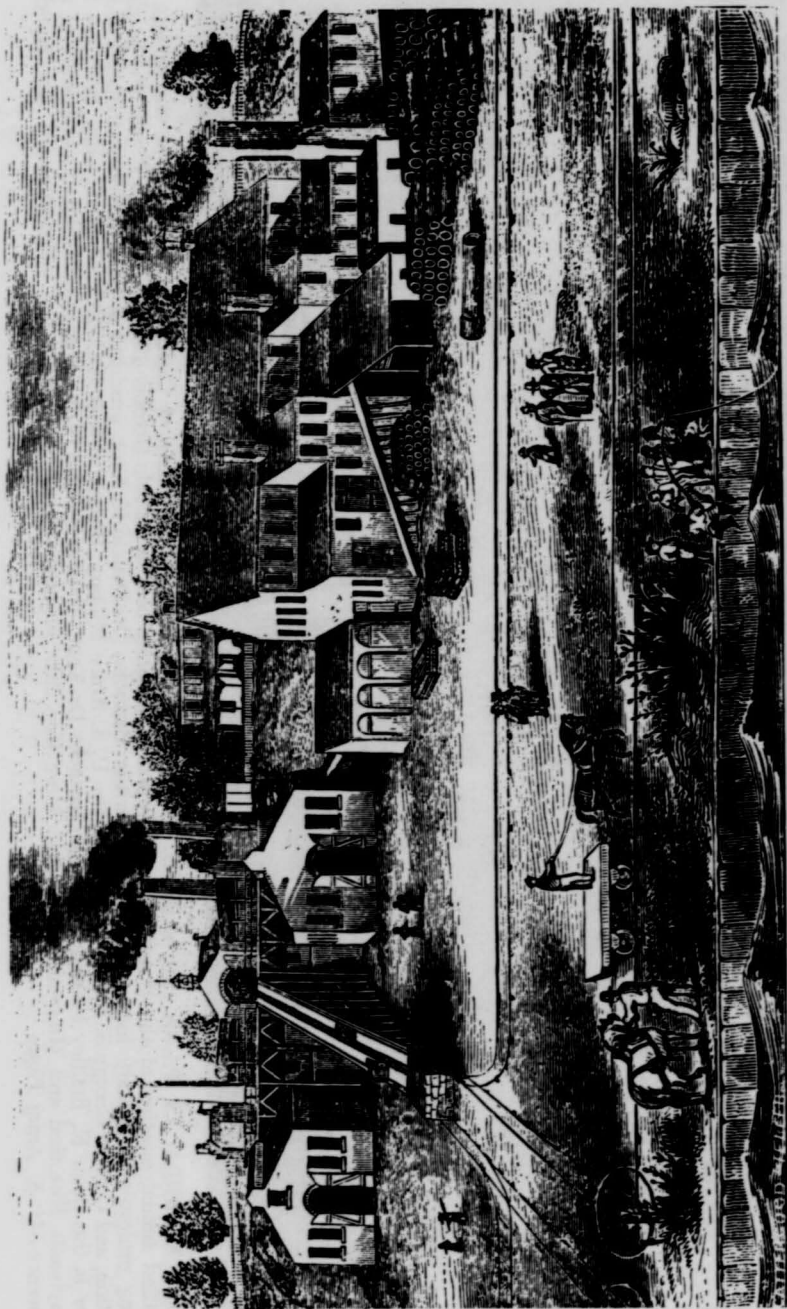




LEBANON IRON WORKS

Eli Bowen, *The Pictorial Sketch-Book of Pennsylvania* (Philadelphia, 1854), 109.

THE END OF COLONIALISM IN THE MIDDLE ATLANTIC IRON INDUSTRY

BY JOSEPH E. WALKER*

BRITISH political control over her American colonies came to a decisive end in the Declaration of July, 1776, and the subsequent recognition of a *fait accompli* by his majesty's government in the treaty of 1783. Other aspects of British leadership were not so clearly eliminated by the outcome of the Revolutionary War. British merchants and manufacturers made attempts to regain their hold on the United States market after the war. American writers and artists were stigmatized by the term "colonials" for a generation after independence. In manufacturing the United States took time to acquire the technological skills which the Industrial Revolution had implanted in the mother country, particularly since the British pursued a mercantilist philosophy that restricted the colonies to the production of raw materials. The iron industry of the middle Atlantic states demonstrated the inability to move away from the colonialism imposed before the Revolution.

For almost a century British ironmasters had been unable to provide iron fabricators with a sufficient quantity of pig iron and bar iron. England purchased large quantities of pig iron from Sweden and Russia. Why not, Englishmen reasoned, encourage the colonials to produce pig and bar iron and exchange it for rolled iron, steel, and iron manufactured articles provided by superior British technicians?¹ Most colonial activity in iron,

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¹ Extensive discussion of the problems of the British iron industry and colonial controls may be followed in B. R. Mitchell, ed., *Abstract of British Historical Statistics* (Cambridge, 1962); United States, Bureau of the Census, *Historical Statistics of the United States, Colonial Times to 1957* (Washington, 1960); Lawrence Henry Gipson, *The British Isles and the American Colonies* (Vol. III of *The British Empire Before the American Revolution*, New York, 1960); Great Britain, *Journals of the House of Com-*

therefore, was tied to the relatively simple operation of the bloomery, the foundry, the furnace, and the forge. This colonialism continued after the Revolution. The American iron industry needed three-quarters of a century of borrowing, adapting, and innovating before it could equal the British in the more sophisticated technology of fabrication and speciality production.

The middle Atlantic colonies were well endowed by nature with the ingredients for an iron industry. Bog ore and oyster shells along the coast, mined ore and limestone at numerous points inland, and everywhere forests for charcoal and flowing streams for power provided the basis for the operation of bloomeries, furnaces, and forges. By the early eighteenth century all of the colonies of this area had begun to mold cast-iron wares and hammer wrought iron into bars. Local blacksmiths made agricultural and building tools, nails, hoops, tires, and hinges. This kind of basic iron industry supplied the largest demands of a frontier society and likewise fitted the mercantilist philosophy of British colonial administration.

Despite criticism of government economic controls by Sir Josiah Child, Bernard de Mandeville, David Hume, and Adam Smith, British policy in the quarter century prior to the American Revolution sought to preserve the colonial market for her industrial products and to direct the colonies to produce raw materials for British manufacturers. For the iron industry, Parliament formalized this policy in the Iron Act of 1750 and several subsequent modifying statutes. Even after the American colonies won independence, England attempted, with some success, to maintain the iron industry of the United States in a status of subservience to British iron production.

