Steam, Culture and the Industrial Revolution

Most experts will tell you that the Industrial Revolution started just before our War for Independence, in the middle 1700s, and continued for a century or more. Let us not get hung up on the dates. The truth is that the Industrial Revolution really started slowly around 1700 and continued until well after 1900 in the US.

Life before and after the Revolution was completely changed. In fact, if you were beamed back to 1700 to live, you would find it very strange, while you'd probably be much more at home in 1850.

One reason the revolution took so long was that so many things had to change. Another reason is that there were so many ways things could be improved upon.

Before the revolution, wind and muscles were the prime movers of the world. Sails provided movement over water. Everywhere else muscles did the work—either human or animal. The speed of movement was slow—limited by the walking speed of a horse or the wind—and it had not changed for three thousand years. Or to be blunt, Alexander the Great and George Washington both travelled at the same speed—slow. And a horse drawn wagon was the largest general unit of transfer.

Before the revolution, people did not have the same values as afterwards. Artisans such as gunsmiths and blacksmiths would seldom attempt to make any two items identical. In fact, there was no concept of interchangeable parts. There were no standards for threads so each screw had its one corresponding nut. Similarly, there was no concept of precision since precision is only required of repeatability is important.

So let's take a mental trip back in time to the mid 1600s. The first east coast colonies were thriving in the new world, but the society was definitely not industrial yet. In England, the use of metals and coal had spurred the mining industry. Mines were going deeper and this meant trouble with water seeping into the mines from the surface. Some mines even extended under the beaches and out underneath the ocean. Removing the water from the mines became as big of a problem as digging the ore. The deeper the mine, the more water came in.

At first buckets were used, but that did not work very well.

Next, simple hand pumps were placed on the surface but they could only reach down about 30 feet. Mines quickly became deeper and needed a better solution.

Horses, oxen, and mules were used to power all manner of creative designs to bring water up out of the mines, but this was a slow, expensive, and unsatisfactory solution.

Then along came Thomas Savery. In 1689, he invented a machine which allowed steam to move large amounts of water out of deep mines. Many will argue this was the first steam engine, but I'll let you decide. Savery's machine was driven by a boiler and required a human to operate it via a series of controls. Imagine a large empty, sealed tank. Place a valve on the bottom and extend its pipe down into a pool of water. Steam would be admitted to the tank from the boiler until it began to bubble out of the bottom pipe at which time the boiler feed would be stopped.

The steam in the tank would cool and convert back to water. This would also create a partial vacuum which would suck water up the feed pipe and into the tank.

The operator would then close the bottom valve and open a second valve on the bottom of the tank which was piped to the surface. And the boiler connection would be opened to push steam into the tank, pressurizing the tank and pushing the water out through the pipe to the surface.

This pump could move huge amounts of water and required nothing more than a fire and a human to move the levers. One machine could perform the same job as several horses. Furthermore, the cost of coal—especially to a coal mine—was cheaper than horse feed.

Savery's invention was crude, but its implementation was worse. There was no way to build strong boilers in that day. Even the low pressures of Savery's pump were often strains on the pipes and valves available in that era. Savery's machines were inefficient, prone to breaking and also known to explode killing people. It is also important to realize that since Savery's pump used a vacuum to suck in water, the pump needed to be no more than about 30 feet above the water level. This often necessitated placing one of these machines down into the mine. Deeper mines used cascading sets of pumps to move water incrementally toward the surface.

Savery's steam pump was revolutionary. It was a machine which did useful, even vital, work yet it did not depend upon the muscles of a mammal. The development of Savery's design quickly hit a limit based upon the technology available to build pumps. And Savery's demands helped to generate better technology since now the various types of smiths could actually profit from better techniques.

From an efficiency standpoint, Savery's engine earns a big "F" since it wastes most of the energy from the fire. But it was cheap enough to be practical even when it was inefficient—until other engineers figured out how to build a better, more efficient and versatile engine.

Thomas Newcomen's engine came along a dozen years later and was more reasonably called a steam engine. It even had moving parts where Savery's didn't.

Newcomen replaced Savery's tank with a large piston which could move up and down. Steam pressure would allow the piston to move upwards. Then cooling the steam below the piston would create a vacuum which would pull the piston back down. To speed the cooling, some engines sprayed cold water into the cylinder. Overhead, a huge ‘walking beam’ or see-saw mechanism would reverse the motion so that it could be sent down into a deep mine to operate a traditional mechanical pump. In fact, more than one pump could be driven by Newcomen’s beast.

Unlike Savery’s design, Newcomen’s engine operated without human intervention. The opening and closing of the various valves was performed automatically as the engine progressed through its cycle. A human was required to keep the boiler full of water and supplied with fuel. Newcomen’s design was so popular that it was used in more than 2000 mines in the UK alone.

But, again, Newcomen’s design was only marginally more efficient than Savery’s. The heat required to warm the cylinder was a lost whenever the steam was condensed to produce a vacuum. But cylinder would need to be warmed for the next cycle. Furthermore, the energy in the steam was not being used well. Finally, this machine was only good for reciprocating motion. There was no rotation yet.

It took until1781 for someone to come up with a better way. That person was James Watt – we name our modern unit of power, the Watt, after him.

Watt’s engines had several key differences. The first was that he added a flywheel and a crankshaft so that the vertical reciprocating motion could be converted to rotation. The second was that Watt used the pressure of the boiler to push the piston rather than discarding the heat to create a vacuum. Watt’s engine was many times more efficient, much smaller, and capable of driving rotating equipment such as blowers, pumps, machine tools or to grind grain. The steam engine came into its own at this point.

