

Coal-burning Locomotives: A Technological Development of the 1850's

HISTORIANS frequently write about technological developments by dealing with specific inventors and inventions. While the historian must recognize the stroke of genius in the individual inventor, he must also recognize that significant discoveries often have not been the result of a specific inventor but more of what Siegfried Giedion, the Swiss historian of mechanization, called anonymous history.¹ The conversion from wood to coal as a locomotive fuel in the United States fits this concept. No one inventor solved the problems concerning the burning of coal as a locomotive fuel, yet during the decade of the 1850's these difficulties were mastered and a significant technological advancement was achieved.

By 1840 there was little doubt that the United States was becoming conscious of the importance of railroads as a means of transportation and communication. Malin points out that by 1840 the railroad system of the United States had assumed the greatest magnitude in the world with 2,270 miles in operation and 2,346 miles under construction.²

Wood was the principal fuel used by locomotives during the 1830's and 1840's, and, although the supply was still plentiful, concern was expressed for future needs. In 1837 the *American Railroad Journal* reprinted an article from the *Geneva* (New York) *Gazette* on the importance of fuel, stating that:

In this climate a supply of fuel is of the first necessity; without it, the country could not have been inhabited. Hitherto, the forests have afforded this supply, and will continue to do so, for years to come. But the time will arrive, when we must look to other sources for this indispensable article.³

¹ Siegfried Giedion, *Mechanization Takes Command* (New York, 1948), 2-4.

² James C. Malin, *The Contriving Brain and the Skillful Hand in the United States* (Lawrence, 1955), 122.

³ *Geneva Gazette*, as cited in *American Railroad Journal*, VI (Dec. 23, 1837), 684-685.

Coal was the "other source" that the *Journal* proposed to replace wood, and, in 1845, M. Carey Lea predicted in the *Merchants' Magazine* that "coal is evidently destined at some future period to entirely supersede wood as fuel."⁴ After making a study of England's fuel supply, John Griscom, a chemist at Rutgers College, strongly recommended coal as a fuel in American mills and factories.⁵

Congress also was aware of the problems of providing fuel for the nation's new steam navy and commissioned Professor Walter R. Johnson of Philadelphia to analyze coal as a substitute for wood. In 1844 Johnson reported favorably on the use of coal as a fuel but was cognizant of the difficulties which would accompany its use in steam boilers. In the preface to his "Report to the Navy Department of the United States on American Coal," he remarked that:

The heat generated from burning coal warns us what to expect in regard to the durability of grate bars, and the adhesion of scoriae to those important appendages of the furnace. All subjects must necessarily engage the attention of engineers and furnace managers, and no little portion of the good or bad character in coal may be considered to depend on these circumstances.⁶

Most of the coal burned during the early years was anthracite. It was found mainly in the northeastern part of Pennsylvania and was readily accessible to the large centers of population by means of navigable rivers, canals, and railroads. Bituminous coal was distributed over a larger geographical area but did not come into general use until after the Civil War. Anthracite coal, a comparatively clean burning fuel, was preferred to bituminous because it was also easier to handle. The heat yield per pound was found to be about the same for either fuel.⁷

Comparing the heating value of coal with wood, the equation frequently employed was that one ton of bituminous or anthracite coal equaled at least one and three-fourths cords of wood commonly

⁴ M. Carey Lea, "Coal of Pennsylvania and other States," *Merchants' Magazine*, XIII (July, 1845), 67-72.

⁵ John W. Oliver, *History of American Technology* (New York, 1956), 149.

⁶ Walter R. Johnson, "A Report to the Navy Department of the United States on American Coal," *Senate Docs.*, 28th Cong., 1 Sess. No. 386 (Serial 436), vi, vii.

