Secondary Level

RAILROAD MUSEUM OF PENNSYLVANIA

Real Trains. Real History. Real Excitement.

Prime Movers

Curriculum Guide

Grades 9-12/Ages 15-18

Tours:

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Our mission *is to collect, interpret and preserve significant objects related to Pennsylvania's railroading history and to educate the public about that history through exhibits, special events, research and other programs.*

Our education programs *satisfy specific Pennsylvania Academic Standards in many subject areas, including Pennsylvania and United States History (8.2 C-D & 8.3 C-D); Geography (7.3 A-D & 7.4 A-B); Economics (6.4 D & G); Civics & Government (5.3 C-D); Health (10.3 A); Science & Technology (3.4 B-C & 3.6 C); Language Arts (1.1 – 1.6); and Arts & Humanities (9.2).*

The Railroad Museum of Pennsylvania is administered by the Pennsylvania Historical & Museum Commission with the active support of the Friends of the Railroad Museum of Pennsylvania.

Prime Movers:

The Evolution of Locomotion

Secondary Level Program

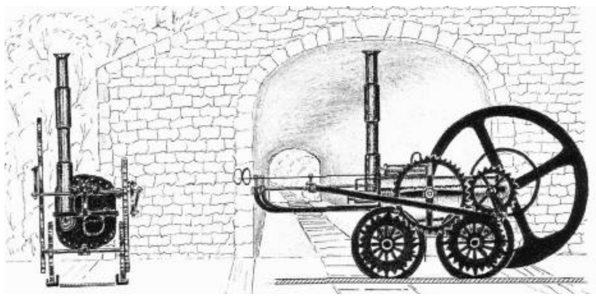
Grades 9-12/Ages 15-18

Museum Tour

Students receive an up-close tour through the development of the engines that pull the trains, from the humble beginnings of steam locomotion in the early 19th century through the magnetically levitated trains of tomorrow. The Museum's historic steam, electric and diesel locomotives star in this informative program.

Background Information

Steam engines have been called the driving force behind the Industrial Revolution, powering machinery in factories and mills, pumping stations, and pulling the products of these mills and factories to markets faster than a team of horses and wagons. By applying the principles of pressurized steam to ships, locomotives and other vehicles, goods and services could be delivered to cities and towns faster and in greater quantities than ever before, driving a new market economy. But it took many decades of trial and error to develop vehicles that could harness high-pressure steam in a safe and practical way to jumpstart the Industrial Revolution.



The world's earliest railways used horses to pull carts on rails. Following James Watt's improvements to steam engines in the mid-1700s, attempts were made to apply them to roads and rails, particularly in Great Britain. The earliest steam locomotive was built and tested in Wales in 1804 by Richard Trevithick. Builders continued to refine these initial efforts. The earliest master steam locomotive builders were George and Robert Stephenson, who built *Locomotion* No. 1 for the Stockton & Darlington, the world's first modern railroad, in 1825. Their locomotive, *Rocket*, winner of the Rainhill Trials in 1829 on the Liverpool and Manchester Railway, became one of the most popular designs exported to the United States in the 1830s.

In fact, many of the first locomotives in the United States were imported from England. The British-built *Stourbridge Lion*'s rumble down the crude wooden tracks of the Delaware and Hudson Canal Company in 1828 was the first locomotive trip in the Western Hemisphere. In 1831, Camden & Amboy Railroad of New Jersey imported the *John Bull* from England. (Today, the original *John Bull*, seen in the photo below, is at the Smithsonian Institution in Washington, DC. A 1939 replica can be seen at the Railroad Museum of Pennsylvania.)

In 1826, Colonel John Stevens demonstrated the feasibility of steam locomotion on a circular track at his estate in Hoboken, New Jersey. He is sometimes called "the father of American railroads," because of his experimental locomotive and his attempts to charter a railroad in the United States as early as 1812. (A replica of his "steam waggon" can be seen at the Railroad Museum of Pennsylvania.) Although his locomotive ultimately proved a failure, Col. Stevens' efforts inspired other American manufacturers to build their own, beginning with the Baltimore and Ohio Railroad's *Tom Thumb* in 1829. The *Tom Thumb* was built by Peter Cooper to convince B&O directors that a steam locomotive could pull their trains. Although it was the first American locomotive to pull a railway coach with passengers, it never operated in regular service due to its small size. In 1830, *The Best Friend of Charleston* was the first American-built locomotive to haul paying passengers on the first successful revenue-earning steam railway in the US, the South Carolina Railroad.

By the early 1840s, British influence on American locomotive design began to wane. In 1841, only about 25 percent of locomotives on American railroads were imported, and this number continued to decrease. Because America's size and more varied topography, mechanics and builders began to customize British technology for use on American rails. For example, the Camden & Amboy Railroad heavily modified its imported *John Bull* locomotive, adding a "pilot," or a set of lead wheels, that helped it go around tight curves and provide better balance. These extra wheels were mounted to a "cowcatcher," or plow-shaped device intended to push animals and debris out of the path of the train. This was the first use of either device on an American locomotive. Eventually, the *John Bull* was fitted with an oil-fired headlight, bell, whistle and a separate compartment behind the cab called a "tender" for storing fuel and water.

Railroads ordered locomotives tailored to their needs, though basic similarities remained. They also developed specific tastes in locomotive design. For example, the Pennsylvania Railroad had a preference for the "Belpaire" firebox, while the Delaware and Hudson Railroad was famous for its elaborately flanged smokestacks. Second, steam locomotives required regular service and overhaul (often at government-regulated intervals). New appliances were added, unsatisfactory features removed, and cylinders improved or replaced. Any part of the locomotive, including its boiler, could be replaced or upgraded at any point in its service life.