Colonial concern with pig and bar iron was encouraged by British fabricators, and the policy of the British mercantilist economists, formalized in the Iron Act of 1750, has been called, "a perfect case of the application of the mercantilist policy" because it encouraged the importation of crude iron from the American colonies and preserved the colonial market for English wrought iron and steel.² Lawrence Gipson wrote that the Iron

mons, 1640-1800, XXIII; Thomas Southcliffe Ashton, *Iron and Steel in the Industrial Revolution* (Manchester, 1951).

² Broadus Mitchell and Louise Pearson Mitchell, *American Economic History* (Boston, 1947), 127.

Act illustrates "the motivation of those who were responsible for guiding imperial policy" and shows the "enormous complexity of the problems involved in attempting to rectify the maladjustments of the mercantile system."³

Impulse for passage of the Iron Act came from the exclusion of Russian and Swedish bar iron from the English market during the War of Spanish Succession.⁴ The first step came when Joshua Gee, an English ironmaster, petitioned the House of Commons to remove the tariff on American pig and bar iron and to place a premium on such imports.⁵ However, he also warned that Britains,

. . . ought always to keep a watchful eye over our colonies, to restrain them from setting up any of the manufactures which are carried on in Great Britain, and any such attempt should be crushed in the beginning, for if they are suffered to grow up to maturity it will be difficult to suppress them.⁶

By buying crude iron from the American colonies instead of Sweden and Russia, the British iron industry expected to save £180,000 annually and to maintain a monopoly market for finished products.⁷

The result of this economic pressure resulted in the passage of the Iron Act of 1750 which removed all duties on pig and bar iron imported from the colonies. At the behest of British forgers, bar iron could only be received through the port of London and could not be shipped more than ten miles from the city. The act also stipulated that:

. . . from and after the twenty-fourth Day of June one thousand seven hundred and fifty, no Mill or other Engine for Slitting or Rolling of Iron, or any Plating Forge to work with a Tilt Hammer, or any Furnace for making steel, shall be erected in any of the said colonies. . . .

³ Gipson, *The British Isles and the American Colonies*, 206.

⁴ Ashton, *Iron and Steel in the Industrial Revolution*, 119. Earlier attempts to encourage shipment of pig and bar iron to England from the colonies had been defeated in 1719, 1721, and 1738 by opposition from British forgers.

⁵ Arthur Cecil Bining, *Pennsylvania Iron Manufacture in the Eighteenth Century* (Harrisburg, 1938), 150.

⁶ Great Britain, *Journals of the House of Commons, 1640-1800*, XXIII, 113.

⁷ Reginald C. McGrane, *The Economic Development of the American Nation* (Boston, 1942), 58.

Governors of all colonies received orders to enforce the act and were subject to a fine of £50 for failure to do so. Persons guilty of violating the act were subject to a fine of £200.⁸

Parliament made minor changes in the law during the next fifteen years. In 1757 it removed the area restriction on bar iron;⁹ the Revenue Act of 1763 prohibited shipment of iron to any European country except Great Britain, and two years later Ireland was placed on the same basis as Great Britain for iron shipments.¹⁰

Most historians who write about the effect of the iron acts have followed Arthur Bining's conclusion that the regulations had little effect upon the development of the American iron industry. No American ironworks were destroyed, and no Americans were reported as having been prosecuted for violations of the act.¹¹ James A. Barnes wrote, "In general British regulations were ineffective, and the stream of well-made articles that poured from the blacksmith shops throughout the Atlantic seaboard swelled year after year."¹² Douglas Fisher said, "The colonists . . . circumvented the main purpose of the Act [of 1750] by working up most of their iron into articles to meet their own needs, leaving little surplus for export to England."¹³ In spite of parliamentary restrictions, a contemporary writer expressed enthusiasm for American progress in the absence of help from England and went on to say, "We have further improved upon it [iron] by converting in into steel; which was entered upon without previous skill, and wrought and beat out by frequent experiments and by continual practice."¹⁴

Colonial governors did not seek out violators very diligently even when they operated in the capital cities. When Governor James Hamilton of Pennsylvania, as required by the act, reported in 1750 on the iron works in his colony, he listed two steel fur-

⁸ Great Britain, *Statutes at Large* (London, 1786), 23 George II, c. 29, VI, 490-492.

⁹ Gipson, *The British Isles and the American Colonies*, 229.

¹⁰ Arthur L. Jensen, *The Maritime Commerce of Colonial Philadelphia* (Madison, 1963), 154-157.

¹¹ Arthur Cecil Bining, *British Regulation of the Colonial Iron Industry* (Philadelphia, 1933).

¹² James A. Barnes, *Wealth of the American People* (New York, 1949), 73.

¹³ Douglas Alan Fisher, *The Epic of Steel* (New York, 1963), 78.

¹⁴ Jared Eliot, *Essays Upon Field Husbandry in New England and Other Papers, 1748-1762* (New York, 1934), 8.

naces, one slitting mill, and one plating forge.¹⁵ He definitely missed Coventry Steel Works and may have missed others.¹⁶ His successors in the next quarter century were also officially unaware of the building of the Offley's Anchor Forge in 1754, Samuel Potts's Steel Furnace and Whitehead Humphrey's Steel Furnace in 1762, Eckert and Voights's Wire Mill in Berks County and Potts's Slitting Mill, the Charming Forge Slitting Mill, Mark Bird's Slitting Mill, and a steel furnace built by Bird in 1775.¹⁷ Governors of New Jersey, New York, and Maryland took little, if any, more care in observing the law than did those of Pennsylvania.¹⁸

Even though England exported large quantities of ironwares to the colonies, the expected growth of trade under the iron acts did not materialize. Available statistics for British exports of iron products to her American colonies fail to show a pattern of steady growth after 1750.¹⁹ The number of anchors, axes, nails, and scythes shipped increased;²⁰ but the quantities remained too small to make a great addition to the British economy. The shipment of steel actually declined several years before the Revolution. Wrought iron shipments doubled between 1750 and 1773.²¹ However, the same rate of increase occurred for all British exports to the colonies during the same period.²² Boycotts during the 1760s hurt British ironmongers. One of them said in 1766 that he normally sent nails to America valued at £50,000 annually, but the embargo over the Stamp Tax had forced him to discharge

¹⁵ James M. Swank, *History of the Manufacture of Iron in all Ages, and Particularly in the United States for Three Hundred Years, From 1585 to 1885* (Philadelphia, 1884), 479 ff.

