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- POLYTECHNIC OF EGYPT -

History of Engineering and Technology

Lecture 6: Expansive Engineering

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Expansive Engineering

(~1800 AD→~1940 AD)

Expansive Engineering (~1800 AD→~1940 AD)

- Progress and Engineering
- Steam Railroad .
- Materials Processing
- Electrification.
- Automotive Transport .
- Electrical Communication
- Air Transport.
- Heavy Industry .
- Large Structures.
- Summary.

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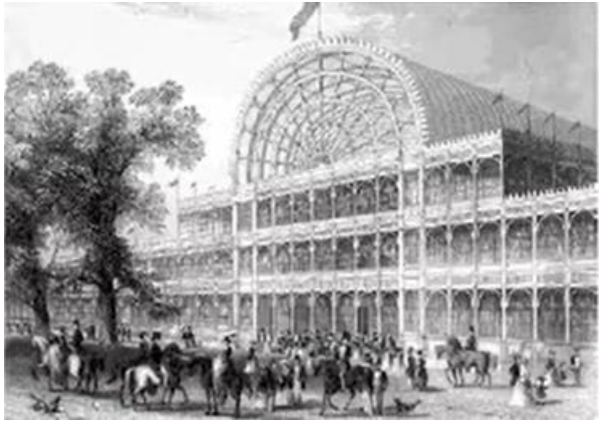
Progress and Engineering

Progress and Engineering

- In these emerging days of expansive thinking engineers were a proud and confident community.
- The 1800 → 1940 period could be renamed
  the Exponential Growth Engineering Era
  and with it came the increasing recognition of engineering as avital profession.
- Engineers of the day could well direct their skills and aspirations to the expanded making of especially ingenious devices and buildings such as the crystal palace in London 1851.



Progress and Engineering

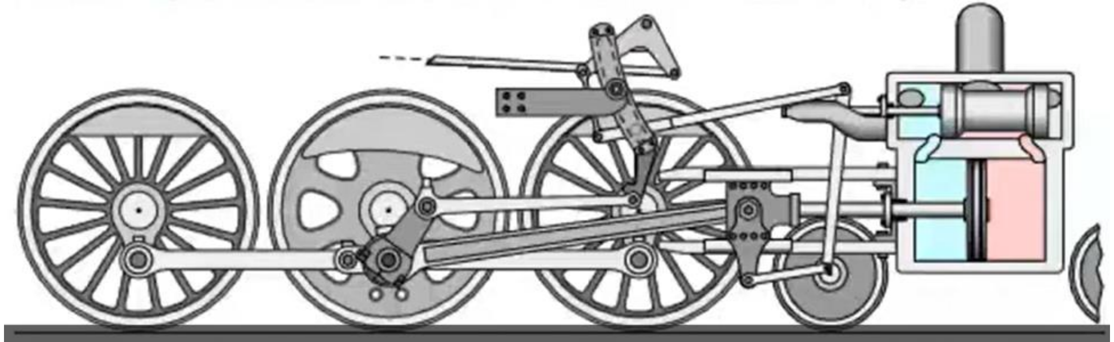
The Bicycle

- Though DaVinci had already designed a bicycle, practical versions did not appear for another 300 years
- In the 1820s appeared as a two-wheeled walking device with a seat and steering mechanism Then improved with pedals, chain, and gears.
- Worldwide production of bicycles has increased to ~100 M/year with China alone producing about 40 M/year.

Steam Railroad

Steam Railroad

1. The original use of the steam engine during the 1700s, was to pump water out of coal mines.
2. It then became the dominant means to power factories.
3. Soon it had become evident that a steam engine on a platform equipped with wheels could become self-propelling.
4. In 1825 the first public railway entered service near London.
5. By 1840, a locomotive boiler design appeared with maximum steam production and hence reduced fuel consumption.
6. This basic design, subject to numerous modifications over time, remains operational in some countries even today.