Specialized manufacturers sprang up to constructed locomotives for all railroads all over the United States. The Baldwin Locomotive Works in Philadelphia, the American Locomotive Works (ALCO) in New York, and the Lima Locomotive Works were among the more significant early companies. In addition, most railroads had their own shops capable of heavy repairs to their equipment. Some railroads, like the Pennsylvania and the Reading, even constructed locomotives from scratch in their own shops or in conjunction with major manufacturers. Furthermore, it was not uncommon for locomotives to be sold from one railroad to another.

King Coal

From the early 1800s until the 1860s, Pennsylvania's steam locomotives burned wood for fuel. In 1831, Phineas Davis, a well-known clockmaker and inventor living in York, Pennsylvania, had built America's first successful coal-fired locomotive, *The York*, acquired by the Baltimore & Ohio Railroad. By 1855, the Pennsylvania Railroad was burning 60,000 cords of wood per year, depleting supplies of timber along the line. After experimenting with stronger fireboxes, the PRR began to burn coal in all its steam locomotives by 1865, making it one of the first to stop relying on wood for fuel. Soon, other railroads found that burning coal was not only cheaper but allowed their locomotives to pull heavier and longer trains.

As designs began to diverge in the late 1800s, freight locomotives at first emphasized pulling power or "tractive effort," while passenger locomotives favored speed. In the 1920s the focus in the United States turned to horsepower, epitomized by the "superpower" concept promoted by the Lima Locomotive Works, although tractive effort was still the prime consideration after World War I to the end of the steam era. Freight trains were to run faster, while passenger locomotives needed to pull heavier loads at speed.

Last Years of Steam

The introduction of electric locomotives at the turn of the 20th century, and the diesel-electric in the mid-1920s, spelled the beginning of the end of the steam era. As diesel power, particularly with electric transmission, became more reliable in the 1930s, it inevitably became the main form of motive power from the mid-20th century to the present. Pure electrics continue to be used, but the high cost of the infrastructure—including overhead wires and electrified third rails—limit them to cities and other more populated areas. For the most part, by the late 1950s, railroads had ceased using steam locomotives, opting instead for diesel, electric or both.

Steam locomotives dominated the railroad scene for more than a century, and they continued to be used in other countries throughout the world long after they were abandoned in the United States. And they could be built to be just as powerful and reliable as anything else on the rails, so why give them up? Steam locomotives simply could not compete with the cost savings inherent in diesel and electric locomotives. Those engines did not have delicate boilers that had to be maintained and rebuilt regularly to keep them safe. Diesel locomotives have an availability of 90 percent or better, compared to 30-40 percent for the average steamer. And the average diesel could replace about ten steam locomotives.

For example, in 1945 the PRR was busy preparing for the arrival of 50 T1 streamlined steam locomotives styled by industrial designer Raymond Loewy. They hoped the T1s would make diesels obsolete. At the same time, they also took delivery of two new class E7 diesel-electric locomotives from the Electro-Motive Division of General Motors (one of which is preserved at the Railroad Museum of Pennsylvania). After six months, the E7s had completed 69,000 miles on the Harrisburg-to-Detroit line without any time in the repair shops due to road failure. During that same period, the best performing T1 steam locomotive of the fleet had made only 2,800 miles before having a breakdown. Simply put, a T1 steam passenger locomotive's repairs cost the company an average of 54 cents per mile, while a typical passenger diesel cost only 32 cents. A PRR Q2 steam freight locomotive's repairs cost 69 cents per mile, compared to just 40 cents per mile for a comparable 6,000-horsepower diesel.

Diesel and electric locomotives did not require an extra crewman tending to their fires. A whole string of these locomotives could be controlled remotely from the front unit, whereas steam locomotives required a crew of two in each one. While steam locomotives required many hours to heat the waters in their boilers before going out on the rails, diesels and electrics could start up in a matter of a few minutes. Fewer fuel and water stops were necessary, as diesels require little water, allowing the retirement of $50,000,000 worth of equipment to supply water to steam locomotives. Ultimately, with cheaper operating and repair costs, these new locomotives saved money for the railroads, since their main concern was making money.

Locomotion Today

Today, America's railroads use diesel-electric and pure electric locomotives. Electrics are mainly used in cities or between urban centers that are very close together, as in the Boston-to-Washington "Northeast Corridor." In Pennsylvania, the Philadelphia-to-Harrisburg "Keystone Corridor" uses electrics for commuter traffic, and diesels between Philadelphia and Pittsburgh. But their numbers are relatively small compared to the fleets of diesel-electric locomotives. Since diesels create their own onboard electricity for traction, and are not limited to areas where sources of electricity are present, they can go practically anywhere and do anything.

Today's diesel-electrics are impressive machines. From their early days in the mid-20th century, where a single unit could boast between 1,500 and 1,700 horsepower, diesels can now easily achieve up to 6000. Modern diesels use high-tech features like ground radar to determine speed and then feed this information to computers that prevent wheel slippage under heavy loads. Other diesels are equipped to run additional "mid-train" helper locomotives by means of radio control, allowing one crew to run as many as three separate units at the same time. Today, General Electric in Erie, PA is the number one builder in North America, followed closely by General Motors Electro-Motive Division diesel facility in Canada. Both builders have seen a boom in recent years, as railroads have expanded their markets for bulk commodities, truck trailers, and shipping containers.

Activity – Timelines

Have your students make a transportation timeline. First, plot the major milestones in the development of railroad technology. Second, add dates for the introduction of competing forms of transportation, including automobiles, airplanes, etc.

