Title: Inventions in the Century

Author: William Henry Doolittle

Release date: July 18, 2011 [EBook #36776]

Language: English

Credits: Produced by Chris Curnow, Stephanie Kovalchik and the
Online Distributed Proofreading Team at http://www.pgdp.net
(This file was produced from images generously made
available by The Internet Archive)

Transcriber's Notes:

Misspellings in the source text have been corrected.

Missing page entries for "Wooden shoes" was assigned a page number by the transcriber.

Index entry for "Stamfield, Jas." was removed since this name does not occur in the main text.

THE NINETEENTH CENTURY SERIES

INVENTIONS IN THE CENTURY

BY

WILLIAM H. DOOLITTLE

Expert and Patent Solicitor, Ex-Examiner in the Patent Office and Assistant Commissioner of Patents at Washington, Writer of Inventions, etc.

THE LINSCOTT PUBLISHING COMPANY
TORONTO AND PHILADELPHIA

W. & R. CHAMBERS, LIMITED
LONDON AND EDINBURGH

1903

CONTENTS.

PAGE

CHAPTER I.

INTRODUCTORY.
INVENTIONS AND DISCOVERIES.

Inventions and Discoveries.—Distinctions and Contrast.—The One, Useful Contrivances of Man; the Other, New Things Found in Nature.—Galileo and the Telescope.—Newton and the Law of Gravitation.—Often United as Soul and Body.—Inventions and Discoveries do not Precede or Succeed in Order.—Inventions—Alphabetical Writing; Arabic Notation; The Mariner's Compass; The Telescope; The Steam Engine.—Discoveries;—Attraction of Gravitation; Planetary Motions; Circulation of Blood; Velocity of Light.—Nineteenth Century Inventions and Discoveries.—Further Definitions.—Law of Development.—Contrivances, not Creations.—Man Always an Inventor.—Prof. Langley on Slow Growth of Inventions.—Inventions of this Century Outgrowth of Past Ones.—Egyptian Crooked Stick, Precursor of Modern Plough.—Hero of Alexandria and James Watt.—David's Harp and the Grand Piano.—Electrical Science in 1600 and the Present Day.—Evolution and Interrelation of the Arts.—Age of Machine Inventions.—Its Beginning.—The Inducements to Invention.—Necessity not Always the Mother.—Wants of Various Kinds.—Accident.—Governmental Protection the Greatest Incentive.—Origin and Growth of Patent Laws.—Influence of Personal, Political and Intellectual Freedom and Education.—Arts of Civilization Due to the Inventor.—Macaulay's Estimate.—Will Inventions Continue to Increase or Decrease.—Effect of Economic, Industrial and Social Life upon Inventions.—What Inventions have Done for Humanity.—Thread of the Centuries.—The Roll of Inventions too Vast for Enumeration. 1

CHAPTER II.

AGRICULTURE AND ITS IMPLEMENTS.

The Egyptians the Earliest and Greatest Agriculturists.—Rome and Farming.—Cato, Varro, Virgil.—Columella.—Pliny.—Palladius.—The Decline of Agriculture.—Northern Barbarism.—Lowest Ebb in the Middle Ages.—Revival in the Fifteenth and Sixteenth Centuries.—With Invention of Printing.—Publications then, Concerning.—Growth in Seventeenth and Eighteenth Centuries.—Jethro Tull.—Arthur Young.—Washington.—Jefferson.—The Art

Scientifically Commenced with Sir Humphry Davy's Lectures on Soils and Plants, 1802-1812.—Societies.—"Book Farming" and Prejudice of Farmers.—A Revisit of Ruth and Cincinnatus at Beginning of Nineteenth Century.—Their Implements still the Common Ones in Use.—The Plough and its History.—Its Essential Parts and their Evolution to Modern Forms.—Originated in Holland.—Growth in England and America.—Small, Jefferson, Newbold.—Lord Kames' Complaint.—The American Plough.—Cutting Disks.—Steam Ploughs: Implements for Preparing the Soil for Planting.—Various Forms of Harrows. 13

CHAPTER III.

AGRICULTURAL IMPLEMENTS.

The Sowing of Grain.—The Sower of the Parables.—His Art and its Defects Lasted until Nineteenth Century.—The Problems to be Solved.—Assyrian and Chinese Seeding Implements.—India.—Italy First to Introduce a Grain Sowing Machine, Seventeenth Century.—Zanon's Work on Agriculture, 1764.—Austria and England.—A Spaniard's Invention.—Don Lescatello.—The Drill of Jethro Tull.—A Clergyman, Cooke's Machine.—Washington and Others.—Modern Improvements in Seeders and their Operation and Functions.—Force Feed and Gravity Feed.—Graduated Flow.—Divided Feeds for Separate Grains and Fertilizing Material.—Garden Ploughs and Seeders.—Gangs of Heavy Ones.—Operated by Steam.—Corn Planters.—Walking and Riding.—Objects of Proper Planting.—How Accomplished by Machinery.—Variety of Machines.—Potatoes and the Finest Seeds.—Transplanters.—Cultivators.—Their Purposes and Varieties.—Primitive and Modern Toilers.—Millet.—Tillers of the Soil no Longer "Brothers of the Ox." 23

CHAPTER IV.

AGRICULTURAL INVENTIONS.

Harvesting in Ancient Times.—The Sickle.—Pliny's Machine.—Now the Clover Header.—Palladius' Description.—Improved in 1786.—Scotchman's Grain Cradle in 1794.—The Seven Ancient Wonders and the Seven Modern Wonders.—The Modern Harvester and the Cotton Gin.—Requirements of the Harvester.—Boyce.—Meares.—Plucknett.—Gladstone and the First Front Draft Machine, 1806.—Salonen introduced Vibrating Knives over Stationary Blades, 1807.—Ogle and Reciprocating Knife Bar, 1822.—Rev. Patrick Bell, 1823, Cuts an Acre of Grain in an Hour.—Mowers and Reapers in America in 1820.—Reaper and Thresher combined by Lane, of Maine, 1828.—Manning's Harvester, 1831.—Schnebly.—Hussey.—McCormick, 1833-34.—Harvesters and Mowers at World's Fair, London, 1851.—Automatic Binders.—Wire and Twine.—Advances Shown at Centennial Exhibition, 1876.—Inventions Beyond the Wildest Dreams of Former Farmers.—One Invention Generates Another.—Lawn Mowers.—Hay Forks and Stackers.—Corn, Cotton, Potato, Flax Harvesters.—Threshing.—The Old Flail.—Egyptian and Roman Methods.—The First Modern Threshing Machine.—Menzies, Leckie, Meikle.—Combined Harvesters and Threshers.—Flax Threshers and Brakes.—Cotton Gins.—Eli Whitney.—Enormous Importance of this Machine in Cotton Products.—Displacement of Labour. 32

CHAPTER V.

AGRICULTURAL INVENTIONS (*continued*).

Harvest Ended, Comes the Preparation of Grain and Fruits for Food.—Cleaning.—Separating.—Grinding.—Fanning Mills and Sir Walter Scott.—The Rudimentary Mills.—Egyptian.—Hebrew, Grecian, and Roman Methods, Prevailed until Middle of Eighteenth Century.—The Upper and Nether Mill Stone in Modern Dress.—Modern Mills Invented at Close of Eighteenth Century.—Oliver Evans of America, 1755-1819.—Evans' System Prevailed for Three Quarters of a Century.—New System.—Middlings.—Low Milling.—High Milling.—Roller Mills.—Middlings Separators.—Dust Explosions and Prevention.—Vegetable Cutters.—Choppers.—Fruit Parers and Slicers.—Great Range of Mechanisms to Treat the Tenderest Pods and Smallest Seeds.—Crushing Sugar Cane.—Pressing and Baling.—Every Product has its own Proper Machine for Picking, Pressing, Packing, or Baling.—Cotton Compress.—Extensive and Enormous Cotton Crops of the World.—Cotton Presses of Various Kinds.—Hay and its Baling.—Bale Ties.—Fruits and Foods.—Machines for Gathering, Packing, Preserving, etc., all Modern.—Drying and Evaporating.—Sealing.—Transporting.—Tobacco.—Its Enormous Production.—The Interdict of James I., and of Popes, Kings, Sultans, etc.—Variety of Machines for its Treatment. 45

CHAPTER VI.

CHEMISTRY, MEDICINES, SURGERY, DENTISTRY.

Chemistry among the Ancients.—Egyptians.—Phœnicians.—Israelites.—Greeks and Romans.—Chinese.—Became a Science in the Seventeenth and Eighteenth Centuries.—Libavius.—Van Helmont.—Glauber—Tachenius.—Boyle.—Lémery.—Becher.—Stahl.—Boerhaave.—Black.—Cavendish.—Lavoisier.—Priestley.—Chemistry of Nineteenth Century a New World.—Atomic and Molecular Theories.—Light, Heat, and Electricity.—Correlation and Conservation of Forces.—Spectrum Analysis.—Laws of Chemical Changes.—John Dalton.—Wollaston.—Gay.—Lussac.—Berzelius.—Huygens' and Newton's Discoveries in Light in Seventeenth Century.—Unfolded and Developed by Fraunhofer, Kirchoff.—Bunsen in the Nineteenth.—Young of America.—Combination of Spectroscope and Telescope.—Huggins of England, Spectrum Analysis of the Stars.—Heat and other Forces.—Count Rumford.—Davy.—Mayer.—Helmholtz.—Colding.—Joule.—Grove.—Faraday.—Sir William Thomson.—Le Conte and Martin.—French Revolution and Agricultural Chemistry.—Lavoisier, Berthollet.—Guyton.—Fourcroy.—Napoleon.—Sir Humphry Davy.—Liebig.—Fermentation.—Alcohol.—Yeast.—Malt.—Wines.—Beer.—Huxley's Lecture on Yeast, 1871.—Protein.—Protoplasm.—Evolution from one all-pervading Force.—Alcohol and Pasteur.—Manufacture of Liquors.—Carbonating.—Soils and Fertilisers.—Liquids, Oils, Sugar and Fats.—Bleaching and Dyeing.—Aniline Colours.—Perfumes.—Electro-Chemical Methods.—Applied to the Production of Artificial Light.—Abradants.—Disinfectants.—Pigments.—Mineral Analysis.—Purification of Water and Sewage.—Electroplating Metals.—Chemicals and the Fine Arts.—Redemption of Waste Materials.—Medicines and Surgery.—Their Growth from Empiricism.—Anæsthetics.—Davy.—Morton.—Jackson.—Innumerable Medical Compounds.—Antiseptic Treatment of Wounds.—Vast Variety of Surgical Instruments Invented.—Four Thousand Patents in United States Alone.—Dentistry.—Its Ancient Origin.—Account of Herodotus.—Revolution in, during Nineteenth Century.—Instruments.—Artificial Teeth.—Vast Relief from Pain. 58

CHAPTER VII.

STEAM AND STEAM ENGINES.

Prophecy of Dr. Darwin in Eighteenth Century.—Review of the Art from Hero to James Watt.—Pumping Engines.—Road Carriages.—Watt.—Cugnot.—Rumsey.—Fitch.—Oliver Evans.—Read.—Symington.—Trevithick.—Locomotives.—Blenkinsop.—Griffith.—Bramah.—Horse Engine.—Hancock.—Blackett.—George Stephenson.—Hackworth.—Braithwaite.—Ericsson.—Huskisson First Victim of Railroad Accident.—Seguin.—John C. Stevens.—Horatio Allen.—Peter Cooper.—Symington.—Lord Dundas.—Fulton and Livingston.—The First Successful Steamboat.—Transatlantic Steam Navigation.—Scarborough of Georgia.—Bell of Scotland.—Cunard Line; Paddle Wheels.—Screw Propellers.—The Age of Kinetic Energy.—Professor Thurston.—Variety of Engines and Boilers.—Corliss.—Bicycle and Automobile Engines.—Napoleon's Stage Trip and Present Locomotion.—Daniel Webster's Survey of the Art. 73

CHAPTER VIII.

ENGINEERING AND TRANSPORTATION.

The Duties of a Civil Engineer.—Great Engineering of the Past.—The Divisions.—Steam.—Mining.—Hydraulic.—Electrical.—Marine.—Bridge Making, Its Development.—First Arched Iron Bridge.—Darby.—Telford.—Leading Bridges of the Century.—Suspension.—Tubular.—Tubular Arch.—Truss.—Cantilever.—Spider's Web and Suspension.—Sir Samuel Brown.—The Tweed.—Menai Straits and Telford.—M. Chaley and Fribourg.—J. K. Brunel and Isle of Bourbon.—British America and the United States united in 1855—Niagara.—John A. Roebling.—The Brooklyn Bridge.—Caissons and the Caisson Disease.—Tubular Bridge at Menai.—"The Grandest Lift in Engineering."—Robert Stephenson.—The Tubular Arch at Washington.—Captain Meigs and Captain Eads.—St. Louis Bridge.—Truss System and Vast Modern Bridges.—Cantilever Succeeded the Suspension.—New Niagara and River Forth.—Schneider.—Hayes.—Fowler and Baker.—Milton's Description.—Lighthouses.—Smeaton.—Douglass.—Bartholdi.—Eiffel.—Excavating, Dredging, Draining.—Road-making.—Railroads.—Canals.—Tunnels.—Excavating.—Desert Lands Reclaimed.—Holland and Florida Swamps.—The Tunnels of the Alps.—Suez Canal.—Engineering, as seen from a Pullman Car.—Cable Transportation.—Pneumatic Lock System.—Grain Elevators—Progress in Civilisation. 93

CHAPTER IX.

ELECTRICITY.

Theories and Definitions.—Franklin's and a Modern One.—Varieties of the Force.—Generation.—Dynamic Energy.—Discoveries before the Nineteenth Century.—Magnetism and Electricity.—Fathers of the Science.—Doctor Gilbert.—Otto von Guericke.—Sir Isaac Newton.—Gray.—Dufay.—Professor Muschenbroeck.—Cuneus.—Charles Morrison.—Franklin and Galvani.—Volta.—The Door to Nineteenth Century Inventions then Opened.—Fabroni.—Sir Humphry Davy, Wollaston, Nicholson, and Carlisle.—Ritter Followed—Electrolysis.—Faraday and its Laws.—Davy and the Electric Light.—Batteries.—Daniell.—Grove.—Bunsen.—Brilliant Discoveries from 1800 to 1820.—Oersted, Schweigger.—Magnetising Helix.—Indicators.—Arago and Davy.—Ampère's Discoveries.—Sturgeon and the first Electro-Magnet, 1825.—Telegraphy.—Gauss, Weber, Schilling.—Professor Barlow's Demonstration that Telegraphy was Impracticable.—Joseph Henry.—Powerful Magnets.—Modern and Ancient Telegraphy of Various Kinds.—The Third Decade.—George Simon Ohm.—Steinheil.—Telegraph of Morse, Vail, Dana, Gale.—Wheatstone.—U.S. Supreme Court on Morse System.—His Alphabet and Submarine Telegraph.—Michael Faraday and

Science of Magnets.—Steam and Magneto-Dynamo Machines.—Chemical Affinity and Electricity.—Helmholtz, Faraday, Henry, and Pixii.—Ruhmkorff Coil.—Page.—Electrical Light.—Decomposition of Water.—Professor Nollet.—First Practical Electric Light Shone on the Sea, 1858.—Faraday and Holmes.—Lighthouse Illumination.—Dr. W. Siemens.—Wilde's Machine.—Other Powerful Magnetic Machines.—Field Magnets.—Z. Gramme.—The Various Ways and Means of Developing Electric Light.—Geissler Tubes.—First House Lighted in America.—Moses G. Farmer.—Jablochoff's Candle.—French Regulators.—Outdoor and Indoor Illumination.—Siemens, Farmer, Brush, Maxim, Westinghouse, Edison, Swan, Lane—Fox and Others.—Arc Lamps of Heffner von Alteneck.—Ocean Cables.—Cyrus W. Field.—John Bright's Expression.—Weak Currents.—Thomson's Remedy.—Mirror Galvanometer.—Centennial Exhibition and the Telephone.—Alexander Graham Bell, 1875.—The Telephone and Helmholtz' Theory of Tone.—Scott's Phonautograph.—Page's Production of Galvanic Music and Researches of Reis.—Its Slow Growth.—The Ideas of Faraday and Henry still the Basis of the Great Machines.—"Lines of Force."—Electric Railway.—Storage Batteries.—Dynamos.—First Railway at Berlin, 1879.—Then Saxony, Paris, London, New York.—Telpherage by Professor Jenkin.—Problems Solved.—Electrical Magicians.—Edison and Tesla.—Recent Improvements in Telegraphy.—The Talks Both Ways at Same Time and Multiplied.—Printing Systems by Types and Otherwise.—Electrical Elevators.—Microphone.—Ticks of a Watch and the Tread of a Fly Recorded.—Musical Sounds from Minerals and Other Substances.—Signalling and Other Appliances.—The X Rays.—Wireless Telegraphy. 111

CHAPTER X.

HOISTING, CONVEYING, AND STORING.

Drudgery of Ancient Times Relieved by Modern Inventions.—The Labour of Men and Beasts now Done by Steam Giants.—Labour-Saving Appliances for Transportation.—Tall Buildings and Elevators.—Evolution Slow until 19th Century.—Carrying of Weights.—The Pyramids.—Modern Methods.—Ship-Loading.—The Six Ordinary Powers Alone Used until the Time of Watt.—Elevator Mills of Oliver Evans.—The Hydraulic Press of Bramah.—The Lifting of Tubular Bridge by Robt. Stephenson.—Compressed Air Elevator of Slade.—Counterbalance Lifts of Van Elvean.—Modern Elevator of Otis, 1859.—Steam-Water.—Compressed Air.—Electricity: Elevators, how Controlled.—Store Service Conveyors.—Pneumatic Transmission: Dodge's Air Blast Conveyor.—Mode of Switching Conveyors.—"Lazy Tongs" Conveyors.—Buffers.—Endless Cables.—Clutches, Safety.—Labour-Saving Devices and Derangement of Labour.—In One Sense, Inventions Labour-Increasing Devices. 152

CHAPTER XI.

HYDRAULICS.

Old as the Thirst of Man.—Prehistoric Inventions.—China.—Pliny's Record.—Egyptian, Carthaginian, Greek and Roman Water Works.—"Pneumatics of Hero."—Overshot, Undershot, and Breast Wheels, Ancient.—Screw of Archimedes.—Frontinus, a Roman Inspector.—1593, Servière Invents the Rotary Pump.—1586, Stevinus of Holland, Father of the Elementary Science.—Galileo, Torricelli, Pascal, and Sir Isaac Newton in the Seventeenth Century.—Bernoulli, D'Alembert, Euler, Abbé Bossut, Venturi, and Eylewein in the Eighteenth.—Water Distribution then Originated.—Peter Maurice and the London Bridge Pumps.—La Hire's Double Acting Pump.—Dr. John Allen and David Ramsey of England.—Franklin's Force Pump.—Water Ram of Whitehurst and Montgolfier.—Nineteenth Century Opens with Bramah's Pumps.—Water and Steam.—Pumps the Strong Hands of Hydraulics.—Review of Past Inventions: Pascal's Paradox.—Turbines of Forneyron.—Power of Niagara and Turbines there.—Jonval's.—Euler's Old Centrifugal Pumps Revived.—Massachusetts and Appold Systems.—Lowlands of Holland, Marshes of Italy, Swamps of Florida, Drained.—Injectors.—Giffard.—Intensifiers.—Hydraulicising.—Hydraulic Jack and Cleopatra's Needle.—Flow of Cold Metal.—Lead Pipe Made, and Cold Steel Stretched by Water Pressure.—Cotton Presses, Sir Wm. Armstrong's Inventions.—Tweddle and Sir Wm. Fairbairn.—Water Motors.—Baths and Closets.—Results of Modern Improvements.—Germ Theory and Filters. 164

CHAPTER XII.

PNEUMATICS AND PNEUMATIC MACHINES.

The Slow March of the Human Mind.—Burke.—The Age of Mechanical Inventions not until nearly Watt's Steam Engine.—Review of "Learning" until that Time.—Motor Engines not Produced until Seventeenth Century.—Suggested by the Bellows and the Cannon.—Huygens and Papin.—Van Helmont the Author of the Term "Gas," 1577-1644.—Robert Boyle and the Air Pump.—Law of Gases.—Mariotte.—Abbé Hauteville, 1682.—The Heart and a Motor.—Sun Burner.—Murdock, 1798, Uses Coal Gas for Illumination.—John Barber and Carburetted Hydrogen.—Street's Heated Gas.—1801, Lebon Proposes Coal Gas Motor.—Investigations of Dalton and Gay-Lussac, 1810.—Heat engines: Air, Gas, Steam, Vapor, Solar.—Explosive.—Temperature the Tie that Binds them as One Family.—1823-26, Sir Samuel Brown.—Gunpowder and Gas Engine.—Davy and Faraday.—Gas to a Liquid State.—

Wright, 1833.—Burdett's Compressed Air Engine, 1838.—Lenoir's.—Hugon's.—Beau de Rohes' Investigations.—Oil Wells of United States, 1860.—Petroleum Engines.—Brayton, Spiel.—Otto's Gas Engine and Improvements.—Ammoniacal Gas Engines.—Nobels' Inventions.—Storm's Gunpowder Engine.—Gas and Vapour Compared with Steam.—Prof. Jenkins' Prediction.—Gas to Supplant Steam.—Compressed Air Engines.—Innumerable Applications of Pneumatic Machines.—A Number Mentioned.—Their Universal Application to the Useful and Fine Arts. 182

CHAPTER XIII.

ART OF HEATING, VENTILATING, COOKING, REFRIGERATING AND LIGHTING.

Prometheus and the Modern Match.—1680, Godfrey Hanckwitz Invented First Phosphorous Match.—Other Forms of Matches.—Promethean Matches in 1820.—John Walker.—Lucifer.—Tons of Chemicals, Hundreds of Pine Trees Yearly Made into Matches.—Splints and Machines.—Reuben Partridge.—Poririer.—Pasteboard Box.—Machines for Assorting and Dipping, Drying and Boxing.—Cooking and Heating Stoves.—History of, from Rome to Ben Franklin.—The Old-Fashioned Fireplace.—Varieties of Coal Stoves.—Stove Fireplace.—Ventilation.—Hot Air Furnaces.—How Heat is Distributed, Retained, and Moistened.—Hot Water Circulation.—Incubators.—Baking Ovens, the Dutch and the Modern.—Vast Number of Stove and Furnace Foundries in United States.—Ventilation.—Parliament Buildings and U. S. Capitol.—Eminent Scientific Men who have Made Ventilation a Study.—Best Modes.—Its Great Importance.—Car Heaters.—Grass and Refuse Burning Stoves.—Oil, Vapour, and Gas Stoves, their Construction and Operation.—Sterilising.—Electric Heating and Cooking.—Refrigeration.—Messrs. Carré of France, 1870.—Artificial Ice.—Sulphuric Acid and Ammonia Processes.—Absorption and Compression Methods Described.—Refrigerating Cars.—Liquid Air. 199

CHAPTER XIV.

METALLURGY.

The Antiquity of the Art.—The "Lost Arts" Rediscovered.—The Earliest Forms of Smelting Furnaces.—Ancient Iron and Steel.—India and Africa.—Early Spain and the Catalan Furnace.—The Armour of Don Quixote.—Bell's History of the Art.—Germany.—Cast Iron Made by Ancients, Disused for 15 Centuries.—Reinvented by Page and Baude in England, 1543.—German Furnaces.—Dud Dudley, the Oxford Graduate and his Furnace, 1619.—Origin of Coke in England.—Use in United States.—Revival of Cast Iron.—Cast Steel in England, Huntsman, 1740.—Henry Cort and Puddling, 1784, and its Subsequent Wonderful Value.—Steam Engine of Watt and Iron.—Refining of Precious Metals.—Amalgamating Process.—Review of the 18th Century.—Herschel's Distinction of Empirical and Scientific Art.—The Nineteenth Century, Scientific Metallurgy.—Steam, Chemistry, Electricity.—Rogers' Iron Floor.—Neilson's Hot Air Blast, 1828, Patent Sustained.—Anthracite Coal.—Colossal Furnaces.—Gas Producers.—Bunsen's Experiments.—Constituents of Ores.—Squeezing Process.—Burden's Method.—Mechanical Puddlers.—Rotary.—Henry Bessemer's Great Process—1855-1860.—Steel from Iron.—Holley's Apparatus.—Effects of and Changes in Bessemer Process.—Old Methods and Means Revived and Improved.—Eminent Inventors.—New Metals and New Processes Discovered.—Harveyised Steel.—Irresistible Projectiles and Impenetrable Armour Plate.—Krupp's Works.—Immense Manufactures in United States.—Treatment of Gold, Silver, Copper, Lead, etc.; Mining Operations, Separation, Reduction.—Chemical Methods: Lixiviation or Leaching.—MacArthur.—Forrest.—Sir Humphry Davy.—Scheele.—Chlorine and Cyanide Processes.—Alloys.—Babbitting.—Metallic Lubricants.—Various Alloys and Uses.—Reduction of Aluminium and other Metals.—Electro-Metallurgy.—Diamonds to be Made.—All Arts have Waited on Development of this Art. 218

CHAPTER XV.

METAL WORKING PROCESSES AND MACHINES.—TUBE MAKING.—WELDING.—ANNEALING AND TEMPERING.—COATING AND METAL FOUNDING.—METAL WARE.—WIRE WORKING.

Metal Working Tools One of the Glories of 19th Century.—Wood Working and Metal Working.—Ancient and Modern Lathe.—Turning Metal Lathe.—A Lost Art in Use in Egypt and in Solomon's Time.—Revived in Sixteenth Century.—Forgotten and Revived again in Eighteenth.—Sir Samuel Bentham and Joseph Bramah Laid Foundation of Nineteenth Century Tools.—The Slide Rest and Henry Maudsley.—Nasmyth's Description.—Vast Rolls, and Most Delicate Watch Mechanisms, cut by the Lathe and its Tools.—Metal Planing.—Eminent Inventors, 1811-1840.—Many Inventions and Modifications Resulting in a Wonderful Evolution.—Metal-Boring Machines.—Modern Vulcan's Titanic Work-Shop.—Screw Making.—Demand Impossible to Supply under Old Method.—Great Display at London Exhibition, 1851, and Centennial, Philadelphia, 1876.—J. Whitworth & Co., of England, Sellers & Co., of America, and Others.—The Great Revelation.—Hoopes and Townsend and the Flow of Cold, Solid Metal.—Cold Punching, etc.—Machine-Made Horse-

Shoes.—The Blacksmith and Modern Inventions.—Making of Great Tubes.—Welding by Electricity, and Tempering and Annealing.—How Armour Plate is Hardened.—Metals Coated.—Electro-Plating and Casting.—Great Domes Gilded.—Moulds for Metal Founding.—Machines and Methods.—Steel Ingots.—Sheet Metal and Personal Ware.—Great Variety of Machines for Making.—Wire Made Articles.—Description of Great Modern Work-Shop. 240

CHAPTER XVI.

ORDNANCE, ARMS, AMMUNITION, AND EXPLOSIVES.

This Art Slow in Growth, but no Art Progressed Faster.—The Incentives to its Development.—The Greatest Instruments in the New Civilisation.—Peace and its Fruits Established by them.—Its History.—Chinese Cannon.—India.—The Moors.—Arabs.—Cannon at Cordova in 1280.—The Spaniards and Gibraltar, 1309.—The Spread of Artillery through Europe.—Description of Ancient Guns.—Breech Loaders and Stone Cannon Balls.—Wrought Iron Cannon and Shells in 15th Century.—Big Cannon of the Hindoos and Russians.—Strange Names.—France under Louis XI.—Improvements of the Sixteenth Century.—Holland's Mortar Shells and Grenades in the Seventeenth.—Coehorn Mortars and Dutch Howitzers.—Louis XIV.—French Artillery Conquers Italy.—Eighteenth Century.—"Queen Ann's Pocket Piece."—Gribeauval the Inventor of the Greatest Improvements in the Eighteenth.—His System Used by Bonaparte at Toulon, the French Revolution, and in Italy.—Marengo, 1800.—Small Arms, their History.—From the Arquebus to the Modern Rifle.—Rifle, the Weapon of the American Settler, and the Revolution.—Puckle's Celebrated Breech-Loading Cannon Patent, and Christian and Turk Bullets.—1803, Percussion Principle in Fire-arms, Invented by a Clergyman, Forsyth.—1808, Genl. Shrapnel.—Bormann of Belgium.—1814, Shaw and the Cap.—Flint Locks Still in Use, 1847.—Colt's Revolvers, 1835-1851.—History of Cannon again Reverted to.—Columbiads of Bomford.—Paixhan in 1822.—Shells of the Crimea.—Kearsarge and Alabama.—Requirements of Modern Ordnance.—Rodman One of the Pioneers.—Woodbridge's Wire Wound Guns, Piezometer, and Shell Sabot.—Sir William Armstrong and Sir Jos. Whitworth.—Krupp's Cannon and Works.—The Latest Improvements.—Compressed Air Ordnance.—Constructions of Metals and Explosives.—The "Range Finder."—Small Arms again Considered.—History of the Breech Loader and Metallic Cartridges.—Wooden Walls and Stone Forts disappeared.—Monitor and Merrimac.—Blanchard and Hall.—Gill.—Springfield Rifle.—Machine Guns.—Electric Battery.—Gatling's, Hotchkiss'.—Explosives.—Torpedoes.—Effect of Modern Weapons. 252

CHAPTER XVII.

PAPER AND PRINTING, TYPEWRITING AND THE LINOTYPE.

Paper-making Preceded the Art of Printing.—The Wasp Preceded Man.—The Chinese, the Hindoos, Egyptians, and other Orientals had Invented Both Arts.—History of Papyrus.—Parchment.—Twelfth Century Documents Written on Linen Paper still Extant.—Water Marks.—Wall Paper, Substitute for Tapestry, 1640.—Holland in Advance, Seventeenth Century.—Rittenhouse of Holland Introduces Paper-Making in America, Eighteenth Century.—Paper a Dear Commodity.—The Revolution of the Nineteenth Century.—400 Different Materials now Used.—Nineteenth Century Opens with Robert's Paper-Making Machine.—Messrs. Fourdrinier.—Immense Growth of their System.—Modern Discoveries of Chemists.—Soda Pulp and Sulphite Processes.—Paper Mills.—Paper Bag Machines, etc.—Printing.—Chinese Invented Both Block and Movable Types.—European Inventors.—The Claims of Different Nations.—From Southern Italy to Sweden.—Spread of the Art.—Printing Press and the Reformation.—First Printing Press in New World Set up in Mexico, 1536.—Then in Brazil.—Then in 1639 in Massachusetts.—Types and Presses.—English and American.—Ramage and Franklin.—Blaew of Amsterdam.—Nineteenth Century Opens with Earl of Stanhope's Hand Press.—Clymer of Philadelphia, 1817.—The First Machine Presses.—Nicholson in Eighteenth.—Konig and Bauer in Nineteenth Century, 1813.—London Times, 1814.—1815, Cowper's Electrotype plates.—1822, First Power Press in United States.—Treadwell.—Bruce's Type Casting Machines.—Hoe's Presses.—John Walter's.—German and American Presses.—Capacities of Modern Presses.—Mail Marking.—Typewriting.—Suggested in Eighteenth Century.—Revived by French in 1840.—Leading Features Invented in U. S., 1857.—Electro-Magnet Typewriters.—Cahill.—Book-binding.—Review of the Art.—Linotype "Most Remarkable Machine of Century."—Merganthaler.—Rogers.—Progress and Triumphs of the Art. 273

CHAPTER XVIII.

TEXTILES.

The Distaff and the Spindle, without a Change from Ancient Days to Middle of Fourteenth Century.—Ancient and Modern Cloth Making.—Woman the Natural Goddess of the Art.—The Ancient and Isolated Weavers of Mexico.—After 40 Centuries of Hand-Weaving Comes John Kay, of England, 1733.—The Spinning Machines of Wyatt and Hargreaves.—1738-1769, Richard Arkwright.—The "Spinning Jenny" and the "Throstle."—The Steam Engine and Weaving.—1776, Crompton and the "Mule."—1785, Cartwright and Power Looms.—1793, Eli Whitney and the Cotton Gin.—1793-1813, Samuel Slater, Lowell, and Cotton

Factories of America.—The Dominion of the Nineteenth Century.—What it Comprises in the Art of Spinning and Weaving.—Description of Operations.—Bobbins of Asa Arnold and the Ring Frame of Jenks.—Spooling Machines.—Warping and Dressing and other Finishing Operations.—Embroidery.—Cloth Finishing.—The Celebrated Jacquard Loom.—Jacquard and Napoleon.—Bonelli's Electric Loom.—Fancy Woollen Looms of George Crompton.—Bigelow's Carpet Looms.—Figuring, Colouring, Embossing.—Cloth Pressing and Creasing.—Felting.—Ribbons.—Comparison of Penelopes of Past and Present.—Knitting Days of our Grandmothers and Knitting Machines.—A Mile of Stockings.—Fancy Stocking and Embroidery Machines.—Netting and Turkish Carpets.—Matting.—Spun Glass, etc.—Hand, and the Skilled Labour of Machinery. 292

CHAPTER XIX.

GARMENTS.

"Man is a Tool-using Animal, of which Truth, Clothes are but one Example."—Form of Needle not Changed until 1775.—Weisenthal.—Embroidery Needle.—Saint's Sewing Machine, 1790.—John Duncan's Tamboring Machine, 1804.—Eye Pointed Needles for Rope Matting, 1807.—Madersperger's Sewing Machine, 1814.—France and the Thimonnier Machine, 1830-1848-50, Made of Wood.—Destroyed by Mob.—English Embroidering Machine, 1841.—Concurrent Inventions in Widely Separated Countries.—Thimonnier in France, Hunt in America, 1832, 1834.—Elias Howe, 1846.—Description of Howe's Inventions.—Recital of his Struggles and final Triumphs.—The Test of Priority.—Leather Sewing Machines of Greenough and Corliss, 1842-43.—Bean's Running Stitch, 1843.—The Decade of 1849-1859, Greatest in Century in Sewing Machine Inventions.—Hood's "Song of the Shirt," a Dying Drudgery.—Improvements after Howe.—Blodgett and Lerow's Dip Motion.—Wilson's Four-Motion Feed.—Singer's Inventions, their Importance, his Rise from Poverty to Great Wealth.—The Grover and Baker.—The Display in 1876 at the Centennial.—Vast Growth of the Industry.—Extraordinary Versatility of Invention in Sewing and Reaping Machines, and Breech-Loading Fire-arms.—Commercial Success due to Division of Labour and Assembling of Parts.—Innumerable Additions to the Art.—Seventy-five Different Stitches.—Passing of the Quilting Party.—Embroidery and Button-hole Machines.—Garment-cutting Machines.—Bonnets and Inventions of Women.—Hat Making.—Its History.—Bonjeau's Improvements in Plain Cloths, 1834.—Effect of Modern Inventions on Wearing Apparel and Condition of the Poor.—The Epoch of Good Clothes. 310

CHAPTER XX.

INDUSTRIAL MACHINES.

Inventions Engender Others.—Co-operative Growth.—Broom Making.—Crude Condition until the Modern Lathe, Mandrel, Shuttle and Sewing Machine.—Broom Sewing Machines.—Effect on Labour.—The Brush and Brush Machines.—A Hundred Species of Brushes, each Made by a Special Machine.—First Successful Brush Machine, Woodbury's, 1870.—Wonderful Operations.—Street-Sweeping Machines, 1831.—Most Effective Form.—Abrading Machines.—Application of Sand Blast.—Nature's Machine Patented by Tilghman in 1870.—Things Done by the Sand Blast and How.—Emery and Corundum Machines.—Vast Application in Cutting, Grinding, Polishing.—Washing and Ironing Machines.—Their Contribution to Cleanliness and Comfort.—Laundry Appliances.—Old and the New Mangle.—Starch Applying.—Steam Laundry Machinery.—Description of Work done in a Modern Laundry. 328

CHAPTER XXI.

WOOD-WORKING.

Contrast of Prehistoric Labour and Implements and Modern Tools.—The Ages of Stone, Bronze, Iron, and the Age of Wood.—The Slow Growth of Wood-working Inventions.—Tools of the Egyptians.—Saw of the Greeks.—Known to Hindoos and Africans.—Accounts of Pliny and Ansonius as to Planes and Marble Sawing.—Saw-mills of France, Germany, Norway, Sweden.—Holland 100 Years ahead of England, and Why.—William Penn Found Saw-mills in America in 1682.—What made Americans Inventors.—Progress Unknown where Saw-mills are not.—Steam and Saw Mills.—Splendid System and Inventions of Samuel Bentham, Bramah and Branch at Close of Eighteenth Century.—First Decade of Nineteenth Century Produces Wonderful Inventor, Thomas Blanchard.—His Life and Inventions.—Machines for Turning Irregular Forms in Wood and Metal.—The Boring Worm and Boring Machine.—Gun-making and Mortising Machines.—Complicated Ornamental Wood-cutting and Carving Machines.—Whatever Made by Hand can be Better Made by Machinery.—Pattern-Cutting Machines.—Xyloplasty.—Art of Hand Carving Revived.—Bending of Wood by Fire and Steam.—The Problems Solved by Wood-working Inventors.—Great Saws at the Vienna Exposition, 1873.—Boring Tools, Augers, Planes, Lathes, etc. How Improved and by Whom.—"The Universal Wood Workers."—Flexible Shafting.—Shingles and Tiles.—A Great Log, how Turned into Bundles of Shingles.—Veneering.—What Pliny Thought of It.—Brunel's Machines, 1805-1808.—Homes Made Beautiful by Modern Wood-working.—Objects without and Within a House, Made by Such Machinery.—Array of Wood-working Machinery at International Expositions.—The Art of Forestry. 339

CHAPTER XXII.