⁷ Jules I. Bogen, *The Anthracite Railroads* (New York, 1927), 3; Alfred W. Bruce, *The Steam Locomotive in America* (New York, 1952), 36; Courtney Robert Hall, *History of American Industrial Science* (New York, 1954), 48.

used for fuel purposes.⁸ This is a convenient figure by which to judge the relative costs of wood and coal for locomotive fuel purposes. Of course, costs of both wood and coal for fuel purposes varied according to nearness to source, but during the 1830's and 1840's George W. Whistler, Jr., reported in the *Journal of the Franklin Institute* that for railroads in the Northeast a figure of \$8.00 a ton was general for coal. A common price for firewood in the Northeast during the 1830's was listed by the *American Railroad Journal* at \$2.50 to \$3.00 per cord.⁹ As more and more coal was brought to market,¹⁰ however, the situation changed. In 1849 the *Journal* reported that anthracite coal could be purchased in Philadelphia for \$3.25 to \$3.50 per ton.¹¹ At such prices coal was competitive with wood and railroad managers looked forward to greatly reduced operating expenses since fuel wood constituted fifty-five per cent of the operating costs of a wood-burning locomotive.¹²

In addition to lower fuel costs there were other advantages to be gained from burning coal. For one thing, frequent stoppages were necessary on wood-burners to "wood-up," and it was particularly costly to stop heavy through-trains for long periods of time. As a train could not carry both freight and sufficient wood for long hauls, wood sheds had to be maintained at regular intervals and serviced by special wood trains. This meant, in most cases, that the wood was carried twice over most of the line: first by the wood train and then by the locomotive tender of the train that consumed it. This extra hauling also contributed to increased wear on both the rolling stock and the railway. In addition, coal burns at a more even temperature than wood, hence, a more regular supply of steam could be maintained. Finally, there were problems of theft from unguarded wood sheds. One railroad superintendent estimated that

⁸ Alexander L. Holley, *American and European Railway Practice in the Economical Generation of Steam* (New York, 1861), 71.

⁹ George W. Whistler, Jr., "Report upon the Use of Anthracite Coal in Locomotive Engines, made to the President of the Reading Railroad Company, April 20, 1849," *Journal of the Franklin Institute*, XLVIII (August, 1849), 82; *American Railroad Journal*, II (Jan. 12, 1833), 23.

¹⁰ The yearly coal production in the United States increased from 174,764 tons in 1830 to 805,414 tons in 1840. By 1850 the output was up to 3,332,614. Figures taken from *Debows Commercial Review*, XXV (August, 1858), 239.

¹¹ *American Railroad Journal*, XXIV (Jan. 11, 1851), 32.

¹² Zerah Colburn, *The Locomotive Engine* (Boston, 1851), 66.

one-fourth of the population within a half-mile of a wood shed was supplied with railroad wood.¹³

Lower coal prices during the 1840's encouraged experimentation with the use of this fuel in locomotives. In June, 1847, at the monthly meeting of the Franklin Institute, Professor Johnson reviewed the attempts of various railroads to burn anthracite coal. He observed that whereas anthracite coal was being successfully burned in the fireboxes of stationary steam engines and steam vessels, many difficulties had been encountered in its use in locomotives. Some short-haul lines, such as the Beaver Meadow and Hazleton railroads, were successfully burning anthracite on round trips of thirty to forty miles. Other lines, such as the Reading Railroad, however, were having a great deal of difficulty in burning the fuel on trips of approximately two hundred miles. Johnson noted that the Reading Railroad spent \$202,061 for wood during 1846, and that savings as high as \$125,000 per annum could have been realized by the use of anthracite coal. The difficulties in burning anthracite for locomotive purposes were summed up by Johnson when he listed the following impediments to its use:

1. The want of rapid ignition, and free, lively combustion.
2. The intense, concentrated, local heat, which is said to destroy the grate bars, to attack the rivets and laps of the fire-box and even to cause blisters to rise in the plates of which it is composed; and, finally, to fuse the ashes into a troublesome clinker.
3. The sharp, angular particles of coal projected by the violent, fitful blast of the escape-steam, obliquely into the ends of copper tubes, cuts them away within a few inches of the fire end. . . .
4. The difficulties of fitting in iron tubes, so as to make perfect joints. . . .¹⁴

In addition to the impediments listed by Johnson, certain other phenomena associated with burning coal should be mentioned. First of all, when a lump of coal was placed directly upon an open fire, it tended to disengage small particles, some possessing sufficient velocity to injure the sides of the firebox.¹⁵ This was particularly destructive to the copper sheets that were introduced after the poor

¹³ Charles B. George, *Forty Years on the Railroad* (Chicago, 1887), 31; Holley, 72.