Activity – Flowcharts

Construct a simple flowchart on the chalkboard or bulletin board showing how each of the following locomotive types derives their power: Steam, Electric and Diesel-Electric. Discuss the differences between each one. Explain the advantages and disadvantages of each one. Keep your flowchart simple. Each form of "motive power" should contain no more than five or six main steps:

Steam = Fire (Wood, Coal or Oil) ➔ Water in Boiler ➔ Steam (Steam Dome) ➔ Pistons ➔ Rods ➔ Wheels (Exhaust, Steam and Smoke)

Electric = Power Plant ➔ Overhead Wires or Third Rail ➔ Transformer (Inside Engine) ➔ Traction Motors ➔ Wheels (No Exhaust, Excess Heat Energy from Braking Returned to System)

Diesel-Electric = Diesel Fuel ➔ Motor ➔ Generator ➔ Traction Motors ➔ Wheels (Exhaust, Smoke and Excess Heat Energy from Dynamic Braking)

Activity – Pulling the Load

Ours is an energy-dependent society. Our energy needs have shifted considerably at each stage of our country's economic development. Consider the energy needs of the colonists, the Industrial Revolution of the 1800s, the eras of World Wars I and II, the rise of the Interstate system and the needs of today. To what degree did developments in transportation affect changes?

The uses of energy for transportation, heat and light are usually quite apparent to students. Ask students to look into the energy needed to produce and distribute everyday products – food, clothing (consider natural and synthetic fibers), paper, automobiles, household chemicals, etc. Consider the importance of fuel-efficient transportation in various stages of production and distribution.

The search for greater fuel-efficiency is nothing new in American railroad history. Power means fuel, and the rising costs of oil worldwide had placed a priority upon finding ways to conserve and to save money. While the diesel-electric locomotive is the nation's current dominant form of motive power, with electric locomotives limited to urban areas, most railroads are still tied to fossil fuels for their trains. Stretch the discussion of fuel sources into a study of forms of power used throughout the history of railroads in America. Have students investigate the current research into alternative power sources. Ask them to weigh the pros and cons of each new source. How has the recent attention on global warming and ecosystem preservation affected research in these areas? How have the public and private sectors worked with one another, if at all, to achieve their goals?

How much electricity is generated by a diesel?

Think about how you get electricity at home. An electric power plant miles away from your home generates power using a variety of sources including coal, water, or even wind. This electricity is sent by overhead wires to your home for consumption.

Think of a diesel-electric locomotive as its own power plant, generating its own electricity. It gets its power by using a diesel motor, which runs a generator which produces electricity to drive traction motors that turn axles and the wheels of the locomotive.

Diesel Fuel ➔ Motor ➔ Generator ➔ Traction Motors ➔ Wheels

Use these numbers…

E = Voltage (volts) = 1,200 volts

I = Current (amperes) = 975 amps

Question 1:

Electric Power (P) is the rate at which electric energy is converted to another form such as mechanical energy, heat, or light. Use the calculator to find the P of a medium-sized freight locomotive, like the Conrail GP-30 #2233, as seen in the photo below.

Do the math…

P = E x I

P = 1,200 x 975

P= ______1,170,000______ watts

Question 2:

How many 100 watt light bulbs could this power?

_____11,700_______

How powerful is a steam locomotive?

Most steam locomotives were designed with specific uses in mind. Some were built to pull people, some to pull freight. The bigger the drive wheels, generally 6' in diameter or more, the more likely it was built for *speed*, meaning passenger service. The smaller the wheels, generally 4' in diameter or less, the more likely it was built for power, meaning freight service. Both types greatly expanded the ability of people, goods and services to move across our state and country, helping to build our nation and ignite its prosperity.

Question 1:

Tractive Effort (TE) is used to compare the relative pulling power or force of steam locomotives. Use the calculator to find the TE (pulling power) of Pennsylvania Railroad steam locomotive #1223, a 4-4-0 American-type locomotive. (See a photo at the bottom of the page.)

Use this formula…

TE = D^2 x S x P

D = Cylinder Diameter = 20.5 inches

S = Piston Stroke = 26 inches

P = Pressure = .85 x 175 pounds of boiler pressure divided by 68 inches (the diameter of each driving wheel)

Do the math…

TE = D^2 x S x P

TE = (20.5 x 20.5) x 26 x (.85 x 175 divided by __68__)

TE = __23901.7__ force pounds

Question 2:

Given the size of the driving wheels on this steam locomotive, is it a freight or passenger engine? __Passenger__

If another steam locomotive has smaller driving wheels (*power*) but creates much more tractive effort than #1223, is it more likely to be a freight or passenger engine? __Freight__

How quickly can a freight train stop?

You are the engineer of a 100-car freight train weighing 15,000 tons traveling at 50 mph when suddenly you see the signal turn red. Let's find out how long it takes to stop and how far the train will travel in that time…

Use these numbers…

W = Weight of train (in tons) = 15,000 tons

V = Velocity or speed (in miles per hour) = 50 mph

F = Braking force (in tons) = 500 tons (x 2000 lbs) = 1,000,000 lbs

<u>Question 1:</u>

How far (in feet) does it take to stop the train if the braking force is 500 tons?

Do the math…

$D = 70 \times W \times V^2/F$

D = 70 x 15,000 x (50 x 50) divided by 1,000,000

D = ______2.625______ feet

<u>Question 2:</u>

Once the brakes are applied, how long will it take to stop?

Do the math…

$T = 95.6 \times W \times V/F$

T = 95.6 x 15,000 x 50 divided by 1,000,000

T = ______72.38______ seconds

Vocabulary

Amtrak – An acronym for "America, Travel and Track," Amtrak opened for service in 1971 as the nation's government-supported intercity passenger rail service.

Boiler – Part of a steam engine where water is heated and turned into steam for power.