¹⁶ Pennsylvania, *Statutes at Large, 1700-1809* (18 volumes, edited by James T. Mitchell and Henry Flanders, Harrisburg, 1896-1915), IX, 723, 791.

¹⁷ Bining, *Pennsylvania Iron Manufacture in the Eighteenth Century*, 158, 189.

¹⁸ *New Jersey Archives* (30 volumes, edited by W. A. Whitehead et al., Newark, 1880-1906), First Series, VII, 560; Gipson, *The British Empire Before the American Revolution*, II, 57, III, 217; Charles S. Boyer, *Early Forges and Furnaces in New Jersey* (Philadelphia, 1963), 229-236.

¹⁹ Neither British nor American statistics for the iron industry are very reliable before the middle of the nineteenth century. They are of value mainly to indicate trends.

²⁰ United States, Bureau of Census, *Historical Statistics of the United States, Colonial Times to 1957*, 765.

²¹ *Ibid.*

²² Mitchell, ed., *Abstract of British Historical Statistics*, 144-145.

300 workmen.²³ The embargoes also stimulated American manufacturing of scythes, spades, and axes²⁴ which American farmers learned to prefer instead of those made in England.²⁵

Trade statistics appear to support the view that the Iron Act did no damage to the colonial industry. American iron production expanded rapidly. From 1750 to 1775 the output increased from 10,000 to 30,000 tons annually. But there was no sharp increase of either exports or imports to indicate that the Iron Act was accomplishing its purpose. Statistics on English imports for these years show that the increase in American production was not caused by any large expansion of shipments of pig and bar iron to England. The percentage of American output disposed of on the British market declined over these years. Peak years such as 1765-1767 and 1771 were occasioned by depression in the American market and overexpansion of Pennsylvania's ironworks. In 1772 Pennsylvania iron apparently found a market nearer home because its shipments to England dropped more than 50 percent. In most of these years Maryland and Virginia supplied more than half of the American iron which went to England. Pennsylvania, with the largest production of any colony, sold relatively little to England, and most of that was pig iron. Bar iron shipments fell off sharply from a peak of 357 tons in 1768.²⁶

A comparison of tonnages likewise shows that the Iron Act of 1750 did not solve England's need for crude iron. In the peak year of imports, 1772, England bought 57,800 tons of iron. Of that total the American colonies supplied about 4,700 tons or only 8.1 percent. At no time did the colonies supply more than 10 percent of the British need for iron imports.²⁷

Such statistical information supports the conclusion that the Iron Act neither hurt the American iron industry nor solved the problem of British dependence upon continental iron. But there are other factors less easy to analyze. For example, a growth of British exports of steel could have been at the expense

²³ *Birmingham Gazette*, February 24, 1766.

²⁴ Gipson, *The British Isles and the American Colonies*, 219.

²⁵ Ashton, *Iron and Steel in the Industrial Revolution*, 126.

²⁶ Jensen, *Maritime Commerce of Colonial Philadelphia*, 9; Mitchell, ed., *Abstract of British Historical Statistics*, 140-145.

²⁷ United States, Bureau of Census, *Historical Statistics of the United States*, 761-763.

of an expansion of the American steel industry which was hobbled, even if not stopped, by the parliamentary restriction.

Some more specific implications may be drawn from an examination of incoming and outgoing ship cargoes. American imports from England included a wide range of fabricated iron products such as axes, hoes, shovels, nails, saws, hardware, hoop and sheet iron, watch springs, scientific instruments, anvils, anchors, cables, tailors' irons, bonnet wire, sickles, rolled bar iron, and cutlery. Sheffield cutlery and Birmingham iron goods had become traditional with American consumers, and the low price of rolled bar iron, produced by improved technical methods in Great Britain, could not be matched in this country.²⁸ Newspaper advertisements show that in the ten years prior to the Revolutionary War, American ironworks offered for sale mill spindles, iron axletrees, cast mill rounds, gudgeons, gristmill rounds, firebacks, Franklin stoves, and stove plates.²⁹ These American products were made by the molder; some of the British products were possible only by more sophisticated processes. It seems reasonable to assume that British regulations retarded the development of American iron beyond the relatively simple products of a colonial iron industry.

Adam Smith professed to see a subtle deterioration of colonial relations when he argued that, while the mercantilist restrictions did not hurt the American industries, they were unwise because they were, ". . . impertinent badges of slavery, imposed upon them, without sufficient reason, by the groundless jealousies of the merchants and manufacturers of the mother country."³⁰ It is not clear whether William Allen protested against the Iron Act because he was an ironmaster or because he was Chief Justice of Pennsylvania.³¹ The near unanimity of support for the Revolution among ironmasters indicates that they were at an economic disadvantage.

Lawrence A. Harper pointed out an indirect influence of the controls on iron manufacturing. He noted that capital investments

²⁸ Edward C. Kirkland, *A History of American Economic Life* (New York, 1946), 220.

²⁹ For many examples see *Pennsylvania Gazette* for the years 1765-1775.

³⁰ Adam Smith, *An Inquiry into the Nature and Causes of the Wealth of Nations* (New York, 1937), 538-551.

³¹ Carl Bridenbaugh and Jessica Bridenbaugh, *Rebels and Gentlemen: Philadelphia in the Age of Franklin* (New York, 1962), 185.

in the American iron industry were discouraged by possible seizure of an illegal mill or involvement in a legal action for violating the Iron Act.³² Theories of negative action are always difficult to sustain statistically, and Harper admitted as much. However, two ambitious examples of British-financed ironworks in the middle Atlantic colonies must have been discouraging for prospective investors. Peter Hasenclever purchased 50,000 acres of land in northern New Jersey in 1764 and imported 535 workers from Germany and England for his American Iron Company. He was financed by £40,000 invested by a group of Englishmen. Hasenclever spent more than £54,000 before he had any returns from the investment, and it is doubtful that the investors got a return on their money by 1770 when Hasenclever went bankrupt.³³ The British investors in the large Principio Works in Maryland were successful from 1726 to the outbreak of the Revolution, but they lost their investment when Maryland seized the works. After the war the British government compensated three of the owners for their losses in the amount of £24,000.³⁴

The Revolutionary War ended legal restrictions and created a tremendous demand for American iron to make war materials and to replace articles previously imported from England. Congress recognized the value of the ironworks by exempting workers at furnaces and forges from military service and by providing subsidies for the erection of new furnaces.³⁵ Besides the stoves, Dutch ovens, bake plates, still plates, still bars, axles, and Franklin stoves which ironmasters marketed in 1773, Pennsylvania ironworks began to produce cannons, shot, salt pans, muskets, rifles, swords, pikes, sheet iron, camp kettles, blaze pans, frying pans, stew pans, teakettles, iron plates, slit iron, steel, nails and

³² Carl Ubbelohde, *The American Colonies and the British Empire, 1607-1763* (New York, 1969), 67.