¹⁴ Walter R. Johnson, "Use of Anthracite Coal in Locomotives," *Journal of the Franklin Institute*, XLIV (August, 1847), 110-114.

¹⁵ William M. Barr, *A Practical Treatise on the Combustion of Coal* (Indianapolis, 1879), 105.

quality iron sheets of the day proved unsatisfactory. These copper sheets became very ductile at high temperatures and were soon cut away by the mechanical action of the sharp particles of coal impinging upon them.¹⁶ Also, the boiler sections, away from the fire, were attacked by sulphurous acid formed when combustion gases combined with moisture.¹⁷

Bituminous coal presented additional problems. When bituminous coal was first tossed onto a burning fire the bituminous portion had to be volatilized before the lump would burn. The process of volatilization is very cooling as anyone who has ever poured alcohol or ether on his hand can testify. Considerable heat was necessary to volatilize the bituminous constituents and a corresponding temperature drop was effected in the firebox. The gases, as emitted from the lump of coal, would not burn unless additional oxygen was supplied. The result was that they usually escaped, unburned, through the smokestack along with the combustion gases.¹⁸

In April, 1849, railroad engineer George W. Whistler, Jr., reported on the use of anthracite coal to the president of the Reading Railroad. He first listed comparative costs of various wood and coal-burning locomotives.¹⁹

<i>Name or Class of Engine</i>	<i>Cost of Fuel</i> (per 100 tons transported)
Baltimore Engine	\$ 5.50 (coal-burner)
Novelty	7.95 (coal-burner)
Baldwin Large	13.09 (wood-burner)
Champlain	10.93 (wood-burner)
Reading Engine	14.40 (wood-burner)

In terms of fuel costs per unit weight of freight hauled, coal was far preferable to wood. But, as Whistler pointed out, coal-burners

¹⁶ Whistler, 79

¹⁷ Barr, 162-168.

¹⁸ Charles W. Williams, *The Combustion of Coal and the Prevention of Smoke* (London, 1854), 7-8.

¹⁹ Whistler, 9-11, 79-85. This Whistler was the father of the celebrated American artist. In addition to his work with American railroads he was also actively involved in the construction of the Russian railway system in the 1840's. Indeed, the present five-foot gauge used by all Russian railways at the present time was based upon Whistler's recommendations in the building of the St. Petersburg-Moscow line. See J N Westwood, *A History of Russian Railways* (London, 1964), 30-31.

became more expensive to run because of the costs of repairing their burned-out fireboxes. The expense of renewing the firebox on the Baltimore engine of the Reading Railroad was listed at \$486. The old copper taken out could be sold for \$108, making the replacement price \$378. The firebox needed replacement after fourteen months' service, making the yearly expense \$324. Whistler deducted \$75 as the depreciation of a wood-burning firebox during the same period, leaving \$249 per annum as the extra cost of maintaining the firebox of the anthracite-burning locomotive. The total cost per year over wood-burning engines for each Baltimore coal engine on the Reading Railroad was listed at \$456. This included grate replacement, boiler tube repairs, and various small repairs. The repairs took seven months, during which time the engine was inoperative. The extra yearly cost over wood-burners of an engine burning bituminous coal on the Baltimore and Ohio Railroad was given at \$250.²⁰

Whistler made some recommendations as to how repairs could be reduced, but even after considering these improvements the total yearly cost of an anthracite-burning engine over that of a wood-burning engine was estimated at \$379.50²¹ Clearly this was a cost the railroads did not want to incur, yet the increasing scarcity of wood presented problems they could not overlook.

Experiments continued throughout the late 1840's and early 1850's. In 1848 the Mine Hill and Schuylkill Haven Railroad announced that their experiments with coal-burners had been sufficiently encouraging to warrant the purchase of three new coal-burners for trial.²² A. L. Roumfort reported in 1850 on the experiments conducted with the locomotive "Henry A. Muhlenberg" of the Columbia and Philadelphia Railroad. The "Muhlenberg" was fitted with a detachable firebox which did not solve the problems of burning coal without its destructive effects, but merely reduced the repair time for firebox replacement. The replacement cost was from \$500 to \$1,000, but it could be accomplished in twenty-four hours.²³

²⁰ *Ibid.*, 79-85.

²¹ *Ibid.*, 179.