Brakes – Devices that help with controlling the speed and stopping the train.

Catenary – A series of electrical wires suspended over the tracks to provide electricity for trains and trolleys equipped to receive it and convert it for use in locomotion.

Coupler – The device on the ends of a rail car which allows it to be connected to another car; "coupling" means connecting cars to one another to make up a train; "uncoupling" means removing or disconnecting one or more cars from a train.

Diesel – Short for a "diesel-electric," a locomotive that burns diesel fuel to turn a generator which powers traction motors attached to the axles.

Drivers – The wheels of a steam locomotive that are connected to the pistons by a series of steel rods. These wheels are the "muscle" of the steam locomotive, giving it motion.

Dynamic Braking – Dynamic braking is the use of the electric traction motors of a locomotive as generators to slow the train. Diesel-electric locomotives generally use a system whereby the generated electrical power is dissipated as heat in brake grid resistors. Electric locomotives use "regenerative" braking in which power is returned to the supply line. Dynamic braking lowers the wear of friction braking components. Additionally, regenerative braking can lower overall energy consumption.

Electric Locomotive – A locomotive that runs on electricity, which is transferred to the engine either by a third, outside rail or through a series of overhead wires, called "catenary".

Engineer – A railroad worker who runs the locomotive that pulls the train.

Fireman – A railroad worker who feeds the locomotives fire with wood or coal, adds water and greases the parts as needed.

Freight Train – A train that carries goods going to market or factories to be made into other goods**.**

Link-and-Pin Coupler – An early design for connecting rail cars to one another. Each car was equipped with an iron chain link at either end, and a brakeman had to physically drop or remove a long iron pin which connected the links of two or more rail cars. Often, brakemen were seriously injured or even killed when two cars came together too quickly, not giving them time to get out of the way. Their use on railroads was banned with the Railway Safety and Appliance Act of 1893.

Knuckle Coupler – A more modern design for connecting rail cars to one another developed after the Civil War. Appearing like the fingers of a cupped right hand, the knuckle coupler must open (extend) to uncouple cars from the train and close to couple and lock them together. The Railway Safety and Appliance Act of 1893 mandated their use on America's railroad cars. Most can be activated by pulling a lever while standing along side the rail car. Modern knuckle couplers can also be activated electronically.

Pantograph – A collapsible tower on the roof of a trolley or electric locomotive used to pick up electrical current from overhead wires, called "catenary".

Pilot (Cowcatcher) – The triangular-shaped device located on the front of many locomotives that served to protect the front of the train from animal, brush and other debris laying on the tracks directly in its path. Some pilots have extra wheels mounted on them to help the locomotive stay on the tracks and navigate tight curves. Over the years, pilots on locomotives became less pronounced, evolving into shield or bumper-like plates protruding from their frames or hoods. Historically, it is claimed that the John Bull (like the Railroad Museum's 1939 replica) was the first locomotive in America to have such a device installed when it began service in the early 1830s.

Roundhouse – A building where the light repair and maintenance of locomotives is done; a roundhouse typically encircles a turntable, whose spur tracks all radiate outward from its path of rotation.

Steam Locomotive – Burns wood, coal or oil to convert water into high-pressure steam and then into motion.

Streamlining – A popular industrial design trend of the 1930s, 40s and 50s in which trains, planes, cars, trucks and buses were built or modified to provide less air resistance and a more pleasing appearance.

Stoker – Both a nickname for a fireman and a device introduced on many steam locomotives after 1900 that greatly reduced the need for fireman to shovel coal into the firebox of a steam locomotive by hand. The stocker features a horizontal, screw-shaved, rotating rod running beneath the floor of the tender that both crushes and moves coal chunks forward to another vertical screw that elevates and sprays the smaller coal bits into the firebox of the locomotive.

Tender – A type of rail car hauled directly behind for storing and transporting extra fuel and water.

Track Pan – Also called a "water trough," a metal channel laid between the rails and filled with water which can be collected by passing locomotives outfitted with a "water scoop."

Traction Motor – The electric motor that turns the axles of a locomotive.

Turntable – A device which pivots in the center allowing engines to be turned or placed into a particular engine shed or roundhouse stall.

Water Scoop – A device mounted to the underside of a steam locomotive’s tender to allow water to be collected from a track pan while the train is moving. First introduced in 1860, water pans were intended to cut down on water stops to improve the range of steam locomotives and expedite traffic schedules.

Wye – a “Y”-shaped series of tracks and turnouts, used for turning locomotives and rail cars where no turntable is available.

Yard – A collection of tracks in a given area designed for making up trains or storing rail cars and equipment.

Bibliography

Many of these sources are available at the Railroad Museum of Pennsylvania. Contact us to inquire about these and other titles:

Books

Barry, Steve. *Rail Power*. St. Paul, MN: Voyageur, 2006.

Halberstadt, Hans. *Vintage Diesel Locomotives*. St. Paul, MN: MBI Publishing, 1996.

Schafer, Mike. *Modern Diesel Locomotives*. Osceola, WI: MBI Publishing, 1998.

Solomon, Brian. *Electric Locomotives*. St. Paul, MN: MBI Publishing, 2003.

Weitzman, David. *The John Bull: A British Steam Locomotive Comes to America.* NY: Farrar Straus Giroux, 2004.

Weitzman, David. *Superpower: The Making of a Steam Locomotive*. Lincoln, MA: David R. Godine, 1995.

Videos

"The Steam Locomotive." *America's Railroads: The Steam Train Legacy*. Disc 1. Chapter 4. Edi Video, 2001.

When Giants Roamed: The Golden Age of Steam. History Channel. DVD. A&E Home Video, 2005.