FURNITURE.—BOTTLING, PRESERVING, AND LAMPLIGHTING.

Universal Supply of Convenient and Ornamental Furniture Due to Modern Inventions and Machinery.—The Furniture of the Egyptians, Greeks and Romans.—Tables.—Modern Improvements.—Combined Tables, Desks, and Chairs.—Special Forms of Each.—Beds: Advance from the Ponderous Bedsteads of Former Times.—Modern, Ornamental, Healthful Styles.—Iron, Brass, Springs, Surgical and Invalid Chairs and Beds.—Kitchen Utensils.—Vast Amount of Drudgery Relieved.—Curtains, Shades, and Screens.—Great Changes Produced by Steaming and Bending Wood.—The Bentwood Ware Factories of Austria, Hungary, Moravia (1870-73), in Vast Beech Forests Followed in other Countries.—Modern Chairs of Various Kinds.—The Dentist and the Theatre.—Bottle Stoppers.—Enormous Demand for Cork Exhausting the Supply.—Modern Substitutes.—Fruit Jars, etc.—Lamplighting, Ancient and Modern.—Revolution Produced by Petroleum.—Wickless and Electric Lamps. 354

CHAPTER XXIII.

LEATHER.

Leather and Prehistoric Man.—Earliest Implements and Processes Forerunners of Modern Inventions.—Modern Leather Unknown to the Earliest Races.—Tanning.—Leathers of Different Nations.—Hand Tools and Variety of Operations.—Inventions of Nineteenth Century—Labour-Saving Machinery and New Processes.—Epoch of Modern Machinery.—1780, John Bull and his Scraping Machine, Hide-mill, Pioneer Machine of Century.—Fleshing Machines.—Tanning Apparatus.—Reel Machines.—Tanning Processes and the Chemists.—Machines for Different Operations.—Pendulum Lever Machine.—Leather Splitting, and other Remarkable Machines.—Boots and Shoes, their Character before Modern Inventions.—Randolph's Riveting Machine of 1809.—Great Civil Engineer, J. M. Brunel's Machines.—1818, Walker Invents the Wooden Peg.—Peg-making Machines.—1858, Sturtevant's Great Improvement.—Fifty-five Million Pairs of Boots and Shoes then Annually Pegged.—Metal Wire, and Screw Pegs.—Last-turning Machines of Blanchard.—McKay's Shoe Sewing Machine.—Revolution in Shoe Making.—Special Machines for Making Every Part.—One Machine Makes 300 Pairs a Day.—Many Millions made Daily.—Vast Increase of Labourers as the Art Advances.—Illustrations of Yankee Enterprise.—Modern and Ancient Harnesses.—Embossed Leather.—Book Covers and the many Useful and Beautiful Leather Articles.—The Vast and Important Leather Manufactures. 361

CHAPTER XXIV.

MINERALS.—WELLS.

Ancient Tools and the Art of Building.—The Parthenon.—Aqueducts of Rome.—Tombs of India.—Halls of Alhambra.—Gothic Cathedrals.—Steam First Drew Coal, then Sawed Wood and then Stone.—Stone-cutting Machinery.—Carving.—Dressing.—Drilling.—Tunnels.—Wonderful Work of Stone-Boring Machine on Pillars of Ohio State Capitol.—Stone Drills and Compressed Air.—Hell Gate.—Crushing Stones and Ores.—Blake's Crusher.—"Road Metal."—Different Form of Crushers.—Assorting Coal.—Steam and Coal, strong Brothers.—Compressed Air for Mining Machinery.—Mighty Picks Driven by Air.—Electric Motor.—Machines for Screening, Loading, and Weighing.—Ore Mills.—Separators.—Centrifugal Action.—Ore Washing.—Amalgamators: Electric, Lead, Mercury, Plate, Vacuum, Vapour, etc.—The Revolution in Mining.—Well Boring an Ancient Art.—Artesian Wells.—Coal Oil and Coal Wells.—Preceded by Discovery of Paraffine and its Uses.—Reichenbach, Young.—Petroleum Discovery.—New Industry.—Col. Drake and First Oil Well.—Sudden Riches of Farmers.—Boring Water Wells.—Green's Driven Wells.—The Deserts Made to Bloom as the Rose. 373

CHAPTER XXV.

HOROLOGY AND INSTRUMENTS OF PRECISION.

Time Measuring Instruments of Antiquity.—Sun-dial.—Clepsydra, Hour-glass, Graduated Candle.—Plato's Bell.—The Clepsydra of Ctesibius.—Incense Sticks of Chinese.—Sun-dials of Greeks and Romans.—Candles of Alfred the Great.—Wonderful Clocks of the Middle Ages.—Henry de Vick of France, 1370.—Two Hundred Years without Advance.—Astronomers, Brache and Valherius.—1525, Zech's Fusee.—Progenitors of Modern Watch, 1500.—1582, Swinging Lamp of Galileo.—1639, Galileo's Book.—Huygens and the Pendulum.—Dr. Hooke's and David Ramsey's Inventions.—Hair-Spring Balances.—George the Third's Small Time-Piece.—Eighteenth Century Division of Time Pieces into Hours, Minutes and Seconds.—Stem Winders.—Astronomical Discoveries and Chronometers.—Dutch, Leading Clockmakers; Germany, Switzerland.—Systems Followed in these

Countries.—Minute Sub-divisions of Labour.—Watch and Clock Making in the United States.—American System.—Wonderful Machines for every Part.—Watch factories.—Pope's Simile.—Revolution in Nineteenth Century.—Electric System.—4000 Patents in U.S. since 1800.—Registering Devices.—"A Mechanical Conscience."—Cash Registers.—Voting Machines.—Electrical Recorders.—Cyclometers.—Speed Indicators.—Weighing Scales and Machines, History of.—The Fairbanks of Vermont, 1831.—Platform and other Scales.—Spring Weighing.—Automatic Recorders of Weight and Prices.—Testing Machines, English, German, American.—The Emery Scales.—Gages, Dynamometers.—Hydraulic Testing.—Delicate Operations.—Strength of a Horse-hair and Great Steel Beam, Tested by Same Machine.—Effect on Public Works. 384

CHAPTER XXVI.

MUSIC, ACOUSTICS, OPTICS, PHOTOGRAPHY, FINE ARTS.

Musical Instruments Old as Religion.—Abounded before the Lyre of Apollo or the Harp of Orpheus.—Their Evolution.—To Meet Wants and Growing Tastes.—Nineteenth Century and the Laws of Helmholtz.—The Story of the Piano, the Queen, Involves whole History of the Art of Music.—Ancient Harp and Growth.—Psaltery and Dulcimer of Assyrians and Hebrews.—No Inventions by Greeks and Romans in this Art.—Fifteenth Century and the Clavicitherium.—Sixteenth Century, the Virginal and the Spinet.—Seventeenth Century, the Clavichord and Harpsichord.—Italian Cembello.—Bach, Mozart, Handel, Haydn.—Cristofori of Florence, Schreiber of Germany and Modern Piano.—Eighteenth Century, Pianos of Broadwood and Clementi of London, Erard of Strasburg, Petzold of Paris and Others.—Two Thousand Years Taken to Ripen the Modern Piano.—Description of Piano Parts.—Helmholtz's Great Work, 1862.—Effect on System of Music and Musical Instruments.—The Organ, King in the Realm of Music.—History of, from Earliest Times.—Improvements of the Nineteenth Century.—The Auto-harp.—Self-playing Instruments.—The Science of Acoustics and Practical Applications.—Auricular Tubes.—Telephone, Phonograph, Graphophone, Gramophone.—Their Evolution and their Inventors.—Optical Instruments.—Their Growth.—Lippersheim, Galileo, Lieberkulm, John Dolland.—The Improvements and Inventors of the Nineteenth Century.—Brewster and the Kaleidoscope, Stereoscope.—Lenticular Lenses.—Lighthouse Illumination.—Faraday and Tyndall.—Abbé Moigno's Troubles.—Ophthalmoscope.—Spectroscope.—Making of Great Lenses.—Solarmeter.—Measuring the Position and Distances of Unseen Objects.—Light Converted into Music.—Daguerre and Photography.—History and Development.—Colour Reproduction.—Pencils.—Painting.—Air Brushes.—Telegraphic Photographs. 400

CHAPTER XXVII.

SAFE AND LOCKS.

Safes, how Constructed before this Century.—Classification.—Century Starts out to Make Safes Fireproof.—Scott in 1801.—Marr, 1834.—Result of Great Fire in New York, 1835.—Wilder's and Herring's Safes.—Burglar-proof Safes, 1835.—Chubb, Newton, Thompson, Hall, Marvin and Others.—Electricity.—Seal Locks from 1815.—Locks of Various Kinds in Ancient Days.—Of Ponderous Size.—Key of the House of David.—Lock of Penelope's House.—Locks of the Middle Ages.—Letter Locks of the Dutch, 1650.—Carew's Verse.—Eighteenth Century Locks.—Tumblers.—Joseph Bramah's Locks.—Combination, Permutation and Time Locks.—Yale Locks.—Modern Locks Invented for Special Uses.—Master or Secondary Key Locks.—Value of Simple, Cheap, Effective Locks.—Mail Locks and Others.—Greater General Security for Property of all Kinds now Obtained. 420

CHAPTER XXVIII.

CARRIAGES AND CARRYING MACHINES GENERALLY.

Review of Conveyances from Time of Ptolemy's Great Procession, 270 B. C., until Nineteenth Century.—The Old Stage Coaches.—Coaches of the Rich, the Middle Classes and the Poor.—The Past Art Compared with the Art as Exhibited at Centennial Exhibition in 1876 at Philadelphia.—The Varieties of Different Vehicles there Displayed by Different Nations.—Velocipedes and Bicycles.—1800 to 1869.—French, German, English, Scotch.—The "Draisine" of Von Drais, 1816.—Johnson's "Curricle," 1818.—Gompertz's "Dandy" and "Hobby Horse," 1821.—Michaux's, 1863.—Lallement's of France, 1866, Crank and Pedal.—America and Europe Adopts it, 1866, 1869.—Pneumatic Rubber Tire Invented by Thomson, 1845.—Sleeps Forty Years.—Improvements since 1869.—Motor Vehicles and Automobiles.—Traction Engines.—Brakes, Railway, Air and Electric.—Automatic Couplers, Buffers, and Vestibule Trains. 428

CHAPTER XXIX.

SHIPS AND SHIP BUILDING.

"Ships are but Boards."—"The Great Harry."—Noah's Ark the Prototype of the Modern

"Whale-back."—Phœnicians.—Northmen.—Dutch, French, English, and American Types.—Nineteenth Century, the Yankee Clippers.—Donald McKay.—"Great Republic."—Steam as Motive Power in Ships the Leading Event in the Art.—Lord Dundas and Steam Canal Boats.—Iron Ships in Place of Wood, 1829-30.—John Laird of Birkenhead.—Sir William Fairbairn.—Clyde Works.—Comparison of Wood and Iron.—1844, the Great Britain.—John Ericsson.—Monitor and Merrimac.—Composite Style of Vessels.—Marine Propulsion.—Paddle Wheels.—Screws.—1804, John Stevens.—1807, Fulton.—Screw Propeller of Ericsson.—The Ogden, the Stockton and the Princeton, the First Naval Warship of its Kind.—The Two Revolutions Produced by Ericsson.—Pneumatic Propellers.—Description of a Warship.—The Deutschland.—Torpedo Boats.—Franklin and Oil on the Waves.—Air Ships.—Count Zeppelin's Boat.—Other Plans of Air Navigation.—The Problems to be Solved. 438

CHAPTER XXX.

ILLUMINATING GAS.

What Artificial Light has done for Man.—Its Condition before the Nineteenth Century.—Experiments of Dr Clayton, Hon. R. Boyle, Dr. Hales, Bishop Watson, Lord Dundonald, Dr. Rickel, and William Murdock in Eighteenth Century.—1801, Le Bon Makes Gas, Proposes to Light Paris.—1803, English Periodicals Discuss the Subject.—1806, Melville of Newport, U. S., Lights House and Street.—1817, First Lighthouse Lit by Gas.—The Beaver Tail on Atlantic Coast.—Parliament in 1813, London Streets Lit in 1815, Paris, 1820, American Cities 1816-25.—Gas Processes.—Chemistry.—Priestley and Dalton.—Berthollet, Graham, and Others.—Clegg of England and his Gas Machines.—Art Revolutionised by Invention of Water Gas, 1823-1847.—Donovan, Lowe, White.—T. S. C. Lowe, Anthracite Process, 1873.—Competition with Electricity.—Siemens' Regenerative System.—The Generators, Carburetors, Retorts, Mixers, Purifiers, Meters, Scrubbers, Holders, Condensers, Governors, Indicators, Registers, Chargers, Pressure Regulators, etc.—Portable Gas Apparatus.—Argand Burners.—Acetylene Gas.—Calcium Carbide.—Magnesium.—Bunsen Burner and Welsbach Mantle. 450

CHAPTER XXXI.

POTTERY, PLASTICS, PORCELAINS, STONEWARE, GLASS, RUBBER, CELLULOID.

Brickmaking from the Earliest Ages to Nineteenth Century.—Pottery, its Origin Unknown.—Its Evolution.—Women the First Inventors in Ceramic and Textile Arts.—Progress of Man Traced in Pottery.—Review of Pottery from Time of Homer to the Wedgwood Ware of Eighteenth Century.—Labour-Saving Devices of Nineteenth.—Operations in Brickmaking and Machinery.—The Celebrated Pug Mill, the Pioneer.—Moulding and Pressing.—Drying and Burning.—The Slow Growth of Methods.—Useful Contrivances never wholly Supplanted.—Modern Heat Distributors.—Hoffman's Kilns.—Wedgwood's Pottery in Eighteenth.—Siemens' Regenerators in Nineteenth, and other Kilns.—Susan Frackelton's.—The Filter Press.—Chinese and French Porcelains—Battam's Imitations of Marbles and Plaster Moulds.—Faience.—Porcelain Moulding and Colours.—Atomisers and Backgrounds.—Rookwood Pottery and Miss Fry.—Enamelled Ware.—Artificial Stone.—Modern Cements.—Glass the Sister of Pottery.—The Inventors of Blowing, Cutting, Trimming by Shears and Diamond Cutting, Ancient and Unknown.—Glass Windows and Mirrors Unknown to the Poor Prior to Eighteenth Century.—The Nineteenth Century the Scientific Age of Glass.—Its Commercial Development.—Crystal Palace of 1851.—Description of Modern Discoveries.—Materials.—Colours and Faraday's Discovery in 1824.—Gaffield's Extensive Experiments in Producing Colours.—The German Glass Works at Jena of Abbe and Schott.—Methods Followed for Different Varieties.—Machines for Different Purposes.—Cut Glass and other Beautiful Ware.—Cameo Cutting.—Porcelain Electroplating.—Rubber, History of, in Seventeenth, Eighteenth and Nineteenth Centuries.—Sketch of Goodyear.—His Inventions and Present State of the Art.—Glass Wool of Volcano of Kilauea and Krupp's Blast Furnaces. 457

INVENTIONS IN THE CENTURY.

CHAPTER I.

INTRODUCTORY—INVENTIONS AND DISCOVERIES—

THEIR DEVELOPMENT.

In treating of the subject of Inventions it is proper to distinguish them from their scientific kindred—Discoveries.

The history of inventions is the history of new and useful contrivances made by man for practical purposes. The history of scientific discoveries is the record of new things found in Nature, its laws, forces, or materials, and brought to light, as they exist, either singly, or in relation, or in combination.

Thus Galileo invented the telescope, and Newton discovered the law of gravitation. The practical use of the invention when turned to the heavenly bodies served to confirm the truth of the discovery.

Discovery and invention may be, and often are, united as the soul is to the body. The union of the two produces one or more inventions. Thus the invented electro-telegraph consists of the combination of discoveries of certain laws of electricity with an apparatus, by which signs are communicated to distances by electrical influence.

Inventions and discoveries do not precede or follow each other in order. The instrument may be [Pg 2]
made before the laws which govern its operation are discovered. The discovery may long precede its adaptation in physical form, and both the discovery and adaptation may occur together.

Among the great *inventions* of the past are alphabetical writing, Arabic notation, the mariner's compass, the telescope, the printing-press, and the steam-engine. Among the great *discoveries* of the past are the attraction of gravitation, the laws of planetary motion, the circulation of the blood, and velocity of light. Among the great inventions of the nineteenth century are the spectroscope, the electric telegraph, the telephone, the phonograph, the railways, and the steam-ships. Among the great discoveries of this century are the correlation and conservation of forces, anæsthetics, laws of electrical energy, the germ theory of disease, the molecular theory of gases, the periodic law of Mendeljeff in chemistry, antiseptic surgery, and the vortex theory of matter. This short enumeration will serve to indicate the different roads along which inventions and the discoveries of science progress.

By many it is thought that the inventions and discoveries of the nineteenth century exceed in number and importance all the achievements of the kind in all the ages of the past.

So marvellous have been these developments of this century that, not content with sober definitions, men have defined *invent*, even when speaking only of mechanical productions, as "creating what had not before existed;" and this period has been described as an age of new creations. The far-off cry of the Royal Preacher, "There is no new thing under the sun: Is there
anything whereof it may be said, see this is new, it hath been already of old time which was [Pg 3]
before us," is regarded as a cry of satiety and despair, finding no responsive echo in the array of inventions of this bright age.

But in one sense the Preacher's words are ever profoundly true. The forces and materials of Nature always exist, awaiting man's discovery, and at best he can but vary their relations, re-direct their course, or change their forms. In a still narrower sense the truth of the Preacher's declaration is apparent:—

In an address before the Anthropological Society of Washington in 1885, the late Prof. F. A. Seely, of the United States Patent Office, set forth that it was one of the established laws of Invention, that,

"Every human invention has sprung from some prior invention, or from some prior known expedient."

Inventions, he said, do not, like their protectress, Pallas Athene, spring forth full grown from the heads of their authors; that both as to modern inventions and as to those whose history is unrecorded, each exhibits in itself the evidence of a similar sub-structure; and that, "in the process of elimination we go back and back and find no resting place till we reach the rude set of expedients, the original endowment of men and brutes alike."

Inventions, then, are not creations, but the evolution of man-made contrivances.

It may be remarked, however, as was once said by William H. Seward: "The exercise of the inventive faculty is the nearest akin to that of the Creator of any faculty possessed by the human mind; for while it does not create in the same sense that the Creator did, yet it is the nearest approach to it of anything known to man."

There is no history, rock-record, or other evidence of his existence as man, which discloses a [Pg 4]
period when he was not an inventor.

Invention is that divine spark which drove, and still drives him to the production of means to meet his wants, while it illuminates his way. From that inward spark must have soon followed the invention of that outer fire to warm and cheer him, and to melt and mould the earth to his desires. Formed for society, the necessity of communication with his fellows developed the power of speech. Speech developed written characters and alphabets. Common communication developed concert of action, and from concert of action sprung the arts of society.

But the evolution of invention has not been uniform. Long periods of slowness and stagnation have alternated with shorter or longer periods of prolific growth, and these with seasons of slumber and repression.

Thus, Prof. Langley has said that man was thousands of years, and possibly millions, in evolving a cutting edge by rubbing one stone on another; but only a few thousand years to next develop bronze tools, and a still shorter period tools of iron.

We cannot say how long the period was from the age of iron tools to the building of the pyramids, but we know that before those stupendous structures arose, the six elementary mechanical powers, the lever, the wheel, the pulley, the inclined plane, the wedge and the screw, were invented. And without those powers, what mechanical tool or machine has since been developed? The age of inventions in the times of the ancients rested mainly upon simple applications of these mechanical powers. The middle ages slumbered, but on the coming of the fifteenth and sixteenth centuries, the inventions of the ancients were revived, new ones added, and their growth and [Pg 5] development extended with ever-increasing speed to the present time.

The inventions of the nineteenth century, wonderful and innumerable as they are, and marvellous in results produced, are but the fruit of the seed sown in the past, and the blossom of the buds grown upon the stalks of former generations. The early crude stone hatchet has become the keen finished metal implement of to-day, and the latter involves in itself the culmination of a long series of processes for converting the rough ore into the hard and glistening steel.

The crooked and pointed stick with which the Egyptian turned the sands of the Nile has slowly grown to be the finished plough that is now driven through the sod by steam.

The steam-operated toys of Hero of Alexandria were revived in principle and incorporated in the engines of Papin and the Marquis of Worcester in the seventeenth century; and the better engines of Savery, Newcomen, and more especially of James Watt in the eighteenth century, left the improvements in steam-engines of the nineteenth century—great as they are—inventions only in matter of detail.

It has been said that electrical science began with the labours of Dr. Gilbert, published in 1600. These, with the electrical discoveries and inventions of Gray, Franklin, Galvani, and others in the next century, terminating with the invention of his battery by Volta in 1800, constituted the framework on which was built that world of flashing light and earth-circling messages in which we now live.

The study of inventions in any one or all eras cannot proceed intelligently unless account is taken [Pg 6] not only of their mode of construction, and of their evolution one from another, but of the evolution of distinct arts, their relation, their interdependence in growth, and their mutual progress.

The principles adopted by the ancients in weaving and spinning by hand are those still in force; but so great was the advance of inventions from hand-operated mechanisms to machines in these and other arts, and especially in steam, in the last half of the eighteenth century, that it has been claimed that the age of machine production or invention then for the first time really began.

When the humble lift became the completed elevator of to-day, the "sky-scraper" buildings appeared; but these buildings waited upon the invention of their steel skeletons, and the steel was the child of the Bessemer process.

The harp with which David stirred the dead soul of Saul was the prototype of the sweet clavichord, the romantic virginal, the tinkling harpsichord, and the grand piano. The thrumming of the chords by the fingers was succeeded by the striking keys; and the more perfect rendition of tones awaited the application of new discoveries in the realm of musical sounds. The keys and the levers in the art of musical instruments were transferred to the art of printing, and are found to-day striking a more homely music on the type-writer and on those other and more wonderful printing instruments that mould, and set, and distribute the type. But these results of later days did not reach their perfected operations and forms until many other arts had been discovered and developed, by which to treat and improve the wood, and the wire, and all the other materials of which those early instruments were composed, and by which the underlying principles of their [Pg 7] operations became known.

Admitting that man possesses the faculty of invention, what are the motives that induce its exercise? Why so prolific in inventions now? And will they continue to increase in number and importance, or decrease?

An interesting treatise of bulky dimensions might be written in answer to these queries, and the answers might not then be wholly satisfactory. Space permits the submission of but a few observations and suggestions on these points:——

Necessity is still the mother of inventions, but not of all of them. The pressing needs of man in fighting nakedness and hunger, wild beasts and storms, may have driven him to the production of most of his early contrivances; but as time went on and his wants of every kind multiplied, other factors than mere necessity entered into the problem, and now it is required to account for the multiplicity of inventions under the general head of *Wants*.

To-day it is the want of the luxuries, as well as of the necessities of life, the want of riches, distinction, power, and place, the wants of philanthropy and the wants of selfishness, and that restless, inherent, unsatisfied, indescribable want which is ever pushing man onward on the road of progress, that must be regarded as the springs of invention.

Accident is thought to be the fruitful source of great inventions. It is a factor that cannot be ignored. But accidents are only occasional helps, rarely occurring,—flashes of light suddenly revealing the end of the path along which the inventor has been painfully toiling, and unnoticed except by him alone. [Pg 8] They are sudden discoveries which for the most part simply shorten his journey. The rare complete contrivance revealed by accident is not an invention at all, but a discovery.

The greatest incentive in modern times to the production of inventions is governmental protection.

When governments began to recognize the right of property in inventions, and to devise and enforce means by which their author should hold and enjoy the same, as he holds his land, his house, or his horse, then inventions sprung forth as from a great unsealed fountain.

This principle first found recognition in England in 1623, when parliament, stung by the abuse of the royal prerogative in the grant of exclusive personal privileges that served to crush the growth of inventions and not to multiply them, by its celebrated Statute of Monopolies, abolished all such privileges, but excepted from its provisions the grant of patents "for the sole working or making of any manner of new manufactures within this realm to the true and first inventor" thereof.

This statute had little force, however, in encouraging and protecting inventors until the next century, and until after the great inventions of Arkwright in spinning and James Watt in steam-engines had been invaded, and the attention of the courts called more seriously thereby to the property rights of inventors, and to the necessity of a liberal exposition of the law and its proper enforcement.

Then followed in 1789 the incorporation of that famous provision in the Constitution of the United States, declaring that Congress shall have the power "To promote the progress of science and useful arts by securing for limited times to authors and inventors the exclusive right to their [Pg 9] respective writings and discoveries."

In 1791 followed the law of the National Assembly of France for the protection of new inventions, setting forth in the preamble, among other things, "that not to regard an industrial invention as the property of its author would be to attack the essential rights of man."

These fundamental principles have since been adopted and incorporated in their laws by all the nations of the earth.

Inventions in their nature being for the good of all men and for all time, it has been deemed wise by all nations in their legislation not to permit the inventor to lock up his property in secret, or confine it to his own use; and hence the universal practice is to enact laws giving him, his heirs, and assigns, exclusive ownership to this species of his property for a limited time only, adjudged sufficient to reward him for his efforts in its production, and to encourage others in like productions; while he, in consideration for this protection, is to fully make known his invention, so that the public may be enabled to freely make and use it after its exclusive ownership shall have expired.

In addition to the motives and incentives mentioned inducing this modern mighty outflow of inventions, regard must be had to the conditions of personal, political and intellectual freedom, and of education. There is no class of inventors where the mass of men are slaves; and when dense ignorance abounds, invention sleeps.

In the days of the greatest intellectual freedom of Greece, Archimedes, Euclid, and Hero, its great inventors, flourished; but when its political *status* had reduced the mass of citizens to [Pg 10] slaves, when the work of the artisan and the inventor was not appreciated beyond the gift of an occasional crown of laurel, when manual labour and the labourer were scorned, inventions were not born, or, if born, found no nourishment to prolong their lives.

In Rome, the labourer found little respect beyond the beasts of burden whose burdens he shared, and the inventor found no provision of fostering care or protection in her mighty jurisprudence. The middle ages carefully repressed the minds of men, and hid away in dark recesses the instruments of learning. When men at length awoke to claim their birthright of freedom, they invented the printing-press and rediscovered gunpowder, with which to destroy the tyranny of both priests and kings. Then arose the modern inventor, and with him came the freedom and the arts of civilisation which we now enjoy.

What the exercise of free and protected invention has brought to this century is thus summarised by Macaulay:

"It has lengthened life; it has mitigated pain; has extinguished diseases; has increased the fertility of the soil; given new security to the mariner; furnished new arms to the warrior; spanned great rivers and estuaries with bridges of form unknown to our fathers; it has guided the thunderbolt innocuously from heaven to earth; it has lighted up the night with splendour of the day; it has extended the range of human vision; it has multiplied the power of the human muscles; it has accelerated motion; it has annihilated distance; it has facilitated intercourse, correspondence, all friendly offices, all despatch of business; it has enabled man to descend to the depths of the sea, to soar into the air, to penetrate securely into the noxious recesses of the [Pg 11] earth; to traverse the land in carts which whirl along without horses; to cross the ocean in ships which run many knots an hour against the wind. Those are but a part of its fruits, and of its first fruits, for it is a philosophy which never rests, which is never perfect. Its law is progress. A point which yesterday was invisible is its goal to-day, and will be its starting point to-morrow."

The onward flow of inventions may be interrupted, if not materially stayed, by the cessation of some of the causes and incentives which now give them life. When comfort for all and rest for all, and a suitable division of labour, and an equal distribution of its fruits are reached, in that state of society which is pictured in the visions of the social philosopher, or as fast as such conditions are reached, so soon will cease the pricking of those spurs of invention,—individual rewards, the glorious strife of competition, the harrowing necessities, and the ambitions for place and power. If all are to co-operate and share alike, what need of exclusive protection and fierce and individual struggle? Why not sit down now and break the loaf and share it, and pour the wine, and enjoy things as they are, without a thought for the morrow?

The same results as to inventions may be reached in different but less pleasant ways: When all the industries are absorbed by huge combinations of capital the strife of competition among individuals, and the making of individual inventions to meet such competition, will greatly disappear. Or, the same results may be effected by stringent laws of labour organisations, in restricting or repressing all individual independent effort, prescribing what shall be done or what [Pg 12] shall not be done along certain lines of manufacture or employment. So that the progress of future inventions depends on the outcome of the great economic, industrial, and social battles which are now looming on the pathway of the future.

But what the inventions of the nineteenth century were and what they have done for Humanity, is a chapter that must be read by all those now living or to come who wish to learn the history of their race. It is a story which gathers up all the threads of previous centuries and weaves them into a fabric which must be used in all the coming ages in the attainment of their comforts, their adornments, and their civilisations.

To enumerate all the inventions of the century would be like calling up a vast army of men and proclaiming the name of each. The best that can be done is to divide the wide field into chapters, and in these chapters give as best one may an idea of the leading inventions that have produced the greatest industries of the World.

[Pg 13]

CHAPTER II.

AGRICULTURE AND ITS IMPLEMENTS.

The Egyptians were the earliest and greatest agriculturists, and from them the art was learned by the Greeks. Greece in the days of her glory greatly improved the art, and some of her ablest men wrote valuable treatises on its different topics. Its farmers thoroughly ploughed and fertilised the soil, used various implements for its cultivation, paid great attention to the raising of fruits,—the apple, pear, cherry, plum, quince, peach, lemon, fig and many other varieties suitable to their climate, and improved the breeds of cattle, horse and sheep. When, however, social pride and luxurious city life became the dominant passions, agriculture was left to menials, and the art gradually faded with the State. Rome in her best days placed farming in high regard. Her best writers wrote voluminously on agricultural subjects, a tract of land was allotted to every citizen, which was carefully cultivated, and these citizen farmers were her worthiest and most honoured sons. The condition and needs of the soil were studied, its strength replenished by careful fertilisation, and it was worked with care. There were ploughs which were made heavy or light as the different soils required, and there were a variety of farm implements, such as spades, hoes, harrows and rakes. Grains, such as wheat, barley, rye and oats, were raised, a variety of fruits and vegetables, and great attention paid to the breeding of stock. Cato and Varro, Virgil [Pg 14] and Columella, Pliny and Palladius delighted to instruct the farmer and praise his occupation.

But as the Roman Empire grew, its armies absorbed its intelligent farmers, the tilling of the soil was left to the menial and the slave, and the Empire and agriculture declined together.

Then came the hordes of northern barbarians pouring in waves over the southern countries and burying from sight their arts and civilisation. The gloom of the middle ages then closed down upon the European world. Whatever good may have been accomplished in other directions by the crusades, agriculture reached its lowest ebb, save in those instances where the culture of the soil received attention from monastic institutions.

The sixteenth century has been fixed upon as the time when Europe awoke from its long slumber. Then it was after the invention of the printing press had become well established that publications on agriculture began to appear. The *Boke of Husbandrie*, in 1523, by Sir Anthony Fitzherbert; Thomas Tusser's *Five Hundred Points of Good Husbandry*; Barnaby Googe's *The Whole Art of Husbandry*; *The Jewel House of Art and Nature*, by Sir Hugh Platt; the *English Improver* of Walter Blithe, and the writings of Sir Richard Weston on the husbandry of Brabant and Flanders, were the principal torches by which the light on this subject was handed down through the sixteenth and seventeenth centuries. Further awakening was had in the eighteenth century, the chief part of which was given by Jethro Tull, an English agriculturist, who lived, and wrote, and laboured in the cause between 1680 and 1740. Tull's leading idea was the thorough [Pg 15] pulverisation of the soil, his doctrines being that plants derived their nourishment from minute particles of soil, hence the need of its pulverisation. He invented and introduced a horse hoe, a grain drill, and a threshing machine.

Next appeared Arthur Young, of England, born in 1741, whose life was extended into the 19th century, and to whom the world was greatly indebted for the spread of agricultural knowledge. He devoted frequent and long journeys to obtaining information on agricultural subjects, and his writings attracted the attention and assistance of the learned everywhere. His chief work was the making known widely of the beneficial effects of ammonia and ammoniacal compounds on vegetation. Many other useful branches of the subject, clearly treated by him, are found in his *Annals of Agriculture*. It was this same Arthur Young with whom Washington corresponded from his quiet retreat at Mount Vernon. After the close of the War of Independence in 1783 and before the adoption of the Constitution in 1789 and his elevation to the Presidency in that year, Washington devoted very much of his time to the cultivation of his large estate in Virginia. He took great interest in every improvement in agriculture and its implements. He invented a plough and a rotary seed drill, improved his harrows and mills, and made many inquiries relative to the efficacy of ploughs and threshing machines made in England and other parts of Europe. It was during this period that he opened an interesting correspondence with Young on improvements in agriculture, which was carried on even while he was President, and he availed himself of the proffer of Young's services to fill an order for seeds and two ploughs from a London merchant. He [Pg 16] also wrote to Robert Cary & Co., merchants in London, concerning an engine he had heard of as being constructed in Switzerland, for pulling up trees and their stumps by the roots, and ordered one to be sent him if the machine were efficient.

Jefferson, Washington's great contemporaneous statesman and Virginia planter, and to whom has been ascribed the chief glory of the American patent system, himself also an inventor, enriched his country by the full scientific knowledge he had gained from all Europe of agricultural pursuits and improvements.

The progress of the art, in a fundamental sense, that is in a knowledge of the constituents, properties, and needs of the soil, commenced with the investigations of Sir Humphry Davy at the close of the 18th century, resulting in his celebrated lectures before the Board of Agriculture from 1802 to 1812, and his practical experiments in the growth of plants and the nature of fertilisers. Agricultural societies and boards were a characteristic product of the eighteenth century in Europe and America. But this birth, or revival of agricultural studies, the enthusiastic interest taken therein by its great and learned men, and all its valuable publications and discoveries, bore comparatively little fruit in that century. The ignorance and prejudice of the great mass of farmers led to a determined, and in many instances violent resistance to the introduction of labour-saving machinery and the practical application of what they called "book-farming." A fear of driving people out of employment led them to make war upon new agricultural machines and their inventors, as they had upon weaving and spinning inventions. This war was more marked in England than elsewhere, because there more of the new machines [Pg 17] were first introduced, and the number of labourers in those fields was the greatest. In America the ignorance took the milder shape of contempt and prejudice. Farmers refused, for instance, to use cast-iron ploughs as it was feared they would poison the soil.

So slow was the invention and introduction of new devices, that if Ruth had revisited the earth at the beginning of the nineteenth century, she might have seen again in the fields of the husbandmen everywhere the sickle of the reapers behind whom she gleaned in the fields of Boaz, heard again the beating on the threshing floor, and felt the old familiar rush of the winnowing wind. Cincinnatus returning then would have recognised the plough in common use as about the same in form as that which he once abandoned on his farm beyond the Tiber.

But with the spread of publications, the extension of learning, the protection now at last obtained and enforced for inventions, and with the foundations laid and the guide-posts erected in nearly every art and science by previous discoverers, inventors and writers, the century was now ready to start on that career of inventions which has rendered it so glorious.

As the turning over and loosening of the sod and the soil for the reception of seed was, and still is the first step in the art of agriculture, the plough is the first implement to be considered in this review.

A plough possesses five essential features,—a frame or beam to which the horses are attached and which is provided with handles by which the operator guides the plough, a share to sever the bottom of a slice of land—the furrow—from the land beneath, a mould board following the share to turn the furrow over to one side, and a landside, the side opposite the mould board and which [Pg 18] presses against the unploughed ground and steadies the plough. To these have been commonly added a device called the coulter, which is a knife or sharp disk fastened to the frame in advance of the share and adapted to cut the sod or soil so that the furrow may be more easily turned, an adjustable gauge wheel secured to the beam in advance of the coulter, and which runs upon the surface of the soil to determine by the distance between the perimeter of the wheel at the bottom and the bottom of the plough share the depth of the furrow, and a clevis, which is an adjustable metal strap attached to the end of the beam to which the draught is secured, and by which the pitch of the beam and the depth and width of the furrow are regulated. The general features, the beam, handles, and share, have existed in ploughs from the earliest ages in history. A plough with a metal share was referred to by the prophecy of Isaiah seven centuries before Christ, "They shall beat their swords into plough-shares;" and such a plough with the coulter and gauge wheel added is found in the Caylus collection of Greek antiquities. The inventions of centuries in ploughs have proceeded along the lines of the elements above enumerated.

The leading features of the modern plough with a share and mould board constructed to run in a certain track and turn its furrows one over against the other, appear to have originated in Holland in the 18th century, and from there were made known to England. James Small of Scotland wrote of and made ploughs having a cast-iron mould board and cast and wrought iron shares in 1784-85.