Steam Railroad

- By about 1820, the concept and expected utility of steam railroading over longer distances had become widely recognized.
- Railway bridges were built, tunnels were bored, tracks were laid, and stations built
- National interests in unification and regional economic consequences became associated with these steam railroad projects, well represented by the primal.

$$N(t)\begin{Bmatrix} \textit{water,} \\ \textit{iron,} \\ \textit{coal,} \\ \textit{land} \end{Bmatrix} \rightarrow E(t)\begin{Bmatrix} \textit{design and} \\ \textit{manufacture,} \\ \textit{transportation} \\ \textit{networks} \end{Bmatrix} \rightarrow D(t)\begin{Bmatrix} \textit{steam} \\ \textit{powered} \\ \textit{locomotives,} \\ \textit{trains} \end{Bmatrix}$$

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Materials Processing

Materials Processing

- The railway network was growing more rapidly than justified by the available iron technology. Railway tracks were failing, steam pressure vessels were bursting, and a general recognition emerged that it was the quality of iron which was unsatisfactory. But gradually the manufacturing of iron and steel became clearer.

Some of the most significant chemical and material engineering process of the mid-1800s were:

1. Hard Steel

- The inventive idea(1856) of Henry Bessemer, England, is to force air through molten iron so that the carbon in the iron could combine with the oxygen from the air to form gases CO and CO_2, which would then exit from the molten material.
- This was a breakthrough yielding high quality steel in large quantities and rapid production rates and all at low cost.

$$N(t)\left\{\begin{array}{c}\text{iron,}\\ \text{oxygen,}\\ \text{heat}\end{array}\right\} \rightarrow E(t)\left\{\begin{array}{c}\text{chemical reactions,}\\ \text{atom/molecule}\\ \text{migration,}\\ \text{high-temperature}\\ \text{control}\end{array}\right\} \rightarrow D(t)\left\{\begin{array}{c}\text{high grade}\\ \text{steel}\\ \text{products}\end{array}\right\}$$

Materials Processing

2. Synthetic Dye

- Chemical processing became of considerable relevance, primarily affecting the textile industry.
- Textiles involved vegetable fibers (flax and cotton) and animal fibers (wool and silk), which were colored using a small selection of available natural plant-grown and marine-life dyes.
- These dyes were limited, prone to fade, and their colors were often difficult to reproduce.
- In 1856 and after, William Perkins, England, discovered that the selective distillation - and further redistillation - of coal tar or other selected petroleum grades could yield deep violets, bright reds, shining blues, and clear green dyes, any of which would bind to fiber and thus be long lasting.
- Further, these synthetic dyes could be inexpensively produced there by contributing to significant growth of the textile industry.

Here, one may identify the underlying primal

$$N(t)\begin{Bmatrix}\textit{fibers,}\\ \textit{hydrocarbons}\end{Bmatrix} \rightarrow E(t)\begin{Bmatrix}\textit{distillation,}\\ \textit{mixing}\end{Bmatrix} \rightarrow D(t)\begin{Bmatrix}\textit{colored}\\ \textit{textile}\end{Bmatrix}$$

3. Vulcanized Rubber

- A chemical process of treating naturally available rubber which had a most pronounced impact on the future of transportation.
- Natural rubber, consisting of air-cured sap which oozes from the bark of the South American tree Havea brasiliens is, became brittle at moderately low temperature and sticky at moderately high temperatures.
- In 1830, an American hardware merchant discovered that mixing this natural rubber with sulfur and heating the resultant mixture, yielded astable compound which remained elastic over a larger temperature range.
- The inventor, Charles Goodyear, called this process vulcanization. Unknown to Goodyear, he had discovered a way of producing a synthesized elastic polymer.

For this invention, one may evidently write as the ingenious primal.

$$N(t)\begin{Bmatrix} \text{natural} \\ \text{rubber, sulfur} \end{Bmatrix} \rightarrow E(t)\begin{Bmatrix} \text{mixing,} \\ \text{heating} \end{Bmatrix} \rightarrow D(t)\begin{Bmatrix} \text{synthetic} \\ \text{rubber} \end{Bmatrix}$$

Materials Processing

4. Dynamite

The taming of nitroglycerine-an unstable and dangerous explosive compound obtained by mixing glycerol with nitric and sulfuric acids.