Websites

How Diesel Locomotives Work. HowStuffWorks, Inc. <http://travel.howstuffworks.com/diesel-locomotive.htm>

How Steam Engines Work. HowStuffWorks, Inc. <http://www.howstuffworks.com/steam.htm>

How Subways Work. HowStuffWorks, Inc. < http://travel.howstuffworks.com/subway.htm>

Railroad History Timeline. Railroad Museum of Pennsylvania. <http://www.rrmuseumpa.org/education/historytimeline1.htm>

Prime Movers:

The Railroaders

Secondary Level Program

Grades 9-12/Ages 15-18

Museum Tour

Students are given an in-depth look at what it was like to work on the railroad. Labor-management relations, technological innovation, safety practices, and gender and race issues are just some of the themes addressed. Tours for students with vision and hearing impairments are also available.

Background Information

By the mid-19th century, railroads became major employers of tens of thousands of men, and some women. Not only did they work for the carriers themselves but also in supporting industries throughout Pennsylvania. These included firms that built locomotives, rail cars, air brakes, signals, and steel rails, and, of course, the suppliers of lumber, the raw iron and steel that went into making such items. With the rapid growth of the railroad industry, its impacts on society were both inevitable and far-reaching.

Safety

In those first decades, railroad companies responded slowly to safety issues. With hand brakes and old-fashioned link-and-pin couplers, work was extremely dangerous to both life and limb. And many insurance companies refused to write policies for trainmen. The need for accident and death benefits led railroaders to organize their own benevolent mutual insurance brotherhoods. In time, they joined the emerging organized labor movement to counter the influence of capital. Fueled by labor unrest, a backlash against the railroads boiled over in strikes and riots in most Pennsylvania cities in 1877, sometimes with fatal results.

Such dangerous conditions for workers inspired inventors to come up with innovative solutions to these problems. In 1868, Eli Hamilton Janney patented an automatic car coupler that latched on impact and could be released from alongside the car. This greatly reduced the risk to workers. In the same year, George Westinghouse invented powerful airbrakes for trains. Brakemen on the tops of cars would no longer have to set the brakes by hand. However, railroad companies were more concerned with profits than the safety of their workers, so at first they refused to adopt these new inventions. Lorenzo Coffin, an Iowa farmer turned Railroad Commissioner, became involved with testing air brakes in the mid-1880s. In 1893, he convinced Congress to pass the Railroad Safety Appliance Act. For the first time, railroad managers were forced to take safety seriously. Automatic couplers, air brakes and other safety devices would become standard equipment on American railroads.

The Nature of the Work

Railroads also changed the nature of work. Train crews were on call around the clock, so daily rhythms of eating and sleeping were continually disrupted. Maintaining a normal social life was nearly impossible. When they reached the end of their run over a division (usually 100 miles), crews were often stuck in that city on layovers, sometimes for days, waiting to work a train back to their home terminal. With time and money on their hands, and separated from family and home routines, some trainmen became addicted to gambling, drinking, or other vices to escape the pressures of work.

For many, the railroad became a lifetime career. The seniority system encouraged railroaders to stick with a single company. They knew that they could expect better jobs and more pay as the years passed. Even for low-level workers, railroad careers provided opportunities for promotion not found elsewhere. But a lifetime commitment to railroading also had disadvantages. The risk of serious injury or death meant railroaders often did not reach retirement age. They often had to spend long periods away from home. And even off-duty, they could be called to return to work at a moment’s notice.

The Role of Ethnicity and Race

Through both union rules and management preference, railroads also enforced ethnic and racial divisions. Menial jobs such as grading and laying track went first to Irish laborers, and later to Italians, Eastern Europeans, African Americans, and, during World War II, Mexicans. For African-Americans, in addition to being track laborers, they were often limited to serving as locomotive firemen, coach cleaners, station janitors, redcaps, or dining-car waiters. Even the highest-ranking job for African-Americans – Pullman sleeping-car porter – was still a subservient position.

Many African-Americans found service on Pullman cars, the best work open to them in a segregated era. Porters worked in dining, club, and sleeping cars, making sure passengers had the most comfortable ride possible. The Pullman Company forced employees to work long hours with low pay. Porters could not advance to higher positions within the company. The best they could expect was to become a head porter. But many porters felt lucky to have positions in the cars, rather than the back-breaking labor of track gangs. And often porters worked closely with friends and relatives, whom they had helped to get jobs.

The Role of Gender

While little remembered today, telegraphy was the first area in the railroad industry to employ significant numbers of women, as early as the mid-19th century. Women telegraphers comprised a subculture of technically educated workers whose skills, mobility and independence often set them apart from their contemporaries. The 1870 US Census, the first to list occupations of women, reported that Pennsylvania had the highest number of female telegraph operators of any state. Here are some other facts:

- The Atlantic & Ohio Telegraph Company provided employment to Emma Hunter in West Chester and Helen Mills in Greenville in the early 1850s.
- Elizabeth Cogley of Lewistown became perhaps the earliest woman to work as a telegrapher for the Pennsylvania Railroad in 1855. She was soon joined by two Pittsburgh operators: Abbie Strubel Vaughan, who operated for the Baltimore & Ohio, and Maria Hogan, who joined her cousin, Andrew Carnegie, on the Pennsylvania Railroad.
- Hettie Ogle, manager of the Johnstown Western Union office, lost her life while remaining at her station to warn others of the impending Johnstown Flood in 1889.

Women worked mainly as telegraphers or tower operators until World Wars I and II, when railroads hired them to replace men who went overseas to fight. Nicknamed "Rosie the Riveter," these women filled industrial jobs normally occupied by men. Their efforts demonstrated that women could hold down a fulltime job while fulfilling their duties at home. Women also proved that they could perform the majority of railroad jobs just as well as men. As women gradually became accepted in the workplace, the issue of equal pay began to be raised. If a woman could do a job equally as well as a man, they ought to be paid the same amount. Railroad companies were still reluctant, however, to grant women seniority. They preferred to give the men returning from the war their jobs back.