³³ Boyer, *Early Forges and Furnaces in New Jersey*, 12-25; Edward C. Kirkland, *A History of American Economic Life* (New York, 1969), 49.

³⁴ Inventory of the property of the Principio Company, AC#683; Eleutherian Mills Historical Library (EMHL); Fred Albert Shannon, *America's Economic Growth* (New York, 1940), 91-92; Mitchell and Mitchell, *American Economic History*, 105.

³⁵ Many such actions are listed in *Journals of the Continental Congress* (34 volumes, various editors, Washington, 1904-1937). For example see June 23-24, 1777, VIII, 495-496; Boyer, *Early Forges and Furnaces in New Jersey*, 15-16; Joseph E. Walker, *Hopewell Village: A Social and Economic History of an Iron-Making Community* (Philadelphia, 1966), 25.

nail rods, anchors, and hoops.³⁶ The most highly publicized product of middle Atlantic iron furnaces was the chain used to block navigation on the Hudson River which Peter Townsend made at the Sterling Iron Works in New York.³⁷

Political independence did not bridge the technological gap between the British and American iron industries. Despite notable advances by the iron industry, it still became necessary during the war for the United States to secure large quantities of French munitions and military supplies.³⁸ Other evidence indicates that the American iron industry was not capable of filling the demand for finished products. Among the examples were the orders for nails and hardware placed with British ironmongers by American merchants soon after the end of the war. Twenty years later England still sold nails to the value of almost £800,000 in the United States. The New York water works was forced to order iron pipe from the Wilkinson ironworks in England in the 1790s because it was unobtainable from American ironmasters.³⁹ And attempts to make good American wire did not succeed until after 1800.

Statistics for the iron industry in the decade after the Revolutionary War are scarce. But surviving evidence points to an industry in trouble. The list of bankruptcies would constitute a fair who's who of early American ironmasters. Hopewell Furnace in Pennsylvania experienced five sheriffs' sales by 1800. Many furnaces and forges shut down in the face of falling prices and renewed British competition.⁴⁰

An examination of the products made during the Revolutionary War reveals that there had been little advancement in scientific knowledge or technical skill except in the large castings for cannons, the expanded production of bored rifle barrels, and the in-

³⁶ Journal, 1776-1802, Cornwall Furnace Papers, Pennsylvania Historical and Museum Commission (PHMC); Frederic K. Miller, *The Rise of an Iron Community* (published in three parts, Lebanon, Pa., 1950-1952), 110-112; Bining, *Pennsylvania Iron Manufacture in the Eighteenth Century*, 182.

³⁷ Bining, *Pennsylvania Iron Manufacture*, 182; Boyer, *Early Forges and Furnaces in New Jersey*, 222-226.

³⁸ Arthur Cecil Bining, *The Rise of American Economic Life* (New York, 1956), 93.

³⁹ Ashton, *Iron and Steel in the Industrial Revolution*, 140.

⁴⁰ "Brief of Title of Hopewell Property," Hopewell Papers, Cataloged Documents, 8730407, Hopewell Village National Park Site Library (HVNPSL).

roduction of grooved rollers for slitting nail rods. The war had made more nearly absolute the separation from the techniques and knowledge being developed by England's Industrial Revolution, and the British government aimed at keeping the Americans from advancing beyond their colonial status by copying English innovations in iron production and fabrication.⁴¹

To formalize a policy, England passed a law in 1785 forbidding the export to any country of "tools, machinery, engines, models or plans of machines used in the iron industry" and also imposed heavy penalties upon anyone caught "enticing English workmen employed in iron and steel manufacture." Anyone guilty of exporting machines, models, etc., was to be fined £200, suffer forfeiture of goods, and serve one year in jail. For enticement the penalty was a fine of £500 and a year in jail for each person enticed. For any subsequent offense the penalty was to be doubled.⁴²

In 1795 Parliament extended the act and made it more explicit to include a prohibition against export of "... the several descriptions of machines, implements, utensils, and models, or parts thereof, employed in rolling, slitting, pressing, casting, boring, stamping, piercing, scoring, shaping, or chasing and die-sinking iron and other metals."⁴³ In 1799 enticing Scottish coal miners to emigrate was added to the punishable offenses.⁴⁴ Despite gaps in enforcement, these acts did prevent the free flow of technical data and engineering plans across the Atlantic.

England's wartime economy in 1797 brought an act intended to keep American iron in a position of primary production close to that imposed by the Iron Act of 1750. Pig and bar iron from the United States were admitted to the British Isles at the same rates as from British colonies and duty free if carried in British ships. When iron was carried in American ships, the rate was 10 percent lower than that paid by nations other than the United States.⁴⁵ Once again England encouraged American ironmasters

⁴¹ For a discussion in detail see Carroll W. Pursell, Jr., *Early Stationary Steam Engines in America* (Washington, 1969). Pursell shows how a dependence upon British engineers slowed the development of heavy castings for an American steam engine.

⁴² Great Britain, *Statutes at Large*, 25 George III, c. 67.

⁴³ Swank, *History of the Manufacture of Iron*, 364.

⁴⁴ *Ibid.*, 367.

⁴⁵ Great Britain, *Statutes at Large*, 37 George III, c. 97, Section 11.

to concentrate on raw iron production by favorable terms for trade in Great Britain.

American ironworkers apparently remained unacquainted with the new scientific and technical changes being developed in Europe in the eighteenth century, but in the three decades between the Revolution and the War of 1812 many additions occurred in the kinds and quantities of products going to market from the middle Atlantic furnaces and forges. The quarter century of war in Europe, a tariff on iron imports, and President Jefferson's embargo on American exports opened new foreign and domestic markets for American iron and cut off the flow of European tools and supplies.