²² "Report of the Board of Managers to the Stockholders of the Mine Hill and Schuylkill Haven Railroad Company, at their Annual Meeting, January 10th, 1848," *Journal of the Franklin Institute*, XLV (March, 1848), 153.

²³ A. L. Roumfort, "Report of A. L. Roumfort, Superintendent Columbia and Philadelphia R.R., on the Experiments made with the Coal Burner, 'Henry A. Muhlenberg,'" *Journal of the Franklin Institute*, XLIX (February, 1851), 138-139.

In 1852, Richard E. Dibble, a mechanical engineer from New York, wrote to the editor of the *American Railroad Journal*, stating that:

The economy of coal over wood as a fuel for steam purposes is demonstrated beyond a question, as applied to steamboats and stationary engines, and there is no good reason why there may not be the same economy when applied to our railroads. . . . In any locality where coal can be delivered at \$5, or less, per ton, it is a cheaper fuel than wood over \$2 per cord.²⁴

From the standpoint of fuel costs Dibble was correct, but the problems of burning coal effectively still remained. Indeed, by 1853, so little had been achieved in the use of coal as a locomotive fuel that the 1849 report of Whistler was still regarded by the *American Railroad Journal* as the standard work on the subject.²⁵

As the problems of burning raw coal seemed almost insurmountable, railroad men turned to coke. Coke was used almost universally in England, and many of the railroads, such as the Manchester and Liverpool, were required by Act of Parliament to use coke exclusively for reasons of smoke abatement.²⁶ Professor Johnson's report of 1844 stated that coke evaporated more water per pound than free-burning coal, and he recommended the use of coke in locomotive boilers "in preference to any fuel where the price does not interfere to prevent it."²⁷ The Baltimore and Ohio and other railroads experimented with coke during the early 1850's and found it especially useful for passenger trains as it made few sparks and cinders, and was practically smokeless. By July, 1853, the *American Railroad Journal* had become enthusiastic about the use of coke, proclaiming:

It is evident that a great revolution is about to take place in the fuel employed in the propulsion of locomotives. Coke made from coal of the Cumberland region will, in a short time, be substituted for wood on all railroads in the Atlantic States that can obtain the requisite supplies.²⁸

Coke, however, did not receive sufficient support in the United States. Although the fuel possessed advantageous burning properties,

²⁴ *American Railroad Journal*, XXV (Feb. 14, 1852), 106.

²⁵ *Ibid.*, XXVI (July 2, 1853), 435.

²⁶ John Holland, *Fossil Fuel, the Collieries and Coal Trade* (London, 1841), 424.

²⁷ Johnson, 307.

²⁸ *American Railroad Journal*, XXVI (June 4, 1853), 360; (July 23, 1853), 475.

it was expensive. Coke had increased locomotive fuel costs in England forty per cent.²⁹ Moreover, the United States did not have good coking coal accessible to the majority of its railroads.³⁰

The impracticability of burning coke as a locomotive fuel in the United States turned attention to the problems connected with the burning of raw coal. Many reports of coal-burning locomotives were made during the period 1853–1857, and, although they gave promise that progress had been made, the major difficulties still remained. For example, in November, 1854, the *Philadelphia Public Ledger* reported that a coal-burning locomotive, built on the design of Leonard Phleger of Tamaqua, was operating on the Wilmington and Delaware Railroad between Philadelphia and Havre de Grace.³¹ In July, 1855, the *American Railroad Journal* reported that the locomotive "Taunton," using a boiler constructed upon the patent plan of F. P. Dimphel, was successfully burning anthracite coal.³² Both the Phleger and Dimphel designs are good examples of the various ways that railroad men were attempting to solve the problems of burning coal. The Phleger design used water-cooled grates to prevent them from burning, and the Dimphel plan called for water tubes around the firebox to lessen the injurious effects of intense heat. While they both helped to reduce firebox deterioration, they were too complex to gain wide acceptance. The Dimphel plan, in particular, was inadequate in that the maze of water tubes in the firebox region made repairs extremely difficult and costly.

