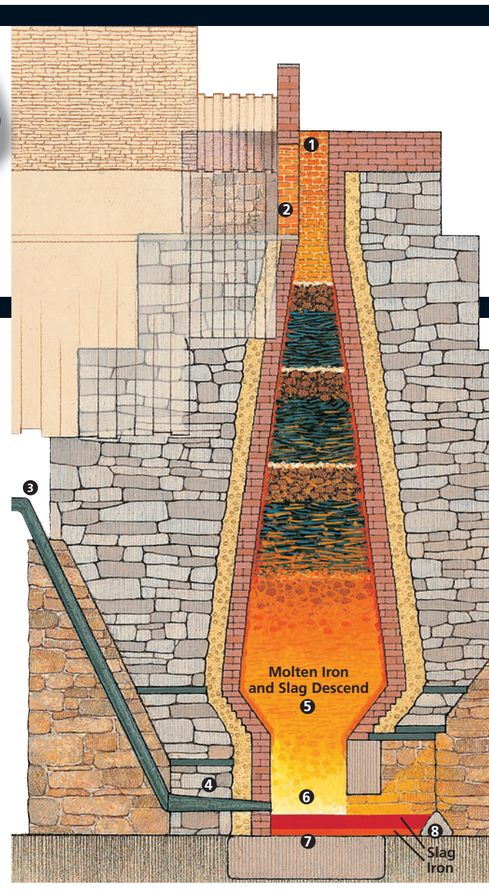
They tended the furnace, the glowing heart of their community; it yielded iron and a way of life.

Raw Materials of Iron Making

The basic ingredients of iron making—iron ore, limestone, and carbon fuel—are some of the most common materials on Earth, but are not found everywhere. Early furnaces were built where these materials were available. Iron is usually found in combination in the form of hematite, the magnetite used at Hopewell, or other **iron ores**. Most iron ore was dug in small surface mines. Any substance that contained calcium, like sea shells, could be used as a flux, but for most furnaces, **limestone** was cheap and abundant.

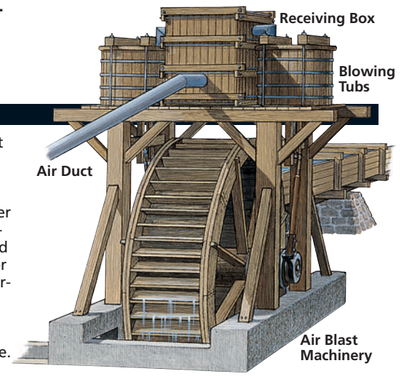

Iron Ore


Limestone



American forests were so vast—and bringing in coal so expensive before railroads were built—that early iron plantations like Hopewell made their own fuel. They slowly burned carefully built piles of wood to make **charcoal**, an almost purely carbon fuel that burns with intense heat. The great demand for charcoal meant that early furnaces were sited on woodlands. One other ingredient was needed: air. It was directed into the hearth under pressure by the water-powered blast machinery, raising the fire in the furnace to smelting temperature.


Charcoal

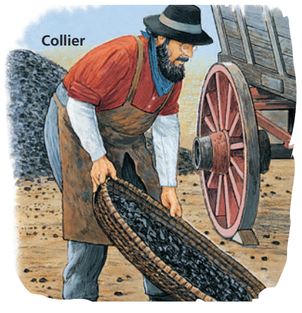


The Work Force

Historians have styled rural iron making operations like Hopewell's, called "iron plantations," as feudal. This was a self-sufficient community of craftsmen and laborers living lives directly or indirectly governed by the furnace. It could be a difficult taskmaster—dirty, noisy, dangerous at times, ever needing to be fed and tapped. But a demanding furnace also meant community prosperity. A silent furnace meant lean times.

A traditional hierarchy governed the furnace's operations. At the pinnacle was the ironmaster, director of the enterprise and often an owner. Good ironmasters had to be financier, technician, bill collector, market analyst, personnel director, purchasing agent, and host to prospective buyers. His was a volatile job: bad luck or poor judgment usually meant failure. Success often brought wealth. A clerk helper kept the books, ordered supplies, served as paymaster, and managed the office store. The job well performed could be a stepping stone to ironmaster.

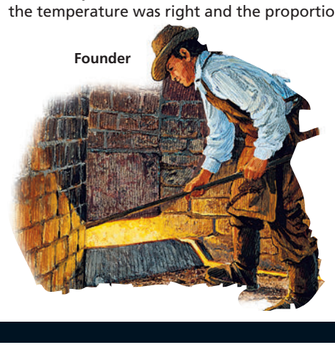
The quality of the iron was in the founder's hands. His job: keep the furnace blowing at peak efficiency. He supervised the other furnace workers: keepers helped him monitor the furnace and took the night shift; fillers charged the furnace with raw materials; and guttermen directed molten iron as it flowed from the furnace. Moulders, the highest-paid workers, had the exacting job of casting the iron. Colliers (charcoal makers), miners, and woodcutters provided the raw materials for the furnace. Other workers included teamsters, who drove the wagons carrying raw materials and finished products; cleaners, often women and children, who finished the cast products; and teachers. Women supplemented family incomes by sewing, lodging and boarding single workers, and laundering. Some made extra income working as woodcutters and miners. Farmers fed the community, and some worked the furnace for part of the year. African Americans also worked furnaces—enslaved at first, later as temporarily employed runaway slaves and free blacks.