The China trade, begun in the 1780s, encouraged American shipbuilding and created a market for spikes, chain plates, and rudder iron.⁴⁶ The westward movement created a large demand for farm implements, moldplates, nails, bolts, tools, hinges, locks, sleds, wagons, window sashweights, clockweights, spindles, grate bars for slitting mills, forge plates, and plates for fineries.⁴⁷ A strong nationalist sentiment among ironmasters may have been responsible for selecting the name Federal Slitting Mill for establishments in both Pennsylvania and New Jersey.⁴⁸

The financial instability of the post-revolutionary period, with its numerous bankruptcies and sheriffs' sales, did not discourage new and old ironmasters from starting ironworks. From 1775 to 1800 Pennsylvania welcomed as additions to its industrial establishments: 42 forges, 28 furnaces, 8 rolling and slitting mills, 6 ironworks—unspecified as to kinds, 6 steel furnaces, 5 bloomeries, and 1 tilt mill.

Tench Coxe estimated in 1794 that one-third of all the ironworks then operating in Pennsylvania had been built in the previous seven years.⁴⁹ The important changes were a decline in bloomeries and a large expansion of forges and furnaces. The addition of eight rolling and slitting mills and six steel furnaces showed an advance in techniques of production beyond the primary stages, and even these were not entirely new to America.

⁴⁶ Tench Coxe, *A View of the United States* (Philadelphia, 1794), 71-72.

⁴⁷ Journals, 1772-1794 and 1776-1802, Blast and Pig Book, 1798-1807, Cornwall Furnace Papers, PHMC.

⁴⁸ Lukens Steel Company Records, EMHL.

⁴⁹ Coxe, *A View of the United States*, 490.

For example, Governor Belcher of New Jersey reported in 1750 that only one rolling and slitting mill existed in that colony although it was not in use.⁵⁰ And Delaware had at least one rolling and slitting mill during the Revolution because John Gregg headed a company which in 1779 began rolling iron for nail bars near Wilmington.⁵¹

Another boost to the iron industry came from the invention of new machines and processes. The list of patents issued by James Madison in 1805 reveals the importance attached to the fabrication of iron products. Seventy-one of the first 598 patents, about one of eight, issued by the United States Patent Office before 1805 went for making iron products or using new methods in the iron industry. Forty-four concerned nail-making machines or methods of making nails. Important among these patentees, Oliver Evans ushered in a new age for the iron industry when he received patent number 520 for making "stronger boilers for Steam Engines to increase power of boats."⁵²

From 1780 to 1810 the number of furnaces in Pennsylvania increased from seventeen to forty-four and their output of pig and cast iron jumped from 6,000 to 26,878 tons. Another remarkable expansion can be observed in the increase in the number of rolling and slitting mills, trip hammers, and naileries. The output of steel in New Jersey and Pennsylvania represented more than 90 percent of the 910 tons that the nation produced annually. Bloomeries continued to decline sharply except in New Jersey.

On the basis of the statistics collected in the census of 1810, Tench Coxe issued an optimistic report on the achievements of the American iron industry. He declared:

The iron branch has been fruitful in inventions and labor-saving devices, both at home and abroad. In the moments, when we feared difficulty and injury from the want of certain necessary things, the manufacture had suddenly been attained and established. This is remark-

⁵⁰ *New Jersey Archives*, First Series, VII, 558.

⁵¹ Carroll W. Pursell, Jr., "The Delaware Iron Works, a Nineteenth-Century Rolling Mill," *Delaware History*, VIII (March, 1959), 294-309.

⁵² James Madison, "A List of the Names of Persons Who Have Invented any New and Useful Art, Machine, Manufacture or Composition of Matter, or any Improvement Thereon, and to Whom Patents Have Been Issued for the Same" (Washington, 1811). This list includes patents issued through December 31, 1804. A copy can be consulted at EMHL. The importance of Evans's steam engine to the iron industry will be discussed later.

ably the case, as to *common steel, iron wire and edge tools*, the manufacture of all which have been greatly advanced. The improvement and extension of the cast iron manufactures, including cannon cast solidly and bored out, have been very great. The saving of the labor of . . . the tilt and trip-hammers, have given extraordinary activity to this branch of the iron manufactory.⁵³

Coxe optimistically believed it was time for the United States to move away from the colonial status for iron products by removing the tariff from pig and bar iron, and to encourage its importation because, he believed, American furnaces and forges were now capable of supplying the demand of the fabricators of iron and steel products.⁵⁴ Despite his optimism, Coxe recognized that in certain areas of the iron industry America lagged behind Great Britain. He listed the use of steam power for operating the bellows of furnaces and the "charring of pit coal" to produce fuel suitable for furnace and forge fires as British innovations which the United States should attempt to emulate.⁵⁵

Coxe could have looked a little further, however, and seen other reasons why American iron had trouble matching Great Britain in a struggle for world markets and even for the American market. A few examples will illustrate the backwardness of American iron technology as compared with the British: furnaces and forges had not increased their size or capacity and were still using a blast heated by charcoal, a process too expensive to compete with stone coal and coke even in a region where forests were not depleted; every ton of steel produced in America in 1810 came from furnaces using the outmoded, slow, and costly cementation process; not one reverberatory furnace and very few flat-roll rolling mills were in operation; few American furnaces had substituted blowing tubs for the bellows to produce their blasts; cupola furnaces for foundry work were scarce; America was unable to produce malleable castings or fine finished sheet iron of the kind Russia had made famous; Americans were using Watt-Boulton steam engines shipped in parts from

⁵³ Tench Coxe, *A Statement of the Arts and Manufactures of the United States of America for the Year 1810* (Philadelphia, 1814), 9-14, 32. Emphasis was in the document as published.

⁵⁴ *Ibid.*, 55.

⁵⁵ *Ibid.*, 32.

England or badly cast after British models in this country;⁵⁶ most ironworks used a water wheel as the sole source of power; and America was operating its iron industry by tradition and without any scientific analysis of ores or of the products of the various processes of iron production and use.

Since England had made, during the eighteenth century, advances in all of these areas except the rolling of Russian sheet iron, it is evident that the United States iron industry was still in a dependent position technically and would be in a disadvantageous posture in competing with Great Britain in a world restored to peaceful commerce. During the wars from 1793 to 1815 European demand, tariffs, and the embargo had made it possible for American ironmasters to continue outmoded procedures; but after 1815 British iron undersold similar American products in the American market to an extent that the demand for pig iron from local furnaces dropped.