Alfred Nobel of Sweden, made the chance discovery in 1866 that mixing nitroglycerine with a compound called kieselguhr produced a very stable mixture which he called Dynamite

Dynamite could more safely be used as a powerful explosive, but the mixture now required a detonating device. This innovation constitutes the primal progression indicating also the importance of compensatory device components.

$$N(t)\begin{Bmatrix} various \\ materials \end{Bmatrix} \rightarrow E(t)\begin{Bmatrix} mixing, \\ trigger \end{Bmatrix} \rightarrow D(t)\begin{Bmatrix} controlled \\ explosive \end{Bmatrix}$$

Materials Processing

5. Petroleum Products

- Petroleum products and selected derivatives first emerged in the mid 19th century in Canada and USA.
- Then in the late 1800s, natural gas was discovered in the USA, providing a more suitable substitute for coal gas.
- More importantly, larger oil fields were soon discovered (USA, Persia, Arabia,...) prompting large investments in the technology of oil extraction, oil transportation, and fractional distillation to yield various product streams
- Three of the early products were kerosene for lamps, moderate octane gasoline suitable for the emerging internal combustion engine, and oil for lubrication purposes.

$$N(t)\begin{Bmatrix} gas, \\ liquid \end{Bmatrix} \rightarrow E(t)\begin{Bmatrix} exploration,\ extraction \\ distillation \end{Bmatrix} \rightarrow D(t)\begin{Bmatrix} fuels, \\ lubricants \end{Bmatrix}$$

Electrification

Electrification

- A device which produced minimal electrical current was the pile built by A. Volta, Italy, in 1800. This first ever battery, consisting of alternate layers of zinc and silver disks separated by soaked paper.
- Moreover, in 1831, Michael Faraday, England, demonstrated that an electrical conductor moving through the field of a magnet would result in electricity flow in the conductor and, conversely, when an electrical current surged through a conductor a nearby suspended magnet would be deflected. Both principles on which electrical generators and electric motors are based were thus established.
- Soon after, hand-operated electric current generators in which a horseshoe magnet is rotated near the ends of coils - generally called dynamos - replaced the Voltaic pile as a current source; a commutator was also invented at that time to produce direct current.

Electrification

- It had also been recognized by others that a direct current passing through a sufficiently thin wire might cause incandescence before disintegrating. An inert gas environment or high vacuum was evidently required, and such experiments had been undertaken by Joseph Swan of England, in the 1850s, producing incandescence of varying duration.
- Then, Thomas Edison, USA, used a charred cotton filament in a highly evacuated glass bulb and produced a continuous glow of light for over 13hours-the year was 1879.Already in 1880, Edison and Swan joined forces to power 3000 light bulbs in London, to the utter amazement of the public. Similar installations were introduced in New York City in 1882.

Electrification

- By the 1890s, steam locomotives had experienced extensive improvements but the need for repeated water stops and large quantities of wood or coal, time required to build-up steam pressure, unavoidable noise, and smoke, all combined to suggest that perhaps electric motors with AC electricity supplied by overhead wires or a covered extra rail, would be a most desirable improvement in populated areas. This view was promoted by George Westinghouse, USA, and by Wilhelm Siemens, Germany-England.
- Based on the ideas of the brilliant thought, Nikola Tesla, Serbia-USA, who had already invented a practical generator (1884) and motor (1888), Westinghouse promoted AC current because longer distance transmission were feasible

Electrification

- And so began the DC/AC Battle-of-the-Currents eventually won by AC, with power from Niagara Falls in 1896 as the first large-scale electric power source. For the next~100 years, AC electrification in the USA and Europe-and subsequently Russia and other countries became an enormous undertaking involving substantial development of water turbines, dam construction, coal fired thermo-electric powerplants, high voltage transmission, and step-down voltage transformers.