In America, about the same time, Thos. Jefferson studied and wrote upon the proper shape to be [Pg 19] given to the mould board.

Charles Newbold in 1797 took out the first patent in the United States for a plough—all parts cast in one piece of solid iron except the beam and handles.

It is a favourite idea with some writers and with more talkers, that when the necessity really arises for an invention the natural inventive genius of man will at once supply it. Nothing was more needed and sought after for thirty centuries among tillers of the soil than a good plough, and what finally supplied it was not necessity alone, but improved brains. Long were the continued efforts, stimulated no doubt in part by necessity, but stimulated also by other motives, to which allusion has already been made, and among which are the love of progress, the hope of gain, and legislative protection in the possession of inventive property.

The best plans of writers and inventors of the eighteenth century were not fully developed until the nineteenth, and it can be safely said that within the last one hundred years a better plough has been produced than in all of the thousands of years before. The defects which the nineteenth century's improvements in ploughs were designed to remedy can best be understood by first realising what was the condition of ploughs in common use when the century opened.

Different parts of the plough, such as the share and coulter, were constructed of iron, but the general practice among farmers was to make the beam and frame, handles and mould board of strong and heavy timber. The beam was straight, long, and heavy, and that and the mould generally hewed from a tree. The mould board on both sides to prevent its wearing out too rapidly was covered with more or less thick plates of iron. The handles were made from crooked [Pg 20] branches of trees. "The beam," it is said, "was set at any pitch that fancy might dictate, with the handles fastened on almost at right angles with it, thus leaving the ploughman little control over his implement which did its work in a very slow and imperfect manner." It was some such plough that Lord Kames complained about in the *Gentleman Farmer* in 1768, as being used in Scotland—two horses and two oxen were necessary to pull it, "the ridges in the fields were high and broad, in fact enormous masses of accumulated earth, that could not admit of cross ploughing or cultivation; shallow ploughing universal; ribbing, by which half the land was left untilled, a general practice over the greater part of Scotland; a continual struggle between the corn and weeds for superiority." As late as 1820 an American writer was making the same complaint. "Your furrows," he said, "stand up like the ribs of a lean horse in the month of March. A lazy ploughman may sit on the beam and count every bout of his day's work; besides the greatest objection to all these ploughs is that they do not perform the work well and the expense is enormous for blacksmith work." It was complained by another that it took eight or ten oxen to draw it, a man to ride upon the beam to keep it on the ground, and a man followed the plough with a heavy iron hoe to dig up the "baulks."

The improvements made in the plough during the century have had for their object to lessen the great friction between the wide, heavy, ill-formed share and mould board, and the ground, which has been accomplished by giving to the share a sharp clean tapering form, and to the mould board a shape best calculated to turn the furrow slice; to improve the line of draught so that the [Pg 21] pull of the team may be most advantageously employed, which has been effected after long trials, study and experiment in the arrangement of beam, clevis and draft rod, setting the coulter at a proper angle and giving the landside a plane and parallel surface; to increase the wear and lessen the weight of the parts, which has been accomplished by ingenious processes in treating the metal of which the parts are composed, and lessening the number of parts; to render the plough easily repairable by casting the parts in sets and numbering them, by which any part may be replaced by the manufacturer without resort to the blacksmith. In short there is no part of the plough but what has received the most careful attention of the inventor. This has been evidenced by the fact that in the United States alone nearly eleven thousand patents on ploughs were issued during the nineteenth century. When it is considered that all the applications for these patents were examined as to their novelty, before the grant of the patent, the enormous amount of study and invention expended on this article can be appreciated. Among the century's improvements in this line is the use of disks in place of the old shovel blades to penetrate the earth and revolve in contact therewith. Cutting disks are harnessed to steam motors and are adapted to break up at one operation a wide strip of ground. The long-studied problem of employing a gang of ploughs to plough back and forth and successfully operated by steam has been solved, and electricity is now being introduced as a motor in place of steam. Thus millions of broad acres which never would have been otherwise turned are now cultivated. The tired muscle-strained ploughman who homeward plodded his weary way at night may now comfortably ride at his ease upon the plough, [Pg 22] while at the same time the beasts that pull it have a lighter load than ever before.

Next to the plough among the implements for breaking, clearing and otherwise preparing the soil for the reception of seed, comes the *harrow*. From time immemorial it has been customary to arm some sort of a frame with wooden or iron spikes to scratch the earth after the ploughing. But this century has greatly improved the old constructions. Harrows are now found everywhere made in sections to give flexibility to the frame; collected in gangs to increase the extent of operation; made with disks instead of spikes, with which to cut the roots of weeds and separate the soil, instead of merely scratching them. A still later invention, curved spring teeth, has been found far superior to spikes or disks in throwing up, separating and pulverising the soil. A harrow comprising two ranks of oppositely curved trailing teeth is especially popular in some countries. These three distinct classes of harrows, the disk type, the curved spring tooth type, and gangs of sections of concavo-convex disks, particularly distinguish this class of implements from the old forms of previous ages.

CHAPTER III.

AGRICULTURAL IMPLEMENTS.

It is wonderful for how many generations men were contented to throw grain into the air as the Parable relates:

"Behold, a sower went forth to sow, and when he sowed some seeds fell by the way side, and the fowls came and devoured them up: some fell on stony places where they had not much earth, and forthwith they sprung up, because they had no deepness of earth; and when the sun was up they were scorched; and because they had no root they withered away. And some fell among thorns and the thorns sprung up and choked them. But others fell into good ground and brought forth fruit, some a hundredfold, some sixtyfold, and some thirtyfold."

Here are indicated the defects in depositing the seed that only the inventions of the century have fully corrected. The equal distribution of the seed and not its wide scattering, its sowing in regular drills or planting at intervals, at certain and uniform depths, the adaptation of devices to meet the variations in the land to be planted, and in short the substitution of quick, certain, positive mechanisms for the slow, uncertain, variable hand of man. Not only has the increase an hundredfold been obtained, but with the machines of to-day the sowing and planting of a hundredfold more land has been made possible, the employment of armies of men where idleness would have reigned, and the feeding of millions of people among whom hunger would otherwise [Pg 24] have prevailed. Not only did this machinery not exist at the beginning of the century, but the agricultural machines and devices in this line of the character existing fifty years ago are now discarded as useless and worthless.

It is true that, as in the case of the ploughs, attempts had been made through the centuries to invent and improve seeding implements. The Assyrians 500 years B. C. had in use a rude plough in which behind the sharp wooden plough point was fixed a bowl-shaped hopper through which seed was dropped into the furrow, and was covered by the falling back of the furrow upon it. The Chinese, probably before that time, had a wheelbarrow arrangement with a seed hopper and separate seed spouts. In India a drilling hopper had been attached to a plough. Italy claims the honour among European nations of first introducing a machine for sowing grain. It was invented about the beginning of the seventeenth century and is described by Zanon in his *Work on Agriculture* printed at Venice in 1764. It was a machine mounted on two wheels, that had a seed box in the bottom of which was a series of holes opening into a corresponding number of metal tubes or funnels. At their front these tubes at their lower ends were sharpened to make small furrows into which the seed dropped.

Similar single machines were in the course of the seventeenth and eighteenth centuries devised in Austria and England. The one in Austria was invented by a Spaniard, one Don Joseph de Lescatello, tested in Luxembourg in 1662. The inventor was rewarded by the Emperor, recommended to the King of Spain, and in 1663 and 1664 his machines were made and sold at [Pg 25] Madrid. The knowledge of this Spaniard's invention was made known in England in 1699 by the Earl of Sandwich and John Evelyn. Jethro Tull in England shortly after invented and introduced a combined system of drilling, ploughing and cultivating. He sowed different seeds from the same machine, and arranged that they might be covered at different depths. Tull's machines were much improved by James Cooke, a clergyman of Lancashire, England; and also in the last decade of the eighteenth century by Baldwin and Wells of Norfolk, England.

Washington and others in America had also commenced to invent and experiment with seeding machines. But as before intimated, the nineteenth century found the great mass of farmers everywhere sowing their wheat and other grains by throwing them into the air by hand, to be met by the gusts of wind and blown into hollows and on ridges, on stones and thorny places,—requiring often a second and third repetition of the same tedious process.

In 1878 Mr. Coffin, a distinguished journalist of Boston, in an address before the Patent Committee of the U. S. Senate, set forth the advantages obtained by the modern improvements in seeders as follows:

"The seeder covers the soil to a uniform depth. It sows evenly, and sows a specific quantity. You may graduate it so that, after a little experience, you can determine the amount per acre even to a quart of wheat. They sow all kinds of grain,—wheat, clover, and superphosphate, if need be, at once. They harrow at the same time. They make the crop more certain. It is the united testimony of manufacturers and farmers alike that the crop is increased from one-eighth to one-fourth, [Pg 26] especially in the winter wheat. Winter wheat, you are aware, in the freezing and thawing season, is apt to heave out. It is desirable to bury the seed a uniform and proper depth and to throw over the young plant such an amount of soil that it shall not heave with the freezing and thawing. Of the 360,000,000 bushels of wheat raised last year I suppose more than 300,000,000 was winter wheat. One-eighth of this is 37,700,000 bushels."

It would seem to many that after the adoption of a seed hopper, and spouts with sharpened ends that cut the drill rows in the furrows and deposited the seed therein, that little was left to be done in this class of inventions; but a great many improvements were necessary. Gravity alone could not be depended upon for feeding the seed. Means had to be devised for a continuous and regular discharge from each grain tube; for varying the quantity of the seed fed by varying the escape openings, or by positive mechanical movements variable in speed; for fixing accurately the quantity of seed discharged; for changing the apparatus to feed coarse or fine seed; and for rendering the apparatus efficient on different surfaces—steep hillsides, level plains, irregular lands.

An important step was the substitution of what is called the "force feed" for the gravity feed. There is a variety of devices for this purpose, the principle of one of them being a revolving feed wheel located beneath the hopper, and above each spout, the two casings between which the feed wheel revolves forming the outer walls of a complete measuring channel, or throat, through which the grain is carried by the rotary motion of the wheel, thus providing the means of [Pg 27] measuring the seed with as much accuracy as could be done by a small measure. The quantity sown per acre is governed by simply increasing or diminishing the speed of the feed wheel. In one form of device this change of speed is altered by a system of cone gearing. A graduated flow of the seed has also been effected by the employment of a cylinder having a smooth and fluted part working in a cup beneath the hopper with provision for adjustment of the smooth part towards and from the fluted part to cut off or increase the flow.

To avoid the use of a separate apparatus for separate sizes of grain and other seed, the seed holder has been divided into parts—one part for containing wheat, barley and other medium-sized grains, and another for corn, peas and the larger seeds. And as these parts are used on separate occasions, the respective apertures are opened or closed by a sliding bottom and by a single movement of the hand.

Rubber tubes for conducting the seed through the hollow holes were introduced in place of the metal spouts that answered both as a spout and a hoe.

In place of the common hoe drill of a form used in the early part of the century, the hoes being forced into the soil by the use of levers and weights, what are known as "shoe drills" have largely succeeded. A series of shoes are pivoted to the frame, extend beneath the seed box, and are provided with springs for depressing or raising them.

All kinds of seeds and fertilisers, separately or together, may be now sown, and the broadcast sowing of a larger area than that covered by the throw of the hand can now be given by machinery.

Corn and cotton seed are thus also planted, mixed or unmixed with the fertilising material. [Pg 28]

Not only have light ploughs been combined with small seed boxes and one or more seed tubes, for easy work in gardens, but the arrangements varied and graded for different uses until is reached that great machine run by steam power, in which is assembled a gang of heavy harrows in front to loosen and pulverise the soil, then the seed and fertilising drill of capacious width for sowing the grain in rows, followed by a lighter broad harrow to cover the seed, and all so arranged that the steam lifts the heavy frames on turning, and all controlled easily by the man who rides upon the machine.

In planting at intervals or in hills, as corn and potatoes, and other like larger seeds, no longer is the farmer required to trudge across the wide field carrying a heavy load in bag or box, or compel his boys or women folk to drop the seed while he follows on laboriously with the hoe. He may now ride, if he so choose, and the machine which carries him furnishes the motive power for operating the supply and cut-off of the grain at intervals.

The object of the farmer in planting corn is to plant it in straight lines about four feet apart each way, putting from three to five grains into each spot in a scattered and not huddled condition. These objects are together nicely accomplished by a variety of modern machines.

The planting of great fields of potatoes has been greatly facilitated by machinery that first slices them and then sows the slices continuously in a row, or drops them in separate spots or hills, as may be desired. The finest seeds, such as grass and clover, onion and turnip seed, and delicate seed like rice, are handled and sown by machines without crushing or bruising, and with the utmost exactness. Just what seed is necessary to be supplied to the machine for a given area is [Pg 29] decided upon, and the machine distributes the same with the same nicety that a doctor distributes the proper dose of pellets upon the palm of his patient.

Transplanters as well as planters have been devised. These transplanters will dig the plant trench, distribute the fertiliser, set the plant, pack the earth and water the plant, automatically.

The class of machines known as cultivators are those only, properly speaking, which are employed to cultivate the plant after the crop is above the ground. The duties which they perform are to loosen the earth, destroy the weeds, and throw the loosened earth around the growing plant.

Here again the laborious hoe has been succeeded by the labour-saving machine.

Cultivators have names which indicate their construction and the crop with which they are adapted to be used. Thus there are "corn cultivators," "cotton cultivators," "sugar-cane cultivators," etc. Riding cultivators are known as "sulky cultivators" where they are provided with two wheels and a seat for the driver.

If worked between two rows they are termed single, and when between three rows, double cultivators. A riding cultivator adapted to work three rows has an arched axle to pass over the rows of the growing plants and cultivate both sides of the plants in each row. Double cultivators are constructed so that their outside teeth may be adjusted in and out from the centre of the machine to meet the width of the rows between which they operate. A "walking cultivator" is when the operator walks and guides the machine with the hands as with ploughs. Ordinary [Pg 30] ploughs are converted into cultivators by supplying them with double adjustable mould boards. Ingenious arrangements generally exist for widening or narrowing the cultivator and for throwing the soil from the centre of the furrow to opposite sides and against the plant. The depth to which the shares or cultivator blades work in the ground may be adjusted by a gauge wheel upon the draught beam, or a roller on the back of the frame.

Disk cultivators are those in which disk blades instead of ploughs are used with which to disturb the soil already broken. As with ploughs, so with cultivators, steam-engines are employed to draw a gang of cultivating teeth or blades, their framework, and the operator seated thereon, to and fro across the field between two or more rows, turning and running the machine at the end of the rows.

Millet's recent celebrated painting represents a brutal, primitive type of a man leaning heavily on a hoe as ancient and woful in character as the man himself. It is a picture of hopeless drudgery and blank ignorance. Markham, the poet, has seized upon this picture, dwelt eloquently on its horrors, and apostrophised it as if it were a condition now existing. He exclaims,

"O masters, lords and rulers in all lands
How will the future reckon with this man?"

The present has already reckoned with him, and he and his awkward implement of drudgery nowhere exist, except as left-over specimens of ancient and pre-historic misery occasionally found in some benighted region of the world.

The plough and the hoe are the chief implements with which man has subdued the earth. Their use has not been confined to the drudge and the slave, but men, the leaders and ornaments of [Pg 31] their race, have stood behind them adding to themselves graces, and crowning labor with dignity. Cincinnatus is only one of a long line of public men in ancient and modern times who have served their country in the ploughfield as well as on the field of battle and in the halls of Legislation. We hear the song of the poet rising with that of the lark as he turns the sod. Burns, lamenting that his share uptears the bed of the "wee modest crimson-tipped flower" and sorrowing that he has turned the "Mousie" from its "bit o' leaves and stibble" by the cruel coulter. The finest natures, tuned too fine to meet the rude blasts of the world, have shrunk like Cowper to rural scenes, and sought with the hoe among flowers and plants for that balm and strength unfound in crowded marts.

But the dignity imparted to the profession of Agriculture by a few has now by the genius of invention become the heritage of all.

While prophets have lamented, and artists have painted, and poets sorrowed over the drudgeries of the tillers of the soil, the tillers have steadily and quietly and with infinite patience and toil worked out their own salvation. They no longer find themselves "plundered and profaned and disinherited," but they have yoked the forces of nature to their service, and the cultivation of the earth, the sowing of the seed, the nourishment of the plant, have become to them things of pleasurable labour.

With the aid of these inventions which have been turned into their hands by the prolific developments of the century they are, so far as the soil is concerned, no longer "brothers of the ox," but king of kings and lord of lords.

[Pg 32]

CHAPTER IV.

AGRICULTURAL INVENTIONS.

If the farmer, toward the close of the 18th century, tired with the sickle and the scythe for cutting his grass and grain, had looked about for more expeditious means, he would have found nothing better for cutting his grass; and for harvesting his grain he would have been referred to a machine that had existed since the beginning of the Christian era. This machine was described by Pliny, writing about A. D. 60, who says that it was used on the plains of Rhætia. The same machine was described by Palladius in the fourth century. That machine is substantially the machine that is used to-day for cutting and gathering clover heads to obtain the seed. It is now called a header.

A machine that has been in use for eighteen centuries deserves to be described, and its inventor remembered; but the name of the inventor has been lost in oblivion. The description of Palladius is as follows:

"In the plains of Gaul, they use this quick way of reaping, and without reapers cut large fields with an ox in one day. For this purpose a machine is made carried upon two wheels; the square surface has boards erected at the side, which, sloping outward, make a wider space above. The board on the fore part is lower than the others. Upon it there are a great many small teeth, wide set in a row, answering to the height of the ears of corn (wheat), and turned upward at the ends. [Pg 33] On the back part of the machine two short shafts are fixed like the poles of a litter; to these an ox is yoked, with his head to the machine, and the yoke and traces likewise turned the contrary way. When the machine is pushed through the standing corn all the ears are comprehended by the teeth and cut off by them from the straw and drop into the machine. The driver sets it higher or lower as he finds it necessary. By a few goings and returnings the whole field is reaped. This machine does very well in plain and smooth fields."

As late as 1786 improvements were being attempted in England on this old Gallic machine. At that time Pitt, in that country, arranged a cylinder with combs or ripples which tore off the heads of the grain-stalks and discharged them into a box on the machine. From that date until 1800 followed attempts to make a cutting apparatus consisting of blades on a revolving cylinder rotated by the rotary motion of the wheels on which the machine was carried.

In 1794, a Scotchman invented the grain cradle. Above the blade of a scythe were arranged a set of fingers projecting from a post in the scythe snath. This was considered a wonderful implement. A report of a Scottish Highland Agricultural Society about that time said of this new machine:

"With a common sickle, seven men in ten hours reaped one and one-half acres of wheat,—about one-quarter of an acre each. With the new machine a man can cut one and one-half acres in ten hours, to be raked, bound, and stacked by two others."

It was with such crude and imperfect inventions that the farmers faced the grain and grass fields [Pg 34] of the nineteenth century.

The Seven Wonders of the ancient world have often been compared with the wonders of invention of this present day.

Senator Platt in an address at the Patent Centennial Celebration in Washington, in 1891, made such a contrast:

"The old wonders of the world were the Pyramids, the Hanging Gardens of Babylon, the Phidian statue of Jupiter, the Mausoleum, the Temple of Diana at Ephesus, the Colossus of Rhodes, and the Pharos of Alexandria. Two were tombs of kings, one was the playground of a petted queen, one was the habitat of the world's darkest superstition, one the shrine of a heathen god, another was a crude attempt to produce a work of art solely to excite wonder, and one only, the lighthouse at Alexandria, was of the slightest benefit to mankind. They were created mainly by tyrants; most of them by the unrequited toil of degraded and enslaved labourers. In them was neither improvement nor advancement for the people." With some excess of patriotic pride, he contrasts these with what he calls "the seven wonders of American invention." They were the cotton-gin; the adaptation of steam to methods of transportation; the application of electricity to business pursuits; the harvester; the modern printing-press; the ocean cable; and the sewing machine. "How wonderful," he adds, "in conception, in construction, in purpose, these great inventions are; how they dwarf the Pyramids and all the wonders of antiquity; what a train of blessings each brought with its entrance into social life; how wide, direct and far-reaching their benefits. Each was the herald of a social revolution; each was a human benefactor; each was a [Pg 35] new Goddess of Liberty; each was a great Emancipator of man from the bondage of labour; each was a new teacher come upon earth; each was a moral force."

Of these seven wonders, the harvester and the cotton-gin will only be described in this chapter. "Harvester" has sometimes been used as a broad term to cover both mowers and reapers. In a recent and more restricted sense, it is applied to a machine that cuts grain, separates it into gavels, and binds it.

The difficulty that confronted the invention of mowers was the construction, location and operation of the cutting part. To convert the scythe or the sickle, or some other sharp blade into a fast reciprocating cutter, to hang such cutter low so that it would cut near the ground, to protect it from contact with stones by a proper guard, to actuate it by the wheels of the vehicle, to hinge the cutter-bar to the frame so that its outer end might be raised, and to arrange a seat on the machine so that the driver could control the operating parts by means of a lever, or handles, were the main problems to be solved.

In 1799, Boyce, of England, had a vertical shaft with six rotating scythes beneath the frame of the implement. This died with the century.

In 1800, Meares, his countryman, tried to adapt shears. He was followed there, in 1805, by Plucknett, who introduced a horizontal, rotating, circular blade. Others, subsequently, adopted this idea, both in England and America. It had been customary, as in olden times, to push the apparatus forward by a horse or horses hitched behind. But, in 1806, Gladstone had patented a front draft machine, with a revolving wheel armed with knife-blades cutting at one side of the [Pg 36] machine and a segment-bar with fingers which gathered the grain and held the straw while the knife cut it.

Then, in 1807, Salonen introduced vibrating knifes over stationary blades, fingers to gather grain to the cutters, and a rake to carry the grain off to one side.

In 1822, Ogle, also of England, was the first to invent the *reciprocating* knife-bar. This is the movement that has been given in all the successful machines since. Ogle's was a crude machine, but it furnished the ideas of projecting the cutter-bar at the side of a reel to gather the grain to the cutter and of a grain platform which was tilted to drop the sheaf.

The world is indebted also to the Rev. Patrick Bell, of Scotland, who had invented and built as early as 1823-26, a machine which would cut an acre of grain in an hour, and is thus described by Knight:

"The machine had a square frame on two wheels which ran loose on the axle, except when clutched thereto to give motion to the cutters. The cutter-bar had fixed triangular cutters between each of which was a movable vibrating cutter, which made a shear cut against the edge of the stationary cutter, on each side. It had a reel with twelve vanes to press the grain toward the cutters, and cause it to fall upon a travelling apron which carried away cut grain and deposited it at the side of the machine. The reel was driven by bevel-gearing."

It was used but a few years and then revived again at the World's Fair in London, in 1851.

In the United States, inventions in mowers and reapers began to make their appearance about 1820. In 1822, Bailey was the first to patent a mowing machine. It was a circular revolving scythe [Pg 37] on a vertical axis, rotated by gearing from the main axle, and so that the scythe was self-sharpened by passing under a whet-stone fixed on an axis and revolving with the scythe and was pulled by a horse in front. In 1828, Lane, of Maine, combined the reaper and thresher. In 1831, Manning had a row of fingers and a reciprocating knife, and in 1833, Schnebly introduced the idea of a horizontal endless apron on which the grain fell, constructed to travel intermittently so as to divide the grain into separate parts or gavels, and deliver the gavels at one side. Hussey, of Maryland, in 1833, produced the most useful harvester up to that time. It had open guard fingers, a knife made of triangular sections, reciprocating in the guard, and a cutter-bar on a hinged frame.

Then came the celebrated reaper of McCormick, of Virginia, in 1834, and his improvements of 1845-1847, and by 1850 he had built hundreds of his machines. Other inventors, too numerous to mention, from that time pushed forward with their improvements. Then came many public trials and contests between rival manufacturers and inventors.

One of the earliest and most notable was the contest at the World's Fair, in London, in 1851. This exhibition, the first of the kind the world had seen, giving to the nations taking part such an astonishing revelation of each other's productions, and stimulating in each such a surprising growth in all the industrial and fine arts, revealed nothing more gratifying to the lover of his kind than those inventions of the preceding half-century that had so greatly lifted the farm labourer from his furrow of drudgery. [Pg 38]

Among the most conspicuous of such inventions were the harvesters. Bell's machine, previously described, and Hussey's and McCormick's were the principal contesting machines. They were set to work in fields of grain, and to McCormick was finally awarded the medal of honour.

This contest also opened the eyes of the world to the fact that vast tracts of idle land, exceeding in extent the areas of many states and countries, could now be sown and reaped—a fact impossible with the scythe and the sickle. It was the herald of the admission into the family of nations of new territories and states, which, without these machines, would unto this day be still wild wildernesses and trackless deserts.

This great trial also was followed by many others, State and International. In 1852, there was in the United States a general trial of reapers and mowers at Geneva, New York; in 1855, at the French Exposition, at Paris, where again McCormick met with a triumph; in 1857, at Syracuse, New York, and subsequently at all the great State and International Expositions. These contests served to bring out the failures, and the still-existing wants in this line of machinery. The earlier machines were clumsy. They were generally one-wheeled machines, lacked flexibility of parts and were costly. They cut, indeed, vast tracts of grain and grass, but the machines had to be followed by an army of men to bind and gather the fallen grain. This army demanded high wages and materially increased the cost of reaping the crop, and sadly diminished the profits.

When the Vienna Exposition, in 1873, was held, a great advance was shown in this and all other classes of agricultural machinery. Reapers and mowers were lighter in construction, and far less [Pg 39] in cost, and stronger and more effective in every way. The old original machines of McCormick on which he had worked for twenty years prior to the 1851 triumph, had been succeeded by another of his machines, on which an additional twenty years of study, experiment and improvement had been expended. An endless number of inventors had in the meantime entered the lists. The frame, the motive gearing, the hinged cutter-bar and knives, the driver's seat, the reel, the divider, for separating the swath of grain to be cut from the uncut, the raising and depressing lever, the self-raker, and the material of which all the parts were composed had all received the greatest attention, and now was awaiting the coming of a perfect mechanical binder that would roll the grain on the machine into a bundle, automatically bind it, and drop the bound bundles on the ground. The latter addition came in an incomplete shape to Vienna. The best form was a crude wire binder. In 1876 at the Centennial Exhibition at Philadelphia, the mowers and reapers blossomed still more fully, but not into full fruition; for it was not until two or three years thereafter that the celebrated *twine* binders, which superseded the wire, were fully developed.

Think of the almost miraculous exercise of invention in making a machine to automatically cut the grain, elevate it to a platform, separate and roll it into sheaves, seize a stout cord from a reel, wrap it about the sheaf, tie a knot that no sailor could untie, cut the cord, and throw the bound sheaf to one side upon the ground!

So great became the demand for this binders' twine that great corporations engaged in its manufacture, and they in turn formed a great trust to control the world's supply. This one item of [Pg 40] twine, alone, amounted to millions of dollars every year, and from its manufacture arose economic questions considered by legislators, and serious litigation requiring the attention of the courts.

At this Centennial Exhibition, besides twenty or more great manufacturing firms of the United States who exhibited reapers and mowers, Canada, far-away Australia, and Russia brought each a fine machine of this wonderful class. And not only these countries, but nearly all of Europe sent agricultural machines and implements in such numbers and superior construction that they surpassed the wildest dreams of the farmer of a quarter of a century before.

Up to this time, about eleven thousand patents have been granted in the United States, all presumably on separate improvements in mowers and reapers alone. This number includes, of course, many patents issued to inventors of other countries.

Before leaving this branch of the subject the lawn-mower should not be overlooked, with its spiral blades on a revolving cylinder, a hand lever by which it can be pushed over a lawn and the grass cut as smooth as the green rug upon a lady's chamber.

It is the law of inventions that one invention necessitates and generates another. Thus the vastly increased facilities for cutting grass necessitated new means for taking care of it when cut. And these new means were the hay tedder to stir it, the horse hay-rake, the great hay-forks to load, and the hay-stackers. Harvesters for grass and grain have been supplemented by Corn, Cotton, Potato and Flax Harvesters.

The threshing-floor still resounds to the flail as the grain is beaten from the heads of the stalks. [Pg 41] Men and horses still tread it out, the wooden drag and the heavy wain with its gang of wheels, and all the old methods of threshing familiar to the Egyptians and later among the Romans may still be found in use in different portions of the world.

Menzies of Scotland, about the middle of the eighteenth century, was the first to invent a threshing machine. It was unsuccessful. Then came Leckie, of Stirlingshire, who improved it. But the type of the modern threshing machine was the invention of a Scotchman, one Meikle, of Tyningham, East Lothian, in 1786. Meikle threw the grain on to an inclined board, from whence it was fed between two fluted rollers to a cylinder armed with blades which beat it, thence to a second beating cylinder operating over a concave grating through which the loosened grain fell to a receptacle beneath; thence the straw was carried over a third beating cylinder which loosened the straw and shook out the remaining grain to the same receptacle, and the beaten straw was then carried out of the machine. Meikle added many improvements, among which was a fan-mill by which the grain was separated and cleaned from both straw and chaff. This machine, completed and perfected about the year 1800, has seen no departure in principle in England, and in the United States the principal change has been the substitution of a spiked drum running at a higher speed for Meikle's beater drum armed with blades.

In countries like California, says the U.S. Commissioner of Patents in his report for 1895, "Where the climate is dry and the grain is ready for threshing as soon as it is cut, there is in general use a type of machine known as a combined harvester and thresher in which a thresher and a [Pg 42] harvester machine of the header type are mounted on a single platform, and the heads of grain are carried directly from the harvester by elevators into the threshing machine, from which the threshed grain is delivered into bags and is then ready for shipment. Some of these machines are drawn by horses and some have a portable engine mounted on the same truck with the harvester propelling the machine, while furnishing power to drive the mechanism at the same time. Combined harvesters and threshers have been known since 1836, but they have been much improved and are now built on a much larger scale."

Flax-threshers for beating the grain from the bolls of the cured flax plant, removing the bolls, releasing and cleaning the seed, are also a modern invention.

Flax and Hemp Brakes, machines by which the woody and cellular portion of the flax is separated from the fibrous portion, produced in practical shape in the century, and flanked by the improved pullers, cutters, threshers, scutchers, hackles, carders, and rovers, have supplanted Egyptian methods of 3,000 years' standing, for preparing the flax for spinning, as well as the crude improvements of the 18th century.

After the foundation of cotton manufacture had been laid "as one of the greatest of the world's industries," in the 18th century by those five great English inventors, Kay, who invented the fly-shuttle, Hargreaves, the "Spinning Jenny," Arkwright, the water-frame, Crompton, the spinning-mule, and Cartwright, the power-loom, came Eli Whitney in 1793, a young school teacher from Massachusetts located in Georgia, who invented the *cotton-gin*. His crude machine, worked by a single person, could clean more cotton in a single day than could be done by a man in several [Pg 43] months, by hand.

The enormous importance of such a machine began to be appreciated at the beginning of the century, and it set cotton up as a King whose dominion has extended across the seas.

Prior to 1871, inventions in this art were mainly directed to perfecting the structure of this primary gin. By that machine only the long staple fibre was secured, leaving the cotton seed covered with a short fibre, which with the seed was regarded as a waste product. To reclaim this short fibre and secure the seed in condition for use, have been the endeavours of many inventors during the last twenty years. These objects have been attained by a machine known as the *delinter*, one of the first practical forms of which appeared about 1883.

In a bulletin published by the U.S. Department of Agriculture in 1895, entitled, "Production and Price of Cotton for One Hundred Years," the period commences with the introduction of Whitney's saw gin, and ends with the year mentioned and with the production in that year of the largest crop the world had ever seen. No other agricultural crop commands such universal attention. Millions of people are employed in its production and manufacture. How insignificant compared with the wonder wrought by this one machine seems indeed any of the old seven wonders of the world! Although the displacement of labour occasioned by the introduction of the cotton-gin was not severely felt, as it was slave labour, yet that invention affords a good illustration of the fact that labour-saving machines increase the supply of the article, the increased supply lowers its price, the lower price increases the demand, the increased demand gives rise to more machines and develops other inventions and arts, all of which results in the [Pg 44] employment of ten thousand people to every one thousand at work on the product originally.

[Pg 45]

CHAPTER V.

AGRICULTURAL INVENTIONS (*continued*).

When the harvest is ended and the golden stores of grains and fruits are gathered, then the question arises what shall be next done to prepare them for food and for shipment to the distant consumer.

If the cleaning of the grain and separating it from the chaff and dirt are not had in the threshing process, separate machines are employed for fanning and screening.

It was only during the 18th century that fanning mills were introduced; and it is related by Sir Walter Scott in one of his novels that some of his countrymen considered it their religious duty to wait for a natural wind to separate the chaff from the wheat; that they were greatly shocked by an invention which would raise a whirlwind in calm weather, and that they looked upon the use of such a machine as rebellion against God.

As to the grinding of the grain, the rudimentary means still exist, and are still used by rudimentary peoples, and to meet exceptional necessities; these are the primeval hollowed stone and mortar and pestle, and they too were "the mills of the Gods" in Egyptian, Hebrew and Early Greek days: the *quern*—that is, the upper running stone and the lower stationary grooved one—was a later Roman invention and can be found described only a century or two before the Christian era. [Pg 46]

Crude as these means were they were the chief ones used in milling until within a century and a quarter ago.

In a very recent bright work published in London, by Richard Bennett and John Elton, on Corn Mills, etc., they say on this point: "The mill of the last century, that, by which, despite its imperfections, the production of flour rose from one of the smallest to one of the greatest and most valuable industries of the world, was essentially a structure of few parts, whether driven by water or wind, and its processes were exceedingly simple. The wheat was cleaned by a rude machine consisting of a couple of cylinders and screens, and an air blast passed through a pair of mill-stones, running very close together, in order that the greatest amount of flour might be produced at one grinding. The meal was then bolted, and the tailings, consisting of bran, middlings and adherent flour, again sifted and re-ground. It seems probable that the miller of the time had a fair notion of the high grade of flour ground from middlings, but no systematic method of procedure for its production was adopted."

The upper and the nether mill-stone is still a most useful device. The "dress," which consists of the grooves which are formed in the meeting faces of the stones, has been changed in many ways to meet the requirements in producing flour in varying degrees of fineness. Machines have been invented to make such grooves. A Swiss machine for this purpose consists of two disks carrying diamonds in their peripheries, which, being put in rapid revolution, cut parallel grooves in the face of the stone.

A great advance in milling was made both in America and Europe by the inventions of Oliver [Pg 47] Evans. Evans was born in the State of Delaware, U.S., in 1755, and died in 1819. He was a poor boy and an apprentice to a wheelwright, and while thus engaged his inventive powers were developed. He had an idea of a land carriage propelled without animal power. At the age of 22 he invented a machine for making card teeth, which superseded the old method of making them by hand. Later he invented steam-engines and steam-boats, to which attention will hereafter be called. Entering into business with his brothers within the period extending from 1785 to 1800, he produced those inventions in milling which by the opening of the 19th century had revolutionised the art. A description of the most important of these inventions was published by him in 1795 in a book entitled *The Young Millwright and Miller's Grist*. Patents were granted Evans by the States of Delaware, Maryland and Pennsylvania in 1787, and by the U.S. Government in 1790 and 1808.

As these inventions formed the basis of the most important subsequent devices of the century, a brief statement of his system is proper:

From the time the grain was emptied from the waggon to the final production of the finest flour at the close of the process, all manual labour was dispensed with. The grain was first emptied into a box hung on a scale beam where it was weighed, then run into an elevator which raised it to a chamber over cleaning machines through which it was passed, and reclaimed by the same means if desired; then it was run down into a chamber over the hoppers of the mill-stones; when ground it fell from the mill-stones into conveyors and as carried along subjected to the heated air of a kiln drier; then carried into a meal elevator to be raised and dropped on to a cooling floor [Pg 48] where it was met by what is called a hopper boy, consisting of a central round upright shaft revolving on a pivot, and provided with horizontal arms and sweeps adapted to be raised and lowered and turned, by which means the meal was continually stirred around, lifted and turned on the floor and then gathered on to the bolting hoppers, the bolts being cylindrical sieves of varying degrees of fineness to separate the flour from its coarser impurities, and when not bolted sufficiently, carried by a conveyor called a drill to an elevator to be dumped again into the bolting hoppers and be re-bolted. When not sufficiently ground the same drill was used to carry the meal to the grind stones. It was the design of the process to keep the meal in constant motion from first to last so as to thoroughly dry and cool it, to heat it further in the meantime, and to run the machines so slowly as to prevent the rise and waste of the flour in the form of dust.

The Evans system, with minor modifications and improvements, was the prevailing one for three-quarters of a century. New mills, when erected, were provided with this system, and many mills in their quiet retreats everywhere awoke from their drowsy methods and were equipped with the new one.

But the whole system of milling has undergone another great change within the last thirty years:

During that time it has been learned that the coarser portion or kernel of wheat which lies next to the skin of the berry and between the skin and the heart is the most valuable and nutritious part, as it consists largely of gluten, while the interior consists of starch, which when dry becomes a pearly powder. Under the old systems this coarser part, known as middlings, was [Pg 49] eliminated, and ground for feed for cattle, or into what was regarded as an inferior grade of flour from which to make coarse bread. It was customary, therefore, under the old method to set the grinding surfaces very close with keen sharp burrs, so that this coarser part was cut off and mixed with the small particles of bran, fine fuzz and other foreign substances, which was separated from the finer part of the kernel by the bolting.