After the World Wars, many women decided to stay in the railroading business. They laid the groundwork for successive generations of women to find their own places on the railroads. Soon they were working as full-time clerks, secretaries, and ticket agents. By the early 1950s, the Pennsylvania Railroad even boasted that it employed several women lawyers in its legal department. Since the 1960s, women are becoming an increasing presence on the railways in all departments, from the shop floors to the board room, and are making their positive mark in the industry. These women owe their jobs to the women of World Wars I and II who joined the battle on the home front and won.

Today's Railroad Workers

Locomotive engineers are among the most experienced and skilled workers on the railroad. They operate large trains carrying cargo and passengers between stations. Most engineers run diesel locomotives, while a few operate electrically powered locomotives. Before and after each run, engineers check the mechanical condition of their locomotive and make minor adjustments on the spot. Engineers receive starting instructions from conductors and move controls such as throttles and airbrakes to drive the locomotive. They monitor speed, amperage, battery charge, and air pressure, both in the brake lines and in the main reservoir.

Engineers confer with conductors and traffic-control personnel via two-way radio or phone to issue or receive information concerning stops, delays, and train locations. They interpret and comply with orders, signals, speed limits, and other rules and regulations. They must have a thorough knowledge of the signaling systems, yards, and terminals on routes over which they operate. Engineers must be constantly aware of the condition and makeup of their trains, since each one reacts differently to acceleration, braking and curves, depending on track grades and conditions, the number of cars, the ratio of empty to loaded cars, and the amount of slack.

Railroad conductors coordinate the activities of freight and passenger train crews. Those assigned to freight trains review schedules, switching orders, waybills, and shipping records to obtain loading and unloading information regarding their cargo. Conductors assigned to passenger trains also ensure passenger safety and comfort as they go about collecting tickets and fares, making announcements for the benefit of passengers, and coordinating activities of the crew to provide passenger services.

Before a train leaves the terminal, the conductor and engineer discuss instructions from the dispatcher as to the train's route, timetable, and cargo. During the run, conductors use two-way radios and mobile telephones to communicate with dispatchers, engineers, and other trainmen. They also use electronic monitoring devices that relay information about equipment problems on the train or the rail. They may arrange for the removal of defective cars from the train for repairs at the nearest station or stop. In addition, conductors may discuss alternative routes if there is a defect or obstruction on the rail.

Yardmasters coordinate activities of workers engaged in railroad traffic operations. These activities include making up or breaking up trains and switching inbound or outbound traffic to a specific section of the line. Some cars are sent to unload their cargo on special tracks, while other cars are moved to other tracks to wait being added to new trains destined for different cities. Yardmasters inform engineers where to move the cars to fit the planned train configuration. Switches, many of them operated remotely by computer, divert the locomotive or cars to the proper track for coupling and uncoupling.

Railroad brake, signal, and switch operators perform a variety of activities, including operating track switches to route cars to different sections of the yard. They may signal engineers and set warning signals, help to couple and uncouple rolling stock, or inspect couplings, air hoses, and handbrakes.

Traditionally, freight train crews included six brakemen on average for every eight to ten freight cars—some in the locomotive and some in the caboose. Brakemen worked under the direction of conductors and did the physical work involved in adding and removing cars at railroad stations and in yards. In an effort to reduce costs and take advantage of new technology, most railroads have phased out brakemen. Many modern freight trains use only an engineer and a conductor, riding in the locomotive cab, since new monitoring devices and computers have eliminated the need for cabooses.

Many railroad employees work nights, weekends, and holidays, since trains operate 24 hours a day, seven days a week. Many work more than 40 hours a week. Seniority usually dictates who gets the more desirable shifts. Most freight trains are unscheduled, and few workers on these trains have scheduled assignments. Instead, they place their names on a list and await their turns. Jobs usually are assigned on short notice and often at odd hours. Some work on trains operating between points hundreds of miles apart and may spend several nights at a time away from home. Workers on passenger trains have regular shifts and better accommodations.

Rail yard workers spend most of their time outdoors in varying weather. The work of conductors and engineers on local runs, where trains frequently stop at stations to pick up and deliver cars, is physically demanding. Climbing up and down and jumping off moving cars is both strenuous and dangerous work.

Most railroad workers are employed in either the railroad industry or other support activities. In addition to engineers, conductors and brake, signal, and switch operators, there are also bus and truck drivers, driver/sales workers and those employed in water transportation. Others work mainly for local governments as subway and streetcar operators and for mining and manufacturing companies as operators moving their own railcars containing ore, coal, and other bulk materials. In 2002, railroad workers held more than 100,000 jobs:

- 38,000 conductors and yardmasters
- 33,000 locomotive engineers
- 15,000 brake, signal, and switch operators
- 15,000 subway, streetcar operators and all other rail transportation workers

Most railroad workers begin as yard laborers and may later train to become engineers or conductors. Railroads require that applicants have at last a high school diploma or its equivalent. Applicants must have good hearing, eyesight, and color vision, as well as good hand-eye coordination, manual dexterity, and mechanical aptitude. Employers also require applicants to pass a physical exam, drug and alcohol screening, and a criminal background check. Under federal law, all train crewmembers are subject to random drug and alcohol testing while on duty.