Automotive Transport

Automotive Transport

- In 1673, Christiaan Huygens of the Netherlands first demonstrated the concept of internal combustion by exploding a small charge of gunpowder inside a metal cylinder and there by moving a piston; this idea proved to be impractical at the time but about 200 years later a connection was made with three technical developments:

(A) Availability of combustible coal gas and processed petroleum fuels

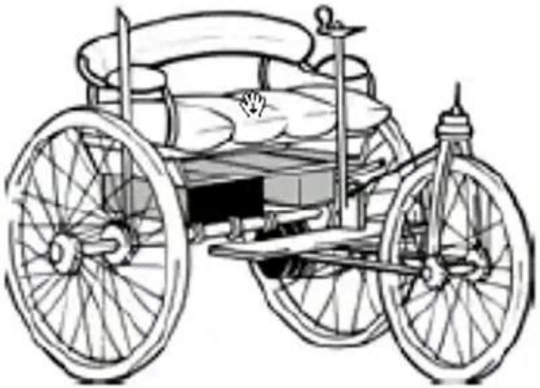
(B) Battery-supplied electrical currents to provide sparking

(c) Practicality of fuel-air mixture ignition by an electrical spark.

- In 1876, Nikolaus Otto, Germany, demonstrated the remarkable and enduring 4-stroke internal combustion cycle-now called the Otto Cycle. This first one-cylinder engine produced 500W(<1 hp), was powered by coal gas, and proved to be sufficiently reliable to power small pumps, lathes, looms, and other machinery; though bulky and about1.5m in height-it sold thousands.

Automotive Transport

- In 1886, it happened. Karl Benz, also of Germany, rear-mounted a petroleum burning variation of the Otto Cycle engine on a 3-wheeledplatform and connected the engine shaft to the rear axle by bicycle chain; Benz also introduced the differential gear box for turning and a radiator for engine cooling. And it all worked



Benz (1886)

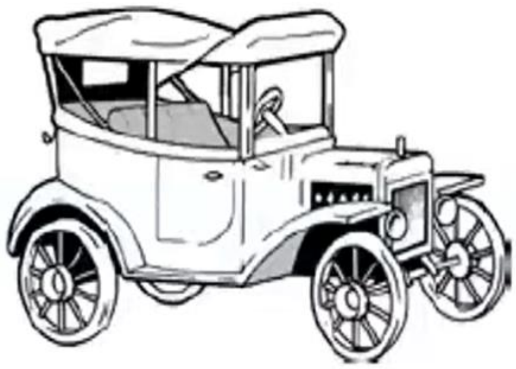
Automotive Transport

- Three years later, fellow country man Gottlieb Daimler built what is generally considered the first modern automobile: it possessed a V-shaped 2-cylinder Otto Cycle engine, a 4-speed transmission, and produced 1.1kW (~1.5hp) at 500 rpm to the crank shaft.
- Before the turn of the century, the Otto/Benz/Daimler automotive developments quickly spread providing also opportunity for related device initiatives. Of particular noteare the inventions of John Dunlop, England(pneumatic tire, 1888) and Louis Renault, France (direct transmission, 1899).

Daimler (1889)

Automotive Transport

- In 1896, Henry Ford, USA had completed his first car, a 2-cylinder2.2kW (-3 hp) front-mounted engine but rear-wheel driven by connection with a sprocket chain. In 1908, Ford began component mass production and assembly of his Universal Car using the concept of interchangeable parts manufacture; this rugged Model T, consisted of a wooden body on a steel frame with a 4-cylinder 15kW (20hp) engine. Indeed, by the mid-1920s, some 250 firms were manufacturing automobiles worldwide and the Ford dominance was challenged.