The new process consists of removing the outer skin and adherent impurities from the middlings, then separating the middlings from the central finer part and then regrinding the middlings into flour.

This middlings flour being superior, as stated, to what was called straight grade, it became desirable to obtain as much middlings as possible, and to this end it was necessary to set the grinding surfaces further apart so as to grind *high*, hence the *high* milling process as distinguished from *low* milling. For the better performance of the high rolling process, roller mills were invented. It was found that the cracking process by which the kernel could be cracked and the gluten middlings separated from the starchy heart could best be had by the employment of rollers or cylinders in place of face stones, and at the same time the heating of the product, which injures it, be avoided.

The rollers operate in sets, and successive crackings are obtained by passing and repassing, if necessary, the grain through these rollers, set at different distances apart. The operation on grains of different qualities, whether hard or soft, or containing more or less of the gluten middlings, or starchy parts, and their minute and graded separation, thus are obtained with the greatest nicety. [Pg 50]

The Hungarians, the Germans, the Austrians, the Swiss, the English and the Americans have all invented useful forms of these rollers.

This process was accompanied by the invention of new forms of middlings separators and purifiers, in which upward drafts of air are made to pass up through flat, graded shaking bolts, in an enclosed case, by which the bran specks and fuzz are lifted and conveyed away from the shaken material. In some countries, such as the great wheat state of Minnesota, U.S., where the wheat had before been of inferior market value owing to the poorer grade of flour obtained by the old processes, that same wheat was made to produce the most superior flour under the new processes, thus increasing the yearly value of the crops by many millions of dollars.

Disastrous flour dust explosions in some of the great mills at Minneapolis, in 1877-78, developed the invention of dust collectors, by which the suspended particles of flour dust are withdrawn from the machinery and the mill, and the air is cleared for respiration and for the production of the finest flour, while the mill is kept closed and comfortable in cold seasons. One of the latest forms of such a collector has for its essential principle the vertical or rotatory air current, which it is claimed moves and precipitates the finest particles.

The inventions in the class of mills have so multiplied in these latter days, that nearly every known article that needs to be cleaned and hulled, or ground, or cracked or pulverized, has its own specially designed machine. Wind and water as motive powers have been supplanted by steam and electricity. It would be impossible in one volume to describe this great variety. Knight, [Pg 51] in his Mechanical Dictionary, gives a list under "Mills," of more than a hundred distinct machines and processes relating to grinding, hulling, crushing, pulverising and mixing products.

Vegetable Cutters.—Modern ingenuity has not neglected those more humble devices which save the drudgery of hand work in the preparation of vegetables and roots for food for man and beasts, and for use especially when large quantities are to be prepared. Thus, we find machines armed with blades and worked by springs and a lever, for chopping, others for cutting stalks, other machines for paring and slicing, such as apple and potato parers and slicers, others for grating and pulping, others for seeding fruits, such as cherries and raisins, and an entire range of mechanisms, from those which handle delicately the tenderest pod and smallest seed, to the ponderous machines for cutting and crushing the cane in sugar making.

Pressing and Baling.—The want of pressing loose materials and packing bulky ones, like hay, wool, cotton, hops, etc, and other coarser products, into small, compact bales and bodies, to facilitate their transportation, was immediately felt on the great increase of such products in the century.

From this arose pressing and baling machines of a great variety, until nearly every agricultural product that can be pressed, packed or baled has its special machine for that operation. Besides those above indicated relating to agricultural products, we have cane presses, cheese presses, butter presses, cigar and tobacco presses, cork presses, and flour packers, fruit and lard presses, peat presses, sugar presses and others. Leading mechanical principles in presses are also [Pg 52] indicated by name, as screw presses, toggle presses, beater press, revolving press, hydraulic press, rack and pinion press, and rolling pressure press and so on.

There are the presses also that are used in compressing cotton. When it is remembered that cotton is raised in about twenty different countries, and that the cotton crop of the United States of 1897-98 was 10,897,857 bales, of about 500 lbs. each; of India, (estimated) for the same period, 2,844,000, of 400 lbs each; of China about 1,320,000, of 500 lbs each, and between two and three million bales in the other countries, it is interesting to consider how the world's production of this enormous mass of elastic fibre, amounting to seventeen or eighteen million bales, of four and five hundred pounds each, is compressed and bound.

The screw press was the earliest form of machine used, and then came the hydraulic press. Later it has been customary to press the cotton by screw presses or small hydraulic presses at the plantation, bind it with ropes or metal bands and then transport it to some central or seaboard station where an immense establishment exists, provided with a great steam-operated press, in which the bale from the country is placed and reduced to one-fourth or one-third its size, and while under pressure new metallic bands applied, when the bale is ready for shipment. This was a gain of a remarkable amount of room on shipboard and on cars, and solved a commercial problem. But now this process, and the commercial rectangular bale, seem destined to be supplanted by roller presses set up near the plantations themselves, into which the cotton is fed directly from the gin, rolled upon itself between the rollers and compressed into round bales of [Pg 53] greater density than the square bale, thus saving a great amount of cost in dispensing with the steam and hydraulic plants, with great additional advantages in convenience of handling and cost of transportation.

It is so arranged also that the cotton may be rolled into clean, uniform dense layers, so that the same may be unwound at the mill and directly applied to the machines for its manufacture into fabrics, without the usual tedious and expensive preliminary operations of combing and re-rolling.

It has also remained for the developed machine of the century to convert hay into an export commodity to distant countries by the baling process. Bale ties themselves have received great attention from inventors, and the most successful have won fortunes for their owners.

Most ingenious machines have been devised for picking cotton in the fields, but none have yet reached that stage of perfection sufficient to supplant the human fingers.

Fruits and Foods.—To prepare and transport fruits in their natural state to far distant points, while preserving them from decay for long times, is, in the large way demanded by the world's great appetites, altogether a success of modern invention.

To gather the fruit without bruising by mechanical pickers, and then to place the fruit, oranges for instance, in the hands of an intelligent machine which will automatically, but delicately and effectually, wrap the same in a paper covering, and discharge them without harm, are among the recent inventive wonders. In the United States alone 67 patents had been granted up to 1895 for [Pg 54] fruit wrapping machines.

Inventions relating to drying and evaporating fruit, and having for their main object to preserve as much as possible the natural taste and colour of the fruit, have been numerous. Spreading the fruit in the air and letting the sun and air do the rest is now a crude process.

These are the general types of drying and evaporating machines:

First, those in which trays of fruit are placed upon stationary ledges within a heated chamber; second, those in which the trays are raised and lowered by mechanical means toward or farther from the source of heat as the drying progresses; third, those in which the fruit is placed in imperforate steam jacketed pans. Many improvements, of course, have been made in detail of form, in ventilation, the supplying and regulating of heat and the moving of trays.

The hermetically sealed glass or earthenware fruit jar, the lids of which can be screwed or locked down upon a rubber band, after the jar is filled and the small remainder of air drawn out by a convenient steam heater, now used by the million, is an illustration of the many useful modern contrivances in this line.

Sterilisation.—In preserving, the desirability of preventing disease and keeping foods in a pure state has developed in the last quarter of a century many devices by which the food is subjected to a steam heat in chambers, and, by devices operated from the outside, the cans or bottles are opened and shut while still within the steam-filled chamber.

Diastase.—By heating starchy matters with substances containing diastase, a partial [Pg 55] transformation is effected, which will materially shorten and aid its digestion, and this fact has been largely made use of in the preparation of soluble foods, especially those designed for infants and invalids, such as malted milk and lactated food.

Milkers.—Invention has not only been exercised in the preservation and transportation of milk, but in the task of milking itself. Since 1860 inventors have been seeking patents for milkers, some having tubes operated by air-pumps, others on the same principle in which the vacuum is made to increase and decrease or pulsate, and others for machines in which the tubes are mechanically contracted by pressure plates.

Slaughtering.—Great improvements have been made in the slaughtering of animals, by which a great amount of its repulsiveness and the unhealthfulness of its surroundings have been removed. These improvements relate to the construction of proper buildings and appliances for the handling of the animals, the means for slaughtering, and modes of taking care of the meat and transporting the same. Villages, towns, and even many cities, are now relieved of the formerly unsavoury slaughter-houses, and the work is done from great centres of supply, where meats in every shape are prepared for food and shipment.

It would be impossible in a bulky volume, much less in a single chapter, to satisfactorily enumerate those thousands of inventions which, taking hold of the food products of the earth, have spread them as a feast before the tribes of men.

Tobacco.—Some of the best inventive genius of the century has been exercised in providing for man's comfort, not a food, but what he believes to be a solace. [Pg 56]

> "Sublime Tobacco! which from East to West
> Cheers the tar's labour or the Turkman's rest."

In the United States alone, in the year 1885, there were 752,520 acres of land devoted to the production of tobacco, the amount in pounds grown being 562,736,000, and the value of which was estimated as $43,265,598. These amounts have been somewhat less in years since then, but the appetite continues, and any deficiency in the supply is made up by enormous importation. Thus, in 1896, there were imported into the United States, 32,924,966 pounds of tobacco, of various kinds, valued at $16,503,130. There are no reliable statistics showing that, man for man, the people of that country are greater lovers of the weed than the people of other countries, but the annual value of tobacco raised and imported by them being thus about $60,000,000, it indicates the strength of the habit and the interest in the nurture of the plant throughout the world. Neither the "Counterblaste to Tobacco" of King James I., and the condemnations of kings, popes, priests and sultans, that followed its early introduction into Europe, served to choke the weed in its infancy or check its after growth. Now it is attended from the day of its planting until it reaches the lips of the consumer by contrivances of consummate skill to fit it for its destined purpose. Besides the ploughs, the cultivators and the weeders of especial forms used to cultivate the plant, there are, after the grown plant is cut in the field, houses of various designs for drying it, machines for rolling the leaves out smoothly in sheets; machines for removing the stems from the leaves and for crushing the stem; machines for pressing it into shape, and for pressing it, [Pg 57] whether solid or in granular form, into boxes, tubs and bags; machines for granulating it and for grinding it into snuff; machines for twisting it into cords; machines for flavouring the leaf with saccharine and other matters; machines for making cigars, and machines of a great variety and of the most ingenious construction for making cigarettes and putting them in packages.

Samples of pipes made by different ages and by different peoples would form a collection of wonderful art and ingenuity, second only to an exhibition of the means and methods of making them.

CHAPTER VI.

CHEMISTRY, MEDICINES, SURGERY, DENTISTRY.

Chemistry, having for its field the properties and changes of matter, has excited more or less attention ever since men had the power to observe, to think, and to experiment.

Some knowledge of chemistry must have existed among the ancients to have enabled the Egyptians to smelt ores and work metals, to dye their cloths, to make glass, and to preserve their dead from decomposition; so, too, to this extent among the Phœnicians, the Israelites, the Greeks and the Romans; and perhaps to a greater extent among the Chinese, who added powder to the above named and other chemical products. Aristotle speculated, and the alchemists of the middle ages busied themselves in magic and guess-work. It reached the dignity of a science in the seventeenth and eighteenth centuries, by the labours of such men, in the former century, as Libavius, Van Helmont, Glauber, Tachenius, Boyle, Lémery and Becher; Stahl, Boerhaave and Hamberg in both; and of Black, Cavendish, Lavoisier, Priestley and others in the eighteenth.

But so great have been the discoveries and inventions in this science during the nineteenth century that any chemist of any previous age, if permitted to look forward upon them, would have felt

"Like some watcher of the skies
When a new planet swims into his ken."

Indeed, the chemistry of this century is a new world, of which all the previous discoveries in that line were but floating nebulæ.

So vast and astonishingly fast has been the growth and development of this science that before the century was two-thirds through its course Watts published his *Dictionary of Chemistry* in five volumes, averaging a thousand closely printed pages, followed soon by a thousand-page supplement; and it would have required such a volume every year since to adequately report the progress of the science. Nomenclatures, formulas, apparatuses and processes have all changed. It was deemed necessary to publish works on *The New Chemistry*, and Professor J. P. Cooke is the author of an admirable volume under that title.

We can, therefore, in this chapter only step from one to another of some of the peaks that rise above the vast surrounding country, and note some of the lesser objects as they appear in the vales below.

The leading discoveries of the century which have done so much to aid Chemistry in its giant strides are the atomic and molecular theories, the mechanics of light, heat, and electricity, the correlation and conservation of forces, their invariable quantity, and their indestructibility, spectrum analysis and the laws of chemical changes.

John Dalton, that humble child of English north-country Quaker stock, self-taught and a teacher all his life, in 1803 gave to the world his atomic theory of chemistry, whereby the existence of matter in ultimate atoms was removed from the region of the speculation of certain ancient philosophers, and established on a sure foundation.

The question asked and answered by Dalton was, what is the relative weight of the atoms composing the elementary bodies?

He discovered that one chemical element or compound can combine with another chemical element, to form a new compound, in two different proportions by weight, which stand to each other in the simple ratio of one to two; and at the same time he published a table of the *Relative weight of the ultimate particles of Gaseous and other Bodies*. Although the details of this table have since been changed, the principles of his discovery remain unchanged. Says Professor Roscoe:

> "Chemistry could hardly be said to exist as a science before the establishment of the laws of combination in multiple proportions, and the subsequent progress of chemical science materially depended upon the determination of these combined proportions or atomic weights of the elements first set up by Dalton. So that among the founders of our science, next to the name of the great French Philosopher, Lavoisier, will stand in future ages the name of John Dalton, of Manchester."

Less conspicuous but still eminently useful were his discoveries and labours in other directions, in the expansion of gases, evaporation, steam, etc.

Wollaston and Gay-Lussac, both great chemists, applied Dalton's discovery to wide and most important fields in the chemical arts.

Also contemporaneous with Dalton was the great German chemist, Berzelius, who confirmed and extended the discoveries of Dalton. More than this, it has been said of Berzelius:

> "In him were united all the different impulses which have advanced the science since the beginning of the present epoch. The fruit of his labors is scattered throughout the [Pg 61] entire domain of the science. Hardly a substance exists to the knowledge of which he has not in some way contributed. A direct descendant of the school of his countryman, Bergman, he was especially renowned as an analyst. No chemist has determined by direct experiment the composition of a greater number of substances. No one has exerted a greater influence in extending the field of analytical chemistry."

As to light, the great Huygens, the astronomer and mathematician, the improver of differential calculus and of telescopes, the inventor of the pendulum clock, chronometers, and the balance wheel to the watch, and discoverer of the laws of the double refraction of light and of polarisation, had in the 17th century clearly advanced the idea that light was propagated from luminous bodies, not as a stream of particles through the air but in waves or vibrations of ether, which is a universal medium extending through all space and into all bodies. This fundamental principle now enters into the explanation of all the phenomena of light.

Newton in the next century, with the prism, decomposed light, and in a darkened chamber reproduced all the colours and tints of the rainbow. But there were dark lines in that beam of broken sunlight which Newton did not notice.

It was left to Joseph von Fraunhofer, a German optician, and to the 19th century, and nearly one hundred years after Newton's experiments with the prism, to discover, with finer prisms that he had made, some 590 of these black lines crossing the solar spectrum. What they were he did not know, but conjectured that they were caused by something which existed in the sun and stars [Pg 62] and not in our air. But from that time they were called Fraunhofer's dark lines.

From the vantage ground of these developments we are now enabled to step to that mountain peak of discovery from which the sun and stars were looked into, their elements portrayed, their very motions determined, and their brotherhood with the earth, in substance, ascertained.

The great discovery of the cause of Fraunhofer's dark bands in the broken sunlight was made by Gustave Robert Kirchoff, a German physician, in his laboratory in Heidelberg, in 1860, in conjunction with his fellow worker, Robert Bunsen.

Kirchoff happened to let a solar ray pass through a flame coloured with sodium, and through a prism, so that the spectrum of the sun and the flame fell one upon another. It was expected that the well known yellow line of sodium would come out in the solar spectrum, but it was just the opposite that took place. Where the bright yellow line should have fallen appeared a dark line.

With this observation was coupled the reflection that heat passes from a body of a higher temperature to one of a lower, and not inversely. Experiments followed: iron, sodium, copper, etc., were heated to incandescence and their colours prismatically separated. These were transversed with the same colours of other heated bodies, and the latter were absorbed and rendered black. Kirchoff then announced his law that all bodies absorb chiefly those colours which they themselves emit. Therefore these vapours of the sun which were rendered in black lines were so produced by crossing terrestrial vapors of the same nature. [Pg 63]

Thus by the prism and the blowpipe were the same substances found in the sun, the stars, and the earth. The elements of every substance submitted to the process were analysed, and many secrets in the universe of matter were revealed.

Young, of America, invented a splendid combination of spectroscope and telescope, and Huggins of England was the first to establish by spectrum analysis the approach and retreat of the stars.

It was prior to this time that those wonderful discoveries and labours were made which developed the true nature of heat, which demonstrated the kinship and correlation of the forces of Nature, their conservation, or property of being converted one into another, and the indestructibility of matter, of which force is but another name.

The first demonstrations as to the nature of heat were given by the American Count Rumford, and then by Sir Humphry Davy, just at the close of the 18th century, and then followed in this the brilliant labours and discoveries of Mayer and Helmholtz of Germany, Colding of Denmark, and Joule, Grove, Faraday, Sir William Thomson of England, of Henry, Le Conte and Martin of America, as to the correlation and convertibility of all the forces.

The French revolution, and the Napoleonic wars, isolating France and exhausting its resources, its chemists were appealed to devote their genius and researches to practical things; to the munitions of war, the rejuvenation of the soil, the growing of new crops, like the sugar beet, and new manufacturing products.

Lavoisier had laid deep and broad in France the foundations of chemistry, and given the science nomenclature that lasted a century. So that the succeeding great teachers, Berthollet, Guyton, Fourcroy and their associates, and the institutions of instruction in the sciences fostered by them, and inspired in that direction by Napoleon, bent their energies in material directions, and a tremendous impulse was thus given to the practical application of chemistry to the arts and manufactures of the century. [Pg 64]

The same spirit, to a less extent, however, manifested itself in England, and as early as 1802 we find Sir Humphry Davy beginning his celebrated lectures on the *Elements of Agricultural Chemistry* before a board of agriculture, a work that has passed through many editions in almost every modern language.

When the fact is recalled that agricultural chemistry embraces the entire natural science of vegetable and animal production, and includes, besides, much of physics, meteorology and geology, the extent and importance of the subject may be appreciated; and yet such appreciation was not manifested in a practical manner until the 19th century. It was only toward the end of the 18th century that the vague and ancient notions that air, water, oil and salt formed the nutrition of plants, began to be modified. Davy recognized and explained the beneficial fertilizing effects of ammonia, and analysed and explained numerous fertilizers, including guano. It is due to his discoveries and publications, combined with those of the eminent men on the continent, above referred to, that agricultural chemistry arose to the dignity of a science. The most brilliant, eloquent and devoted apostle of that science who followed Davy was Justus von Liebig of Germany, who was born in Darmstadt in 1803, the year after Davy commenced his lectures in [Pg 65]
England. It was in response to the British Association for the Advancement of Science that he gave to the world his great publications on *Chemistry in its application to Agriculture, Commerce, Physiology, and Pathology*, from which great practical good resulted the world over. One of his favorite subjects was that of fermentation, and this calls up the exceedingly interesting discoveries in the nature of alcohol, yeast, mould—aging malt, wines and beer—and their accompanying beneficial results.

In one of Huxley's charming lectures—such as he delighted to give before a popular audience—delivered in 1871, at Manchester, on the subject of "Yeast," he tells how any liquid containing sugar, such as a mixture of honey and water, if left to itself undergoes the peculiar change we know as fermentation, and in the process the scum, or thicker muddy part that forms on top, becomes yeast, carbonic acid gas escapes in bubbles from the liquid, and the liquid itself becomes spirits of wine or alcohol. "Alcohol" was a term used until the 17th century to designate a very fine subtle powder, and then became the name of the subtle spirit arising from fermentation. It was Leeuwenhoek of Holland who, two hundred years ago, by the use of a fine microscope he invented, first discovered that the muddy scum was a substance made up of an enormous multitude of very minute grains floating separately, and in lumps and in heaps, in the liquid. Then, in the next century the Frenchman, Cagniard de la Tour, discovered that these bodies grew to a certain size and then budded, and from the buds the plant multiplied; and thus that this yeast was a mass of living plants, which received in science the name of "torula," that [Pg 66]
the yeast plant was a kind of fungus or mould, growing and multiplying. Then came Fabroni, the French chemist, at the end of the 18th century, who discovered that the yeast plant was of bag-like form, or a cell of woody matter, and that the cell contained a substance composed of carbon, hydrogen, oxygen and nitrogen. This was a vegeto-animal substance, having peculiarities of "animal products."

Then came the great chemists of the 19th century, with their delicate methods of analysis, and decided that this plant in its chief part was identical with that element which forms the chief part of our own blood. That it was protein, a substance which forms the foundation of every animal organism. All agreed that it was the yeast plant that fermented or broke up the sugar element, and produced the alcohol. Helmholtz demonstrated that it was the minute particles of the solid part of the plant that produced the fermentation, and that such particles must be growing or alive, to produce it. From whence sprang this wonderful plant—part vegetable, part animal? By a long series of experiments it was found that if substances which could be fermented were kept entirely closed to the outer air, no plant would form and no fermentation take place. It was concluded then, and so ascertained, that the torulae in the plant proceeded from the torulae in the atmosphere, from "gay motes that people the sunbeams." Concerning just how the torulae broke up or fermented the sugar, great chemists have differed.

After the discovery that the yeast was a plant having cells formed of the pure matter of wood, and containing a semi-fluid mass identical with the composition which constitutes the flesh of animals, came the further discovery that all plants, high and low, are made up of the same kind of [Pg 67]
cells, and their contents. Then this remarkable result came out, that however much a plant may otherwise differ from an animal, yet, in essential constituents the cellular constructure of animal and plant is the same. To this substance of energy and life, common in the minute plant cell and the animal cell, the German botanist, Hugo von Mohl, about fifty years ago gave the name "protoplasm." Then came this astounding conclusion, that this *protoplasm* being common to both plant and animal life, the essential difference consisted only in the manner in which the cells are built up and are modified in the building.

And from that part of these great discoveries which revealed the fact that the sugary element was infected, as it were, from the germs of the air, producing fermentation and its results, arose that remarkable theory of many diseases known as the "germ theory." And, as it was found in the yeast plant that only the solid part or particle of the plant germinated fermentation and reaction, so, too, it has been found by the germ theory that only the solid particle of the contagious matter can germinate or grow the disease.

In this unfolding of the wonders of chemistry in the nineteenth century, the old empirical walls between forces and organisms, and organic and inorganic chemistry, are breaking down, and celestial and terrestrial bodies and vapours, living beings, and growing plants are discovered to be the evolution of one all-pervading essence and force. One is reminded of the lines of Tennyson:

"Large elements in order brought
And tracts of calm from tempest made,
And world fluctuation swayed [Pg 68]
In vassal tides that followed thought.

One God, one law, one element,
And one far-off divine event
To which the whole creation moves."

In the class of alcohol and in the field of yeast, the work of Pasteur, begun in France, has been followed by improvements in methods for selecting proper ferments and excluding improper ones, and in improved processes for aging and preserving alcoholic liquors by destroying deleterious ferments. Takamine, in using as ferment, koji, motu and moyashi, different forms of mould, and proposing to do entirely away with malt in the manufacture of beer and whiskey, has made a noteworthy departure. Manufacturing of malt by the pneumatic process, and stirring malt during germination, are among the improvements.

Carbonating.—The injecting of carbonic acid gas into various waters to render them wholesome, and also into beers and wines during fermentation, and to save delay and prevent impurities, are decided improvements.

The immense improvements and discoveries in the character of soils and fertilisers have already been alluded to. Hundreds of instruments have been invented for measuring, analysing, weighing, separating, volatilising and otherwise applying chemical processes to practical purposes.

To the chemistry of the century the world is indebted for those devices and processes for the utilisation and manufacture of many useful products from the liquids and oils, sugar from cane and beets, revivifying bone-black, centrifugal machinery for refining sugar, in defecating it by chemicals and heat, in evaporating it in pans, in separating starch and converting it into glucose, [Pg 69] etc.

Oils and Fats.—Up to within this century the vast amount of cotton seed produced with that crop was a waste. Then by the process, first of steaming the seed and expressing the oil, now by the process of extraction by the aid of volatile solvents, and casting off the solvents by distillation, an immensely valuable product has been obtained.

The utilising of oils in the manufacture of oilcloth and linoleum and rubber, has become of great commercial value. Formerly sulphur was the vulcanising agent, now chloride of sulphur has been substituted for pure sulphur.

Steam and the distillation processes have been applied with great success to the making of glycerine from fat and from soap underlye and in extracting fat from various waste products.

Bleaching and Dyeing.—Of course these arts are very old, but the old methods would not be recognised in the modern processes; and those who lived before the century knew nothing of the magnificent colours, and certain essences, and sweet savours that can be obtained from the black, hand-soiling pieces of coal. In the making of illuminating gas, itself a finished chemical product of the century, a vast amount of once wasted products, especially coal tar, are now extensively used; and from coal tar and the residuum of petroleum oils, now come those splendid aniline dyes which have produced such a revolution in the world of colours. The saturation of sand by a dye and its application to fabrics by an air blast; the circulation of the fluid colors, or of fluids for bleaching or drying, or oxidising, through perforated cylinders or cops on which the cloths are wound; devices for the running of skeins through dyes, the great improvements in [Pg 70] carbon dyes and kindred colours, the processes of making the colours on the fibre, and the perfumes made by the synthetic processes, are among the inventions in this field.

The space that a list of the new chemical products of this age and their description would fill, has already been indicated by reference to the great dictionary of Watts. Some of the electro-chemical products will be hereinafter referred to in the Chapter on Electricity, and the chemistry of Metallurgy will be treated under the latter topic.

Electro-chemical Methods.—Space will only permit it to be said that these methods are now employed in the production of a large number of elements, by means of which very many of them which were before mere laboratory specimens, have now become cheap and useful servants of mankind in a hundred different ways; such as aluminium, that light and non-corrosive metal, reduced from many dollars an ounce a generation ago, to 30 and 40 cents a pound now; carborundum, largely superseding emery and diamond dust as an abradant; artificial diamonds; calcium carbide, from which the new illuminating acetylene gas is made; disinfectants of many kinds; pigments, chromium, manganese, and chlorates by the thousand tons. The most useful new chemical processes are those used in purifying water sewage and milk, in electroplating metals and other substances, in the application of chemicals to the fine arts, in extracting grease from wool, and the making of many useful products from the waste materials of the dumps and garbage banks.

Medicines and Surgery.—One hundred years ago, the practice of medicine was, in the main, empirical. Certain effects were known to usually follow the giving of certain drugs, or the application of certain measures, but why or how these effects were produced, was unknown. The great steps forward have been made upon the true scientific foundation established by the discoveries and inventions in the fields of physics, chemistry and biology. The discovery of anaesthetics and their application in surgery and the practice of medicine, no doubt constitutes the leading invention of the century in this field. [Pg 71]

Sir Humphry Davy suggested it in 1800, and Dr. W. T. Morton was the first to apply an anaesthetic to relieve pain in a surgical operation, which he did in a hospital in Boston in 1846. Both its original suggestion and application were also claimed by others.

Not only relief from intense pain to the patient during the operation, but immense advantages are gained by the long and careful examination afforded of injured or diseased parts, otherwise difficult or impossible in a conscious patient.

The exquisite pain and suffering endured previous to the use of anaesthetics often caused death by exhaustion. Many delicate operations can now be performed for the relief of long-continued diseases which before would have been hazardous or impossible. How many before suffered unto death long-drawn-out pain and disease rather than submit to the torture of the knife! How many lives have been saved, and how far advanced has become the knowledge of the human body and its painful diseases, by this beneficent remedy!

Inventions in the field of medicine consist chiefly in those innumerable compositions and compounds which have resulted from chemical discoveries. Gelatine capsules used to conceal unpalatable remedies may be mentioned as a most acceptable modern invention in this class. [Pg 72] Inventions and discoveries in the field of surgery relate not only to instrumentalities but processes. The antiseptic treatment of wounds, by which the long and exhausting suppuration is avoided, is among the most notable of the latter. In instruments vast improvements have been made; special forms adapted for operation in every form of injury; in syringes, especially hypodermic, those used for subcutaneous injections of liquid remedies; inhalers for applying medicated vapours and devices for applying volatile anaesthetics, and devices for atomising and spraying liquids. In the United States alone about four thousand patents have been granted for inventions in surgical instruments.

Dentistry.—This art has been revolutionised during the century. Even in the time of Herodotus, one special set of physicians had the treatment of teeth; and artificial teeth have been known and used for many ages, but all seems crude and barbarous until these later days. In addition to the use of anaesthetics, improvements have been made in nearly every form of dental instruments, such as forceps, dental engines, pluggers, drills, hammers, etc., and in the means and materials for making teeth. Later leading inventions have reference to utilising the roots of destroyed teeth as supports on which to form bridges to which artificial teeth are secured, and to crowns for decayed teeth that still have a solid base.

There exists no longer the dread of the dentist's chair unless the patient has neglected too long the visit. Pain cannot be all avoided, but it is ameliorated; and the new results in workmanship in the saving and in the making of teeth are vast improvements over the former methods.

[Pg 73]

CHAPTER VII.

STEAM AND STEAM ENGINES.

"Soon shall thy arm, unconquered steam! afar
Drag the slow barge, or drive the rapid car;
Or in wide waving wings expanded bear
The flying chariot through the field of air."

Thus sang the poet prophet, the good Dr. Darwin of Lichfield, in the eighteenth century. Newcomen and Watt had not then demonstrated that steam was not unconquerable, but the hitching it to the slow barge and the rapid car was yet to come. It has come, and although the prophecy is yet to be rounded into fulfilment by the driving of the "flying chariot through the field of air," that too is to come.

The prophecy of the doctor poet was as suggestive of the practical means of carrying it into effect as were all the means proposed during the first seventeen centuries of the Christian Era for conquering steam and harnessing it as a useful servant to man.

Toys, speculations, dreams, observations, startling experiments, these often constitute the framework on which is hung the title of Inventor; but the nineteenth century has demanded a better support for that proud title. He alone who first transforms his ideas into actual work and useful service in some field of man's labor, or clearly teaches others to do so, is now recognised [Pg 74] as the true inventor. Tested by this rule there was scarcely an inventor in the field of steam in all the long stretches of time preceding the seventeenth century. And if there were, they had no recording scribes to embalm their efforts in history.

We shall never know how early man learned the wonderful power of the spirit that springs from heated water. It was doubtless from some sad experience in ignorantly attempting to put fetters on it.

The history of steam as a motor generally commences with reference to that toy called the aeolipile, described by Hero of Alexandria in a treatise on pneumatics about two centuries before Christ, and which was the invention of either himself or Ctesibius, his teacher.

This toy consisted of a globe pivoted on two supports, one of which was a communicating pipe leading into a heated cauldron of water beneath. The globe was provided with two escape pipes on diametrically opposite sides and bent so as to discharge in opposite directions. Steam admitted into the globe from the cauldron escaped through the side pipes, and its pressure on these pipes caused the globe to rotate.

Hero thus demonstrated that water can be converted into steam and steam into work.

Since that ancient day Hero's apparatus has been frequently reinvented by men ignorant of the early effort, and the principle of the invention as well as substantially the same form have been put into many practical uses. Hero in his celebrated treatise described other devices, curious siphons and pumps. Many of them are supposed to have been used in the performance of some of the startling religious rites at the altars of the Greek priests.

From Hero's day the record drops down to the middle ages, and still it finds progress in this art [Pg 75] confined to a few observations and speculations. William of Malmesbury in 1150 wrote something on the subject and called attention to some crude experiments he had heard of in Germany. Passing from the slumber of the middle ages, we are assured by some Spanish historians that one Blasco de Garay, in 1543, propelled a ship having paddle wheels by steam at Barcelona. But the publication was long after the alleged event, and is regarded as apocryphal.

Observations became more acute in the sixteenth and seventeenth centuries, experiments more frequent, and publications more full and numerous.

Cardan Ramelli and Leonardo da Vinci, learned Italians, and the accomplished Prof. Jacob Besson of Orleans, France, all did much by their writings to make known theoretically the wonderful powers of steam, and to suggest modes of its practical operation, in the latter part of the sixteenth century.

Giambattista della Porta, a gentleman of Naples, possessing high and varied accomplishments in all the sciences as they were known at that day, 1601, and who invented the magic-lantern and *camera obscura*, in a work called *Spiritalia*, described how steam pressure could be employed to raise a column of water, how a vacuum was produced by the condensation of steam in a closed vessel, and how the condensing vessel should be separated from the boiler. Revault in France showed in 1605 how a bombshell might be exploded by steam.

Salomon de Caus, engineer and architect to Louis XIII, in 1615 described how water might be raised by the expansion of steam.

In 1629 the Italian, Branco, published at Rome an account of the application of a steam jet upon the vanes of a small wheel to run it, and told how in other ways Hero's engine might be employed [Pg 76] for useful purposes.

The first English publication describing a way of applying steam appeared in 1630 in a patent granted to David Ramseye, for a mode of raising water thereby. This was followed by patents to Grant in 1632 and to one Ford in 1640. During that century these crude machines were called "fire engines." It seems to have been common in some parts of Europe during the seventeenth century to use a blast of steam to improve the draft of chimneys and of blast furnaces. This application of steam to smoke and smelting has been frequently revived by modern inventors with much flourish of originality.

It is with a certain feeling of delight and relief, after a prolonged search through the centuries for some evidence of harnessing this mighty agent to man's use, that we come to the efforts of the good Marquis of Worcester—Edward Somerset. He it was who in 1655 wrote of the *Inventions of the Sixteenth Century*. He afterwards amplified this title by calling his book *A Century of Names and Scantlings of such Inventions as at present I call to mind to have tried and perfected*, etc.

There are about one hundred of these "Scantlings," and his descriptions of them are very brief but interesting. Some, if revived now and put to use, would throw proposed flying machines into the background, as they involved perpetual motion.

But to his honor be it said that he was the first steam-engine builder. A patent was issued to him in 1663. It was about 1668 that he built and put in successful operation at Raglan Castle at Vauxhall, near London, a steam engine to force water upward. He made separate boilers, which he worked alternately, and conveyed the steam from them to a vessel in which its pressure [Pg 77] operated to force the water up. Unfortunately he did not leave a description of his inventions sufficiently full to enable later mechanics to make and use them. He strove in vain to get capital interested and a company formed to manufacture his engines. The age of fear and speculation as to steam ceased when the Marquis set his engine to pumping water, and from that time inventors went on to put the arm of steam to work.

In 1683 Sir Samuel Morland commenced the construction of the Worcester engines for use and sale; Hautefeuille of France taught the use of gas, described how gas as well as steam engines might be constructed, and was the first to propose the use of the piston. The learned writings of the great Dutch scientist and inventor, Huygens, on heat and light steam and gas, also then came forth, and his assistant, the French physicist and doctor, Denis Papin, in 1690, proposed steam as a universal motive power, invented a steam engine having a piston and a safety valve, and even a crude paddle steamer, which it is said was tried in 1707 on the river Fulda. Then in 1698 came Thomas Savery, who patented a steam engine that was used in draining mines.

The eighteenth century thus commenced with a practical knowledge of the power of steam and of means for controlling and working it.

Then followed the combined invention of Newcomen, Cawley and Savery, in 1705, of the most successful pumping engine up to that time. In this engine a cylinder was employed for receiving the steam from a separate boiler. There was a piston in the cylinder driven up by the steam admitted below it, aided by a counterpoise at one end of an engine beam. The steam was then cut [Pg 78] off from the boiler and condensed by the introduction beneath the piston of a jet of water, and the condensed steam and water drawn off by a pipe. Atmospheric pressure forced the piston down. The piston and pump rods were connected to the opposite ends of a working beam of a pumping engine, as in some modern engines. Gauge cocks to indicate the height of water, and a safety valve to regulate the pressure of steam, were employed. Then came the ingenious improvement of the boy Humphrey Potter, connecting the valve gear with the engine beam by cords, so as to do automatically what he was set to do by hand, and the improvement on that of the Beighton plug rod. Still further improved by others, the Newcomen engine came into use through out Europe.

Jonathan Hulls patented in England in 1736 a marine steam engine, and in 1737 published a description of a Newcomen engine applied to his system for towing ships. William Henry, of Pennsylvania, tried a model steamboat on the Conestoga river in 1763.

This was practically the state of the art, in 1763, when James Watt entered the field. His brilliant inventions harnessed steam to more than pumping engines, made it a universal servant in manifold industries, and started it on a career which has revolutionized the trade and manufactures of the world.

To understand what the nineteenth century has done in steam motive power we must first know what Watt did in the eighteenth century, as he then laid the foundation on which the later inventions have all been built.

Taking up the crude but successful working engine of Newcomen, a model of which had been [Pg 79] sent to him for repairs, he began an exhaustive study of the properties of steam and of the means for producing and controlling it. He found it necessary to devise a new system.