So by about the year 1800, a small, ten horsepower steam engine could be installed in an area the size of a large modern pickup. Ten horsepower was enough to power a small factory, providing power to many machines at once.

Quickly, new factory machines came to market. These new machines performed the same jobs as before, only now they were designed to use mechanical power rather than human power. The result was hugely increased productivity and repeatability. Almost immediately, steam engines were powering the tools making steam engines. The cycle of improvement resulted in several big changes in the way people thought:

- First, precision was now possible and workers could suddenly see the value in precision and even in interchangeable parts. By the later part of the 1800s, there were established standards for pipe and screw threads along with other commodities which only reinforced thismove.

- Second, with machines doing the heavy work, larger machines could be built. Bigger machines then in turn allowed the construction of even bigger machines. Watt's original 10 horsepower machine from around 1800 grew to over 10,000 horsepower only 80 years later.

- Third, tougher and stronger metals could be used. Blacksmiths had only limited ability to work steel. The 1800s saw the development of many types of steel along with ways to treat it for different uses. Similarly, designs could include many metals to take advantage of their characteristics.

It wasn't until the 1840s that railroads began to impact society. It is hard to underestimate the changes. Railroads went faster than horses—and remember that horses had travelled at the same speed forever. People referred to railroads as conquering time since in that day people equated distance with time based upon the speed of a horse-drawn carriage. Railroads could also operate around the clock. In 1840, the vast majority of folks were born, lived, and died within a few miles radius—often having never wandered far from home. If one tried hard, 10 to 12 hours of horse travel could move you 50 miles. But the train could maintain speeds of between 10 and 20 miles per hour around the clock. In 1876, the TransContentntal Express crossed from New York City to San Francisco in 83 hours or about three and a half days. That same trip would have taken six months or more a decade earlier.

Railroads were able to carry huge loads. Suddenly, large machines could be manufactured in one city and shipped to another. A factory could specialize in large machinery and sell that machinery to all corners of the country. This drove up volumes, which lowers costs, and helped the railroads to grow even more quickly.

Finally, railroads were cheap and dependable. It was much cheaper to move a ton of grain via rail than by horse drawn cart or by boat. Railroads operated on schedules designed to maximize profits and make maximum use of the huge capital investment required to build and maintain the railroad's infrastructure.

So we had a cycle: Iron mines produced ore which was loaded onto trains. The trains took the ore along with coal or coke to the steel mills where the ore was processed into steel and placed on trains. The trains took the steel to factories where the steel was converted into machinery such as plows, steam engines or train parts. Then those newly manufactured products would be loaded onto the trains for delivery to the purchaser.

Notice how trains made each step of the cycle possible.

I could draw dozens of similar cycles. As factories were built, they needed equipment and raw materials. Textile mills were popular In New England. Huge steam powered spinning and weaving machinery would convert yarn or thread to cloth. Very quickly most of the Southern US's farms converted to cotton production once Eli Whitney's Cotton Engine or 'cotton gin' as it was called, made it economically possible to make quality thread from native cotton. As the businesses grew, the factories grew and demanded larger, more powerful and sophisticated equipment. In 1800, people routinely wore homespun clothes – with cloth created at home via a manual loom. And cotton clothes were the most expensive—more expensive than wool or silk. Today, hardly anyone wears clothes made at home, much less via a home loom. And cotton clothing is less costly than wool or silk, though newer artificial fabrics are now available which are even lower cost. In 1800 people often only had two or three changes of clothing where today even the poorest amongst us have access to many changes.

Before the Industrial Revolution, most men worked as farmers of some type. Most women worked on the family farm in some capacity. Families would be large for two reasons: first, childhood diseases and accidents often claimed children, so bigger families were popular. Second, farms needed the children for the various daily chores.

After the industrial revolution, more than 90% of the farm families had moved to cities to take up high paying factory and industrial jobs. The newer, better technologies of the industrial revolution allowed a single farmer to work more land and to produce more food than a dozen farmers a few decades earlier.

Before the industrial revolution, it was difficult to have a large city of a million or more people. The few huge cities were intimately connect to a port—London and Paris are good examples of large cities where supplies could be brought in via boat and waste could be removed. But sail driven boats have their limits so there was a practical maximum size for a city.

But, once trains came along, it became possible to supply cities more efficiently. Food and other consumables could be transported hundreds of miles even in winter. Chicago was originally a nexus for communication between Midwest farmers and the large cities on the eastern seaboard. The availability of infinite amounts of thick block ice in the winters made it possible to ice down perishable commodities such as meat, eggs, and milk headed eastword. In fact, Chicago became famous for its stock yards and slaughter houses. Cattle and hogs were butchered in Chicago, iced down and shipped eastward. Once again, separating the production from the consumption of product.

We exited the Revolution with a totally changed society. The average person's personal wealth was increased immensely. We were a nation of city dwellers where before we had been a nation of farmers. The value of each worker's labor improved every few years when new equipment made the worker more productive.

The principle of investing capital into the means of production was proven time and time again. Workers learned the new skills required by the changing environment. Education became more important and access to education became easier.

The modern consumer was created. Henry Ford made his Model T car at a low price so that the average family could purchase one. By World War II, most families had radios, indoor plumbing, cars, electricity and a refrigerator.

We are at the beginning of a second industrial revolution which will be driven by computing and adaptability. Where the first industrial revolution made it possible to create knives and forks – identical – for low prices in huge quantities, the second industrial revolution will create products in high quantity but tailored specifically for the use. Already we see companies offering to custom build clothes based upon information gathered by a cell phone app.