Collier

Furnace Operations

1. **Chimney:** Smelting by-products—CO and CO_2 gases and smoke—are expelled.
2. **Tunnel Head:** Limestone, iron ore, and charcoal are dumped into the furnace.
3. **Air Duct:** Air under pressure is brought from air blast machinery.
4. **Tuyere:** Narrowing pipe directs air blast into the crucible, where temperature is boosted to 2,600°–3,000°F.
5. **Bosh:** Iron is becoming molten; with slag, it descends towards crucible.
6. **Crucible:** Narrowest and hottest part of furnace, where iron becomes fully molten.
7. **Hearth Stone:** Molten iron and slag settle on this stone.
8. **Dam Stone:** Holds molten iron and slag in hearth until the slag is drawn off and the iron is tapped.

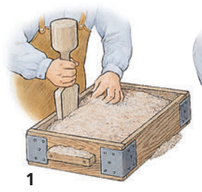
Iron plantation life revolved around the always-running, roaring furnace. It shut down usually once a year—to refurbish its inner walls and hearth. While it was "in blast," its cycles of filling and tapping set life's rhythm at Hopewell. It demanded close attention. Workers constantly fed it, watched its flame, and listened to the sound of its blast. For workers around the furnace, it was a hot, hard job requiring protective shoes and aprons. Every half-hour fillers dumped into the tunnel head 400 to 500 pounds of iron ore, 30 to 40 pounds of limestone, and 15 bushels of charcoal. With no gauge, the founder used his practiced eye to judge the shape and color of the flame from the chimney and the color and consistency of the molten iron. This told whether the temperature was right and the proportions of ingredients correct. In temperatures that could reach 3,000°F, the molten iron flowed down toward the hearth, to be tapped when the founder judged it ready. At Hopewell he generally tapped the furnace every 12 hours, at 6 am and 6 pm. After the guttermen drew off the slag, the iron could be tapped in two ways: It could flow directly into the "pig bed" in the cast house floor (it looked like a litter of nursing pigs), where it hardened into pig iron ready for market. Or it could be tapped into large ladles, then cast in molds *(see Moulder, bottom center)*. This process was repeated twice daily as long as the furnace was in blast.


Founder


Gutterman

The Moulder's Art

In the "flask casting" method of casting, both sides of a stove plate were molded. This let the moulder produce a relatively light, curved plate. The flask was two wooden frames. The moulder laid the bottom half, the "drag," on a piece of wood called the "follow board," placing the wooden pattern inside. He then sifted fine sand over the pattern and packed the rest of the drag with coarse, damp sand **1**. After scraping away excess sand with the "strike" **2**, he placed another follow board on top and turned over the drag. He then removed the first follow board, blew away loose sand from the edges of the pattern with a bellows **3**, and "dressed" the edge with a moulder's spoon. He attached the "cope," the flask's top half, to the drag and again added fine and coarse sands. Before packing the sand he inserted a wooden wedge to form a "gate" **4**, allowing the molten iron to enter. Next he removed the wedge, separated drag and cope, and carefully removed the pattern with a pair of lifters **5**. He next secured the two halves of the flask with iron clamps. The final step was to pour the molten iron **6** through the gate. After the iron had cooled, he separated the halves of the flask and removed the gate from the plate. Other workers brushed off sand and filed rough edges, readying the plate for market.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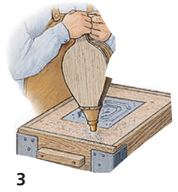
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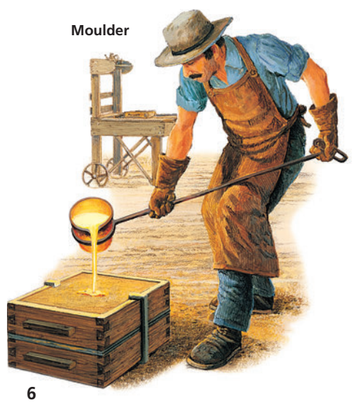

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Finished Products

To make the most money from molten iron you would cast finished products at the furnace. Moulders cast several items: plowshares, pots, sash and scale weights, cannon, and shot. But as iron stoves grew more common in 1800s homes, Hopewell built its operation on stove plates.

Cast products made profits, but the age also demanded goods that the furnace's brittle high-carbon iron was not suitable for. The tough, malleable wrought iron needed for plow moldboards, nails, and horseshoes had to be obtained through an indirect process not in place at Hopewell. The molten iron was cast into pig iron bars shipped elsewhere for refining. At a finery forge, the iron was remelted and much of its carbon was oxidized, raising the melting point. The iron partially solidified into a pasty lump. The lump was then beaten to drive out the slag and align the fibers, producing wrought iron. More processing converted this iron into the bars and rods used by blacksmiths.

A lengthier process was used to convert iron to steel. Hopewell's owners often held interests in local forges and mills.

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