Watt saw that the alternate heating and cooling of the cylinder made the engine work slowly and caused an excessive consumption of steam. He concluded that "the cylinder should always be as hot as the steam that entered it." He therefore closed the cylinder and provided a separate condensing vessel into which the steam was led after it raised the piston. He provided an air-tight jacket for the cylinder, to maintain its heat. He added a tight packing in the cylinder-head for the piston-rod to move through, and a steam-tight stuffing-box on the top of the cylinder. He caused the steam to alternately enter below and above the piston and be alternately condensed to drive the piston down as well as up, and this made the engine double-acting, increasing its power and speed. He converted the reciprocating motion of the piston into a rotary motion by the adoption of the crank, and introduced the well-known parallel motion, and many other improvements. In short, he demonstrated for the first time by a practical and efficient engine that the expansive force of steam could be used to drive all ordinary machinery. He then secured his inventions by patents against piracy, and sustained them successfully in many a hard-fought battle. It had taken him the last quarter of the 18th century to do all these things.

Watt was the proper precursor of the nineteenth century inventions, as in him were combined the power and attainments of a great scientist and the genius of a great mechanic. The last eighteen years of his life were passed in the 19th century, and he was thus enabled to see his inventions [Pg 80] brought within its threshold and applied to those arts which have made this age so glorious in mechanical achievements.

Watt so fitly represents the class of modern great inventors in his character and attainments that the description of him by Sir Walter Scott is here pertinent as a tribute to that class, and as a delineation of the general character of those benefactors of his race of which he was so conspicuous an example:—

Says Sir Walter:—

> "Amidst this company stood Mr. Watt, the man whose genius discovered the means of multiplying our national resources to a degree, perhaps, even beyond his own stupendous powers of calculation and combination; bringing the treasures of the abyss to the summit of the earth—giving to the feeble arm of man the momentum of an Afrite

—commanding manufactures to rise—affording means of dispensing with that time and tide which wait for no man—and of sailing without that wind which defied the commands and threats of Xerxes himself. This potent commander of the elements—this abridger of time and space—this magician, whose cloudy machinery has produced a change in the world, the effects of which, extraordinary as they are, are perhaps only beginning to be felt—was not only the most profound man of science, the most successful combiner of powers and calculator of numbers, as adapted to practical purposes, was not only one of the most generally well-informed, but one of the best and kindest of human beings."

The first practical application of steam as a working force was to pumping, as has been stated. [Pg 81] After Watt's system was devised, suggestions and experiments as to road locomotives and carriages were made, and other applications came thick and fast. A French officer, Cugnot, in 1769 and 1770, was the first to try the road carriage engine. Other prominent Frenchmen made encouraging experiments on small steamboats—followed in 1784-86 by James Rumsey and John Fitch in America in the same line. Watt patented a road engine in 1784. About the same time his assistant, Murdock, completed and tried a model locomotive driven by a "grasshopper" engine. Oliver Evans, the great American contemporary of Watt, had in 1779 devised a high-pressure non-condensing steam engine in a form still used. In 1786-7 he obtained in Pennsylvania and Maryland patents for applying steam to driving flour mills and propelling waggons. Also about this time, Symington, the Scotchman, constructed a working model of a steam carriage, which is still preserved in the museum at South Kensington, London. Symington and his fellow Scotchmen, Miller and Taylor, in 1788-89 also constructed working steamboats. In 1796 Richard Trevithick, a Cornish marine captain, was producing a road locomotive. The century thus opened with activity in steam motive power. The "scantlings" of the Marquis of Worcester were now being converted into complete structures. And so great was the activity and the number of inventors that he is a daring man who would now decide priority between them. The earliest applications in this century of steam power were in the line of road engines.

On Christmas eve of 1801, Trevithick made the initial trip with the first successful steam road locomotive through the streets of Camborne in Cornwall, carrying passengers. In one of his trips [Pg 82] he passed into the country roads and came to a tollgate through which a frightened keeper hastily passed him without toll, hailing him as the devil.

Persistent efforts continued to be made to introduce a practical steam road carriage in England until 1827. After Trevithick followed Blenkinsop, who made a locomotive which ran ten miles an hour. Then came Julius Griffith, in 1821, of Brompton, who patented a steam carriage which was built by Joseph Bramah, one of the ablest mechanics of his time. Gordon, Brunton and Gurney attempted a curious and amusing steam carriage, resembling a horse in action—having jointed legs and feet, but this animal was not successful. Walter Hancock, in 1827, was one of the most persistent and successful inventors in this line; but bad roads and an unsympathetic public discouraged inventors in their efforts to introduce steam road carriages, and their attention was turned to the locomotive to run on rails or tracks especially prepared for them. Wooden and iron rails had been introduced a century before for heavy cars and wagons in pulling loads from mines and elsewhere, but when at the beginning of the century it had been found that the engines of Watt could be used to drag such loads, it was deemed necessary to make a rail having its top surface roughened with ridges and the wheels of the engine and cars provided with teeth or cogs to prevent anticipated slipping.

In England, Blackett and George Stephenson discovered that the adhesion of smooth wheels to smooth rails was sufficient. Without overlooking the fact that William Hendley built and operated a locomotive called the *Puffing Billy* in 1803, and Hackworth one a little later, yet to the genius of [Pg 83] Stephenson is due chiefly the successful introduction of the modern locomotive. His labours and inventions continued from 1812 for twenty years, and culminated at two great trials: the first one on the Liverpool and Manchester Railway in 1829, when he competed with Hackworth and Braithwaite and Ericsson, and with the *Rocket* won the race; and the second at the opening of the same road in 1830, when with the *Northumbrian*, at the head of seven other locomotives and a long train of twenty-eight carriages, in which were seated six hundred passengers, he ran the train successfully between the two towns.

On this occasion Mr. Huskisson, Home Secretary in the British Cabinet, while the cars were stopping to water the engines, and he was out on the track talking with the Duke of Wellington, was knocked down by one of the engines and had one of his legs crushed. Placed on board of the *Northumbrian*, it was driven at the rate of thirty-six miles an hour by Stephenson to Eccles. Mr. Huskisson died there that night. This was its first victim, and the greatest speed yet attained by a locomotive.

The year 1829 therefore can be regarded as the commencement of the life of the locomotive for transportation of passengers. The steam blast thrown into the smokestack by Hackworth, the tubular boiler of Seguin and the link motion of Stephenson were then, as they now are, the essential features of locomotives.

In the meantime America had not been idle. The James Watt of America, Oliver Evans, in 1804 completed a flat-bottomed boat to be used in dredging at the Philadelphia docks, and mounting it on wheels drove it by its own steam engine through the streets to the river bank. Launching the [Pg 84] craft, he propelled it down the river by using the same engine to drive the paddle wheels. He gave to this engine the strange name of *Oruktor Amphibolos*.

John C. Stevens of New Jersey was, in 1812, urging the legislature of the State of New York to build railways, and asserting that he could see nothing to hinder a steam carriage from moving with a velocity of one hundred miles an hour. In 1829 George Stephenson in England had made for American parties a locomotive called *The Stourbridge Lion*, which in that year was brought to America and used on the Delaware and Hudson R. R. by Horatio Allen. Peter Cooper in the same year constructed a locomotive for short curves, for the Baltimore and Ohio Railroad.

Returning now to steam navigation:—Symington again entered the field in 1801-2 and constructed for Lord Dundas a steamboat, named after his wife, the *Charlotte Dundas*, for towing on a canal, which was successfully operated.

Robert Fulton, an American artist, and subsequently a civil engineer, built a steamboat on the Seine in 1803, assisted by R. Livingston, then American Minister to France. Then in 1806 Fulton, having returned to the United States, commenced to build another steamboat, in which he was again assisted by Livingston, and in which he placed machinery made by Boulton and Watt in England. This steamboat, named the *Clermont*, was 130 ft. long, 18 ft. beam, 7 ft. depth and 160 tons burden. It made its first trip on the Hudson, from New York to Albany and return, in August, 1807, and subsequently made regular trips. It was the first commercially successful steamboat [Pg 85] ever made, as George Stephenson's was the first commercially successful locomotive. In the meantime Col. John Stevens of New Jersey was also at work on a steamboat, and had in 1804 built such a boat at his shops, having a screw propeller and a flue boiler. Almost simultaneously with Fulton he brought out the *Phœnix*, a side-wheel steamer having hollow water lines and provided with feathering paddle wheels, and as Fulton and Livingston had a monopoly of the Hudson, Stevens took his boat by sea from New York around to Delaware bay and up the Delaware river. This was in 1808, and was the first sea voyage ever made by a steam vessel.

Transatlantic steamship navigation was started in 1819. A Mr. Scarborough of Savannah, Ga., in 1818 purchased a ship of about three hundred and fifty tons burden, which was named the *Savannah*. Equipped with engine and machinery it steamed out of New York Harbour on the 27th day of March, 1819, and successfully reached Savannah, Georgia. On the 20th of May in the same year she left Savannah for Liverpool, making the trip in 22 days. From Liverpool she went to Copenhagen, Stockholm, St. Petersburg, Cronstadt and Arundel, and from the latter port returned to Savannah, making the passage in twenty-five days.

But Scottish waters, and the waters around other coasts of the British Islands, had been traversed by steamboats before this celebrated trip of the *Savannah*. Bell's steamboat between Glasgow and Greenock in 1812 was followed by five others in 1814; and seven steamboats plied on the Thames in 1817.

So the locomotives and the steamboats and steamships continued to multiply, and when the first forty years of the century had been reached the Iron Horse was fairly installed on the fields of [Pg 86] Europe and America, and the rivers and the oceans were ploughed by its sisters, the steam vessels.

It was in 1840 that the famous Cunard line of transatlantic steamers was established, soon followed by the Collins line and others.

A few years before, John C. Stevens in America and John Ericsson in England had brought forward the screw propeller; and Ericsson was the first to couple the engine to the propeller shaft. It succeeded the successful paddle wheels of Fulton in America and Bell in England.

The nineteenth century is the age of kinetic energy: the energy of either solid, liquid, gaseous or electrical matter transformed into useful work.

It has been stated by that eminent specialist in steam engineering, Prof. R. H. Thurston, that "the steam engine is a machine which is especially designed to transform energy originally dormant or potential into active and useful available kinetic energy;" and that the great problem in this branch of science is "to construct a machine which shall in the most perfect manner possible convert the kinetic energy of heat into mechanical power, the heat being derived from the combustion of fuel, and steam being the receiver and conveyor of that heat."

Watt and his contemporaries regarded heat as a material substance called "Phlogiston." The modern kinetic theory of heat was a subsequent discovery, as elsewhere explained.

The inventors of the last part of the eighteenth century and of the nineteenth century have directed their best labours to construct an engine as above defined by Thurston.

First as to the boiler: Efforts were made first to get away from the little old spherical boiler of [Pg 87] Hero. In the 18th century Smeaton devised the horizontal lengthened cylindrical boiler traversed by a flue. Oliver Evans followed with two longitudinal flues. Nathan Read of Salem, Massachusetts, in 1791, invented a tubular boiler in which the flues and gases are conducted through tubes passing through the boiler into the smokestack. Such boilers are adapted for portable stationary engines, locomotives, fire and marine engines, and the fire is built within the boiler frame. Then in the 19th century came the use of sectional boilers—a combination of small vessels instead of a large common one, increasing the strength while diminishing capacity—to obtain high pressure of steam. Then came improved weighted and other safety valves to regulate and control this pressure. The compound or double cylinder high-pressure engine of Hornblower of England, in 1781, and the high-pressure non-condensing steam engine devised by Evans in 1779, were reconstructed and improved in the early part of the century.

To give perfect motion and the slightest friction to the piston; to regulate the supply of steam to the engine by proper valves; to determine such supply by many varieties of governors and thus control the speed; to devise valve gear which distributes the steam through its cycles of motion by which to admit the steam alternately to each end of the steam cylinder as the piston moves backward and forward, and exhaust valves to open and close the parts through which the steam escapes; to automatically operate such valves; to condense the escaping steam and to remove the water of condensation; to devise powerful steam brakes—these are some of the important details on which inventors have exercised their keenest wits. Then again the extensive inventions of the [Pg 88] century have given rise to a great classification to designate their forms or their uses: condensing and non-condensing, high-pressure or low-pressure—the former term being applied to engines supplied with steam of 50 lbs. pressure to the square inch and upward, and the latter to engines working under 40 lbs. pressure—and the low pressure are nearly always the condensing and the high pressure the non-condensing; reciprocating and rotary—the latter having a piston attached to a shaft and revolving within a cylinder of which the axis is parallel with the axis of rotation of the piston.

Direct acting, where the piston rod acts directly upon the connecting rod and through it upon the crank, without the intervention of a beam or lever; oscillating, in which the piston rods are attached directly to the crank pin and as the crank revolves the cylinder oscillates upon trunnions, one on each side of it, through which the steam enters and leaves the steam chest.

Then as to their use, engines are known as stationary, pumping, portable, locomotive or marine.

The best-known engine of the stationary kind is the Corliss, which is very extensively used in the United States and Europe.

Among other later improvements is the duplex pumping engine, in which one engine controls the valve of the other; compensating devices for steam pumping, by which power is accumulated by making the first half of the stroke of the steam piston assist in moving the piston the other half of the stroke during the expansion of steam; steam or air hand hammers on which the piston is the hammer and strikes a tool projecting through the head into the cylinder; rock drilling, in which [Pg 89] the movement of the valves is operated by the piston at any portion of its stroke; shaft governors, in which the eccentric for operating the engine valves is moved around or across the main or auxiliary shaft; multiple cylinders, in which several cylinders, either single or double, are arranged to co-operate with a common shaft; impact rotary, known as steam turbines, a revival in some respects of Hero's engine. And then, finally, the delicate and ingenious bicycle and automobile steam engines.

Then there are steam sanding devices for locomotives by which sand is automatically fed to the rails at the same time the air brake is applied.

Starting valves used for starting compound locomotives on ascending steep grades, in which both low and high pressure cylinders are supplied with live steam, and when the steam, exhausted from either high or low pressure cylinders into the receivers, has reached a predetermined pressure, the engine works on the compound principle. Single acting compound engines, in which two or more cylinders are arranged tandem, the steam acting only in one direction, and the exhaust steam of one acting upon the piston in the cylinder next of the series, are arranged in pairs, so that while one is acting downward the other is acting upward.

Throttle valves automatically closed upon the bursting of a pipe, or the breaking of machinery, are operated by electricity, automatically, or by hand at a distance.

Napoleon, upon his disastrous retreat from Moscow, anxious to reach Paris as soon as possible, left his army on the way, provided himself with a travelling and sleeping carriage, and with relays of fresh horses at different points managed, by extraordinary strenuous efforts day and night, to [Pg 90] travel from Smorgoni to Paris, a distance of 1000 miles, between the 5th and 10th of December, 1812. This was at the average rate of about two hundred miles a day, or eight or nine miles an hour. It was a most remarkable ride for any age by horse conveyance.

Within the span of a man's life after that event any one could take a trip of that distance in twenty-four hours, with great ease and comfort, eating and sleeping on the car, and with convenient telegraph and telephone stations along the route by which to comunicate by pen, or word of mouth, with distant friends at either end of the journey.

If Napoleon had deemed it best to have continued his journey across the Atlantic to America he would have been compelled to pass several weeks on an uncomfortable sailing vessel. Now, a floating palace would await him which would carry him across in less than six days.

Should mankind be seized with a sudden desire to replace all the locomotives in the world by horse power it would be utterly impossible to do it. It was recently estimated that there were one hundred and fifty thousand locomotives in use on the railroads of the world; and as a fair average would give them five hundred horse power each, it will be seen that they are the equivalent of seventy-five million horses.

Space and time will not admit of minute descriptions, or hardly a mention, of the almost innumerable improvements of the century in steam. Having seen the principles on which these inventions have been constructed, enumerated the leading ones and glanced at the most prominent facts in their history, we must refer the seeker for more particulars to those publications of modern patent offices, in which each regiment and company of this vast army is [Pg 91] embalmed in its own especial and ponderous volume.

A survey of the field will call to mind, however, the eloquent words of Daniel Webster:—

"And, last of all, with inimitable power, and with a 'whirlwind sound' comes the potent agency of steam. In comparison with the past, what centuries of improvement has this single agent compressed in the short compass of fifty years! Everywhere practicable, everywhere efficient, it has an arm a thousand times stronger than that of Hercules, and to which human ingenuity is capable of fitting a thousand times as many hands as belonged to Briareus. Steam is found triumphant in operation on the seas; and under the influence of its strong propulsion, the gallant ship,

'Against the wind, against the tide
Still steadies with an upright keel.'

It is on the rivers, and the boatman may repose upon his oars; it is on highways, and exerts itself along the courses of land conveyances; it is at the bottom of mines, a thousand feet below the earth's surface; it is in the mills and in the workshops of the trades. It rows, it pumps, it excavates, it carries, it draws, it lifts, it hammers, it spins, it weaves, it prints. It seems to say to men, at least to the class of artisans: 'Leave off your manual labour, give up your bodily toil; bestow but your skill and reason to the directing of my power and I will bear the toil, with no muscle to grow weary, no nerve to relax, no breast to feel faintness!' What further improvement may still be made in the use of this astonishing power it is impossible to know, and it were vain to conjecture. What we do know is that it has most essentially altered the face of affairs, and that no [Pg 92] visible limit yet appears beyond which its progress is seen to be impossible."

[Pg 93]

CHAPTER VIII.

ENGINEERING AND TRANSPORTATION.

The field of service of a civil engineer has thus been eloquently stated by a recent writer in *Chambers's Journal*:

"His duties call upon him to devise the means for surmounting obstacles of the most formidable kind. He has to work in the water, over the water, and under the water; to cause streams to flow; to check them from overflowing; to raise water to a great height; to build docks and walls that will bear the dashing of waves; to convert dry land into harbours, and low water shores into dry land; to construct lighthouses on lonely rocks; to build lofty aqueducts for the conveyance of water, and viaducts, for the conveyance of railway trains; to burrow into the bowels of the earth with tunnels, shafts, pits and mines; to span torrents and ravines with bridges; to construct chimneys that rival the loftiest spires and pyramids in height; to climb mountains with roads and railways; to sink wells to vast depths in search of water. By untiring patience, skill, energy and invention, he produces in these several ways works which certainly rank among the marvels of human power."

The pyramids of Egypt, the roads, bridges and aqueducts built by the Chinese and by Rome; the great bridges of the Middle Ages, and especially those built by that strange fraternal order known as the "Brothers of the Bridge"; the ocean-defying lighthouses of a later period—these, [Pg 94] and more than these, attest the fact that there were great engineers before the nineteenth century.

But the engineering of to-day is the hand-maid of all the Sciences; and as they each have advanced during the century beyond all that was imagined, or dreamed of as possible in former times, so have the labours of engineering correspondingly multiplied. No longer are such labours classified and grouped in one field, called Civil Engineering, but they have been necessarily divided into great additional new and independent fields, known as Steam Engineering, Mining Engineering, Hydraulic Engineering, Electrical Engineering and Marine Engineering. Within each of these fields are assembled innumerable appliances which are the offspring of the inventive genius of the century just closed.

We have seen how one discovery, or the development of a certain art, brings in its train and often necessitates other inventions and discoveries. The development and dedication of the steam engine to the transportation of goods and men called for improvements in the roads and rails on which the engine and its load were to travel, and this demand brought forth those modern railway bridges which are the finest examples in the art of bridge making that the world has ever seen.

The greatest bridges of former ages were built of stone and solid masonry. Now iron and steel have been substituted, and these light but substantial frameworks span wide rivers and deep ravines with almost the same speed and gracefulness that the spider spins his silken web from limb to limb. These, too, waited for their construction on that next turn in the wheel of evolution, [Pg 95] which brought better processes in the making of iron and steel, and better tools and appliances for working metals, and in handling vast and heavy bodies.

The first arched iron bridge was over the Severn at Coalbrookdale, England, erected by Abraham Darby in 1777. In 1793 one was erected by Telford at Buildwas, and in the same year Burden completed an arch across the weir at Sunderland. The most prominent classes of bridges in which the highest inventive and constructive genius of the engineers of the century are illustrated are known as the *suspension*, the *tubular* and the *tubular arch*, the *truss and cantilever*.

Suspension bridges consisting of twisted vines, of iron chains, or of bamboo, or cane, or of ropes, have been known in different parts of the world from time immemorial, but they bear only a primitive and suggestive resemblance to the great iron cable bridges of the nineteenth century. The first notable structure of this kind was constructed by Sir Samuel Brown, across the Tweed at Berwick, England, in 1819. Brown was born in London in 1776 and died in 1852. He entered the navy at the age of 18, was made commander in 1811, and retired as captain in 1842. We have alluded to the spider's web, and Smiles, in his *Self Help*, relates as an example of intelligent observation that while Capt Brown was occupied in studying the character of bridges with the view of constructing one of a cheap description to be thrown across the Tweed, near which he lived, he was walking in his garden one dewy autumn morning when he saw a tiny spider's web suspended across his path. The idea immediately occurred to him of a bridge of iron wires. In 1829 Brown also was the engineer for suspension bridges built over the Esk at Montrose and [Pg 96] over the Thames at Hammersmith. Before that time, a span in a bridge of 100 feet was considered remarkably long. Suspension bridges are best adapted for long spans, and have been constructed with spans more than twice as long as any other form. Sir Samuel Brown's bridge had a span of 449 feet. This class of bridges is usually constructed with chains or cables passing over towers, with the roadway suspended beneath. The ends of the chains or cables are securely anchored. The cables are then passed over towers, on which they are supported in movable saddles, so that the towers are not overthrown by the strain on the cables. Nice calculations have to be made as to the tension to be placed on the cables, the allowance for deflection, and the equal distribution of weight. The floor-way in the earlier bridges of this type was supported by means of a series of equidistant vertical rods, and was lacking stiffness, but this was remedied by trussing the road bed, using inclined stays extending from the towers and partially supporting the roadway for some distance out from the tower.

The next finest suspension bridge was constructed by Thomas Telford and finished in 1826, across the Menai Strait to connect the island of Anglesea with the mainland of Wales. Telford was born in Dumfriesshire, Scotland, in 1757, and died in Westminster in 1834. Beginning life as a stone mason, he rose by his own industry to be a master among architects and a prince among builders of iron bridges, aqueducts, canals, tunnels, harbours and docks.

The Menai bridge was composed of chains or wire ropes, each nearly a third of a mile in length, and which descended 60 feet into sloping pits or drifts, where they were screwed to cast-iron [Pg 97] frames embedded in the rocks. The span of the suspended central arch was 560 feet, and the platform was 100 feet above high water. Seven stone arches of 52½ feet span make up the rest of the bridge.

But a suspension bridge was completed in 1834 by M. Challey of Lyon over the Saane at Fribourg, Switzerland, which greatly surpassed the Menai bridge. The span is 880 feet from pier to pier, and the roadway is 167 feet above the river. It is supported by four iron wire cables, each consisting of 1056 wires. It was tested by placing 15 pieces of artillery, drawn by 50 horses and accompanied by 300 men crowded together as closely as possible, first at the centre, and then at each extreme, causing a depression of 39½ inches, but no sensible oscillation was experienced.

Isambard K. Brunel was another great engineer, who constructed a suspension bridge at the Isle of Bourbon in 1823, and the Charing Cross over the Thames at Hungerford in 1845, which was a footbridge, having a span of 675 feet, the longest span of any bridge in England. Then followed finer and larger suspension bridges in other parts of the world. It was across the Niagara in front of the great falls that in 1855 British America and the United States were joined by a magnificent suspension bridge, one of the finest in the world, and the two English speaking countries were then physically and commercially united. At the opening of the bridge, one portion of which was for a railway, the shriek of the locomotive and the roar of the train mingled with the roar of the wild torrent 250 feet below. The bridge, 800 feet long, is a single span, supported by four enormous cables of wire stretching from the Canadian cliff to the opposite United States cliff. The cables pass over the tops of lofty stone towers arising from these cliffs, and each cable [Pg 98] consists of no less than 4,000 distinct wires. The roadway hangs from these cables, suspended by 624 vertical rods.

The engineer of this bridge was John A. Roebling, a native of Prussia, born there in 1806, and who died in New York in 1869. He was educated at the Polytechnic School in Berlin, and emigrated to America at the age of 25. His labors were first as a canal and railway engineer, then he became the inventor and manufacturer of a new form of wire rope, and then turned his attention to the construction of aqueducts and suspension bridges. After the Niagara bridge, above described, he commenced another bridge of greater dimensions over the same river, which was finished within two or three years. His next work was the splendid suspension bridge at Cincinnati, Ohio, which has a clear span of 1057 feet. In 1869, in connection with his son, Washington A. Roebling, he commenced that magnificent suspension bridge to unite the great cities of New York and Brooklyn, and which, by its completion, resulted in the consolidation of those cities as Greater New York. The Roeblings, father and son, were to the engineering of America what George Stephenson and his son Robert were to the locomotive and railway and bridge engineering of Great Britain.

The Brooklyn bridge, known also as the East River bridge, was formally opened to the public on the 24th of May 1883. Most enormous and unexpected technical difficulties were met and overcome in its construction. Its total length is nearly 6,000 feet. The length of the suspended structure from anchorage to anchorage is 3,454 feet. A statement of the general features of this bridge indicates the nature of the construction of such bridges as a class, and distinguishes them [Pg 99] from the comparatively simple forms of past ages. This structure is supported by two enormous towers, having a height of 276 feet above the surface of the water, carrying at their tops the saddles which support the cables, and having a span between them of 1,595 feet. The towers are each pierced by two archways, 31½ feet wide, and 120½ feet high, through which openings passes the floor of the bridge at the height of 118 feet above high water mark. There are four supporting cables, each 16 inches in diameter, and each composed of about 5,000 single wires. The wire is one-eighth size; 278 single wires are grouped into a rope, and 19 ropes bunched to form a cable. The iron saddles at the top of the lofty towers, and on which the cables rest, are made movable to permit its expansion and compression—and they glide through minute distances on iron rollers in saddle plates embedded and anchored in the towers, in response to strains and changes of temperature. The enormous cables pass from the towers shoreward to their anchorages 930 feet away, and which are solid masses of masonry, each 132 x 119 feet at base and top, 89 feet high, and weighing 60,000 tons. The bridge is divided into five avenues: one central one for foot passengers, two outer ones for vehicles, and the others for the street cars. The cost of the bridge was nearly $15,000,000.

Twenty fatal and many disabling accidents occurred during the construction of the bridge. The great engineer Roebling was the first victim to an accident. He had his foot crushed while laying the foundation of one of the stone piers, and died of lockjaw. [Pg 100]

It was necessary to build up the great piers by the aid of caissons, which are water-tight casings built of timber and metal and sunk to the river bed and sometimes far below it, within which are built the foundations of piers or towers, and into which air is pumped for the workmen. A fire in one of the caissons, which necessitated its flooding by water, and to which the son, Washington Roebling, was exposed, resulted in prostrating him with a peculiar form of caisson disease, which destroyed the nerves of motion without impairing his intellectual faculties. But, although disabled from active work, Mr. Roebling continued to superintend the vast project through the constant mediation of his wife.

Tubular Bridges.—These are bridges formed by a great tube or hollow beam through the center of which a roadway or railway passes. The name would indicate that the bridge was cylindrical in form, and this was the first idea. But it was concluded after experiment that a rectangular form was the best, as it is more rigid than either a cylindrical or elliptical tube. The adoption of this form was due to Fairbairn, the celebrated English inventor and engineer of iron structures. The Menai tubular railway bridge, adjacent to the suspension bridge of Telford across the same strait, and already described, was the first example of this type of bridge. Robert Stephenson was the engineer of this great structure, aided by the suggestions of Fairbairn and other eminent engineers. This bridge was opened for railway traffic in March, 1850. It was built on three towers and shore abutments. The width of the strait is divided by these towers into four spans—two of 460 feet each, and two of 230 feet. In appearance, the bridge looked like one huge, long, narrow iron box, but it consisted really of four bridges, each made of a pair of rectangular tubes, and [Pg 101] through one set of tubes the trains passed in going in one direction, and through the other set in going the opposite direction. These ponderous tubes were composed of wrought-iron plates, from three-eighths to three-fourths of an inch thick, the largest 12 feet in length, riveted together and stiffened by angle irons. They varied in height—the central ones being the highest and those nearest the shore the lowest. The central ones are 30 feet high, and the inner ones about 22 feet. Their width was about 14 feet. They were built upon platforms on the Caernarvon shore, and the great problem was how to lift them and put them in place, especially the central ones, which were 460 feet in length. Each tube weighed 1,800 pounds, and they were to be raised 192 feet. This operation has been described as "the grandest lift ever effected in engineering." It was accomplished by means of powerful hydraulic presses. Another and still grander example of this style of bridge is the Victoria at Montreal, Canada. This also was designed by Robert Stephenson and built under his direction by James Hodges of Montreal. Work was commenced in 1854 and it was completed in December, 1859, and opened for travel in 1860. It consists of 24 piers, 242 feet apart, except the centre one, from which the span is 330 feet. The tube is in sections and quadrangular in form. Every plate and piece of iron was made and punched in England and brought across the Atlantic. In Canada little remained to be done but to put the parts together and in position. This, however, was in itself a Herculean task. The enormous structure was to be placed sixty feet above the swift current of the broad St. Lawrence, and wherein huge masses of [Pg 102] ice, each block from three to five feet in thickness, accumulated every winter. The work was accomplished by the erection of a vast rigid stage of timber, on which the tubes were built up plate by plate. When all was completed the great staging was removed, and the mighty tube rested alone and secure upon its massive wedge-faced piers rising from the bedrock of the flood below.

The Tubular Arch Bridge.—This differs from the tubular bridge proper, in that the former consists of a bridge the body of which is supported by a tubular archway of iron and steel, whereas in the latter the body of the bridge itself is a tube. The tubular arch is also properly classed as a girder bridge because the great tube which covers the span is simply an immense beam or girder, which supports the superstructure on which the floor of the bridge is laid. A fine illustration of this style of bridge is seen in what is known as the aqueduct bridge over Rock Creek at Washington, D. C., in which the arch consists of two cast-iron jointed pipes, supporting a double carriage and a double street car way, and through which pipes all the water for the supply of the City of Washington passes. General M. C. Meigs was the engineer.

Another far grander illustration of such a structure, in combination with the truss system, is that of the Illinois and St. Louis bridge, across the Mississippi, of which Captain James B. Eads was the engineer. There are three great spans, the central one of which has a length of about 520 feet, and the others a few feet less. Four arches form each span, each arch consisting of an upper and lower curved member or rib, extending from pier to pier, and each member composed of two parallel steel tubes. [Pg 103]

Truss and truss arched bridges.—These, for the most part, are those quite modern forms of iron or wooden bridges in which a supplementary frame work, consisting of iron rods placed obliquely, vertically or diagonally, and cemented together, and with the main horizontal beams either above or below the same, to produce a stiff and rigid structure, calculated to resist strain from all directions.

Previous to the 19th century, the greatest bridges being constructed mostly of solid masonry piers and arches, no demand for a bridge of this kind existed; but after the use of wrought iron and steel became extensive in bridge making, and as these apparently light and airy frames may be extended, piece by piece across the widest rivers, straits, and arms of the sea, a substitute for the great, expensive, and frequent supporting piers became a want, and was supplied by the system of trusses and truss arches. The truss system has also been applied to the construction of vast modern bridges in places where timber is accessible and cheap. Each different system invented bears the name of its inventor. Thus, we have the Rider, the Fink, the Bollman, the Whipple, the Howe, the Jones, the Linville, the McCallum, Towne's lattice and other systems.

What is called the cantilever system has of late years to a great extent superseded the suspension construction. This consists of beams or girders extending out from the opposite piers at an upward diagonal angle, and meeting at the centre over the span, and there solidly connected together, or to horizontal girders, in such manner that the compression load is thrown on to the supporting piers, upward strains received at the centre, and side deflections provided against. It is supposed that greater rigidity is obtained by this means than by the suspension, and, like the [Pg 104] suspension, great widths may be spanned without an under supporting frame work. Two fine examples of this type are found, one in a bridge across the Niagara adjacent to the suspension bridge above described and one across the river Forth at Queens Ferry in Scotland. The Niagara Bridge is a combination of cast steel and iron. It was designed by C. C. Schneider and Edmund Hayes. It was built for a double-track railroad. The total length of the bridge is 910 feet between the centres of the anchorage piers. The cantilevers rest on two gigantic steel towers, standing on massive stone piers 39 feet high. The clear span between the towers is 470 feet, and the height of the bridge, from the mad rush of waters to the car track is 239 feet.

Messrs Fowler and Baker were the engineers of the Forth railway bridge. It was begun in 1883 and finished in 1890. It is built nearly all of steel, and is one of the most stupendous works of the kind. It crosses two channels formed by the island of Inchgarvie, and each of the channel spans is 1710 feet in the clear and a clear headway of 150 feet under the bridge. Three balanced cantilevers are employed, poised on four gigantic steel tube legs supported on four huge masonry piers. The height of the bridge above the piers is 330 feet. The cantilever portion has the appearance of a vast elongated diamond. Steel lattice work of girders, forms the upper side of the cantilever, while the under side consists of a hollow curve approaching in form a quadrant of a circle drawn from the base of the legs or struts to the ends of the cantilever.

Such is the growth of these great bridges with their tremendous spans across which man is spinning his iron webs, that when seen at night with a fiery engine pulling its thundering train [Pg 105] across in the darkness, one is reminded of Milton's description, "over the dark abyss whose boiling gulf tamely endured a bridge of wondrous length, from Hell continued, reaching the utmost orb of this frail world."

The *lighthouses* of the century, in masonry, do not greatly excel in general principles those of preceding ones, as at Eddystone, designed by Smeaton. Nicholas Douglass, however, invented a new system of dovetailing, and great improvements have been made in the system of illuminating.

Lighthouses are also distinguished from those of preceding centuries by the substitution of iron and cast steel for masonry. The first cast-iron lighthouse was put up at Point Morant, Jamaica, in 1842. Since then they have taken the form of iron skeleton towers.

One of the latest and most picturesque of lighthouses is that of Bartholdi's statue of Liberty enlightening the world, the gift of the French government to the United States, framed by M. Eiffel, the great French engineer, and set up by the United States at Bedloe's Island in New York harbor. It consists of copper plates on a network of iron. Although the statue is larger than any in the world of such composite construction, its success as a lighthouse is not as notable as many farther seaward.

In *excavating*, *dredging* and *draining*, the inventions of the century have been very numerous, but, like numerous advances in the arts, such inventions, so far as great works are concerned, have developed from and are closely related to steam engineering. [Pg 106]

The making of roads, railroads, canals and tunnels has called forth thousands of ingenious mechanisms for their accomplishment. A half dozen men with a steam-power excavator or dredger can in one day perform a greater extent of work than could a thousand men and a thousand horses in a single day a few generations ago.

An excavating machine consisting of steel knives to cut the earth, iron scoops, buckets and dippers to scoop it up, endless chains or cranes to lift them, actuated by steam, and operated by a single engineer, will excavate cubic yards of earth by the minute and at a cost of but a few dollars a day.

Dredging machines of a great variety have been constructed. Drags and scoops for elevating, and buckets, scrapers and shovels, and rotating knives to first loosen the earth, suction pumps and pipes, which will suck great quantities of the loosened earth through pipes to places to be filled—these and kindred devices are now constantly employed to dig and excavate, to deepen and widen rivers, to drain lands, to dig canals, to make harbours, to fill up the waste places and to make courses for water in desert lands.

Inventions for the excavating of clay, piling and burning it in a crude state for ballast for railways, are important, especially for those railways which traverse areas where clay is plentiful, and stones and gravel are lacking.

Sinking shafts through quicksands by artificially freezing the sand, so as to form a firm frozen wall immediately around the area where the shaft is to be sunk, is a recent new idea.

Modern countries especially are waking up to the necessity of good roads, not only as a necessary means of transportation, but as a pre-requisite to decent civilisation in all respects. [Pg 107] And, therefore, great activity has been had in the last third of a century in invention of machines for finishing and repairing roads.

In the matter of sewer construction, regarded now so necessary in all civilised cities and thickly-settled communities as one of the means of proper sanitation, great improvements have been made in deep sewerage, in which the work is largely performed below the surface and with little obstruction to street traffic.

In connection with excavating and dredging machines, mention should be made of those great works in the construction of which they bore such important parts, as drainage and land reclamation, such as is seen in the modern extensions of land reclamation in Holland, in the Haarlem lake district in the North part of England, the swamps of Florida and the drainage of the London district; in modern tunnels such as the Hoosac in America and the three great ones through the Alps: the Mont Cenis, St. Gothard, and Arlberg, the work in which developed an entirely new system of engineering, by the application of newly-discovered explosives for blasting, new rock-drilling machinery, new air-compressing machines for driving the drill machines and ventilating the works, and new hydraulic and pumping machinery for sinking shafts and pumping out the water.