Ford (1908)

Electrical Communication

Electrical Communication

- A new primal progression appropriate to electrical communication emerged:

$$N(t)\begin{Bmatrix} various \\ materials \end{Bmatrix} \rightarrow E(t)\begin{Bmatrix} EM\ transmission \\ and\ detection \end{Bmatrix} \rightarrow D(t)\begin{Bmatrix} telegraph, \\ telephone, \\ radio, \\ television \end{Bmatrix}$$

and all based on the theoretical musings of James Maxwell-some theories can indeed be most practical

Electrical Communication

1. Telegraphy

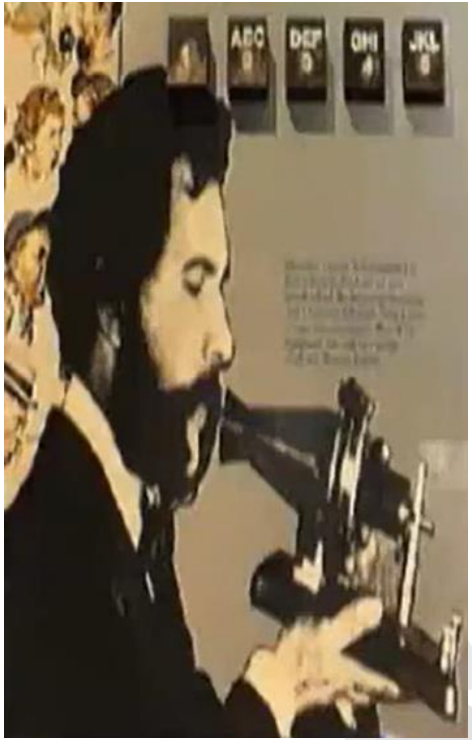
- An early telegraph had been patented in England in 1837 and consisted of a 6-wire battery-driven closed circuit with each letter of the alphabet coded to a current flow in a prespecified number of the six conductors. This system worked well over distances of ~100 km and was used by the railway industry to keep their station masters in formed of railway movements.

- Also in 1837, Samuel Morse, USA, proposed a simpler dot-dash code for the alphabet which could be incorporated into a single wire circuit. It could also be driven by a Voltaic battery and the current would be disrupted by a hand operated tappable key; a corresponding tapping solenoid and diaphragm at the receiver would audibly reproduce the signal. An undersea cable of the English Channel was placed in 1851 and intercontinental telegraphy followed with the first transatlantic cable in 1866. Telegraphy remained a dominant means of long-distance communication for about a century.

Electrical Communication

2. Telephony

A device patented in 1876 by the speech instructor Alexander Graham Bell, Scotland-Canada-USA, which succeeded. Critical to this invention was the vibrational spectrum of a parchment covered granular diaphragm when exposed to speech sound waves. These vibrations would affect the magnetic field of an adjacent electromagnet and induce a corresponding current flow pattern in the battery-driven conducting wire. An inverse process would occur at the receiver's terminus thus reproducing the originating audible sound. In 1878 the first commercial exchange with about 20 subscribers became operational in Boston and in 1884 Boston and New York were linked. The number of telephone installations had grown rapidly and within 100 years it had increased to about 500 million worldwide.



Electrical Communication

3. Radio

- Even before the demonstration of radio waves had been established, James Maxwell, Scotland, had in 1865 formulated a mathematical characterization of the known electrical and magnetic dynamic phenomena which pointed to the existence of an invisible form of radiation propagating through space at the speed of light. Maxwell's idea now suggested: if an electrical phenomenon transmits information in a conducting wire, might not electromagnetic waves also transmit information in the earth's atmosphere? And thus, one may assert, the radio was the first modern device conceived in theory before a working device was demonstrated in practice.
- In 1887, Heinrich Hertz, Germany, provided the first laboratory demonstration of such atmospheric electromagnetic propagation and reception: a resonating circuit was designed to generate a spark between two metallic spheres and the consequent electrical disturbance was transported in air and detected by a near by conducting loop containing a small gap.

