Lesson 74 -The Mystery of Efficiency

The industrial revolution began when factories found large sources of energy to do work. It began with water wheels and ended with the gasoline engine. Water wheels were very efficient (63%) if they allowed the water to fall over the wheel, so industrial cities began to grow along the 'fall line' of rivers.

The steam engine began with Thomas Savory in 1698, who used condensing steam to generate a vacuum which was used to pump water out of mines. Thomas Newcomen (1663-1729) in 1712 improved the design so that 5.5 horsepower could be developed by condensation of steam. This engine had an efficiency of 0.5%. In those days they measured efficiency as 'duty', which was the millions of foot-pounds of work done per bushel of coal burned.

James Watt (1736-1819), the instrument maker for the University of Edinburgh, greatly improved the design of steam engines by introducing the double action piston with a separate chamber for condensation of the steam. Efficiency went up to 4.5% (39 million ft-lbs/bushel). Under this scheme the pressure of the atmosphere moved the pistons of the engine into the vacuum created by the condensing steam.

After 1800, with the expiration of Watt's patent, Richard Trevithick (1771-1833) in England and Oliver Evans (1755-1819) in America independently introduced modified steam engines which used the pressure of the steam rather than atmospheric pressure to run the engine. Designs of engines allowed pressures as high as 10 atm. Now trains, boats, and fixed manufacturing power-plants could be run with steam engines.

In 1824, Sadi Carnot (1796-1832), a French engineer, published ***Réflections sur la puissance motrice du feu*** (Reflections on the Motive Power of Heat) in which he proposed the general idea that all engines generate work only when heat passes from a hot place to a cold place (like water going from high to low in a water wheel). The efficiency of any engine could be only as great as the temperature difference between the hot and cold.

Benoit Paul Emile Clapeyron (1799-1864) in 1834 put this principle into a mathematical form. This is the first statement of what was later called the 'second law of thermodynamics': no engine can be 100% efficient because the exhaust temperature would need to be at absolute zero. What is still left unknown is why this law is true.