The great canals, especially the Suez, developed a new system of canal engineering. Thus by modern inventions of devices for digging and blasting, dredging and draining and attendant operations, some of the greatest works of man on earth have been produced, and evinced the exercise of his highest inventive genius. [Pg 108]

If one wishes an ocular demonstration of the wonders wrought in the 19th century in the several domains of engineering, let him take a Pullman train across the continent from New York to San Francisco. The distance is 3,000 miles and the time is four days and four nights. The car in which the passenger finds himself is a marvel of woodwork and upholstery—a description of the machinery and processes for producing which belongs to other arts. The railroad tracks upon which the vehicle moves are in themselves the results of many inventions. There is the width of the track, and it was only after a long and expensive contest that countries and corporations settled upon a uniform gauge. The common gauge of the leading countries and roads is now 4 feet 8½ inches. A greater width is known as a broad gauge, a less width as a narrow gauge. Then as to the rail: first the wooden, then the iron and now the steel, and all of many shapes and weights. The T-rail invented by Birkensaw in 1820, having two flanges at the top to form a wide berth for the wheels of the rolling stock, the vertical portion gripped by chairs which are spiked to the ties, is the best known. Then the frogs, a V-shaped device by which the wheels are guided from one line of rails to another, when they form angles with each other; the car wheel made with a flange or flanges to fit the rail, and the railway gates, ingenious contrivances that guard railway crossings and are operated automatically by the passing trains, but more commonly by watchmen. The car may be lighted with electricity, and as the train dashes along at the rate of 30 to 80 miles an hour, it may be stopped in less than a minute by the touch of the engineer on an air brake. Is it midwinter and are mountains of snow encountered? They disappear before the [Pg 109] railway snow-plough more quickly than they came. It passes over bridges, through tunnels, across viaducts, around the edges of mountain peaks, every mile revealing the wondrous work of man's inventive genius for encompassing the earth with speed, safety and comfort. Over one-half million miles of these railway tracks are on the earth's surface to-day!

Not only has the railway superseded horse power in the matter of transportation to a vast extent, but other modes of transportation are taking the place of that useful animal. The old-fashioned stage coach, and then the omnibus, were successively succeeded by the street car drawn by horses, and then about twenty years ago the horse began to be withdrawn from that work and the cable substituted.

Cable transportation developed from the art of making iron wire and steel wire ropes or cables. And endless cables placed underground, conveyed over rollers and supported on suitable yokes, and driven from a great central power house, came into use, and to which the cars were connected by ingeniously contrived lever grips—operated by the driver on the car. These great cable constructions, expensive as they were, were found more economical than horse power. In fact, there is no modernly discovered practical motive power but what has been found less expensive both as to time and money than horse power. But the cable for this purpose is now in turn everywhere yielding to electricity, the great motor next to steam. The overhead cable system for the transportation of materials of various descriptions in carriers, also run by a central motor, is still very extensively used. The cable plan has also been tried with some success in the propelling of canal boats. [Pg 110]

Canals, themselves, although finding a most serious and in some localities an entirely destructive rival in the railroad, have grown in size and importance, and in appliances that have been substituted for the old-style locks. The latest form of this device is what is known as the pneumatic balance lock system.

It has been said by Octave Chanute that "Progress in civilisation may fairly be said to be dependent upon the facilities for men to get about, upon their intercourse with other men and nations, not only in order to supply their mutual needs cheaply, but to learn from each other their wants, their discoveries and their inventions." Next to the power and means for moving people, come the immense and wonderful inventions for lifting and loading, such as cranes and derricks, means for coaling ships and steamers, for handling and storing the great agricultural products, grain and hay, and that modern wonder, the *grain elevator*, that dots the coasts of rivers, lakes and seas, receives the vast stores of golden grain from thousands of steam cars that come to it laden from distant plains and discharges it swiftly in mountain loads into vessels and steamers to be carried to the multitudes across the seas, and to satisfy that ever-continuing cry, "Give us this day our daily bread."

[Pg 111]

CHAPTER IX.

ELECTRICITY.

In 1900 the real nature of electricity appears to be as unknown as it was in 1800.

Franklin in the eighteenth century defined electricity as consisting of particles of matter incomparably more subtle than air, and which pervaded all bodies. At the close of the nineteenth century electricity defined as "simply a form of energy which imparts to material substances a peculiar state or condition, and that all such substances partake more or less of this condition."

These theories and the late discovery of Hertz that electrical energy manifests itself in the form of waves, oscillations or vibrations, similar to light, but not so rapid as the vibrations of light, constitute about all that is known about the nature of this force.

Franklin believed it was a single fluid, but others taught that there were two kinds of electricity, positive and negative, that the like kinds were repulsive and the unlike kinds attractive, and that when generated it flowed in currents.

Such terms are not now regarded as representing actual varieties of this force, but are retained as convenient modes of expression, for want of better ones, as expressing the conditions or states of electricity when produced.

Electricity produced by friction, that is, developed upon the surface of a body by rubbing it with a [Pg 112] dissimilar body, and called frictional or static electricity, was the only kind produced artificially in the days of Franklin. What is known as galvanism, or animal electricity, also takes its date in the 18th century, to which further reference will be made. Since 1799 there have been discovered additional sources, among which are voltaic electricity, or electricity produced by chemical action, such as is manifested when two dissimilar metals are brought near each other or together, and electrical manifestations produced by a decomposing action, one upon the other through a suitable medium; inductive electricity, or electricity developed or induced in one body by its proximity to another body through which a current is flowing; magnetic electricity, the conversion of the power of a magnet into electric force, and the reverse of this, the production of magnetic force by a current of electricity; and thermal electricity, or that generated by heat. Electricity developed by these, or other means in contra-distinction to that produced by friction, has been called dynamic; but all electric force is now regarded as dynamic, in the sense that forces are always in motion and never at rest.

Many of the manifestations and experiments in later day fields which, by reason of their production by different means, have been given the names of discovery and invention, had become known to Franklin and others, by means of the old methods in frictional electricity. They are all, however, but different routes leading to the same goal. In the midst of the brilliant discoveries of modern times confronting us on every side we should not forget the honourable efforts of the fathers of the science. [Pg 113]

We need not dwell on what the ancients produced in this line. It was a single fact only:—The Greeks discovered that amber, a resinous substance, when rubbed would attract lighter bodies to it.

In 1600 appeared the father of modern electricity—Dr. Gilbert of Colchester, physician to Queen Elizabeth. He revived the one experiment of antiquity, and added to it the further fact that many substances besides amber, when rubbed, would manifest the same electric condition, such as sulphur, sapphire, wax, glass and other bodies. And thus he opened the field of electrodes. He was the first to use the terms, electricity, electric and electrode, which he derived from the word *elektron*, the Greek name for amber. He observed the actions of magnets, and conjectured the fundamental identity of magnetism and electricity. He arranged an electrometer, consisting of an iron needle poised on a pivot, by which to note the action of the magnet. This was about the time that Otto von Guericke of Magdeburg, Germany, was born. He became a "natural" philosopher, and for thirty-five years was burgomaster of his native town. He invented the air-pump, and he it was who illustrated the force of atmospheric pressure by fitting together two hollow brass hemispheres which, after the air within them had been exhausted, could not be pulled apart. He also invented a barometer, and as an astronomer suggested that the return of comets might be calculated. He invented and constructed the first machine for generating electricity. It consisted of a ball of sulphur rotated on an axis, and which was electrified by friction of the hand, the ball receiving negative electricity while the positive flowed through the person to the earth. With this machine "he heard the first sound and saw the first light in artificially excited electricity." The [Pg 114] machine was improved by Sir Isaac Newton and others, and before the close of that century was put into substantially its present form of a round glass plate rotated between insulated leather cushions coated with an amalgam of tin and zinc, the positive or vitreous electricity thus developed being accumulated on two large hollow brass cylinders with globular ends, supported on glass pillars. Gray in 1729 discovered the conductive power of certain substances, and that the electrical influence could be conveyed to a distance by means of an insulated wire. This was the first step towards the electric telegraph.

Dufay, the French philosopher and author, who in 1733-1737 wrote the *Memoirs of the French Academy*, was, it seems, the first to observe electrical attractions and repulsions; that electrified resinous substances repelled like substances while they attracted bodies electrified by contact with glass; and he, therefore, to the latter applied the term *vitreous* electricity and to the former the term *resinous* electricity. In 1745 Prof. Muschenbroeck of Leyden University developed the celebrated Leyden jar. This is a glass jar coated both inside and outside with tinfoil for about four-fifths of its height. Its mouth is closed with a cork through which is passed a metallic rod, terminating above in a knob and connected below with the inner coating by a chain or a piece of tinfoil. If the inner coating be connected with an electrical machine and the outer coating with the earth, a current of electricity is established, and the inner coating receives what is called a positive and the outer coating a negative charge. On connecting the two surfaces by means of a [Pg 115] metallic discharger having a non-conducting handle a spark is obtained. Thus the Leyden jar is both a collector and a condenser of electricity. On arranging a series of such jars and joining their outer and inner surfaces, and connecting the series with an electrical machine, a battery is obtained of greater or less power according to the number of jars employed and the extent of supply from the machine.

The principle of the Leyden jar was discovered by accident. Cuneus, a pupil of Muschenbroeck, was one day trying to charge some water in a glass bottle with electricity by connecting it with a chain to the sparking knob of an electrical machine. Holding the bottle in one hand he arranged the chain with the other, and received a violent shock. His teacher then tried the experiment himself, with a still livelier and more convincing result, whereupon he declared that he would not repeat the trial for the whole Kingdom of France.

When the science of static electricity was thus far developed, with a machine for generating it and a collector to receive it, many experiments followed. Charles Morrison in 1753, in the *Scots Magazine*, proposed a telegraph system of insulated wires with a corresponding number of characters to be signalled between two stations. Other schemes were proposed at different times down to the close of the century.

Franklin records among several other experiments with frictional electricity accumulated by the Leyden jar battery the following results, produced chiefly by himself: The existence of an attractive and a repulsive action of electricity; the restoration of the equilibrium of electrical force between electrified and non-electrified bodies, or between bodies differently supplied with [Pg 116] the force; the electroscope, a body charged with electricity and used to indicate the presence and condition of electricity in another body; the production of work, as the turning of wheels, by which it was proposed a spit for roasting meat might be formed, and the ringing of chimes by a wheel, which was done; the firing of gunpowder, the firing of wood, resin and spirits; the drawing off a charge from electrified bodies at a near distance by pointed rods; the heating and melting of metals; the production of light; the magnetising of needles and of bars of iron, giving rise to the analogy of magnetism and electricity.

Franklin, who had gone thus far, and who also had drawn the lightning from the clouds, identified it as electricity, and taught the mode of its subjection, felt chagrined that more had not been done with this subtle agent in the service of man. He believed, however, that the day-spring of science was opening, and he seemed to have caught some reflection of its coming light. Observing the return to life and activity of some flies long imprisoned in a bottle of Madeira wine and which he restored by exposure to the sun and air, he wrote that he should like to be immersed at death with a few friends in a cask of Madeira, to be recalled to life a hundred years thence to observe the state of his country. It would not have been necessary for him to have been embalmed that length of time to have witnessed some great developments of his favorite science. He died in 1790, and it has been said that there was more real progress in this science in the first [Pg 117] decade of the nineteenth century than in all previous centuries put together.

Before opening the door of the 19th century, let us glance at one more experiment in the 18th:

While the aged Franklin was dying, Dr Luigi Galvani of Bologna, an Italian physician, medical lecturer, and learned author, was preparing for publication his celebrated work, *De viribus Electricitatis in Motu Musculari Commentarius*, in which he described his discovery made a few years before of the action of the electric current on the legs and spinal column of a frog hung on a copper nail. This discovery at once excited the attention of scientists, but in the absence of any immediate practical results the multitude dubbed him the "frog philosopher." He proceeded with his experiments on animals and animal matter, and developed the doctrine and theories of what is known as animal or galvanic electricity. His fellow countryman and contemporary, Prof. Volta of Pavia, took decided issue with Galvani and maintained that the pretended animal electricity was nothing but electricity developed by the contact of two different metals. Subsequent investigations and discoveries have established the fact that both theories have truth for their basis, and that electricity is developed both by muscular and nervous energy as well as by chemical action. In 1799 Volta invented his celebrated pile, consisting of alternate disks of copper and zinc separated by a cloth moistened with a dilute acid; and soon after an arrangement of cups—each containing a dilute acid and a copper and a zinc plate placed a little distance apart, and thus dispensing with the cloth. In both instances he connected the end plate of one kind with the opposite end plate of the other kind by a wire, and in both arrangements produced a current of electricity. To the discoveries, experiments, and disputes of Galvani and Volta and to those of [Pg 118] their respective adherents, the way was opened to the splendid electrical inventions of the century, and the discovery of a new world of light, heat, speech and power. The discoveries of Galvani and Volta at once set leading scientists at work. Fabroni of Florence, and Sir Humphry Davy and Wollaston of England, commenced interesting experiments, showing that rapid oxidation and chemical decomposition of the metals took place in the voltaic pile.

By the discoveries of Galvani the physicians and physiologists were greatly excited, and believed that by this new vital power the nature of all kinds of nervous diseases could be explored and the remedy applied. Volta's discovery excited the chemists. If two dissimilar metals could be decomposed and power at the same time produced they contended that practical work might be done with the force. In 1800 Nicholson and Carlisle decomposed water by passing the electric current through the same; Ritter decomposed copper sulphate, and Davy decomposed the alkalies, potash and soda. Thus the art of electrolysis—the decomposition of substances by the galvanic current, was established. Later Faraday laid down its laws. Naturally inventions sprung up in new forms of batteries. The pile and cup battery of Volta had been succeeded by the trough battery—a long box filled with separated plates set in dilute acid. The trough battery was used by Sir Humphry Davy in his series of great experiments—1806-1808—in which he isolated the metallic bases, calcium, sodium, potassium, etc. It consisted of 2000 double plates of copper and zinc, each having a surface of 32 square inches. With this same trough battery Davy in 1812 [Pg 119] produced the first electric carbon light, the bright herald of later glories.

Among the most noted new batteries were Daniell's, Grove's and Bunsen's. They are called the "two fluid batteries," because in place of a single acidulated bath in which the dissimilar metals were before placed, two different liquid solutions were employed.

John Frederick Daniell of London, noted for his great work, *Meteorological Essays*, and other scientific publications, and as Professor of Chemistry in King's College, in 1836, described how a powerful and constant current of electricity may be continued for an unlimited period by a battery composed of zinc standing in an acid solution and a sheet of copper in a solution of sulphate of copper.

Sir William Robert Grove, first an English physician, then an eminent lawyer, and then a professor of natural philosophy, and the first to announce the great theory of the Correlation of Physical Forces, in 1839 produced his battery, much more powerful than any previous one, and still in general use. In it zinc and platinum are the metals used—the zinc bent into cylindrical form and placed in a glass jar containing a weak solution of sulphuric acid, while the platinum stands in a porous jar holding strong nitric acid and surrounded by the zinc. Among the electrical discoveries of Grove were the decomposition by electricity of water into free oxygen and hydrogen, the electricity of the flame of the blow-pipe, electrical action produced by proximity, without contact, of dissimilar metals, molecular movements induced in metals by the electric current, and the conversion of electricity into mechanical force. [Pg 120]

Robert Wilhelm Bunsen, a German chemist and philosopher and scientific writer, who invented some of the most important aids to scientific research of the century, who constructed the best working chemical laboratory on the continent and founded the most celebrated schools of chemistry in Europe, invented a battery, sometimes called the carbon battery, in which the expensive pole of platinum in the Grove battery is replaced by one of carbon. It was found that this combination gave a greater current than that of zinc and platinum.

A great variety of useful voltaic batteries have since been devised by others, too numerous to be mentioned here. There is another form of battery having for its object the storing of energy by electrolysis, and liberating it when desired, in the form of an electric current, and known as an accumulator, or secondary, polarization, or storage battery. Prof. Ritter had noticed that the two plates of metal which furnished the electric current, when placed in the acid liquid and united, could in themselves furnish a current, and the inventing of *storage* batteries was thus produced. The principal ones of this class are Gustave Planté's of 1860 and M. Camille Faure's of 1880. These have still further been improved. Still another form are the *thermo-electric batteries*, in which the electro-motive force is produced by the joining of two different metals, connecting them by a wire and heating their junctions. Thus, an electric current is obtained directly from heat, without going through the intermediate processes of boiling water to produce steam, using this steam to drive an engine, and using this engine to turn a dynamo machine to produce power.

But let us retrace our steps:—As previously stated, Franklin had experimented with frictional [Pg 121] electricity on needles, and had magnetised and polarised them and noticed their deflection; and Lesage had established an experimental telegraph at Geneva by the same kind of electricity more than a hundred years ago. But frictional electricity could not be transmitted with power over long distances, and was for practical purposes uncontrollable by reason of its great diffusion over surfaces, while voltaic electricity was found to be more intense and could be developed with great power along a wire for any distance. Fine wires had been heated and even melted by Franklin by frictional electricity, and now Ritter, Pfaff and others observed the same effect produced on the conducting wires by a voltaic current; and Curtet, on closing the passage with a piece of charcoal, produced a brilliant light, which was followed by Davy's light already mentioned.

As early as 1802 an Italian savant, Gian D. Romagnosi of Trent, learning of Volta's discovery, observed and announced in a public print the deflection of the magnetic needle when placed near a parallel conductor of the galvanic current. In the years 1819 and 1820 so many brilliant discoveries and inventions were made by eminent men, independently and together, and at such near and distant places, that it is hard telling who and which was first. It was in 1819 that the celebrated Danish physicist, Oersted of Copenhagen, rediscovered the phenomena that the voltaic current would deflect a magnetic needle, and that the needle would turn at right angles to the wire. In 1820 Prof. S. C. Schweigger of Halle discovered that this deflecting force was increased when the wire was wound several times round the needle, and thus he invented the [Pg 122] magnetising helix. He also then invented a galvano-magnetic indicator (a single-wire circuit) by giving the insulated wire a number of turns around an elongated frame longitudinally enclosing the compass needle, thus multiplying the effect of the current upon the sensitive needle, and converting it into a practical *measuring* instrument—known as the galvanometer, and used to observe the strength of currents. In the same year Arago found that iron filings were attracted by a voltaic charged wire; and Arago and Davy that a piece of soft iron surrounded spirally by a wire through which such a current was passed would become magnetic, attract to it other metals while in that condition, immediately drop them the instant the current ceased, and that such current would permanently magnetise a steel bar. The elements of the *electro-magnet* had thus been produced. It was in that year that Ampère discovered that magnetism is the circulation of currents of electricity at right angles to the axis of the needle or bar joining the two poles of the magnet. He then laid down the laws of interaction between magnets and electrical currents, and in this same year he proposed an electric-magneto telegraph consisting of the combination of a voltaic battery, conducting wires, and magnetic needles, one needle for each letter of the alphabet.

The discoveries of Ampère as to the laws of electricity have been likened to the discovery of Newton of the law of gravitation.

Still no practical result, that is, no useful machine, had been produced by the electro-magnet.

In 1825 Sturgeon of England bent a piece of wire into the shape of a horse-shoe, insulated it with a coating of sealing wax, wound a fine copper wire around it, thus making a helix, passed a [Pg 123] galvanic current through the helix, and thus invented the first practical electro-magnet. But Sturgeon's magnet was weak, and could not transmit power for more than fifty feet. Already, however, it had been urged that Sturgeon's magnet could be used for telegraphic purposes, and a futile trial was made. In the field during this decade also labored the German professors Gauss and Weber, and Baron Schilling of Russia. In 1829 Prof. Barlow of England published an article in which he summarised what had been done, and scientifically demonstrated to his own satisfaction that an electro-magnetic telegraph was impracticable, and his conclusion was accepted by the scientific world as a fact. This was, however, not the first nor the last time that scientific men had predicted impracticabilities with electricity which afterwards blossomed into full success. But even before Prof. Barlow was thus arriving at his discouraging conclusion, Prof. Joseph Henry at the Albany Institute in the State of New York had commenced experiments which resulted in the complete and successful demonstration of the power of electro-magnetism for not only telegraph purposes but for almost every advancement that has since been had in this branch of physics. In March 1829 he exhibited at his Institute the magnetic "spool" or "bobbin," that form of coil composed of tightly-wound, silk-covered wire which he had constructed, and which since has been universally employed for nearly every application of electro-magnetism, of induction, or of magneto-electrics. And in the same year and in 1830 he produced those powerful magnets through which the energy of a galvanic battery was used to lift hundreds of tons of weight. [Pg 124]

In view of all the facts now historically established, there can be no doubt that previous to Henry's experiments the means for developing magnetism in soft iron were imperfectly understood, and that, as found by Prof. Barlow, the electro-magnet which then existed was inapplicable and impracticable for the transmission of power to a distance. Prof. Henry was the first to prove that a galvanic battery of "intensity" must be employed to project the current through a long conductor, and that a magnet of one long wire must be used to receive this current; the first to magnetise a piece of soft iron at a distance and call attention to its applicability to the telegraph; the first to actually sound a bell at a distance by means of the electro-magnet; and the first to show that the principles he developed were applicable and necessary to the practical operation of an effective telegraph system.

Sturgeon, the parent of the electro-magnet, on learning of Henry's discoveries and inventions, wrote: "Professor Henry has been enabled to produce a magnetic force which totally eclipses every other in the whole annals of magnetism; and no parallel is to be found since the miraculous suspension of the celebrated oriental impostor in his iron coffin." (*Philosophical Magazine and Annals*, 1832.)

The third decade was now prepared for the development of the telegraph. As to the telegraph in its broadest sense, as a means for conveying intelligence to a distance quickly and without a messenger, successful experiments of that kind have existed from the earliest times:—from the signal fires of the ancients; from the flag signals between ships at sea, introduced in the seventeenth century by the Duke of York, then Admiral of the English fleet, and afterwards James [Pg 125] II of England; from the semaphore telegraph of M. Chappe, adopted by the French government in 1794, consisting of bars pivoted to an upright stationary post, and made to swing vertically or horizontally to indicate certain signals; and from many other forms of earlier and later days.

As to electricity as an agent for the transmission of signals, the idea dates, as already stated, from the discovery of Stephen Gray in 1729, that the electrical influence could be conveyed to a distance by the means of an insulated wire. This was followed by the practical suggestions of Franklin and others. But when, as we have seen, voltaic electricity entered the field, electricity became a more powerful and tractable servant, and distant intelligent signals became one of its first labors.

The second decade was also made notable by the discovery and establishment by George Simon Ohm, a German professor of Physics, of the fundamental mathematical law of electricity: It has been expressed in the following terms: (a) the current strength is equal to the electro-motive force divided by the resistance; (b) the force is equal to the current strength multiplied by the resistance; (c) the resistance is equal to the force divided by the current strength.

The historical development and evolution of the telegraph may be now summarized:—

1. The discovery of galvanic electricity by Galvani—1786-1790.

2. The galvanic or voltaic battery by Volta in 1800.

3. The galvanic influence on a magnetic needle by Romagnosi (1802) Oersted (1820). [Pg 126]

4. The galvanometer of Schweigger, 1820—the parent of the needle system.

5. The electro-magnet by Arago and Sturgeon—1820-1825—the parent of the magnet system.

Then followed in the third decade the important series of steps in the evolution, consisting of:—

First, and most vital, Henry's discovery in 1829 and 1830 of the "intensity" or spool-wound magnet, and its intimate relation to the "intensity" battery, and the subordinate use of an armature as the signalling device.

Second, Gauss's improvement in 1833 (or probably Schilling's considerably earlier) of reducing the electric conductors to a single circuit by the ingenious use of a dual sign so combined as to produce a true alphabet.

Third, Weber's discovery in 1833 that the conducting wires of an electric telegraph could be efficiently carried through the air without any insulation except at their points of support.

Fourth, Daniell's invention of a "constant" galvanic battery in 1836.

Fifth, Steinheil's remarkable discovery in 1837 that the earth may form the returning half of a closed galvanic circuit, so that a single conducting wire is sufficient for all telegraphic purposes.

Sixth, Morse's adaptation of the armature and electro-magnet of Henry as a recording instrument in 1837 in connection with his improvement in 1838 on the Schilling, Gauss and Steinheil alphabets by employing the simple "dot and dash" alphabet in a single line. He was also assisted by the suggestions of Profs. Dana and Gale. To which must be added his adoption of Alfred Vail's improved alphabet, and Vail's practical suggestions in respect to the recording and other instrumentalities. [Pg 127]

To these should be added the efforts in England, made almost simultaneously with those of Morse, of Wheatstone and Cook and Davy, who were reaching the same goal by somewhat different routes.

Morse in 1837 commenced to put the results of his experiments and investigations in the form of caveats, applications and letters patent in the United States and in Europe. He struggled hard against indifference and poverty to introduce his invention to the world. It was not until 1844 that he reduced it to a commercial practical success. He then laid a telegraph from Washington to Baltimore under the auspices of the United States Government, which after long hesitation appropriated $30,000 for the purpose. It was on the 24th day of May, 1844, that the first formal message was transmitted on this line between the two cities and recorded by the electro-magnet in the dot and dash alphabet, and this was immediately followed by other messages on the same line.

Morse gathered freely from all sources of which he could avail himself knowledge of what had gone before. He was not a scientific discoverer, but an inventor, who, adding a few ideas of his own to what had before been discovered, was the first to combine them in a practical useful device. What he did as an inventor, and what anyone may do to constitute himself an inventor, by giving to the world a device which is useful in the daily work of mankind, as distinguished from the scientific discoverer who stops short of successful industrial work, is thus stated by the United States Supreme Court in an opinion sustaining the validity of his patents, after all the previous art had been produced before it:—

"Neither can the inquiries he made nor the information or advice he received from men of [Pg 128] science in the course of his researches impair his right to the character of an inventor. No invention can possibly be made, consisting of a combination of different elements of power, without a thorough knowledge of the properties of each of them, and the mode in which they operate on each other. And it can make no difference in this respect, whether he derives his information from books, or from conversation with men skilled in the science. If it were otherwise, no patent in which a combination of different elements is used would ever be obtained, for no man ever made such an invention without having first obtained this information, unless it was discovered by some fortunate accident. And it is evident that such an invention as the electro-magnetic telegraph could never have been brought into action without it; for a very high degree of scientific knowledge and the nicest skill in the mechanic arts are combined in it, and were both necessary to bring it into successful operation. The fact that Morse sought and obtained the necessary information and counsel from the best sources, and acted upon it, neither impairs his rights as an inventor nor detracts from his merits."—*O'Reilly vs. Morse, 5 Howard*.

The combination constituting Morse's invention comprised a main wire circuit to transmit the current through its whole length whenever closed; a main galvanic battery to supply the current; operating keys to break and close the main circuit; office circuits; a circuit of conductors and batteries at each office to record the message there; receiving spring lever magnets to close an office circuit when a current passes through the main circuit; adjusting screws to vary the force of the main current; marking apparatus, consisting of pointed pieces of wire, to indent dots and [Pg 129] lines upon paper; clockwork to move the paper indented; and magnet sounders to develop the power of the pointer and of the armatures to produce audible distinguishable sounds.

It was soon learned by operators how to distinguish the signs or letters sent by the length of the "click" of the armature, and by thus reading by sound the reading of the signs on paper was dispensed with, and the device became an electric-magnetic acoustic telegraph.

What is known as the Morse system has been improved, but its fundamental principles remain, and their world-wide use constitute still the daily evidence of the immense value of the invention to mankind.

Before the 1844 reduction to practice, Morse had originated and laid the first submarine telegraph. This was in New York harbour in 1842. In a letter to the Secretary of the United States Treasury, August 10, 1843, he also suggested the project of an Atlantic telegraph.

While Henry was busy with his great magnets and Morse struggling to introduce his telegraph, Michael Faraday was making those investigations and discoveries which were to result in the application of electricity to the service of man in still wider and grander fields.

Faraday was a chemist, and Davy's most brilliant pupil and efficient assistant. His earliest experiments were in the line of electrolysis. This was about 1822, but it was not until 1831 that he began to devote his brilliant talents as an experimentalist and lecturer wholly to electrical researches, and for a quarter of a century his patient, wonderful labours and discoveries [Pg 130] continued. It has been said that "although Oersted was the discoverer of electro-magnetism and Ampère its expounder, Faraday made the science of magnets electrically what it is at the present day."

Great magnetic power having been developed by passing a galvanic current around a bar of soft iron, Faraday concluded that it was reasonable to suppose that as mechanical action is accompanied by an equal amount of reaction, electricity ought to be evolved from magnetism.

"It was in 1831 that Faraday demonstrated before the Royal Society that if a magnetized bar of steel be introduced into the centre of a helix of insulated wire, there is at the moment of introduction of the magnet a current of electricity set up in a certain direction in the insulated wire forming the helix, while on the withdrawal of the magnet from the helix a current in an opposite direction takes place.

"He also discovered that the same phenomenon was to be observed if for the magnet was substituted a coil of insulated wire, through which the current from a voltaic element was passing; and further that when an insulated coil of wire was made to revolve before the poles of a permanent magnet, electric currents were induced in the wires of the coil."—*Journal of the Society of Arts.*

On these discoveries were based the action of all magneto-dynamo electric machines—machines that have enabled the world to convert the energy of a steam engine in its stall, or a distant waterfall, into electric energy for the performance of the herculean labours of lighting a great city, or an ocean-bound lighthouse, or transporting quickly heavy loads of people or freight up [Pg 131] and down and to and fro upon the earth.

As before stated, Faraday was also the first to proclaim the laws of electrolysis, or electro-chemical decomposition. He expressed conviction that the forces termed chemical affinity and electricity are one and the same. Subsequently the great Helmholtz, having proved by experiment that in the phenomena of electrolysis no other force acts but the mutual attractions of the atomic electric charges, came to the conclusion, "that the very mightiest among the chemical forces are of electric origin."

Faraday having demonstrated by his experiments that chemical decomposition, electricity, magnetism, heat and light, are all inter-convertible and correlated forces, the inventors of the age were now ready to step forward and put these theories at work in machines in the service of man. Faraday was a leader in the field of discovery. He left to inventors the practical application of his discoveries.

Prof. Henry in America was, contemporaneously with Faraday, developing electricity by means of magnetic induction.

In 1832, Pixii, a philosophical instrument-maker of Paris, and Joseph Saxton, an American then residing in London, invented and constructed magneto-machines on Faraday's principle of rendering magnetic a core of soft iron surrounded with insulated wire from a permanent magnet, and rapidly reversing its polarity, which machines were used to produce sparks, decompose liquids and metals, and fire combustible bodies. Saxton's machine was the well-known electric shock machine operated by turning a crank. A similar device is now used for ringing telephone call bells. [Pg 132]

Prof. C. G. Page of Washington and Ruhmkorff of Paris each made a machine, well known as the Ruhmkorff coil, by which intense electro-magnetic currents by induction were produced. The production of electrical illumination was now talked of more than ever. Scientists and inventors now had two forms of electrical machines to produce light: the voltaic battery and the magneto-electric apparatus. But a period of comparative rest took place in this line until 1850, when Prof. Nollet of Brussels made an effort to produce a powerful magneto-electric machine for decomposing water into its elements of hydrogen and oxygen, which gases were then to be used in producing the lime light; and a company known as "The Alliance" was organized at Paris to make large machines for the production of light.

We have seen that Davy produced a brilliant electric light with two pieces of charcoal in the electric circuit of a voltaic battery. Greener and Staite revived this idea in a patent in 1845. Shortly after Nollet's machine, F. H. Holmes of England improved it and applied the current directly to the production of electric light between carbon points. And Holmes and Faraday in 1857 prepared this machine for use.

On the evening of December 8, 1858, the first practical electric light, the work of Faraday and Holmes, flashed over the troubled sea from the South Foreland Lighthouse. On June 6, 1862, this light was also introduced into the lighthouse at Dungeness, England. The same light was introduced in French lighthouses in December, 1863, and also in the work on the docks of Cherbourg. At this time Germany was also awake to the importance of this invention, and Dr. Werner Siemens of Berlin was at work developing a machine for the purpose into one of less cost [Pg 133] and of greater use. Inventors were not yet satisfied with the power developed from either the voltaic battery or the magneto-electric machine, and continued to improve the latter.

In 1867, the same year that Faraday died, and too late for him to witness its glory, came out the most powerful magneto-electric machine that had yet been produced. It was invented by Wilde of London, and consisted of very large electro-magnets, or field magnets, receiving their electric power from the "lines of force" discovered by Faraday, radiating from the poles of a soft iron magnet, combined with a small magneto-electric machine having permanent magnets, and by which the current developed in the smaller machine was sent through the coils of the larger magnets. By this method the magnetic force was vastly multiplied, and electricity was produced in such abundance as to fuse thick iron wire fifteen inches long and one-fourth of an inch in diameter, and to develop a magnificent arc light. Quickly succeeding the Wilde machine came independent inventions in the same direction from Messrs. G. Farmer of Salem, Mass., Alfred Yarley and Prof. Charles Wheatstone of England, and Dr. Siemens of Berlin, and Ladd of America. These inventors conceived and put in practice the great idea of employing the current from an electro-magnetic machine to excite its own electric magnet. They were thus termed "self-exciting." The idea was that the commutator (an instrument to change the direction, strength or circuit of the current) should be so connected with the coils of the field magnets that all or a part of the current developed in the armature would flow through these coils, so that all permanent magnets might be dispensed with, and the machine used to excite itself or charge its own field magnets without the aid of any outside charging or feeding mechanism. [Pg 134]

Mr. Z. Gramme, of France, a little later than Wilde made a great improvement. Previously, machines furnished only momentary currents of varying strength and polarity; and these intermittent currents were hard to control without loss in the strength of current and the frequent production of sparks. Gramme produced a machine in which, although as in other machines the magnetic field of force was created by a powerful magnet, yet the armature was a ring made of soft iron rods, and surrounded by an endless coil of wire, and made to revolve between the poles of the magnet with great rapidity, producing a constant current in one direction. By Faraday's discovery, when the coil of the closed circuit was moved before the poles of the magnet, the current was carried half the time in one direction and half in the other, constituting what is called an alternating current. Gramme employed the commutator to make the current direct instead of alternating.

Dynamo-electric machines for practical work of many kinds had now been born and grown to strength.

In addition to these and many other electrical machines this century has discovered several ways by which the electricity developed by such machines may be converted into light. I. By means of two carbon conductors between which passes a series of intensely brilliant sparks which form a species of flame known as the *voltaic arc*, and the heat of which is more intense than that from any other known artificial source. II. By means of a rod of carbon or kaolin, strip of platinum or [Pg 135]
iridium, a carbon filament, or other substance placed between two conductors, the resistance opposed by such rod, strip, or filament to the passage of the current being so great as to develop heat to the point of incandescence, and produce a steady white and pure light. Attempts also have been made to produce illumination by what is called stratified light produced by the electric discharge passing through tubes containing various gases. These tubes are known as Geissler tubes, from their inventor. Still another method is the production of a continuous light from a vibratory movement of carbon electrodes to and from each other, producing a bright flash at each separation, and maintaining the separations at such a rate that the effect of the light produced is continuous. But these additional methods do not appear as yet to be commercially successful.

It must not be overlooked that before dynamo-magneto-electric machines were used practically in the production of the electric light for the purposes of illumination, the voltaic battery was used for the same purpose, but not economically.

The first private dwelling house ever lighted in America, or doubtless anywhere else, by electricity, was that of Moses G. Farmer, in Salem, Massachusetts, in the year 1859. A voltaic battery furnished the current to conducting wires which led to two electric lamps on the mantel-piece of the drawing-room, and in which strips of platinum constituted the resisting and lighting medium. A soft, mild, agreeable light was produced, which was more delightful to read or sew by than any artificial light ever before known. Either or both lamps could be lighted by turning a button, and they were maintained for several weeks, but were discontinued for the reason that [Pg 136]
the cost of maintaining them was much greater than of gas light.

It was in connection with the effective dynamo-electric apparatus of M. Gramme above referred to that the electric candle invented by M. Paul Jablochoff became soon thereafter extensively employed for electric lighting in Paris, and elsewhere in Europe. This invention, like the great majority of useful inventions, is noted for its simplicity. It consists of two carbon pencils placed side by side and insulated from each other by means of a thin plate of some refractory material which is a non-conductor at ordinary temperatures, but which becomes a conductor, and consequently a light, when fused by the action of a powerful current. Plaster of Paris was found to be the most suitable material for this purpose, and the light produced was soft, mellow, slightly rose-coloured, and quite agreeable to the eye.

It having been found that carbon was better adapted for lighting purposes than platinum or other metals, by reason of its greater radiating power for equal temperatures, and still greater infusibility at high temperatures, inventors turned their attention to the production of the best carbon lamp.

The two pointed pieces of hard conducting carbon used for the separated terminals constitute the voltaic arc light—a light only excelled in intense brilliancy by the sun itself. It is necessary in order to make such a light successful that it should be continuous. But as it is found that both carbons waste away under the consuming action of the intense heat engendered by their resistance to the electric current, and that one electrode, the positive, wastes away twice as fast as the opposite negative electrode, the distance between the points soon becomes too great for [Pg 137]
the current longer to leap over it, and the light is then extinguished. Many ingenious contrivances have been devised for correcting this trouble, and maintaining a continuously uniform distance between the carbons by giving to them a self-adjusting automatic action. Such an apparatus is called a *regulator*, and the variety of regulators is very great. The French were among the first to contrive such regulators,—Duboscq, Foucault, Serrin, Houdin, and Lontin invented most useful forms of such apparatus. Other early inventors were Hart of Scotland, Siemens of Germany, Thompson and Houston of England, and Farmer, Brush, Wallace, Maxim, and Weston and Westinghouse of America. Gramme made his armature of iron rods to prevent its destruction by heat. Weston in 1882 improved this method by making the armature of separate and insulated sheets of iron around which the coil is wound. The arc light is adapted for streets and great buildings, etc.; but for indoor illumination, when a milder, softer light is desirable, the *incandescent* light was invented, and this consists of a curved filament of carbon about the size of

a coarse horsehair, seated in a bulb of glass from which the air has been exhausted. In exhausted air carbon rods or filaments are not consumed, and so great ingenuity was exercised on that line. Among the early noted inventors of incandescent carbon filament lamps were Edison and Maxim of New York, Swan, and Lane-Fox of England.