Electrical Communication

- A profound long-distance application of this concept of spark gap induced electromagnetic wave propagation was demonstrated in 1901 by Guglielmo Marconi, Italy-England, when a coded dot-dot-dot electrical signal was triggered in England and received in St. John's, Newfoundland. The era of wireless telegraphy transmission, amplification, receiving, and telecommunication, then began with numerous competing inventions and innovations.
- And then, in 1906, Reginald Fessenden, Canada-USA, invented continuous-wave signal transmission and reception, thereby introducing both the radio and the radio-telephone. This invention led to commercial radio and, decades later, provided the basis for television and the wireless telephone.

Electrical Communication

4. Television

- The concept of transmitting spatial shadings of grayness associated with two-dimensional images became of wide interest. Devices for the scanning and reproduction of planar grayness information now became a focus for inventions. The most important perspectives and device developments can be summarized as follows:
- 1884: Paul Nipkow, Germany, introduced a spiral disc which reduced an image to individual pixels of varying levels of grayness.
- 1923: Vladimir Zworykin, Russia-USA, developed an optical scanning device in which an image is projected onto a screen for continuous and sequential scanning by a narrow electron beam; electron reflection being proportional to grayness thus provided an electronic spatial intensity analog of the source image.
- 1926: John Baird, Scotland, used Nipkow discs to produce television images.
- 1927: Philo Farnsworth, USA, constructed an electronic image scanning and transmission device.
- 1939: Beginning of commercial television in the USA.

Air Transport

Air Transport

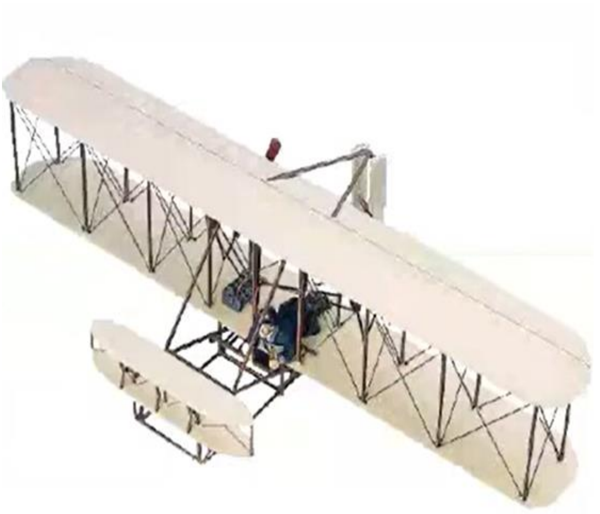
A particularly noteworthy contribution to heavier-than-air devices for flying can be attributed to a multitalented English aristocrat named George Cayley. In the early 1800s, he assembled and further determined much useful information on flying, such as wing area needed to support a given weight, the role of air resistance, stability and control requirements, and eventually specified the need for a power source. Not having such an engine available, he nevertheless did build a marginally effective glider consisting of a 3-wheelplatform suspended from two large wings.

Air Transport

- During the period 1891-1896, Otto Lillienthal, Germany, built various types of shoulder-and-arms harnessed hang glider arrangements which required running downhill to become airborne and by body movement achieve some flight control. He performed about 2000 flights ranging up to 400 min length and in 1896 began work on a powered glider, proposing to use one of the recently developed internal combustion engines. Evidently, Lillienthal was the first human to spend significant time airborne and may well be considered the world's first hang glider.

Air Transport

- The enormous achievement of first controlled powered flight was accomplished by brothers Wilbur and Orville Wright, methodical and highly motivated bicycle mechanics from Dayton, OH. They knew about the Lillienthal experience and in 1900 began assembling and testing large cloth covered wood and wire frame kites and gliders at a windy and sandy barrier island near Kitty Hawk, NC. They began construction of their powered aircraft in1902. This was a 300 kg and 13mwingspan biplane, equipped with a 12kW (16 hp), 4-cylinder, gasoline powered internal combustion engine of their own design and manufacture.