Applicants for locomotive engineer jobs must be at least 21 years old. Employers almost always fill engineer positions with workers who have experience in other railroad-operating occupations. Federal regulations require beginning engineers to complete a formal engineer training program, including classroom, simulator, and hands-on instruction in locomotive operation. The instruction usually is administered by the rail company in programs approved by the Federal Railroad Administration. At the end of the training period, engineers must pass a hearing and visual acuity test, a safety conduct background check, a railroad operation knowledge test, and a skills performance test. The company issues the engineer a license after the applicant passes the examinations. Other conditions and rules may apply to entry-level engineers and usually vary by employer.

To maintain certification, railroad companies must monitor their engineers. In addition, engineers must periodically pass an operational rules efficiency test, an unannounced event requiring them to take active or responsive action in certain situations, like maintaining a particular speed through a curve or yard. Engineers undergo periodic physical exams and drug and alcohol testing to determine their fitness to operate locomotives. In some cases, engineers who fail to meet these standards are restricted to yard service; in other instances, they may be disciplined, trained to perform other work, or even discharged.

Conductors are generally recruited filled from the ranks of experienced railroad workers who have passed tests covering signals, timetables, operating rules, and related subjects. Seniority usually is the main factor in determining promotion. Entry-level conductors must generally be at least 21 years of age and are either trained by their employers or required to complete a formal conductor training program through a community college.
Newly trained engineers and conductors are placed on the "extra board" until permanent positions become available. Extra-board workers receive assignments only when the railroad needs substitutes for regular workers who are absent because of vacation, illness, or other personal reasons. Seniority rules may allow workers with greater seniority to select their type of assignment. For example, an engineer may move from an initial regular assignment in yard service to road service.

For subway and streetcar operator jobs, applicants with a high school education are preferred. Typically, they must start as bus drivers. Applicants also must be in good health, have good communication skills, and be able to make quick, responsible judgments. New operators generally complete training programs that last from a few weeks to 6 months. At the end of their training, applicants must pass qualifying examinations covering the operating system, troubleshooting, and evacuation and emergency procedures. Some operators with sufficient seniority can advance to station manager or other supervisory positions.

Competition for available job opportunities is expected to be keen. Many persons qualify for railroad jobs, since education beyond high school is generally not required. Railroad jobs often attract more applicants than the number of available job openings, because the pay is good and the work is steady.

Employment of most railroad occupations is expected to decline through the year 2012. The need to replace workers who transfer to other occupations or retire will be the main goal of recruitment. Employment in most rail occupations will continue to decline as both railroads and job duties are consolidated. Locomotive engineers and conductors will increasingly take on the duties of other workers as railroads control labor costs to remain competitive. However, employment of subway and streetcar operators will grow about as fast as the average for all occupations as demand increases for light-rail systems nationwide.

Demand for railroad freight service will grow as the economy and the intermodal shipments expand. "Intermodal" systems use trucks to pick up and deliver the shippers' sealed trailers or containers and employ trains to transport them long distance. This practice saves customers time and money because it combines long-distance, door-to-door service. For railroads, the benefit has been an increase in equipment efficiency, allowing each train to make more runs each year. In order to compete with other modes of transportation, such as trucks, ships, and aircraft, railroads are improving delivery times and on-time service while reducing shipping rates.

However, growth in the railroad labor force may be stunted by innovations such as larger, faster, more fuel-efficient trains and computerized yards that make it possible to move freight more economically. Computers keep track of freight cars, match empty cars with the closest loads, and dispatch trains. Computerized devices alert engineers to malfunctions, and work rules now allow trains to operate with only two people.

Most railroaders are paid according to miles traveled or hours worked, whichever leads to higher earnings. Full-time employees have steadier work, more regular hours, increased opportunities for overtime pay, and higher earnings than do those assigned to the extra board. In 2002, hourly earnings were relatively high:

- $23.26 locomotive engineers and crews
- $21.48 subway and streetcar operators and all other rail transportation workers
- $21.39 conductors and yardmasters
- $20.93 brake, signal, and switch operators

Almost three-quarters of railroad workers are union members. Many different unions represent various crafts on the railroads. Most engineers are members of the Brotherhood of Locomotive Engineers, while most other railroad workers are members of the United Transportation Union. Many subway operators are members of the Amalgamated Transit Union, while others belong to the Transport Workers Union of North America.

Discussion Questions

Describe the nature of a railroader's work, then and now.

What events occurred that helped to bring about changes in the working conditions and compensation of railroaders?

If women were not permitted to work on the railroad, where were they supposed to be?

What kinds of things might draw someone—a man or a woman—to work for a railroad today?

Describe the similarities and differences between railroaders, their jobs and their working conditions, more than 100 years ago compared to today.

Activity – Starting Your Own Railroad Company

Have students develop their own fictitious railroad connecting two or more towns or industries in your area. After coming up with a name for their company, have students develop a list of job positions they will need for their company and a job description for each one. In small groups, have students "interview" potential candidates for these new jobs and have them assign fellow students to their new job positions based upon the results of these interviews.

Activity – Today's Railroads

Invite a guest speaker from a local railroad, a safety organization like Operation Lifesaver, or a student's friend or relative who works for a railroad to come to your school and ask that person to share with you some of his or her experiences on the job. Be prepared to ask specific questions, and be sure to thank them for their help and participation.

Take a tour of a railroad historic site or museum. Ride a passenger train. Or spend some time near an operating railroad (where it is safe and permissible to do so). Keep a journal of what you see and hear. Keep track of the number of trains you see in a given time period, the types of cars being pulled, what they were carrying, and their direction or destination. Visit a train station and conduct similar research. Observe and document what you experience.

Vocabulary

Brakes – Devices that help with controlling the speed and stopping the train.

Brakeman – A railroad worker who helps connect rail cars together, throws track switches, checks the brakes and protects the train.