What was needed was a solution that would be both simple and effective; a solution that would not result in any greatly increased price for new coal-burning locomotives and would allow the current wood-burners to be converted to coal with a minimum of expense. During the late fifties the solution was found—a solution which was partly the result of a continuation of the previous trial-and-error experimentation which had dominated the past and partly the result of increased knowledge about the nature of coal combustion.

One major break-through that established coal-burning locomotives on a firm basis was the introduction of the Delano Grate in

²⁹ Holland, 424.

³⁰ *American Railroad Journal*, XXX (Dec. 5, 1857), 777.

³¹ *Public Ledger*, as cited in *Merchants' Magazine*, XXXIII (November, 1854), 635.

³² *American Railroad Journal*, XXVIII (July 7, 1855), 424.

1856. Howard Delano, a locomotive mechanic of Syracuse, New York, designed grates which enabled bituminous coal to be forced from the bottom up through the bed of fire. The *American Railroad Journal* described these grates as follows:

In an old engine, a section is cut out of the bottom of the grate corresponding to the size of the feeding box—say 13 or 14 inches square. Fitted to the space, cut out, is a movable grate to which is attached the feeding box. On drawing back the grate, the box filled with coal occupies its place. By very simple contrivance, the bottom of the box is thrown up to a level with the grate, discharging its contents directly into the furnace. The box is then drawn forward to receive another charge, the bottom of it remaining up until the movable grate gets into place. The bottom is then dropped down, and the box made ready to receive another charge.³³

By this process the grates were shielded from the burning coal, and, more important, the bituminous constituents of the lumps were volatilized slowly, which enabled them to mix with air and burn. The lumps themselves, when finally forced to the top of the fire, had discharged all of their bituminous components and were free to burn. In addition, this gradual heating helped to prevent small coal particles from being projected against the sides of the firebox.

One of the earliest mentions of the Delano Grate in operation is to be found in the September 13, 1856, edition of the Pottsville, Pennsylvania, *Miners' Journal*. The *Journal* reported that the Boston and Worchester Railroad was operating a coal-burning engine with the Delano Grate "which seems so well to meet the wants of the road that all the engines of the Company, used in drawing freight, are to be altered to the new style."³⁴ With reference to the cost of installation, economy, and performance, the *Journal* stated that:

Careful estimations of the precise cost of running this engine have been made, and it appears that with it, for 12 cents per mile, a common freight train can be run and make the usual speed. A wood engine to run the same train costs 30 cents. . . . The cost of altering a common wood engine to fit it for burning coal is but \$150.³⁵

³³ *Ibid.*, XXX (Dec. 5, 1857), 778.

³⁴ Pottsville, *Miners' Journal and Pottsville General Advertiser* (hereinafter cited as *Miners' Journal*), Sept. 13, 1856.

³⁵ *Ibid.*

The Delano Grate was well received, and by June, 1858, the *American Railroad Journal* was able to report that they were in "successful use on several roads."³⁶

The real significance of the Delano Grate was not its mechanical construction, but rather that it solved the problem of burning coal by applying correct methods of combustion. The Delano Grate enabled the most unskilled of firemen to burn coal efficiently and without injurious effects to the firebox. This grate did not continue in use because it was found that educating firemen in the correct methods of burning coal achieved the same end. As the mechanical engineer Zerah Colburn later remarked: "the aim of the stoker must be to have a proportionate mixture of coal in all stages of combustion spread over the grate. . . ."³⁷ Indeed, British firemen had found a way to burn bituminous coal by merely placing the fresh coal under the fire door upon the hind part of the grate and moving it forward as the heat of the fire volatilized its bituminous elements.³⁸

The Delano Grate was based upon sound principles of coal combustion—principles which were successfully applied by all railroad firemen. Indeed, by 1858, it was recognized that simply to burn coal successfully in a wood burner, proper stoking and an arch of firebrick, costing about ten dollars, were all that were necessary.³⁹ Greater expense than this was necessary, however, to convert a wood burner to burn coal with maximum efficiency.

Now that the problem had been resolved into a technique of burning the coal, other successful engines began appearing. One approved locomotive, built according to Boardman's patent, was reported by the *Merchant's Magazine* and the *Miners' Journal* as being well received and running at costs ranging from 10.64 to 12 cents per mile, as compared with 15.14 to 18.2 cents per mile for the best available wood-burners.⁴⁰ By the summer of 1857 the *American Railroad Journal* was able to report that:

³⁶ *American Railroad Journal*, XXXI (June 19, 1858), 393.