However, the period of colonialism was near its end, change was on the way, and in the next forty years America produced iron of such quality and quantity that England was forced to recognize a rival worthy of its best effort. In some cases the new nation was adopting, belatedly, the inventions and innovations of the old; but in other areas America led the way to new techniques which England found profitable to copy. By 1850 pig iron production had increased to more than ten times its 1810 level.⁵⁷

Ashton declared that the British iron industry expanded before 1775 at an annual rate which probably did not exceed one percent, but in the last quarter of the century very rapid growth occurred. He attributed this growth to the manufacture of Watt's steam engine and Henry Cort's combination of a reverberatory

⁵⁶ Carroll W. Pursell tells of an American cast steam cylinder for the New York Water Works which varied five-eighths of an inch in diameter. Early engines built in America were under the supervision of British engineers such as Josiah Hornblower, John Hewett, James Smallman, Christopher Colles, and Benjamin Henry Latrobe. Pursell, *Early Stationary Steam Engines*, 5, 6, 30, 32, 56, 57. Fulton used a Watt-Boulton engine on the *Clermont* (p. 24). Joshua Gilpin saw a cupola furnace in Pittsburgh in 1809. Joshua Gilpin Journal for 1809, Historical Society of Pennsylvania (HSP). For costs of charcoal as furnace fuel see *Documents Relating to the Manufacture of Iron in Pennsylvania* (Philadelphia, 1850), 90.

⁵⁷ United States, Bureau of Census, *Historical Statistics of the United States*, 149; Miller, *Rise of an Iron Community*, 106; Shannon, *America's Economic Growth*, 188.

furnace with a rolling mill.⁵⁸ Similarly, Pursell credits the invention of the high pressure steam engine by Oliver Evans with the new expansion of the American iron industry.⁵⁹

Evans began building his improved steam engine in 1801. He reported in 1812 that he had sold ten engines and was building ten more at his Mars Works in Philadelphia. However, British-trained Benjamin Henry Latrobe denounced the Evans engine as dangerous and unreliable. He convinced enough purchasers of the superiority of the Watt-Boulton low pressure engine to compete with Evans for some years at his Pittsburgh engine works.⁶⁰ By 1830 Pittsburgh was making annually one hundred engines, of both kinds, in several foundries.⁶¹ Other early centers of steam engine manufacturing in the middle Atlantic region were Soho Iron Works, Paterson, Morristown, and Jersey City in New Jersey; New York; Baltimore; Washington; and York, Pennsylvania. The middle Atlantic region became both the largest maker and the largest user of these engines. New York had 255 in use; New Jersey, 85; Pennsylvania, 613; Delaware, 28; and Maryland, 106.⁶²

The high pressure engines required better boiler plate than copper, cast iron, or hammered iron. The answer was rolled iron boiler plate which could be pressed to any thickness and with uniform strength. The rolling and slitting mills turned from an emphasis on nail rods to the production of iron plates in large quantities. A journal of the Brandywine Iron Works, later to change its name to the Lukens Steel Company, has a notation for July 6, 1820, "Delivered to Michael Williamson at Wilmington, Boiler Plates @\$170 and Tank Plates @\$160 per ton." This may have been the first rolled iron boiler plate produced in America. Other grades of rolled iron from the Brandywine mill in the same period included: manufactured iron, sheet iron, door plates, stove pipe, hoop iron, and nails.⁶³ Brandywine rolled plates were

⁵⁸ Ashton, *Iron and Steel in the Industrial Revolution*, 60-86.

⁵⁹ Pursell, *Early Stationary Steam Engines*, 133, 135.

⁶⁰ *Ibid.*, 44-49, 57.

⁶¹ Victor S. Clark, *History of Manufacturers in the United States 1607-1860* (New York, 1929), I, 507.

⁶² Pursell, *Early Stationary Steam Engines*; Clark, *History of Manufactures*, 509; Peter Temin, *Iron and Steel in Nineteenth-Century America* (Cambridge, 1964), 40.

⁶³ Lukens Steel Company Records, IV, 13-87, EMHL.

used in 1826 in the construction at York, Pennsylvania, of the *Codorus*, the first ironclad ship built in America.⁶⁴

The most powerful push on the rolling mills came when the railroads demanded rolled rails. The product of rolling mills is almost ignored in the census data for 1830, but in 1849, 80 percent of Pennsylvania wrought iron came from rolling mills. By 1856 the proportion was up to 95 percent. This is the period when America began to roll rails for the nation's expanding railroads.⁶⁵

England produced the first rolled rails, but the technological gap was narrowing. The crown issued a patent in 1820 to John Birkinshaw for rolled iron rails. These were used on the Stockton and Darlington Railroad which opened in 1825. John Tucker, president of the Reading Railroad, declared in 1844 that he had been unable to secure a single proposal for American rolled rails for the second track of his company. Clement B. Grubbe offered cast rails which were rejected as unsatisfactory, and the Reading imported its rails.⁶⁶

Had Tucker waited just a little longer, he would have had a choice of several rolling mills which could have filled his order. The first rails rolled in America were probably made at Maryland's Mount Savage Iron Company in 1844. These were quickly followed by rails from Danville, Phoenixville, Brady's Bend, Scranton, Johnstown, Safe Harbor in Pennsylvania, and from Trenton, New Jersey.⁶⁷ The Lebanon (Pa.) *Courier* declared on February 6, 1847, that, "Five years ago there was not an iron rail made in this country; now we have about a dozen mills for its manufacture, which produce about one hundred thousand tons annually."

The next advancement came in 1857 when John Fritz installed a three-high rolling mill at the Cambria Iron Works in Johnstown to permit continuous rolling and less cracking of rails because of too rapid cooling. As a result of this pioneering, Cambria took the lead in rail rolling until the introduction of the Bessemer

⁶⁴ Alexander Crosby Brown, *The Sheet Iron Steamboat Codorus* (Newport News, Va., 1950); Alexander C. Brown, "America's First Iron Ship," *Steelways*, September-October, 1966.

⁶⁵ Temin, *Iron and Steel in Nineteenth-Century America*, 100-101.

⁶⁶ Swank, *History of the Manufacture of Iron*, 342.