Caboose – A rail car attached to the rear of the train for use by the conductor and brakemen. Often, the caboose was the rolling office of the conductor, as well as crew quarters for rear-end brakemen while the train was in motion. Brakemen could also keep watch over the train from its specially located windows. Over the years, railroads have retired their cabooses in favor of a compact, electronic "end-of-train" device that can be clipped to the end of the last car of the train.

Conductor – A railroad worker who is usually in charge of the train, but does not operate it. He or she ensures the safe and timely arrival of passengers or freight.

Consist – The cars or equipment that makes up a specific train.

Coupler – The device on the ends of a rail car which allows it to be connected to another car; "coupling" means connecting cars to one another to make up a train; "uncoupling" means removing or disconnecting one or more cars from a train.

Engineer – A railroad worker who runs the locomotive that pulls the train.

Fireman – A railroad worker who feeds the locomotives fire with wood or coal, adds water and greases the parts as needed.

Freight Train – A train that carries goods going to market or factories to be made into other goods**.**

Gandy Dancer – A railroad worker who builds the track. (The name "Gandy" may have come from the Gandy Manufacturing Company, which produced many of the tools used by railroad workers. The name "Dancer" referred to the rhythmic pattern in which track workers swung their hammers to maintain a quick pace and avoid hitting one another.)

Hotbox – An overheated wheel bearing which, if left undetected, can catch on fire and cause a wheel failure and possibly a derailment.

Link-and-Pin Coupler – An early design for connecting rail cars to one another. Each car was equipped with an iron chain link at either end, and a brakeman had to physically drop or remove a long iron pin which connected the links of two or more rail cars. Often, brakemen were seriously injured or even killed when two cars came together too quickly, not giving them time to get out of the way. Their use on railroads was banned with the Railway Safety and Appliance Act of 1893.

Lobbyist – A person who tries to influence government authorities and elected officials, often to enact legislation or to lend political support to a certain cause or point of view.

Knuckle Coupler – A more modern design for connecting rail cars to one another developed after the Civil War. Appearing like the fingers of a cupped right hand, the knuckle coupler must open (extend) to uncouple cars from the train and close to couple and lock them together. The Railway Safety and Appliance Act of 1893 mandated their use on America's railroad cars. Most can be activated by pulling a lever while standing along side the rail car. Modern knuckle couplers can also be activated electronically.

Roundhouse – A building where the light repair and maintenance of locomotives is done. A roundhouse encircles a turntable, whose spur tracks all radiate outward from its path of rotation.

Turnout – Sometimes called a "switch"; a section of track with rails that slide to allow for diverging routes.

Turntable – A device which pivots in the center allowing engines to be turned or placed into a particular engine shed or roundhouse stall.

Yard – A collection of tracks in a given area designed for making up trains or storing rail cars and equipment.

Bibliography

Many of these sources are available at the Railroad Museum of Pennsylvania. Contact us to inquire about these and other titles:

Books

Ambrose, Stephen E. Nothing *Like It in the World: The Men Who Built the Transcontinental Railroad, 1863-1869*. NY: Simon & Shuster, 2000.

Harter, Jim. *American Railroads of the Nineteenth Century: A Pictorial History in Victorian Wood Engravings*. Lubbock, TX: Texas Tech UP, 1998.

Jepsen, Thomas C. *Ma Kiley: The Life of a Railroad Telegrapher*. El Paso, TX: Texas Western Press, 1997.

Jepsen, Thomas C. My *Sisters Telegraphic: Women in the Telegraph Office, 1846-1950*. Athens: Ohio UP, 2000.

Levinson, Nancy Smiler and Shirley Burman. *She's Been Working on the Railroad*. NY: Dutton Juvenile, 1997.

Orr, John W. *Set Up Running: The Life of a Pennsylvania Railroad Engineman, 1904-1949*. University Park, PA: Penn State UP, 2003.

Reinhardt, Richard. *Workin' on the Railroad: Reminiscences from the Age of Steam*. Oklahoma City, OK: U of Oklahoma P, 1970.

Solomon, Brian. *Railway Maintenance: The Men and Machines That Keep the Railroads Running*. Minneapolis, MN: MBI, 2001.

Solomon, Brian. *Working on the Railroad*. Osceola, WI: Voyageur, 2006.

Tye, Larry. Rising *from the Rails: Pullman Porters and the Making of the Black Middle Class*. NY: Holt and Co., 2004.

Weitzman, David. *Superpower: The Making of a Steam Locomotive*. Lincoln, MA: David R. Godine, 1995.

Videos

A Railroader Remembers. Dir. Bob Leff. With Jim Ladwig, Rodney Kreunen and Joe Follmar. DVD. Video Art, 2006.

Men and Mail in Transit. United States Postal Department. Videocassette. Railway Mail Service Library, 2000.

Websites

African-Americans in U.S. Railroad History. A. Philip Randolph Pullman Porter Museum. <http://www.aphiliprandolphmuseum.com/evo_history2.html>.

American Public Transportation Association. <www.apta.com>

Association of American Railroads. <http://www.aar.org>

Brotherhood of Locomotive Engineers. <http://www.ble.org>

The Faces of Railroading. Railroad Museum of Pennsylvania. <http://www.rrmuseumpa.org/about/rrpeopleandsociety/occup.shtml>

Federal Railroad Administration. <http://www.fra.dot.gov>

Women in Railroading. The International Society for the Preservation of Women in Railroading. <http://www.womeninrailroading.com/index.htm>.

Jepson, Thomas C. "Women Telegraphers and the Railroad in Pennsylvania." *Scholar in Residence Lecture Series*. Railroad Museum of Pennsylvania. <http://www.mindspring.com/%7Etjepsen/PHMCPres_files/frame.htm>. February 26, 2003.