Air Transport

- By 1906 several improved aircraft were flying-including improved versions of the Wright Brother's design. At the first ever air show in Paris in 1910, 40 different aircraft from 10 different manufacturers were on display and in the same year governments started acquiring aircraft for military purposes.
- And thus, was born the phenomenal growth industry suggested by the primal

  $$N(t)\{\text{metals, petroleum}\} \rightarrow E(t)\{\text{aeronautics}\} \rightarrow D(t)\{\text{aircraft}\}.$$

- We need to extract from this heavier-than-air flight history the case of lighter-than-air flying, that is extensions of the Montgolfier 1783 hot-air ballooning experiments, to large hydrogen or helium-filled airships with a gondola suspended below for crew and passengers. In the early 1900s, several countries sponsored construction of such airships, 100 to 250 min length. Publicity about round-the-world airship travel generated much attention and in 1919 regular trans-Atlantic travel was initiated.

Air Transport

Some noteworthy reference events associated with the consequent development of air transport are the following:

- 1919: crossing of the Atlantic (5-man USA crew, refueling in Newfoundland and Azores)
- 1927: solo non-stop crossing of the Atlantic (Charles Lindbergh, 33hours)
- 1928: rocket propelled aircraft testing
- 1933: begin of commercial air transport
- 1939: jet aircraft flight demonstration
- 1942: operational helicopter
- 1953: begin of commercial jet transport

And so, the imaginative writers of sky-transport legends had their dreams become reality with engineers as the ingenious facilitators.

Heavy Industry

Heavy Industry

The Production Of Quality Steel Became Successful For 3 Reasons:

(a) Smelters could be readily expanded with few limitations.

(b) cost of steel production decreased by a factor 10.

(c) Demand for steel increased continually to the mid-1900s.

Specific industries required increasingly expanding steel production:

(a) Railways

Which were among the largest industrial employers with a steadily rising need for steel.

(b) Military

World War I initiated an arms race involving steel for heavier tanks, larger warships, and more lethal small arms

Heavy Industry

(c) Toolmaking and Machinery

Increasing mass production demanded durable tools requiring therefore increasing production of specialty steels.

(d) Structures and Transportation

skyscrapers, large domes, large bridges, expanding automotive, farm implements, and shipping industry.

Steel became widely produced metal power-produced primarily from the burning of coal-and therefore leading to extensive environmental pollution.

Large Structures

Large Structures

With the development of land, air, and sea transport and an expanded network for water and energy distribution, a wide range of large structures appeared:

1. CANALS

Canal construction for irrigation purposes dates to Ancient times and canals for inland transport dates to Renascent times

Canals as a means of oceanic distance-of-travel reduction became of international interest beginning in the mid 1800s.

- The 160 km Suez Canal, constructed over the 10-year period 1859-1869
- The 80 km Panama Canal, built during 1894-1914

2. Bridges

The most publically impressive bridges were the family of suspension designs:

A) Brooklyn bridge

Has a span of 500 m, completed in 1883.

Large Structures

A) Golden gate bridge

Has a span of 1300 m and opened to the public in 1937.

Large Structures

New York subway

1. In 1863, London began to operate the first stage of its Underground Tube.
2. New York's Subway became operational in 1868.
3. Paris began building its Metro in1898.
4. Heavy railroad traffic tunnel usage began with the 14 km Mont Cenis Tunnel in the Alps in 1870.
5. Underwater vehicular travel began in 1920 with the 3 km Holland Tunnel under the Hudson River in New York City.