Another problem to be solved arose in the proposed use of arc lamps upon an extended scale, or in series, as in street lighting, wherein the current to all lamps was supplied by a single wire, and where it was found that owing to the unequal consumption of the carbons some were burning well, some poorly, and some going out. It was essential, therefore, to make each lamp independent of the resistance of the main circuit and of the action of the other lamps, and to have its regulating mechanism governed entirely by the resistance of its own arc. The solution of this difficult problem was the invention by Heffner von Alteneck of Germany, and his device came into use wherever throughout the world arc lamps were operated. Westinghouse also improved the direct alternating system of lighting by one wire by the introduction of two conducting wires parallel to each other, and passing an interrupted or alternating current through one, thereby inducing a similar and always an alternating current through the other. Brush adopted a three-wire system; and both obtained a uniform consumption of the carbons. [Pg 138]

In a volume like this, room exists for mention only of those inventions which burn as beacon lights on the tallest hills—and so we must now pass on to others.

Just as Faraday was bringing his long series of experimental researches to a close in 1856-59, and introducing the fruits of his labours into the lighthouses of England, Cyrus W. Field of New York had commenced his trials in the great scheme of an ocean cable to "moor the new world alongside the old," as John Bright expressed it. After crossing the ocean from New York to England fifty times, and baffled often by the ocean, which broke his cables, and by the incredulous public of both hemispheres, who laughed at him, and by electricity, which refused to do his bidding, he at last overcame all obstacles, and in 1866 the cable two thousand miles in length had been successfully stretched and communication perfected. To employ currents of great power, the cable insulation would have been disintegrated and finally destroyed by heat. Therefore only feeble currents could be used. But across that long distance these currents for many reasons grew still weaker. The inventor, Sir William Thomson, was at hand to provide the remedy. First, by his *mirror galvanometer*. A needle in the shape of a small magnet and connected to the current wires, is attached to the back of a small concave mirror having a hole in its centre; opposite the mirror is placed a graduated scale board, having slits through it, and a lighted lamp behind it. The light is thrown through the slits across to the hole at the center of the mirror and upon the needle. The feeblest imaginable current suffices to deflect the needle in one direction, which throws back the little beam of light upon it to the graduated front of the scale. When the current is reversed the needle and its shadow are deflected in the other direction, and so by a combination of right and left motions, and pauses, of the spots of light to represent letters, the message is spelled out. Second, a more expeditious instrument called the *syphon recorder*. In this the galvanometer needle is connected to a fine glass syphon tube conducting ink from a reservoir on to a strip of paper which is drawn under the point of the tube with a uniform motion. The irregular movements given the galvanometer needle by the varying current are clearly delineated on the paper. Or in writing very long cables the point of the syphon may not touch the paper, but the ink by electrical attraction from the paper is ejected from the syphon upon the paper in a succession of fine dots. The irregular lines of dots and dashes were translated into words in accordance with the principles of the Morse telegraph. [Pg 139] [Pg 140]

An instrument was exhibited at the Centennial International Exhibition at Philadelphia in 1876, which was considered by the judges "the greatest marvel hitherto achieved by the electric telegraph." Such was the language used both by Prof. Joseph Henry and Sir Wm. Thomson, and concurred in by the other eminent judges from America, Germany, France, Austria and Switzerland. This instrument was the *Telephone*. It embodied, for the practical purpose of transmitting articulate speech to distances, the union of the two great forces,—sound and electricity. It consisted of a method and an apparatus. The apparatus or means consisted of an electric battery circuit, a transmitting cone placed at one end of the line into which speech and other vocal sounds were uttered, a diaphragm against which the sounds were projected, an armature secured to or forming a part of the diaphragm, an electro-magnet loosely connected to the armature, a wire connecting this magnet with another precisely similar arrangement of magnet, armature, diaphragm, and cone, at the receiving end. When speech was uttered in the transmitter the sound vibrations were received on the diaphragm, communicated to the electricised armature, from thence by induction to the magnet and the connecting wire current, which, undulating with precisely the same form of sound vibrations, carried them in exactly the same form to the receiving magnet. They were then carried through the receiving armature and reproduced on the receiving diaphragm, with all the same characteristics of pitch, loudness and quality.

The inventor was Alexander Graham Bell, by nativity a Scotchman, then a resident of Canada, and finally a citizen of the United States. His father was a teacher of vocal physiology at Edinburgh, and he himself became a teacher of deaf mutes. This occupation naturally led him to a thorough investigation of the laws of sound. He acknowledged the aid he received from the great work of Helmholtz on the *Theory of Tone*. His attention was called to sounds transmitted and reproduced by the electric current, especially by the ease with which telegraph operators read their messages by the duration of the "click" of their instruments. He knew of the old device of a tightly-stretched string or wire between two little boxes. He had read the publication of Prof. [Pg 141]

C. G. Page, of America, in 1837, on the *Production of Galvanic Music*, in which was described how musical notes were transmitted and reproduced by an interrupted magnetic circuit. He became acquainted with the experimental musical telephonic and acoustic researches of Reis, and others of Germany, and those of celebrated scientists in France, especially the phonautograph of Scott, a delicate instrument having a cone membrane and pointer, and used to reproduce on smoked glass the waves of sound. He commenced his experiments with magneto instruments in 1874, continued them in 1875, when he succeeded in reproducing speech, but poorly, owing to his imperfect instruments, and then made out his application, and obtained a patent in the United States in July, 1876.

Like all the other remarkable inventions recorded in these pages, this "marvel" did not spring forth as a sudden creation, but was a slow growth of a plant derived from old ideas, although it blossomed out suddenly one day when audible sounds were accidentally produced upon an apparatus with which he was experimenting. [Pg 142]

It is impossible here to narrate the tremendous conflict that Bell now encountered to establish his title as first inventor, or to enumerate the multitude of improvements and changes made which go to make up the successful telephone of to-day.

The messages of the voice are carried on the wings of electricity wherever any messages are carried, except under the widest seas, and this difficulty inventors are now seeking to overcome.

The story of the marvellous inventions of the century in electricity is a fascinating one, but in length and details it is also marvellous, and we must hasten unwillingly to a close. Numerous applications of it will be mentioned in chapters relating to other arts.

In the generation of this mighty force improvements have been made, but those of greatest power still involve the principles discovered by Faraday and Henry seventy years ago. The ideas of Faraday of the "lines of force"—the magnetic power streaming from the poles of the magnet somewhat as the rays of heat issue on all sides from a hot body, forming the magnetic field—and that a magnet behaves like an electric current, producing an electric wave by its approach to or recession from a coil of wire, joined with Henry's idea of increasing the magnetising effect by increasing the number of coils around the magnet, enter into all powerful dynamo electric machines of to-day. In them the lines of force must flow around the frame and across the path of the armature; and there must be a set of conductors to cut the lines of force twice in every revolution of the cylinder carrying the armature from which the current is taken.

When machines had been produced for generating with some economy powerful currents of electricity, their use for the world's business purposes rapidly increased. [Pg 143] Among such applications, and following closely the electric lighting, came the *electric railway*. A substitute for the slow animal, horse, and for the dangerous, noisy steam horse and its lumbering locomotive and train, was hailed with delight. Inventors came forward with adaptations of all the old systems they could think of for the purpose, and with many new ones. One plan was to adapt the storage battery—that silent chemical monster which carries its own power and its own machine—and place one on each car to actuate a motor connected to the driving wheels. Another plan was to conduct the current from the dynamo machine at its station along the rails on one side of the track to the motor on the car and the return current on the opposite track; another was to carry the current to the car on a third rail between the track, using both the other rails for the return; another to use an overhead wire for the current from the dynamo, and connect it with the car by a rod, one end of which had a little wheel or trolley running on the overhead wire, to take up the current, the other end being connected by a wire to the car motor; another plan to have a trench made leading from the central station underneath the track the whole length of the line, and put into this trench conducting wires from the dynamo, to one of which the car motor should be connected by a trolley rod or "brush," extending down through a central slot between the rails of the track to carry the electric supply into the motor. In all these cases a lever was supplied to cut off communication between the conducting wire and the motor, and a brake lever to stop the car.

All of these plans have been tried, and some of them are still being tried with many [Pg 144] improvements in detail, but not in principle.

The first electrical railway was constructed and operated at Berlin in 1879, by Messrs Siemens and Halske. It was two thousand seven hundred feet long and built on the third rail system. This was an experiment but a successful one. It was followed very soon by another line near Berlin for actual traffic; then still another in Saxony. At the Paris Exposition in 1881, Sir Wm. Siemens had in operation a road about one thousand six hundred feet in length, on which it is estimated ninety-five thousand passengers were conveyed in seven weeks. Then in the next year in London; and then in the following year one in the United States near New York, constructed by Edison. And thus they spread, until every important town and city in the world seems to have its electric plant, and its electric car system, and of course its lighting, telephone and telegraph systems.

In 1882 Prof. Fleeming Jenkin of England invented and has put to use a system called *Telpherage*, by which cars are suspended on an overhead wire which is both the track and electrical conductor. It has been found to be advantageous in the transportation of freight from mines and other places to central stations.

With the coming of the electric railway, the slow, much-abused horse, the puffing steam engine blowing off smoke and cinders through the streets, the great heavy cars, rails and roadbeds, the dangerous collisions and accidents, have disappeared.

The great problems to solve have related to generation, form, distribution and division of the electric current at the dynamos at the central stations for the purposes of running the distant [Pg 145] motors and for furnishing independent supplies of light, heat, sound and power. These problems have received the attention of the keenest inventors and electrical engineers and have been solved.

The description of the inventions made by such electrical magicians as Thomas Edison and Nikola Tesla would fill volumes.

The original plan of sending but one message over a wire at a time has also been improved; and duplex, quadruplex and multiplex systems have been invented (by Stearns, Farmer, Edison and others) and applied, which have multiplied the capacity of the telegraphs, and by which even the alleged all-talk-at-the-same-time habit of certain members of the great human family can be carried on in opposite directions on the same wire at the same time between their gatherings in different cities and without a break.

To understand the manner of multiplying messages or signals on the same line, and using apparently the same electric current to perform different operations, the mind must revert to the theory already referred to, that a current of electricity does not consist of a stream of matter flowing like water through a conductor in one direction, but of particles of subtle ether, vibrating or oscillating in waves from and around the conductor which excites them; that the vibration of this line of waves proceeds at the rate of many thousand miles per second, almost with the velocity of waves of light, with which they are so closely related; that this wave current is susceptible of being varied in direction and in strength, according to the impulse given by the initial pressure of the transmitting and exciting instrument; and that some wave currents have [Pg 146] power by reason of their form or strength to penetrate or pass others coming from an opposite direction. So that in the multiplex process, for instance, each transmission having a certain direction or strength and its own set of transmitting and receiving instruments, will have power to give its own peculiar and independent signal or message. Apparently there is but one continuous current, but in reality each transmission is separated from the others by an almost inconceivably short interval of time.

Among the inventions in the class of Telegraphy should also be mentioned the dial and the printing systems. Ever since the electric telegraph was invented, attempts have been made to use the electric influence to operate either a pointer to point out the letters of the message sent on a dial, or to print them on a moving strip of paper; and also to automatically reproduce on paper the handwriting of the sender or writer of the message. The earliest efforts were by Cooke and Prof. Wheatstone of London, in 1836-37; but it was not until 1839, after Prof. Henry had succeeded in perfecting the electromagnet, that dial and printing telegraphs were successfully produced. Dial telegraphs consist of the combination with magnets, armatures and printed dial plate of a clock-work and a pointer, means to set the pointer at the communicating end (which in some instances has been a piano keyboard) to any letter, the current operating automatically to indicate the same letters at the receiving end. These instruments have been modified and improved by Brequet and Froment of France, Dr. Siemens and Kramer, and Siemens and Halske of Germany, Prof. Wheatstone of England, Chester and Hamblet of America, and others. They have been used extensively upon private and municipal lines both in Europe and the United [Pg 147] States.

The type-printing telegraph was coeval with the dial, and originated with Morse and Vail as early as 1837. The printing of the characters is effected in various ways; sometimes by clockwork mechanism and sometimes by the direct action of an electromagnet. Wheatstone exhibited one in 1841. House of Vermont invented in 1845-1846 the first printing telegraph that was brought into any extensive use in the United States. Then followed that of David E. Hughes of Kentucky in 1855, aided by his co-inventor George M. Phelps of Troy, New York, and which was subsequently adopted by the French government, by the United Kingdom Telegraph Co. of Great Britain, and by the American Telegraph Co in the United States. The system was subsequently greatly improved by Hughes and others. Alexander Bain of Edinburgh in 1845-46 originated the modern automatic chemical telegraph. In this system a kind of punch was used to perforate two rows of holes grouped to represent letters on a strip of paper conducted over a metal cylinder and arranged so as to permit spring levers to drop through the perforations and touch the cylinder, thus forming an electrical contact; and a recording apparatus consisting of a strip of paper carried through a chemical solution of an acid and potash and over a metal roller, and underneath one or two styles, or pens, which pens were connected by live wires with the poles of two batteries at the sending station. The operation is such that colored marks upon the paper were made by the pens corresponding precisely to the perforations in the strip at the sending station. Siemens, Wheatstone and others also improved this system; but none of these systems [Pg 148] have as yet replaced or equalled in extensive use the Morse key and sounder system, and its great acoustic advantage of reading the messages by the click of the instrument. The type-printing system, however, has been recently greatly improved by the inventions of Howe, C. L. Buckingham, Fiske and others in the United States. Special contrivances and adaptations of the telegraph for printing stock reports and for transmitting fire alarm, police, and emergency calls, have been invented.

The erection of tall office and other buildings, some to the height of more than twenty stories, made practicable by the invention of the elevator system, has in turn brought out most ingenious devices for operating and controlling the elevators to insure safety and at the same time produce economy in the motive power.

The utility of the telephone has been greatly increased by the inventions of Hughes and Edison of the *microphone*. This consists, in one form, of pieces of carbon in loose contact placed in the circuit of a telephone. The very slightest vibrations communicated to the wood are heard distinctly in the telephone. By these inventions and certain improvements not only every sound and note of an opera or concert has been carried to distant places, but the slightest whispers, the minute movements of a watch, even the tread of a fly, and the pressure of a finger, have been rendered audible.

By the aid of the electric current certain rays of light directed upon the mineral selenium, and some other substances, have been discovered to emit musical sounds.

So wonderful and mysterious appear these communications along the electric wire that each and every force in the universe seems to have a voice awaiting utterance to man. The hope is indulged that by some such means we may indeed yet receive the "touch of a vanished hand and the sound of a voice that is still." [Pg 149]

In 1879 that eminent English scientist, Prof. Wm. Crookes, published his extensive researches in electrical discharges as manifested in glass tubes from which the air had been exhausted. These same tubes have already been referred to as Geissler tubes, from the name of a young artist of Bonn who invented them. In these tubes are inclosed various gases through which the sparks from an induction coil can be passed by means of platinum electrodes fused into the glass, and on the passage of the current a soft and delicately-tinted light is produced which streams through the tube from pole to pole.

In 1895, Wm. Konrad Roentgen, professor of Physics in the Royal University of Würzburg, while experimenting with these Crookes and Geissler tubes, discovered with one of them, which he had covered with a sort of black cardboard, that the rays emanating from the same and impinging on certain objects would render them self-luminous, or fluorescent; and on further investigation that such rays, unlike the rays of sunlight, were not deflected, refracted or condensed; but that they proceeded in straight lines from the point at which they were produced, and penetrated various articles, such as flesh, blood, and muscle, and thicknesses of paper, cloth and leather, and other substances which are opaque to ordinary light; and that thus while penetrating such objects and rendering them luminous, if a portion of the same were of a character too dense to admit of the [Pg 150] penetration, the dark shadow of such obstacle would appear in the otherwise luminous mass.

Unable to explain the nature or cause of this wonderful revelation, Roentgen gave to the light an algebraic name for the unknown—the X rays.

This wonderful discovery, at first regarded as a figment of scientific magic, soon attracted profound attention. At first the experiments were confined to the gratification of curiosity—the interior of the hand was explored, and on one occasion the little mummified hand of an Egyptian princess folded in death three or four thousand years ago, was held up to this light, and the bones, dried blood, and muscle of the ancient Pharaohs exhibited to the startled eyes of the present generation. But soon surgery and medicine took advantage of the unknown rays for practical purposes. The location of previously unreachable bullets, and the condition of internal injuries, were determined; the cause of concealed disease was traced, the living brain explored, and the pulsations of the living heart were witnessed.

Retardation of the strength of the electric current by the inductive influence of neighboring wires and earth currents, together with the theory that the electric energy pervades all space and matter, gave rise to the idea that if the energy once established could be set in motion at such point above the ordinary surface of the earth as would free this upper current from all inductive disturbance, impulses of such power might be conveyed from one high point and communicated to another as to produce signals without the use of a conducting wire, retaining only the usual batteries and the earth connection. On July 30th, 1872, Mahlen Loomis of Washington, D. C., took out a patent for "the utilization of natural electricity from elevated points" for telegraphic [Pg 151] purposes, based on the principle mentioned, and made successful experiments on the Blue Ridge mountains in Virginia near Washington, accounts of which were published in Washington papers at the time; but being poor and receiving no aid or encouragement he was compelled to give it up. Marconi of Italy has been more successful in this direction, and has sent electric messages and signals from high stations over the English Channel from the shores of France to England. So that now wireless telegraphy is an established fact.

It is certainly thrilling to realize that there is a mysterious, silent, invisible and powerful mechanical agent on every side of us, waiting to do our bidding, and to lend a hand in every field of human labour, and yet unable to be so used without excitement to action and direction in its course by some master, intermediate between itself and man. The principal masters for this purpose are steam and water power. A small portion of the power of the resistless Niagara has been taken, diverted to turn the machinery which excites electricity to action, and this energy in turn employed to operate a multitude of the most powerful motors and machines of many descriptions.

So great is the might of this willing agent that at a single turn of the hand of man it rushes forth to do work for him far exceeding in wonder and extent any labour of the gods of mythological renown.

CHAPTER X. [Pg 152]

HOISTING, CONVEYING AND STORING.

Allusion has been made to the stupendous buildings and works of the ancients and of the middle ages; the immense multitude of workers and great extent of time and labour employed in their construction; and how the awful drudgery involved in such undertakings was relieved by the invention of modern engineering devices—the cranes, the derricks, and the steam giants to operate them, so that vast loads which required large numbers of men and beasts to move, and long periods of time in which to move them, can now be lifted with ease and carried to great heights and distances in a few minutes by the hands of one or of a few men.

But outside of the line of such undertakings there is an immense field of labor-saving appliances adapted for use in transportation of smaller loads from place to place, within and without buildings, and for carrying people and freight from the lower to the upper stories of tall structures. In fact the tall buildings which we see now in almost every great city towering cloudward from the ground to the height of fifteen, twenty and twenty-five stories, would have been extravagant and useless had not the invention of the modern elevator rendered their highest parts as easy of access as their lowest, and at the same time given to the air space above the city lot as great a commercial value in feet and inches as the stretch of earth itself. [Pg 153]

Many of the "sky-scrapers" so called, are splendid monuments of the latest inventions of the century.

It is by means of the modern elevator that the business of a whole town may be transacted under a single roof.

In the multiplicity of modern human contrivances by which the sweat and drudgery of life are saved, and time economised for worthier objects, we are apt to overlook the painful and laborious steps by which they were reached, and to regard with impatience, or at least with indifference, the story of their evolution; and yet no correct or profound knowledge of the growth of humanity to its higher planes can be obtained without noting to what extent the minor inventions, as well as the startling ones, have aided the upward progress.

For instance, consider how few and comparatively awkward were the mechanical means before this century. The innumerable army of men when men were slaves, and when blood and muscle and brain were cheap, who, labouring with the beast, toiled upward for years on inclined ways to lay the stones of the stupendous pyramids, still had their counterpart centuries later in the stream of men carrying on their shoulders the loads of grain and other freight and burdens from the shore to the holds of vessels, from vessels to the shore, from the ground to high buildings and from one part of great warehouses to another. Now look at a vessel moved to a wharf, capable of holding fifty thousand or one hundred thousand bushels of grain and having that amount poured into it in three hours from the spouts of an elevator, to which the grain has been carried in a [Pg 154]
myriad buckets on a chain by steam power in about the same time; or to those arrangements of carriers, travelling on ropes, cords, wires, or cables, by which materials are quickly conveyed from one part of some structure or place to another, as hay and grain in barns or mows, ores from mines to cars, merchandise of all kinds from one part of a great store to another; or shot through pipes underground from one section of a city or town to their destination by a current of air.

True, as it has before been stated, the ancients and later generations had the wedge, the pulley, the inclined plane, the screw and the windlass, and by these powers, modified in form and increased in size as the occasion demanded, in the form of cranes, derricks, and operated by animal power, materials were lifted and transported; but down to the time of the practical and successful application of steam by Watt in the latter part of the 18th century, and until a much later period in most places in the world, these simple means actuated alone by men or animals were the best means employed for elevating and conveying loads, and even they were employed to a comparatively limited extent.

The century was well started before it was common to employ cups on elevator bands in mills, invented by Oliver Evans in 1780, to carry grain to the top of the mill, from whence it was to fall by gravity to the grinding and flouring apparatus below. It was not until 1795 that that powerful modern apparatus—the hydraulic, or hydrostatic, press was patented by Bramah in England. The model he then made is now in the museum of the Commissioner of Patents, London. In this a reservoir for water is provided, on which is placed a pump having a piston rod worked by a hand [Pg 155]
lever. The water is conveyed from the reservoir to a cylinder by a pipe, and this cylinder is provided with a piston carrying at its top a table, which rises between guides. The load to be carried is placed on this table, and as the machine was at first designed to compress materials the load is pressed by the rising table against an upper stationary plate. The elevation of the table is proportionate to the quantity of water injected, and the power proportionate to the receptive areas of the pump and the cylinder. The first great application of machines built on this principle was by Robert Stephenson in the elevation of the gigantic tubes for the tubular bridge across the Menai straits, already described in the chapter on Civil Engineering. The century was half through with before it was proposed to use water and steam for passenger elevators.

In 1852 J. T. Slade in England patented a device consisting of a drum to be actuated by steam, water, or compressed air, around which drum ropes were wound, and to which ropes were attached separate cages in separate wells, to counterbalance each other, the cages moving in guides, and provided with brakes and levers to stop and control the cages and the movement of the drum. Louis T. Van Elvean, also of England, in 1858 invented counterbalance weights for such lifts. Otis, an American, invented and patented in America and England in 1859 the first approach to the modern passenger elevator for hotels, warehouses, and other structures. The motive power was preferably a steam engine; and the elevating means was a large screw placed vertically and made to revolve by suitable gearing, and a cylinder to which the car was attached, having projections to work in the threads of the screw. Means were provided to start and to stop the car, and to retard its otherwise sudden fall and stoppage. [Pg 156]

Elevators, which are now so largely used to raise passengers and freight from the lower to the upper stories of high edifices, have for their motive power steam, water, compressed air, and electricity. With steam a drum is rotated over which a hoisting wire-rope is wound, to which the elevator car is attached. The car for passengers may be a small but elegantly furnished room, which is carried on guide blocks, and the stationary guides are provided with ratchet teeth with which pawls on the car are adapted to engage should the hoisting rope give way. To the hoisting rope is attached a counterbalance weight to partly meet the weight of the car in order to prevent the car from sticking fast on its passage, and also to prevent a sudden dropping of the car should the rope become slack. A hand rope for the operator is provided, which at its lower end is connected with a starting lever controlling the valves of the cylinders into which steam is admitted to start the piston shaft, which in turn actuates the gear wheels, by which movement the ropes are wound around the drums.

In another form of steam elevator the drums are turned in opposite directions, by right and left worms driven by a belt.

In the hydraulic form of elevator, a motor worked by water is employed to lift the car, although steam power is also employed to raise the water. The car is connected to wire cables passing over large sheaves at the top of the well room to a counterbalancing bucket. This bucket fits closely in a water-tight upright tube, or stand-pipe, about two feet in diameter, extending from the basement to the upper story. Near this stand-pipe in the upper story is placed a water supply [Pg 157] tank. A pipe discharges the water from the tank into the bucket, which moves up and down in the stand pipe. There is a valve in the tank which is opened by stepping on a treadle in the car, and this action admits to the bucket just enough weight of water to overbalance the load on the car. As soon as the bucket is heavier than the car it descends, and of course draws the car upward, thus using the minimum power required to raise each load, rather than, when steam is employed, the full power of the engine each and every time. The speed is controlled by means of brakes or clamps that firmly clasp wrought-iron slides secured to posts on each side of the well room, the operator having control of these brakes by a lever on the car. When the car has ascended as far as desired, the operator steps upon another treadle in the car connected with a valve in the bottom of the bucket and thus discharges the water into the receiving tank below until the car is heavier than the bucket, when it then of course descends. The water is thus taken from the upper tank into the bucket, discharged through the stand-pipe into the receiving tank under the floor of the basement and then pumped back again to the upper tank, so that it is used over and over again without loss.

Various modifications have been made in the hydraulic forms. In place of steam, electricity was introduced to control the hydraulic operation. Again, an electric motor has been invented to be placed on the car itself, with connected gearing engaging rack bars in the well.

Elevators have been contrived automatically controlled by switch mechanisms on the landings; and in connection with the electric motor safety devices are used to break the motor circuit and thus stop the car the moment the elevator door is opened; and there are devices to break the [Pg 158] circuit and stop the car at once, should an obstruction, the foot for instance, be accidentally thrust out into the path of the car frame. Columns of water and of air have been so arranged that should the car fall the fall will be broken by the water or air cushion made to yield gradually to the pressure. So many safety devices have been invented that there is now no excuse for accidents. They result by a criminal neglect of builders or engineers to provide themselves with such devices, or by a most ignorant or careless management and operation of simple actuating mechanisms.

Between 1880 and 1890 there was great activity in the invention of what is known as store service conveyors. One of the earliest forms, and one which had been partly selected from other arts, was to suspend from a rigid frame work connected to the floor, roof, or side of the building, a long platform in the direction through the building it was desired the road to run, giving this platform a slight inclination. On this platform were placed tracks, and from the tracks were suspended trucks, baskets, or other merchandise receptacles, having wheels resting on and adapted to roll on the tracks. Double or single tracks could be provided as desired. The cars ran on these tracks by gravity, and considerable ingenuity was displayed in the feature alone of providing the out-going and returning inclined tracks; in hand straps and levers for raising and lowering the carriage, part or all of it, to or from the tracks, and in buffers to break the force of the blow of the carriages when arriving at their stopping places.

Then about 1882-83 it was found by some inventors if moderately fine wires were stretched level, [Pg 159] and as tight as possible, they would afford such little friction and resistance to light and nicely balanced wheels, that no inclination of the tracks was necessary, and that the carriages mounted on such wheels and tracks would run the entire length of a long building and turn corners not too sharp by a single initial push of the hand. In other arrangements a carrier is self-propelled by means of a coiled spring on the carrier, which begins its operation as soon as the carrier is given a start; and to meet the exhausted strength of such spring, coiled springs at different points on the line are arranged to engage and give the carrier an additional push. Before the carrier is stopped its action is such as to automatically rewind its spring.

A system of pneumatic transmission was invented, by which a carrier is caused to travel through a tube by the agency of an air current, created therein by an air compressor, blower, or similar device. The device is so arranged that the air current is caused to take either direction through the tube; and in some instances gravity may be used to assist a vacuum formed behind the carrier. The tube is controlled at each end by one or more sliding gates or valves, and the carrier is made to actuate the gates, and close the one behind it, so that the carrier may be discharged without permitting the escape of the air and consequent reduction of pressure.

An interesting invention has been made by James M. Dodge of Philadelphia in the line of conveyors, whereby pea coal and other quite heavy materials introduced by a hopper into a trough are subjected to a powerful air blast which pushes the material forward; and as the trough is provided with a series of frequently occurring slots or perforations open to the outer air and [Pg 160] inclined opposite the direction of travel, the powerful current from the blower in escaping through such outlets tends to lift or buoy the material and carry it forward in the air current, thereby greatly reducing frictional contact and increasing the impelling operation. The inventor claims that with such an apparatus many tons of material per hour may be conveyed with a comparatively small working air pressure.

In order that a conveyor carriage may be automatically switched off at a certain place or station on the line, one mode adopted was to arrange at a gate or station a sort of pin or projection or other deflector to engage some recess or corresponding feature on the carriage, so as to arrest and turn the carriage in its new direction at that point. Another mode was the adoption of electro-magnets, which would operate at a certain place to arrest or divert the carriage; and in either case the carriage was so constructed that its engaging features would operate automatically only in conjunction with certain features at a particular place on the line.

Signals have been also adopted, in some cases operated by an electric current, by which the operator can determine whether or not the controlling devices have operated to stop the carrier at the desired place. By electric or mechanical means it is also provided that one or more loop branches may be connected with or disconnected from the main circuit.

The "lazy tongs" principle has been introduced, by which a long lazy-tongs is shot forth through a tube or box to carry forward the carriage; and the same principle is employed in fire-escapes to throw up a cage to a great height to a window or other point, which cage is lowered gently and safely by the same means to the ground. Buffers of all kinds have been devised to effect the [Pg 161] stoppage of the carrier without injury thereto under the different degrees of force with which it is moved upon its way, to prevent rebounding, and to enable the carrier to be discharged with facility at the end of its route.

Among the early mechanical means of transporting the carriage was an endless cable moved continuously by an engine, and this adoption of cable principle in store service was co-eval with its adoption for running street cars. Also the system of switching the cars from the main line to a branch, and in different parts of a city, at the same time that all lines are receiving their motive power from the main line, corresponds to the manner of conveying cash to all parts of a building at the same time from many points.

To the great department store or monstrous building wherein, as we have said, the whole business of a town may be transacted, the assemblage and conjoint use of elevators and conveyors seem to be actually necessary.

A very useful and important line of inventions consists in means for forming connections between rotary shafts and their pulleys and mechanisms to be operated thereby, by which such mechanism can be started or stopped at once, or their motion reversed or retarded; or by which an actuating shaft may be automatically stopped. These means are known as *clutches*.

They are designed often to afford a yielding connection between the shaft and a machine which shall prevent excessive strain and wear upon starting of the shaft. They are also often provided with a spring connection, which, in the rotation of the shaft in either direction, will operate to [Pg 162] relieve the strain upon the shaft, or shafts, and its driving motor. Safety clutches are numerous, by which the machine is quickly and automatically stopped by the action of electro-magnets should a workman or other obstruction be caught in the machinery.

Electric auxiliary mechanism has also been devised to start or stop the main machine slowly, and thus prevent injury to small or delicate parts of complicated machines, like printing presses for instance. Clutches are arranged sometimes in the form of weights, resembling the action of the weights in steam governors, whereby centrifugal action is relied upon for swinging the weights outward to effect a clutching and coupling of the shaft, or other mechanism, so that two lines of shafting are coupled, or the machine started, or speeded, at a certain time during the operation. In order to avoid the great mischief arising sometimes from undue strain upon and the breaking of a shaft, a weak coupling composed of a link is sometimes employed between the shaft and the driven machine, whereby, should the force become suddenly too great, the link of weaker metal is broken, and the connection between the shaft thereby destroyed and the machine stopped.

To this class of inventions, as well as to many others, the phrase, "labour-saving", is applied as a descriptive term, and as it is a correct one in most instances, since they save the labour of many human hands, they are regarded by many as detrimental to a great extent, as they result in throwing out of employment a large number of persons.

This derangement does sometimes occur, but the curtailment of the number of labourers is but temporary after all.

The increased production of materials, resulting from cheaper and better processes, and from the reduced cost of handling them, necessitates the employment of a larger number of persons to take care of, in many ways, the greater output caused by the increased demand; the new machinery demands the labour of additional numbers in its manufacture; the increase in the size and heights of buildings involves new modes of construction and a greater number of artisans in their erection; new forms of industry springing from every practical invention which produces a new product or results in a new mode of operation, complicates the systems of labour, and creates a demand for a large number of employers and employees in new fields. Hence, it is only necessary to resort to comparative, statistics (too extensive to cite here) to show that the number of unemployed people in proportion to the populations, is less in the present age than in any previous one. In this sense, therefore, inventions should be classed as labour-*increasing* devices.

CHAPTER XI.

HYDRAULICS.

The science of Hydraulics appears to be as old as the thirst of man.

When prehistoric men had only stone implements, with which to do their work, they built aqueducts, reservoirs and deep wells which rival in extent many great similar works that are the boast of their modern descendants. Modern inventors have also produced with a flourish nice instrumentalities for raising water, agencies which are covered with the moss of untold centuries in China.

It was more than an ancient observation that came down to Pliny's time for record, that water would rise to a level with its source. The observation, however, was put into practical use in his time and long before without a knowledge of its philosophical cause.

Nothing in Egyptian sculpture portraying the arts in vogue around the cradle of the human race is older than the long lever rocking upon a cleft stick, one arm of the lever carrying a bracket and the other arm used to raise a bucket from a well. Forty centuries and more have not rendered this device obsolete.

Among other machines of the Egyptians, the Carthaginians, the Greeks, and the Romans for raising water was the *tympanum*, a drum-shape wheel divided into radial partitions, chambers, or pockets, which were open to a short depth on the periphery of the wheel, and inclined toward the axis, and which was driven by animal or manual power. These pockets scooped up the water from the stream or pond in which the wheel was located as the wheel revolved, and directed it toward the axis of the wheel, where it ran out into troughs, pipes, or gutters. The *Noria*, a chain of pots, and the screw of Archimedes were other forms of ancient pumps. The bucket pumps with some modifications are known in modern times as scoop wheels, and have been used extensively in the drainage of lands, especially by the Dutch, who at first drove them by windmills and later by steam.

The division of water-wheels into overshot, undershot and breast wheels is not a modern system.

In the *Pneumatics of Hero*, which compilation of inventions appeared in 225 B. C., seventy-nine illustrations are given and described of simple machines, between sixty and seventy of which are hydraulic devices. Among these, are siphon pumps, the force pump of Ctesibius, a "fire-pump," having two cylinders, and two pistons, valves, and levers. We have in a previous chapter referred to Hero's steam engine. The fact that a vacuum may be created in a pump into which water will rise by atmospheric pressure appears to have been availed of but not explained or understood.

The employment of the rope, pulley and windlass to raise water was known to Hero and his countrymen as well as by the Chinese before them. The chain pump and other pumps of simple form have only been improved since Hero's day in matters of detail. The screw of Archimedes has been extended in application as a carrier of water, and converted into a conveyor of many other materials.

Thus, aqueducts, reservoirs, water-wheels (used for grinding grain), simple forms of pumps, fountains, hydraulic organs, and a few other hydraulic devices, were known to ancient peoples, but their limited knowledge of the laws of pneumatics and their little mechanical skill prevented much general progress or extensive general use of such inventions.

It is said that Frontinus, a Roman Consul, and inspector of public fountains and aqueducts in the reigns of Nerva and Trajan, and who wrote a book, *De Aquaeductibus Urbis Romae Commentarius*, describing the great aqueducts of Rome, was the first and the last of the ancients to attempt a scientific investigation of the motions of liquids.

In 1593 Serviere, a Frenchman, born in Lyons, invented the rotary pump. In this the pistons consisted of two cog wheels, their leaves intermeshing, and rotated in an elliptical shaped chamber. The water entered the chamber from a lower pipe, and the action of the wheels was such as to carry the water around the chamber and force it out through an opposite upper pipe. Subsequent changes involved the rotating of the cylinder instead of the wheels and many modifications in the form of the wheels. The same principle was subsequently adopted in rotary steam engines.

In 1586, a few years before this invention of Serviere, Stevinus, the great engineer of the dikes of Holland, wrote learnedly on the *Principles of Statics and Hydrostatics*, and Whewell states that his treatment of the subject embraces most of the elementary science of hydraulics and hydrostatics of the present day. This was followed by the investigations and treatises of Galileo, his pupil Torricelli, who discovered the law of air pressure, the great French genius, Pascal, and [Pg 167] Sir Isaac Newton, in the 17th century; and Daniel Bernoulli, d'Alembert, Euler, the great German mathematician and inventor of the centrifugal pump, the Abbé Bossut, Venturi, Eylewein, and others in the 18th century.