⁶⁷ *Ibid.*, 344-345; Katherine A. Harvey, *The Best-Dressed Miners: Life and Labor in the Maryland Coal Region, 1835-1910* (Ithaca, 1969), 11.

process made steel rails economical.⁶⁸ The three-high mill had been used many years earlier in England by Henry Cort, but Fritz produced rails with greater speed and superior quality for American railroads.⁶⁹ By 1860 there were 250 rolling mills in the United States with an annual output of 500,000 tons.⁷⁰

The need for large quantities of iron for the new machines of transportation, the new tools and equipment for agriculture and textiles, building supplies, and home furnishings pushed the American iron makers to multiply their efforts. At first an attempt was made to meet demand by increasing the number of furnaces and forges without changing the techniques or processes. When it became apparent that numerical expansion could not supply the market demand, producers adopted improved procedures already used with success in Great Britain. And in some notable instances Americans experimented with innovations which had not yet been used in Europe.⁷¹

A valuable change in producing iron for the rolling mills came with the adoption of the reverberatory furnace to make puddled iron. Again British leadership was copied in America. Henry Cort combined this type of furnace with a rolling mill in 1785, and the process gained general acceptance in England by 1812. In the United States Isaac Meason erected a rolling mill to use puddled iron in 1816 near Uniontown, Pennsylvania. Its success was reflected by its imitation. Within three years Pittsburgh had a rolling mill with four puddling furnaces, and within eighteen years Rebecca Lukens had a reverberatory furnace at her small Brandywine works in Coatesville. *Niles Weekly Register* reported on January 10, 1835, that M. B. Buckley had succeeded in using anthracite coal in a reverberatory furnace at Pottsville. At mid-century very few bars and blooms were sold to the rolling mills in competition with puddled iron.⁷²

American steel making made little progress of its own or in

⁶⁸ John Fritz, "An Address Delivered at the Lukens Centennial in 1910," Chester County Historical Society.

⁶⁹ *Ibid.*

⁷⁰ Clark, *History of Manufactures*, 515.

⁷¹ Several examples will be cited on subsequent pages. See *Niles Weekly Register*, XLVII (January 10, 1835), 315.

⁷² John Fritz, "A Century and a Quarter in Iron and Steel," *The Iron Age*, (July 4, 1935), 35-51; Swank, *History of the Manufacture of Iron*, 166-167; Myron B. Shank and William H. Thomas, *A Guide to the Old Stone Blast Furnaces in Western Pennsylvania* (Pittsburgh, 1966), 53.

adopting British methods in the first half of the nineteenth century. It was three-quarters of a century after Benjamin Huntsman's development of the crucible process in England in 1743 that the first American crucible steel was made, probably by James Wood at Valley Forge. Keim and Drinkle in Reading sold cast steel in 1820 at the near semi-precious price of \$750 per ton. Cast steel was made at Pittsburgh in the 1830s and crucible steel at Jersey City at about the same time. But steel was scarce and expensive until the development of the Bessemer converter. In 1850 Pennsylvania had thirteen steel furnaces producing three-fourths of the nation's output.⁷³

Large castings for steam engines encouraged the building of foundries to compete with the casting process at the furnaces. In England in 1794 John Wilkinson introduced the cupola to remelt pig iron to produce increased quantities of molten iron for large castings. This process came to the United States in the next decade where it was first used in the foundry shops making steam engines. Hopewell Furnace hoped to compete with the foundries by building its own cupola in 1817 but met with little success. Most of the charcoal furnaces no longer cast iron by 1850 because they could not compete with the greater efficiency of the foundries. Seth Boyden of New Jersey developed malleable iron casting in the United States about 1826 by a process which he accidentally discovered while trying to decarburize the iron with the European method developed in France in 1722.⁷⁴

Along with copying European successes, the United States began to innovate. The Alan Wood Company developed two procedures in their mill at Wooddale, Delaware, which apparently were original and not copied from European sources. One was the patented method of rolling blades for shovels to the proper dimensions and shape so that they needed only to attach

⁷³ Lukens Steel Company Papers, IV, 39, EMHL; Frank H. Taylor, *History of the Alan Wood Iron and Steel Company, 1892-1920* (Published for private distribution by the Alan Wood Iron and Steel Company), 5-8, copy at EMHL; W. T. Jeans, *The Creators of the Age of Steel* (New York, 1884), 30-33; Clark, *History of Manufactures*, 517; *The Making of Steel* (New York, 1964), 6; Ashton, *Iron and Steel in the Industrial Revolution*, 57.

⁷⁴ Hopewell Village Papers, SM7 and SM8, *passim*; H. A. Swartz, *American Malleable Cast Iron* (Cleveland, 1927), 11-12; Temin, *Iron and Steel in Nineteenth-Century America*, 37-44; Miller, *Rise of an Iron Community*, 153; Ashton, *Iron and Steel in the Industrial Revolution*, 141-142; Clark, *History of Manufactures*, 503-506; Walker, *Hopewell Village*, 55.

the handle to complete the tool. Here, also, they provided the first competition to the Russians in rolling finely finished or "planished" sheet iron. For this, John Wood received a silver medal from the Franklin Institute in 1842.⁷⁵ The Alan Wood developments represented a movement toward machine production, replacing hand production of small metal articles. Other Americans invented new machines for shaping nails, tacks, screws, spikes, bolts, files, chains, buttons, and wire.⁷⁶

Despite the diligent, if belated, copying of British inventions and the creation of new machines by Americans, a serious bottleneck still impeded expansion of the iron industry. The bottleneck existed at the first step in the production process, the furnace smelting of pig iron. Fred Shannon had this stage in mind when he said that before 1825 colonial methods of iron production had not changed perceptibly in America;⁷⁷ and James Barnes wrote, "not until after 1825 did iron-making pass beyond the primitive methods. . . ."⁷⁸ Peter Temin declared that, "the American iron industry in 1830 was still operating almost exclusively on the basis of traditional technology, despite the very successful exploitation of a newer technology in England." Great Britain was, therefore, able to export to America quantities of pig and bar iron which provided competition to the American iron industry.⁷⁹

The major hindrances to the expansion of pig iron production by traditional methods were the use of charcoal as fuel, water for power, a limited and inefficient blast, and a lack of scientific knowledge concerning the smelting process. By the middle of the century some success had been attained in each of these areas. Frederick W. Geissenhainer produced the great breakthrough for eastern iron when he demonstrated, in 1836 at Valley Furnace in Pennsylvania, that anthracite coal could be used as a fuel in a blast furnace.⁸⁰ In the west charcoal continued to be used longer than in the east because of early failures in attempts to use

⁷⁵ Patent issued to James Wood, February 10, 1825, Alan Wood Letters and Papers, EMHL; "Alan Wood Steel Fires Up for the Future," *Greater Philadelphia*, November, 1960; Harleston A. Wood, *Alan Wood, A Century and a Half of Steelmaking* (New York, 1957), 11; Pursell, "The Delaware Iron Works, a Nineteenth-Century Rolling Mill," 294-309.

⁷⁶ This list is representative but not all-inclusive.

⁷⁷ Shannon, *America's Economic Growth*, 220.

⁷⁸ Barnes, *Wealth of the American People*, 228.

⁷⁹ Temin, *Iron and Steel in Nineteenth-Century America*, 2, 15.