Large Structures

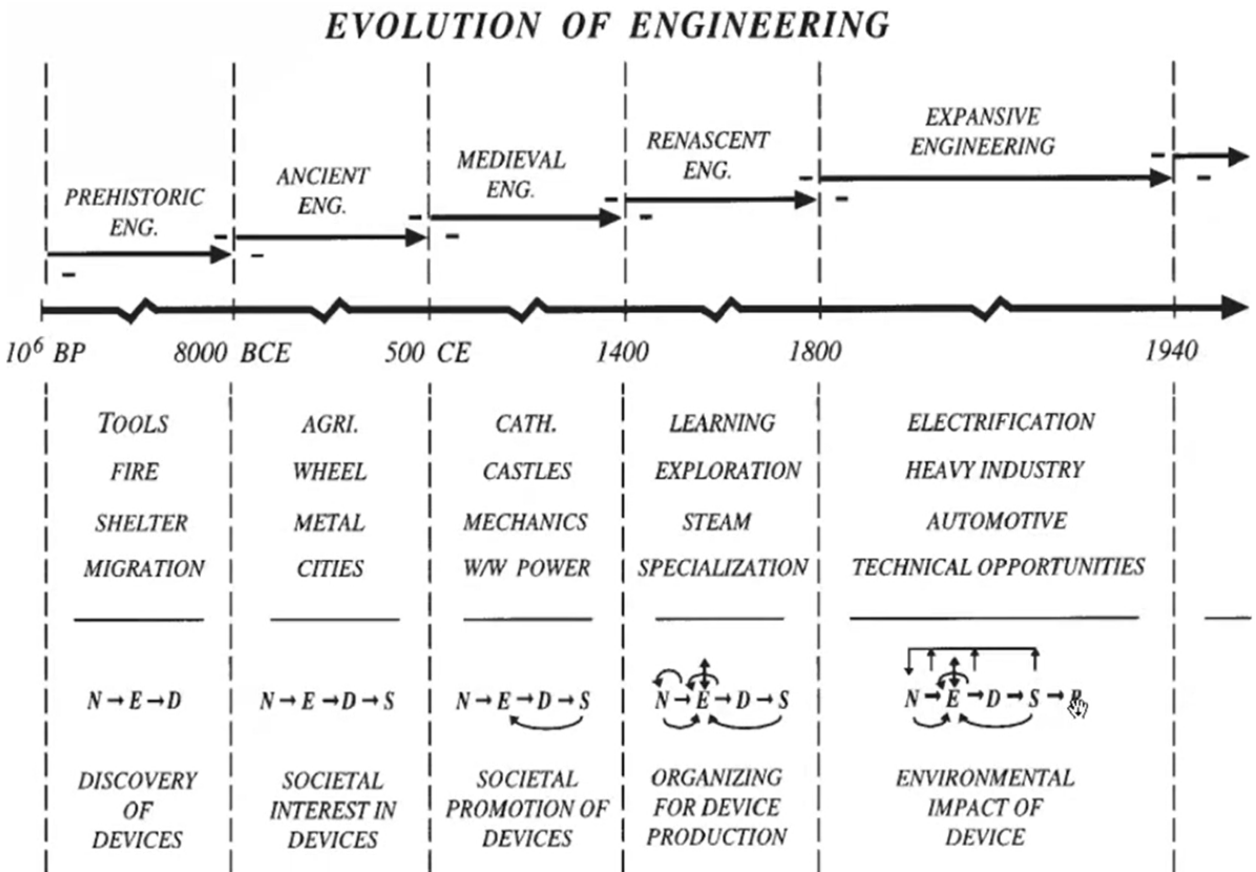
- **Other noteworthy structures of the Expansive Engineering Era.**

The 300 m Eiffel Tower completed in 1884

The 420m Empire State Building which opened in 1931

Summary

Summary


EVOLUTION OF ENGINEERING
PREHISTORIC ENG.
ANCIENT ENG.
MEDIEVAL ENG.
RENASCENT ENG.
EXPANSIVE ENGINEERING
10^6 BP
8000 BCE
500 CE
1400
1800
1940
TOOLS
FIRE
SHELTER
MIGRATION
AGRI.
WHEEL
METAL
CITIES
CATH.
CASTLES
MECHANICS
W/W POWER
LEARNING
EXPLORATION
STEAM
SPECIALIZATION
ELECTRIFICATION
HEAVY INDUSTRY
AUTOMOTIVE
TECHNICAL OPPORTUNITIES
N → E → D
N → E → D → S
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DISCOVERY OF DEVICES
SOCIETAL INTEREST IN DEVICES
SOCIETAL PROMOTION OF DEVICES
ORGANIZING FOR DEVICE PRODUCTION
ENVIRONMENTAL IMPACT OF DEVICE

Thank you !