³⁷ Zerah Colburn, *Locomotive Engineering and the Mechanism of Railways* (London, 1871), 217.

³⁸ *Ibid.*, 296.

³⁹ Zerah Colburn and Alexander L. Holley, *The Permanent Way and Coal-Burning Locomotive Boilers of European Railways* (New York, 1858), 161.

⁴⁰ *Miners' Journal*, Aug. 15, 1857; *Merchants' Magazine*, XXXVII (September, 1857), 379.

The final success claimed for the experiment with coal-burning locomotives at different points perhaps renders it unnecessary further to illustrate the subject. . . . It can now be demonstrated that coal can be used at one-half the cost of wood, and that better time can be made, because of the facility afforded of keeping up a uniformity in generating steam.⁴¹

The reports from the *Merchants' Magazine*, the *American Railroad Journal* and the *Miner's Journal* after 1858 no longer mention problems connected with burning coal, but rather the large number of railroad companies adopting coal and the savings afforded. The Illinois Central Railroad introduced coal-burning locomotives in 1858. The Hudson River Railroad had eight coal-burning locomotives in use during 1858 and reported costs of little more than one-fourth as compared with wood-burners.⁴² Superintendent Watson of the Great Western Railroad was very satisfied with coal-burners, stating that "all that we hoped for them is being realized." He believed that the general adoption of coal as a locomotive fuel would result in yearly savings of "more than \$10,000,000, or one per cent of the entire cost of all the railroads in the United States."⁴³ Early in 1859 the *Miners' Journal* looked to the past year and cast an eye to the future when it reported that:

Sufficient experiments have been made in the last year, to demonstrate the great superiority of Coal as a fuel in Locomotives, producing a saving of fully *one-third* . . . the expenses of wood. Its use for this purpose will cause a large demand for Coal, because all the New Locomotives will be built for its use as fuel, and the old ones altered as rapidly as circumstances will permit, wherever Coal can be procured.⁴⁴

By 1860, the conversion from wood to coal was an accomplished fact. Alexander L. Holley, who was better known for his role in introducing the Bessemer process into the United States but who was also interested in coal-burning locomotives, reported that "since so large a proportion of American railways are committed to the use of coal, the more important question is, not the economy of using coal in place of wood, but *how to burn coal economically*. . . ."⁴⁵

⁴¹ *American Railroad Journal*, XXX (Aug. 29, 1857), 557.

⁴² *Merchants' Magazine*, XXXIX (August, 1858), 250; *American Railroad Journal*, XXXI (June 5, 1858), 364.

⁴³ *Ibid.*, XXXI (June 19, 1858), 393.

⁴⁴ *Miners' Journal*, Jan. 15, 1859.

⁴⁵ Holley, 73.

From 1860 on through the nineteenth century coal became the principal fuel for locomotives, although the use of wood was still common in areas where it was abundant: chiefly the South and parts of New England, or in the West where coal was scarce. In a period of about two decades the problems of burning coal had been met and solved. During that time the railroads had tried solutions in the form of fireboxes made of metals other than iron, other forms of coal (coke), various mechanical contrivances; and finally succeeded by applying correct theories of combustion. As Colburn and Holley stated:

No other reform, so great as that of the fuel bills of our railways, rests upon so few, so simple and so entirely available conditions as those of burning coal correctly. . . . While we have observed the simple laws which science has indicated for our guide, PRACTICE, so omnipotent with practical minds—a practice more intelligent and successful than our own—has proven their absolute correctness.⁴⁶

A great deal of work still remained to be done before the American railroads became the later efficient transporters that revolutionized American transportation. Various technological advances, steel rails and bridges, standardization of track gauges, automatic couplers, air brakes, and other improvements followed. In the meantime, the conversion to coal had its immediate effects. More uniform steam meant that more rigid schedules could be maintained. The use of the cheaper fuel resulted in more economical operating expenses. Most important, however, was the fact that heavy freight trains could now carry sufficient fuel for long hauls without frequent stops.

*The Florida State University,
Tallahassee*

EDWARD F. KEUCHEL

⁴⁶ Colburn and Holley, 161.