⁸⁰ Barnes, *Wealth of the American People*, 229.

bituminous coal. Even though furnaces at Lonaconing and Mount Savage in Maryland and at Clay Furnace in Pennsylvania used soft coal, solid success awaited the production of coke, a product of bituminous coal lacking some of the impurities which had ruined iron made from soft coal.⁸¹ The first regular manufacture of coke began on the Youghiogheny River a few miles below Connellsville, Pennsylvania. Here John Taylor built bee-hive ovens in 1841 for Provance McCormick and James Campbell.⁸² Pig iron production figures for 1854 show a strong trend toward mineral coal in the furnaces. In that year 45 percent of the pig iron was made with anthracite coal, 7.5 percent with bituminous coal or coke, and 47.5 percent with charcoal. In 1860 iron produced by anthracite coal had surpassed in quantity that made by using charcoal.⁸³

By mid-century some furnaces began using steam engines to operate the blast machinery and had adopted blowing tubs to replace the bellows. The tubs provided a more even flow of air and a stronger blast. The steam engine freed the furnace operation from fear of stopping. Ice, drought, or flood often caused the former power source to shut down.⁸⁴ Steam power combined with the use of mineral fuel gave greater flexibility to the location of furnaces and moved major production from rural to urban centers.

In 1828 James B. Neilson patented in England a process for using a hot blast of air to oxidize the fuel in the furnace. Within six years the Scranton brothers installed the hot blast at Oxford Furnace in New Jersey, and David Thomas greatly improved the operation at Catasauqua, Pennsylvania. Thomas raised the blast pressure from three-quarters of a pound to 10 pounds per square inch. Fuel consumption was reduced by using heated instead of cold air, and greater efficiency occurred by utilizing the waste heat from the stack to heat air for the hot blast and water for the steam engine. But perhaps the most important advantage was the

⁸¹ Harvey, *Best-Dressed Miners*, 15.

⁸² Douglas Alan Fisher, *The Epic of Steel* (New York, 1963), 110.

⁸³ Temin, *Iron and Steel in Nineteenth-Century America*, 52; Alfred D. Chandler, Jr., ed., *The Railroads: The Nation's First Big Business* (New York, 1965), 31.

⁸⁴ *Pennsylvania Gazette*, November 22, 1787; American Clergy, Case 9, Box 23, Gratz Collection, HSP; Miller, *Rise of an Iron Community*, 108-109; Walker, *Hopewell Village*, 19, 30, 36, 65.

opportunity to expand greatly both the size and the productive capacity of a furnace. By 1849 half of the furnaces in eastern Pennsylvania and the Juniata Valley used the hot blast. Western Pennsylvania was slower to make the change.⁸⁵

Before 1840 technology in the ironworks appears to have been an effort to create an air of mystery about the processes and perhaps to conceal a lack of knowledge. Alexander Boyden squirted some secret substance into the stack with a little pump. But he never revealed the nature of the liquid or its effect upon the process. Ironmasters operated furnaces largely by guesswork based on such factors as the color of the molten mass, and good results were more hoped for than guaranteed.⁸⁶ However, in the 1840s several scientifically trained men, such as Dr. Charles Clingan at Hopewell Furnace, Dr. Charles Huston at Brandywine Iron Works, and G. D. Coleman at Cornwall Furnace, became interested in the chemical control of iron ores and the physical properties of manufactured iron.⁸⁷

Comparison of statistics from the census of 1850 with the earlier figures for 1810 shows major growth. While the population quadrupled, the output of the iron industry increased five times as fast. America had shed its colonial dependence upon England for technical knowledge in the production of iron. Pursell's statement regarding the steam engine could have been applied to the whole American iron industry when he wrote that in 1850 it "was not radically different from, or better than [the English]. . . . Improvement had gone on independently in the Old World and the New."⁸⁸ There was constant exchange of information through engineers and publications which crossed the Atlantic in each direction.

British iron technicians and ironmasters were familiar with progress that the American iron industry had made. In 1841

⁸⁵ Temin, *Iron and Steel in Nineteenth-Century America*, 58-60; Jeans, *Creators of the Age of Steel*, 318; H. M. Boylston, *An Introduction to the Metallurgy of Iron and Steel* (New York, 1936), 12, 18.

⁸⁶ *American Malleable Iron: A Handbook* (Concord, New Hampshire, 1944), 199-200.

⁸⁷ Hopewell Village Papers, HVNPSL; Lukens Steel Company Papers, EMHL; Miller, *Rise of an Iron Community*, 126; Walker, *Hopewell Village*, 61-71.

⁸⁸ Pursell, *Early Steam Engines in America*, 113; United States, Bureau of Census, *Abstract of the Statistics of Manufactures according to the Returns of the Seventh Census* (compiled by Jos. C. G. Kennedy, Washington, 1858), 63-66.

Matthew Curtis of Manchester told the British Select Committee on the Exportation of Machinery,

I should say that the greatest portion of new inventions lately introduced into this country have come from abroad. . . . I mean not improvements in machines, but rather entirely new inventions. . . . I apprehend that the chief part, or a majority, at all events, of the really new inventions . . . in the carrying out of a certain process by new machinery, or in a new mode, have originated abroad, especially in America.⁸⁹

At about the same time Edward Williams, the technically oriented manager of the Dowlais Iron Works, persuaded the British Iron and Steel Institute to send a "committee of practical ironmasters" to study the advanced technology of American iron.⁹⁰

The editor of the London *Spectator* was, therefore, better informed about the historical than the current situation in the industry when he wrote in 1843 that,

. . . the trade between the two countries, most beneficial to both, must be what is commonly called colonial trade, the new-settled country importing the manufactures of the old in exchange for its own raw produce. In all economic relations the United States still stands to England in the relation of colony to mother country.⁹¹

By mid-century the American iron industry had freed itself from the dependent colonial position of producer only of pig and bar iron and crude castings. Its engineering, technology, and range of products were as sophisticated and complex as those of Great Britain.

⁸⁹ *Select Committee on Exportation of Machinery, Parliamentary Papers*, 1841, vol. VII, First Report, Q. 1544, testimony of Matthew Curtis. He specifically mentioned nail-making machines, among others.

⁹⁰ J. S. Jeans, *Pioneers of the Cleveland Iron Trade* (Middlesbrough-on-Tees, 1875), 294. This committee was formed and visited the United States. They were especially impressed with the puddling furnace technique which its members observed in Cincinnati.

⁹¹ Editorial comment, London *Spectator*, February 25, 1843.