It was not until the 17th and 18th centuries that mankind departed much from the practice of supplying their towns and cities with water from distant springs, rivers and lakes, by pipes and aqueducts, and resorted to water distribution systems from towers and elevated reservoirs. Certain cities in Germany and France were the first to do this, followed in the 18th century by England. This seems strange, as to England, as in 1582 one Peter Maurice, a Dutch engineer, erected at London, on the old arched bridge across the Thames, a series of forcing pumps worked by undershot wheels placed in the current of the river, by which he forced a supply of water to the uppermost rooms of lofty buildings adjacent to the bridge. Before the inventions of Newcomen and Watt in the latter part of the 18th century of steam pumps, the lift and force pumps were operated by wheels in currents, by horses, and sometimes by the force of currents of common sewers.

When the waters of rivers adjacent to towns and cities thus began to be pumped for drinking purposes, *strainers* and *filters* of various kinds were invented of necessity. The first ones of which there is any printed record made their appearance in 1776.

After the principles of hydraulics had thus been reviewed and discussed by the philosophers of the 17th and 18th centuries and applied, to the extent indicated, further application of them was made, and especially for the propelling of vessels. In 1718 La Hire revived and improved the [Pg 168] double-acting pump of Ctesibius, but to what extent he put it into use does not appear. However, it was the double-acting pump having two chambers and two valves, and in which the piston acted to throw the water out at each stroke.

In 1730 Dr. John Allen of England designed a vessel having a tunnel or pipe open at the stern thereof through which water was to be pumped into the air or sea—the reaction thus occasioned driving the vessel forward. He put such a vessel at work in a canal, working the pumps by manual labor, and suggested the employment of a steam engine. A vessel of this kind was patented by David Ramsey of England in 1738. Rumsey of America in 1782 also invented a similar vessel, built one 50 feet long, and ran it experimentally on the Potomac river. Dr. Franklin also planned a boat of this kind in 1785 and illustrated the same by sketches. His plan has since been tried on the Scheldt, but two turbines were substituted for his simple force pump. Further mention will be made later on of a few more elaborate inventions of this kind.

It also having been discovered that the fall of a column of water in a tube would cause a portion of it to rise higher than its source by reason of the force of momentum, a machine was devised by which successive impulses of this force were used, in combination with atmospheric pressure, to raise a portion of the water at each impulse. This was the well-known *ram*, and the first inventor of such a machine was John Whitehurst of Cheapside, England, who constructed one in 1772. From a reservoir, spring, or cistern of water, the water was discharged downward into a long pipe of small diameter, and from thence into a shorter pipe governed by a stop-cock. On the [Pg 169] opening of the stop-cock the water was given a quick momentum, and on closing the cock water was forced by the continuing momentum through another pipe into an air chamber. A valve in the latter-mentioned pipe opened into the air chamber. The air pressure served to overcome the momentum and to close the chamber and at the same time forced the water received into the air chamber up an adjacent pipe. Another impulse was obtained and another injection of water into the chamber by again opening the stop-cock, and thus by successive impulses water was forced into the chamber and pressed by the air up through the discharge pipe and thence through a building or other receptacle. But the fact that the stop-valve had to be opened and closed by hand to obtain the desired number of lifts rendered the machine ineffective.

In 1796 Montgolfier, a Frenchman and one of the inventors of the balloon, substituted for the stop-cock of the Whitehurst machine a loose impulse valve in the waste pipe, whereby the valve was raised by the rush of the water, made to set itself, check the outflow and turn the current into the air chamber. This simple alteration changed the character of the machine entirely, rendered it automatic in action and converted it into a highly successful water-raising machine. For this invention Montgolfier obtained a Gold Medal from the French Exposition of 1802. Where a head can be had from four to six feet, water can be raised to the height of 30 feet. Bodies of water greater in amount than is desired to be raised can thus be utilised, and this simple machine has come into very extensive use during the present century.

Allusion was made in the last chapter to the powerful hydraulic press of Joseph Bramah invented in 1795-1800, its practical introduction in this century and improvements therein of others. After the great improvements in the steam engine made by Watt, water, steam and air pressure joined their forces on the threshold of this century to lift and move the world, as it had never been moved before. [Pg 170]

The strong hands of hydraulics are pumps. They are divided into classes by names indicating their purpose and mode of operation, such as single, double-acting, lift or force, reciprocating or rotary, etc.

Knight, in his celebrated *Mechanical Dictionary*, enumerates 100 differently constructed pumps connected with the various arts. In a broader enumeration, under the head of *Hydraulic Engineering and Engineering Devices*, he gives a list of over 600 species. The number has since increased. About nine-tenths of these contrivances have been invented during the 19th century, although the philosophical principles of the operation of most of them had been previously discovered.

The important epochs in the invention of pumps, ending with the 18th century, were thus the single-acting pump of Ctesibius, 225 B. C., the double-acting of La Hire in 1718, the hydraulic ram of Whitehurst, 1772, and the hydraulic press of Bramah of 1795-1802.

Bramah's press illustrates how the theories of one age often lie dormant, but if true become the practices of a succeeding age. Pascal, 150 years before Bramah's time, had written this seeming hydraulic paradox: "If a vessel closed on all sides has two openings, the one a hundred times as large as the other, and if each be supplied with a piston which fits it exactly, then a man pushing the small piston will equilibrate that of 100 men pushing the piston which is 100 times as large, and will overcome the other 99." This is the law of the hydraulic press, that intensity of pressure is everywhere the same. [Pg 171]

The next important epoch was the invention of Forneyron in 1823, of the water-wheel known as the Turbine and also as the Vortex Wheel. If we will return a moment to the little steam engine of the ancient Hero of Alexandria, called the Eolipile, it will be remembered that the steam admitted into a pivoted vessel and out of it through little opposite pipes, having bent exits turned in contrary directions, caused the vessel to rotate by reason of the reaction of the steam against the pipes. In what is called Barker's mill, brought out in the 18th century, substantially the same form of engine is seen with water substituted for the steam.

A turbine is a wheel usually placed horizontally to the water. The wheel is provided with curved internal buckets against which the water is led by outer curved passages, the guides and the buckets both curved in such manner that the water shall enter the wheel as nearly as possible without shock, and leave it with the least possible velocity, thereby utilising the greatest possible amount of energy.

In the chapter on Electrical inventions reference is made to the mighty power of Niagara used to actuate a great number of electrical and other machines of vast power. This utilisation had long been the dream of engineers. Sir William Siemens had said that the power of all the coal raised in the world would barely represent the power of Niagara. The dream has been realised, and the turbine is the apparatus through which the power of the harnessed giant is transmitted. A canal is dug from the river a mile above the falls. It conducts water to a power house near the falls. At the power house the canal is furnished with a gate, and with cribs to keep back the obstructions, such as sticks. At the gate is placed a vertical iron tube called a penstock, 7½ feet in diameter and 160 feet deep. At the bottom of the penstock is placed a turbine wheel fixed on a shaft, and to which shaft is connected an electric generator or other power machine. On opening the gate a mass of water 7½ feet in diameter falls upon the turbine wheel 160 feet below. The water rushing through the wheel turns it and its shaft many hundred revolutions a minute. All the machinery is of enormous power and dimensions. One electric generator there is 11 feet 7 inches in diameter and spins around at the rate of 250 revolutions a minute. Means are provided by which the speed of each wheel is regulated automatically. Each turbine in a penstock represents the power of 5,000 horses, and there are now ten or more employed. [Pg 172]

After the water has done its work on the wheels it falls into a tunnel and is carried back to the river below the falls. Not only are the manufactures of various kinds of a large town at the falls thus supplied with power, but electric power is transmitted to distant towns and cities.

Turbine pumps of the Forneyron type have an outward flow; but another form, invented also by a Frenchman, Jonval, has a downward discharge, and others are oblique, double, combined turbine, rotary, and centrifugal, embodying similar principles. The term *rotary*, broadly speaking, includes turbine and centrifugal pumps. The centrifugal pump, invented by Euler in 1754, was taken up in the nineteenth century and greatly improved. [Pg 173]

In the centrifugal pump of the ordinary form the water is received at the centre of the wheel and diverted and carried out in an upward direction, but in most of its modern forms derived from the turbine, the principle is adopted of so shaping the vanes that the water, striking them in the curved direction, shall not have its line of curvature suddenly changed.

Among modern inventions of this class of pumps was the "Massachusetts" of 1818 and McCarty's, in 1830, of America, that of some contemporary French engineers, and subsequently in France the Appold system, which latter was brought into prominent notice at the London Exposition of 1851. Improvements of great value were also made by Prof. James Thompson of England.

Centrifugal pumps have been used with great success in lifting large bodies of water to a moderate height, and for draining marshes and other low lands.

Holland, Germany, France, England and America have, through some of their ablest hydraulic engineers and inventors, produced most remarkable results in these various forms of pumps. We have noted what has been done at Niagara with the turbines; and the drainage of the marshes of Italy, the lowlands of Holland, the fens of England and the swamps of Florida bear evidence of the value of kindred inventions.

That modern form of pump known as the *injector*, has many uses in the arts and manufactures. One of its most useful functions is to automatically supply steam boilers with water, and regulate the supply. It was the invention of Giffard, patented in England in 1858, and consists of a steam [Pg 174] pipe leading from the boiler and having its nozzle projecting into an annular space which communicates with a feed pipe from a water supply. A jet of steam is discharged with force into this space, producing a vacuum, into which the water from the feed pipe rushes, and the condensed steam and water are driven by the momentum of the jet into a pipe leading into the boiler. This exceedingly useful apparatus has been improved and universally used wherever steam boilers are found. This idea of injecting a stream of steam or water to create or increase the flow of another stream has been applied in *intensifiers*, to increase the pressure of water in hydraulic mains, pipes, and machines, by additional pressure energy. Thus the water from an ordinary main may be given such an increased pressure that a jet from a hydrant may be carried to the tops of high houses.

In connection with pumping it may be said that a great deal has been discovered and invented during this century concerning the force and utilisation of jets of water and the force of water flowing through orifices. In the art of mining, a new system called *hydraulicising* has been introduced, by which jets of water at high pressure have been directed against banks and hills, which have crumbled, been washed away, and made to reveal any precious ore they have concealed.

To assist this operation *flexible nozzles* have been invented which permit the stream to be easily turned in any desired direction.

Returning to the idea of raising weights by hydraulic pressure, mention must be made of the recent invention of the *hydraulic jack*, a portable machine for raising loads, and which has [Pg 175] displaced the older and less efficient screw jack. As an example of the practical utility of the hydraulic jack, about a half century ago it required the aid of 480 men working at capstans to raise the Luxor Obelisk in Paris, whilst within 30 years thereafter Cleopatra's Needle, a heavier monument, was raised to its present position on the Thames embankment by four men each working one hydraulic jack.

By the high pressures, or stresses given by the hydraulic press it was learned that cold metals have plasticity and can be moulded or stretched like other plastic bodies. Thus in one modification a machine is had for making lead pipes:—A "container" is filled with molten lead and then allowed to cool. The container is then forced by the pump against an elongated die of the size of the pipe required. A pressure from one to two tons per square inch is exerted, the lead is forced up through the die, and the pipe comes out completed. Wrought iron and cold steel can be forced like wax into different forms, and a rod of steel may be drawn through a die to form a piano wire.

By another modification of the hydraulic press pipes and cables are covered with a coating of lead to prevent deterioration from rust and other causes.

Not only are cotton and other bulky materials pressed into small compass by hydraulic machines, but very valuable oils are pressed from cotton seed and from other materials—the seed being first softened, then made into cakes, and the cakes pressed.

If it is desired to line tunnels or other channels with a metal lining, shield or casing, large segments of iron to compose the casing are put in position, and as fast as the tunnel is excavated the casing is pressed forward, and when the digging is done the cast-iron tunnel is complete. [Pg 176]

If the iron hoops on great casks are to be tightened the cask is set on the plate of a hydraulic press, the hoops connected to a series of steel arms projecting from an overhanging support, and the cask is pressed upward until the proper degree of tightness is secured.

In the application of hydraulic power to machine tools great advances have been made. It has become a system, in which Tweddle of England was a pioneer. The great force of water pressure combined with comparatively slow motion constitutes the basis of the system. Sir William Fairbairn had done with steam what Tweddle and others accomplished with water. Thus the enormous force of men and the fearful clatter formerly displayed in these huge works where the riveting of boilers was carried on can now be dispensed with, and in place of the noisy hammer with its ceaseless blows has come the steam or the hydraulic riveting machine, which noiselessly drives the rivet through any thickness of metal, clinches the same, and smooths the jointed plate. The forging and the rolling of the plates are performed by the same means.

William George Armstrong of England, afterward Sir William, first a lawyer, but with the strongest bearing toward mechanical subjects, performed a great work in the advancement of hydraulic engineering. It is claimed that he did for hydraulic machinery, in the storage and transmission of power thereby, what Watt did for the steam engine and Bessemer did for steel. In 1838 he produced his first invention, an important improvement in the hydraulic engine. In 1840, in a letter to the *Mechanics' Magazine*, he calls attention to the advantages of water as a *[Pg 177]* mechanical agent and a reservoir of power, and showed how water pumped to an elevated reservoir by a steam engine might have the potential energy thus stored utilised in many advantageous ways. How, for instance, a small engine pumping continuously could thus supply many large engines working intermittently. In illustration of this idea he invented a crane, which was erected on Newcastle quay in 1846; another was constructed on the Albert dock at Liverpool, and others at other places. These cranes, adapted for the lifting and carrying of enormous loads, were worked by hydraulic pressure obtained from elevated tanks or reservoirs, as above indicated. But as a substitute for such tanks or reservoirs he invented the *Accumulator*. This consists of a large cast-iron cylinder fitted with a plunger, which is made to work water-tight therein by means of suitable packing. To this plunger is attached a weighted case filled with one or many tons of metal or other coarse material. Water is pumped into the cylinder until the plunger is raised to its full height within the cylinder, when the supply of water is cut off by the automatic operation of a valve. When the cranes or other apparatus to be worked thereby are in operation, water is passed from the cylinder through a small pipe which actuates the crane through hydraulic pressure. This pressure of course depends upon the weight of the plunger. Thus a pressure of from 500 to 1,000 pounds per square inch may be obtained. The descending plunger maintains a constant pressure upon the water, and the water is only pumped into the cylinder when it is required to be filled. With sensitive accumulators of this character hydraulic [Pg 178] machinery is much used on board ships for steering them, and for loading, discharging and storing cargoes.

Water Pressure Engines or *Water Motors* of a great variety as to useful details have been invented to take advantage of a natural head of water from falls wherever it exists, or from artificial accumulators or from street mains. They resemble steam engines, in that the water under pressure drives a piston in a cylinder somewhat in the manner of steam. The underlying principle of this class of machinery is the admission of water under pressure to a cylinder which moves the piston and is allowed to escape on the completion of the stroke. They are divided into two great classes, single and double acting engines, accordingly as the water is admitted to one side of the piston only, or to both sides alternately. Both kinds are provided with a regulator in the form of a turn-cock, weight, or spring valve to regulate and control the flow of water and to make it continuous. They are used for furnishing a limited amount of power for working small printing presses, dental engines, organs, sewing machines, and for many other purposes where a light motor is desired.

The nineteenth century has seen a revolution in *baths* and accompanying *closets*. However useful, luxurious, and magnificent may have been the patrician baths of ancient Rome, that system, which modern investigators have found to be so complete to a certain extent, was not nor ever has been in the possession of the poor. It is within the memory of many now living everywhere how wretched was the sanitary accommodations in every populous place a generation or two ago. Now, with the modern water distribution systems and cheap bathing [Pg 179] apparatuses which can be brought to the homes of all, with plunger, valved siphon and valved and washout closets, air valve, liquid seal, pipe inlet, and valve seal traps, and with the flushing and other hydraulic cleaning systems for drains and cesspools, little excuse can be had for want of proper sanitary regulations in any intelligent community. The result of the adoption of these modern improvements in this direction on the health of the people has been to banish plagues, curtail epidemics, and prolong for years the average duration of human life.

How multiplied are the uses to which water is put, and how completely it is being subjected to the use of man!

Rivers and pipes have their metres, so that now the velocity and volume of rivers and streams are measured and controlled, and floods prevented. The supplies for cities and for families are estimated, measured and recorded as easily as are the supplies of illuminating gas, or the flow of food from elevators.

Among the minor, but very useful inventions, are *water scoops* for picking up water for a train while in motion, consisting of a curved open pipe on a car, the mouth of which strikes a current of water in an open trough between the tracks and picks up and deposits in a minute a car load of water for the engine. *Nozzles* to emit jets of great velocity, and ball nozzles terminating in a cup in which a ball is loosely seated, and which has the effect, as it is lifted by the jet, to spread it into an umbrella-shaped spray, are of great value at fires in quenching flame and smoke.

Next to pure air to breathe we need pure water to drink, and modern discoveries and inventions [Pg 180] have done and are doing much to help us to both. Pasteur and others have discovered and explained the germ theory of disease and to what extent it is due to impure water. Inventors have produced *filters*, and there is a large class of that character which render the water pure as it enters the dwelling, and fit for all domestic purposes. A specimen of the latter class is one which is attached to the main service pipe as it enters from the street. The water is first led into a cylinder stored with coarse filtering material which clears the water of mud, sediment and coarser impurities, and then is conducted into a second cylinder provided with a mass of fine grained or powdered charcoal, or some other material which has the quality of not only arresting all remaining injurious ingredients, but destroys organisms, neutralises ammonia and other deleterious matter. From thence the water is returned to the service pipe and distributed through the house. The filter may be thoroughly cleansed by reversing the movement of the water, and carrying it off through a drain pipe until it runs clear and sweet, whereupon the water is turned in its normal course through the filter and house.

In a very recent report of General J. M. Wilson, Chief of Engineers, U.S.A., the subject of filtration of water, and especially of public water supplies in England, the United States, and on the Continent, is very thoroughly treated, and the conclusion arrived at there is that the system termed "the American," or mechanical system, is the most successful one.

This consists, first, in leading the water into one or more reservoirs, then coagulating suspended matter in the water by the use of the sulphate of alumina, and then allowing the water to flow [Pg 181] through a body of coarse sand, by which the coagulated aluminated matter is caught and held in the interstices of the sand, and the bacteria arrested. All objectionable matter is thus arrested by the surface portion of the sand body, which portion is from time to time scraped off, and the whole sand mass occasionally washed out by upward currents of water forced through the same.

By this system great rapidity of filtration is obtained, the rate being 120,000,000 gallons a day per acre.

The English system consists more in the use of extended and successive reservoirs or beds of sand alone, or aided by the use of the sulphate. This also is extensively used in many large cities.

[Pg 182]

CHAPTER XII.

PNEUMATICS AND PNEUMATIC MACHINES.

"The march of the human mind is slow," exclaimed Burke in his great speech on "Conciliation with the Colonies." It was at the beginning of the last quarter of the 18th century that he was speaking, and he was referring to the slow discovery of the eternal laws of Providence as applied in the field of political administration to distant colonies. The same could then have been said of the march of the human mind in the realms of Nature. How slow had been the apprehension of the forces of that kind but silent Mother whose strong arms are ever ready to lift and carry the burdens of men whenever her aid is diligently sought! The voice of Burke was, however, hardly silent when the human mind suddenly awoke, and its march in the realms of government and of natural science since then cannot be regarded as slow.

More than fifteen centuries before Burke spoke, not only had Greece discovered the principles of political freedom for its citizens and its colonies, but the power of steam had been discovered, and experimental work been done with it.

Yet when the famous orator made his speech the Grecian experiment was a toy of Kings, and the steam engine had just developed from this toy into a mighty engine in the hands of Watt. The age of mechanical inventions had just commenced with the production of machines for spinning and [Pg 183] weaving. And yet, in view of the rise of learning, and the appearance from time to time of mighty intellects in the highest walks of science, the growth of the mind in the line of useful machinery had indeed been strangely slow. "Learning" had revived in Italy in the 12th and 13th centuries and spread westward in the 14th. In the 15th, gunpowder and printing had been discovered, and Scaliger, the famous scholar of Italy, and Erasmus, the celebrated Dutch philosopher, were the leading restorers of ancient literature. Science then also revived, and Copernicus, the Pole, gave us the true theory of the solar system. The 16th century produced the great mathematicians and astronomers Tycho Brahe, the Dane, Cardan and Galileo, the illustrious Italians, and Kepler, the German astronomer, whose discovery of the laws of planetary motion supplemented the works of Copernicus and Galileo and illuminated the early years of the 17th century.

In the 17th century appeared Torricelli, the inventor of the barometer; Guericke, the German, inventor of the air pump; Fahrenheit, the inventor of the mercurial thermometer bearing his name; Leibnitz, eminent in every department of science and philosophy; Huygens, the great Dutch astronomer and philosopher; Pascal of France and Sir Isaac Newton of England, the worthy successors of Kepler, Galileo and Copernicus; and yet, with the exception of philosophical discoveries and a few experiments, the field of invention in the way of motor engines still remained practically closed. But slight as had been the discoveries and experiments referred to, they were the mine from which the inventions of subsequent times were quarried. [Pg 184]

One of the earliest, if not the first of pneumatic machines, was the bellows. Its invention followed the discovery of fire and of metals. The bladders of animals suggested it, and their skins were substituted for the bladders.

The Egyptians have left a record of its use, thirty-four centuries ago, and its use has been continuous ever since.

Mention has been made of the cannon. It was probably the earliest attempt to obtain motive power from heat. The ball was driven out of an iron cylinder by the inflammatory power of powder. Let a piston be substituted for the cannon ball, as was suggested by Huygens in 1680 and by Papin in 1690, and the charge of powder so reduced that when it is exploded the piston will not be thrown entirely out of the cylinder, another small explosive charge introduced on the other side of the piston to force it back, or let the cylinder be vertical and the piston be driven back by gravity, means provided to permit the escape of the gas after it has done its work, and means to keep the cylinder cool, and we have the prototype of the modern heat engines. The gunpowder experiments of Huygens and Papin were not successful, but they were the progenitors of similar inventions made two centuries thereafter.

Jan Baptista van Helmont, a Flemish physician (1577-1644), was the first to apply the term, *gas* to the elastic fluids which resemble air in physical properties. Robert Boyle, the celebrated Irish scholar and scientist, and improver of the air pump, and Edwin Mariotte, the French physicist who was first to show that a feather and a coin will drop the same distance at the same time in a reservoir exhausted of air, were the independent discoverers of Boyle's and Mariotte's law of gases (1650-1676). This was that at any given temperature of a gas which is at rest its volume [Pg 185] varies inversely with the pressure put upon it. It follows from this law that the density and tension, and therefore the expansive force of a gas, are proportional to the compressing force to which it is subjected. It is said that Abbé Hauteville, the son of a baker of Orleans, about 1678 proposed to raise water by a powder motor; and that in 1682 he described a machine based on the principle of the circulation of the blood, produced by the alternate expansion and contraction of the heart.

The production of heat by concentrating the rays of the sun, and for burning objects had been known from the time of Archimedes, and been repeated from time to time.

Thus stood this art at the close of the 17th century, and thus it remained until near the close of the 18th.

In England Murdock, the Cornish Steam Engineer, was the first to make and use coal gas for illuminating purposes, which he did in 1792 and 1798. Its utilisation for other practical purposes was then suggested.

Gas engines as motive powers were first described in the English patent to John Barber, in 1791, and then in one issued to Robert Street in 1794. Barber proposed to introduce a stream of carbonated hydrogen gas through one port, and a quantity of air at another, and explode them against the piston. Street proposed to drive up the piston by the expansive force of a heated gas, and anticipated many modern ideas. Phillipe Lebon, a French engineer, in 1799 and in 1801 anticipated in a theoretical way many ideas since successfully reduced to practice. He proposed to use coal gas to drive a piston, which in turn should move the shaft that worked the pumps [Pg 186] which forced in the gas and air, and thus make the machine double-acting; to introduce a charge of inflammable gas mixed with sufficient air to ignite it; to compress the air and gas before they entered the motor cylinder; to introduce the charge alternately on each side of the piston; and he also suggested the use of the electric spark to fire the mixture. But Lebon was assassinated and did not live to work out his ideas.

At the very beginning of the 19th century John Dalton in England, 1801-1807, and Gay-Lussac in France began their investigations of gases and vapours. Dalton was not only the author of the atomic theory, but the discoverer of the leading ideas in the "Constitution of Mixed Gases." These features were the diffusion of gases, the action of gases on each other in vacuum—the influence of different temperatures upon them, their chemical constituents and their relative specific gravity.

Gay-Lussac, continuing his investigations as to expansion of air and gases under increased temperatures, in 1807-10, established the law that when free from moisture they all dilate uniformly and to equal amounts for all equal increments of temperature. He also showed that the gases combine, as to volume, in simple proportions, and that several of them on being compounded contracted always in such simple proportions as one-half, one-third, or one-quarter, of their joint bulk. By these laws all forms of engines which were made to work through the agency of heat are classed as heat engines—so that under this head are included steam engines, air engines, gas engines, vapour engines and solar engines. The tie that binds these engines into [Pg 187] one great family is temperature. It is the heat that does the work. Whether it is a cannon, the power of which is manifested in a flash, or the slower moving steam engine, whose throbbing heart beats not until water is turned to steam, or the sun, the parent of them all, whose rays are grasped and used direct, the question in all cases is, what is the amount of heat produced and how can it be controlled?

It, then, can make no difference what the agent is that is employed, whether air, or gas, or steam, or the sun, or gunpowder explosion, but what is the temperature to be attained in the cylinder or vessel in which they work. Power is the measure of work done in a given time. Horse power is the unit of such measurement, and it consists of the amount of power that is required to raise one pound through a vertical distance of one foot. This power is pressure and the pressure is heat. The unit of heat is the amount of heat required to raise the temperature of a pound of distilled water one degree—from 39 degrees to 40 degrees F. Its amount or measurement is determined in any instance by a dynamometer.

These were the discoveries with which Philosophy opened the nineteenth century so brilliantly in the field of Pneumatics.

Before that time it seemed impossible that explosive gases would ever be harnessed as steam had been and made to do continual successful work in a cylinder and behind a piston. As yet means were to be found to make the engine efficient as a double-acting one—to start the untamed steed at the proper moment and to stop him at the moment he had done his work.

As Newcomen had been the first in the previous century to apply the steam engine to practical work—pumping water from mines—so Samuel Brown of England was the first in this century to invent and use a gas engine upon the water. [Pg 188]

Brown took out patents in 1823 and 1826. He proposed to use gunpowder gas as the motive power. His engine was also described in the *Mechanics' Magazine* published in London at that time. In the making of his engine he followed the idea of a steam engine, but used the flame of an ignited gas jet to create a vacuum within the cylinder instead of steam. He fitted up an experimental boat with such an engine, and means upon the boat to generate the gas. The boat was then operated upon the Thames. He also succeeded experimentally in adapting his engine to a road carriage. But Brown's machines were cumbrous, complicated, and difficult to work, and therefore did not come into public use.

About this time (1823), Davy and Faraday reawakened interest in gas engines by their discovery that a number of gases could be reduced to a liquid state, some by great pressure, and others by cold, and that upon the release of the pressure the gases would return to their original volume. In the condensation heat was developed, and in re-expansion it was rendered latent.

Then Wright in 1833 obtained a patent in which he expounded and illustrated the principles of expansion and compression of gas and air, performed in separate cylinders, the production of a vacuum by the explosion and the use of a water jacket around the cylinder for cooling it.

For William Burdett, in 1838, is claimed the honour of having been the first to invent the means of compressing the gas and air previous to the explosion, substantially the same as adopted in gas engines of the present day. [Pg 189]

The defects found in gas engines thus far were want of proper preliminary compression, then in complete expansion, and finally loss of heat through the walls.

Some years later, Lenoir, a Frenchman, invented a gas engine of a successful type, of which three hundred in 1862 were in use in France. It showed what could be accomplished by an engine in which the fuel was introduced and fired directly in the piston cylinder. Its essential features were a cylinder into which a mixture of gas and air was admitted at atmospheric pressure, which was maintained until the piston made half its stroke, when the gas was exploded by an electric spark. A wheel of great weight was hung upon a shaft which was connected to the piston, and which weight absorbed the force suddenly developed by the explosion, and so moderated the speed. Another object of the use of the heavy wheel was to carry the machine over the one-half of the period in which the driving power was absent.

Hugon, another eminent French engineer, invented and constructed a gas engine on the same principle as Lenair's.

About this time (1850-60) M. Beau de Rohes, a French engineer, thoroughly investigated the reasons of the uneconomical working of gas motors, and found that it was due to want of sufficient compression of the gas and air previous to explosion, incomplete expansion and loss of heat through the walls of the cylinder, and he was the first to formulate a "cycle" of operations necessary to be followed in order to render a gas engine efficient. They related to the size and dimensions of the cylinder; the maximum speed of the piston; the greatest possible expansion, and the highest pressure obtainable at the beginning of the act of expansion. The study and application of these conditions created great advancements in gas engines. [Pg 190]

With the discovery and development of the oil wells in the United States about 1860 a new fuel was found in the crude petroleum, as well as a source of light. The application of petroleum to engines, either to produce furnace heat, or as introduced directly into the piston cylinder mixed with inflammable gas to produce flame heat and expansion, has given a wonderful impetus to the utilisation of gas engines.

G. H. Brayton of the United States in 1873 invented a very efficient engine in which the vapour of petroleum mixed with air constituted the fuel. Adolf Spiel of Berlin has also recently invented a petroleum engine.

Principal among those to whom the world is indebted for the revolution in the construction of gas engines and its establishment as a successful rival to the steam engine is Nicolaus A. Otto of Deutz on the Rhine.

In the Lenair and Hugon system the expansive force of the exploded gas was used directly upon the piston, and through this upon the other moving parts. A great noise was produced by these constant explosions. In the Otto system the explosion is used indirectly and only to produce a vacuum below the piston, when atmospheric pressure is used to give the return stroke of the piston and produce the effective work. The Otto engine is noiseless. This is accomplished by his method of mixing and admitting the gases. He employs two different mixtures, one a "feebly explosive mixture," and the other "a strongly explosive mixture," used to operate on the piston and thus prolong the explosions.

[Pg 191]

The mode of operation of one of Otto's most successful engines is as follows: The large fly wheel is started by hand or other means, and as the piston moves forward it draws into the cylinder a light charge of mixed coal gas and air, and the gas inlet is then cut off. As the piston returns it compresses this mixture. At the moment the down stroke is completed the compressed mixture is ignited, and, expanding, drives the piston before it. In the second return stroke the burnt gases are expelled from the cylinder and the whole made ready to start afresh. Work is actually done in the piston only during one-quarter of the time it is in motion. The fly-wheel carries forward the work at the outset and the gearing the rest of the time.

Otto was associated with Langen in producing his first machine, and its introduction at the Centennial Exposition at Philadelphia in 1876 excited great attention. Otto and E. W. and W. J. Crossley jointly, and then Otto singly, subsequently patented notable improvements.

Simon Bischof and Clark, Hurd and Clayton in England; Daimler of Deutz on the Rhine, Riker and Wiegand of the United States, and others, have made improvements in the Otto system.

Ammoniacal gas engines have been successfully invented. *Aqua ammonia* is placed in a generator in which it is heated. The heat separates the ammonia gas from the water, and the gas is then used to operate a suitable engine. The exhaust gas is cooled, passed into the previously weakened solution, reabsorbed and returned to the generator. In 1890 Charles Tellier of France patented an ammoniacal engine, also means for utilising solar heat and exhaust steam for the
same purpose; and in the same year De Susini, also of France, patented an engine operated by [Pg 192]
the vapour of ether; A. Nobel, another Frenchman, in 1894, patented a machine for propelling torpedoes and other explosive missiles, and for controlling the course of balloons, the motive power of which is a gas developed in a closed reservoir by the chemical reaction of metallic sodium or potassium in a solution of ammonia. These vapour engines are used for vapour launches, bicycles and automobiles.

In 1851 the ideas of Huygens and Papin of two hundred years before were revived by W. M. Storm, who in that year took out a gunpowder engine patent in the United States, in which the air was compressed by the explosions of small charges of gunpowder. About fifteen other patents have been taken out in America since that time for such engines. In some the engines are fed by cartridges which are exploded by pulling a trigger.

As to gas and vapor engines generally, it may now be said, in comparison with steam, that although the steam engine is now regarded as almost perfect in operation, and that it can be started and stopped and otherwise controlled quietly, smoothly, instantaneously, and in the most uniform and satisfactory manner, yet there is the comparatively long delay in generating the steam in the boiler, and the loss of heat and power as it is conducted in pipes to the working cylinder, resulting in the utilisation of only ten per cent of the actual power generated, whereas gas and vapour engines utilise twenty-five per cent of the power generated, and the flame and explosions are now as easily and noiselessly controlled as the flow of oil or water. The world is coming to agree with Prof. Fleeming Jenkins that "Gas engines will ultimately supplant the
steam." [Pg 193]

The smoke and cinder nuisance with them has been solved.

The sister invention of the gas engine is the air engine. There can be no doubt about the success of this busy body, as it is now a swift and successful motor in a thousand different fields. Machines in which air, either hot or cold, is used in place of steam as the moving power to drive a piston, or to be driven by a piston, are known generally as air, caloric, or hot-air engines, air compressors, or compressed air engines, and are also classed as pneumatic machines, air brakes, or pumps. They are now specifically known by the name of the purpose to which they are applied, as air ship, ventilator, air brake, fan blower, air pistol, air spring, etc.

The attention of inventors was directed towards compressed and heated air as a motor as soon as steam became a known and efficient servant; but the most important and the only successful air machine existing prior to this century was the air pump, invented by Guericke in 1650, and subsequently perfected by Robert Boyle and others. The original pump and the Magdeburg hemispheres are still preserved.

It is recorded that Amontons of France, in 1699, had an atmospheric fire wheel or air engine in which a heated column of air was made to drive a wheel.

It has already been noted what Papin (1680-1690) proposed and did in steam. His last published work was a Latin essay upon a new system for raising water by the action of fire, published in 1707.

The action of confined and compressed steam and gases, and air, is so nearly the same in the
machines in which they constitute the motive power that the history, development, construction, [Pg 194]
and operation of the machines of one class are closely interwoven with those of the others.

Taking advantage of what had been taught them by Watt and others as to steam and steam engines, and of the principles and laws of gases as expounded by Boyle, Mariotte, Dalton, and Gay-Lussac, that many of the gases, such as air, preserve a permanent expansive gaseous form under all degrees of temperature and compression to which they had as yet been subjected, that when compressed and released they will expand, and exert a pressure in the contrary direction until the gas and outside atmospheric pressure are in equilibrium, that this compressed gas pressure is equal, and transmitted equally in all directions, and that the weight of a column of air resting on every horizontal square inch at the sea level is very nearly 14.6 pounds, the inventors of the nineteenth century were enabled by this supreme illumination to enter with confidence into that work of mechanical contrivances which has rendered the age so marvellous.

It was natural that in the first development of mechanical appliances they should be devoted to those pursuits in which men had the greatest practical interest. Thus as to steam it was first applied to the raising of water from mines and then to road vehicles. And so in 1800 Thos. Parkinson of England invented and patented an "hydrostatic engine or machine for the purpose of drawing beer or any other liquid out of a cellar or vault in a public house, which is likewise intended to be applied for raising water out of mines, ships or wells. By the use of a sort of an air pump he maintained an air pressure on the beer in an air-tight cask situated in the cellar, which [Pg 195] was connected with pipes having air-tight valves, with the upper floor. The liquid was forced from the cellar by the air pressure, and when turned off, the air pressure was resumed in the cask, which "preserved the beer from being thrown into a state of flatness." Substantially the same device in principle has been reinvented and incorporated in patents numerous times since.

In the innumerable applications of the pneumatic machines and air tools of the century, especially of air-compressing devices, to the daily uses of life, we may, by turning first to our home, find its inner and outer walls painted by a pneumatic paint-spraying machine, for such have been made that will coat forty-six thousand square feet of surface in six hours; and it is said that paint can be thus applied not only more quickly, but more thoroughly and durably than by the old process. The periodical and fascinating practice of house cleaning is now greatly facilitated by an air brush having a pipe with a thin wide end in which are numerous perforations, and through which the air is forced by a little pump, and with which apparatus a far more efficient cleaning effect upon carpets, mattresses, curtains, clothes, and furniture can be obtained than by the time-honoured broom and duster.

Is the home uncomfortable by reason of heat and summer insects? A compressor having tanks or cisterns in the cellar filled with cool or cold air may be set to work to reduce the temperature of the house and fan the inmates with a refreshing breeze.

Air engines have been invented which can be used to either heat or cool the air, or do one or the other automatically. The heating when wanted is by fuel in a furnace forced up by a working cylinder, and the cooling by the circulation of water around small, thin copper tubes through [Pg 196] which the air passes to the cylinder.

Do the chimes of the distant church bells lead one to the house of worship? The worshipper goes with the comforting assurance that the chimes which send forth such sweet harmonies are operated not by toiling, sweating men at ropes, but by a musician who plays as upon an organ, and works the keys, valves and stops by the aid of compressed air, and sometimes by the additional help of electricity.

Mention has already been made of office and other elevators, in which compressed air is an important factor in operating the same and for preventing accidents.

If a waterfall is convenient, air is compressed by the body of descending water, and used to ventilate tunnels, and deep shafts and mines, or drive the drills or other tools.

The pneumatic mail tube despatch system, by which letters, parcels, etc., are sent from place to place by the force of atmospheric pressure in an air-exhausted tube, is a decidedly modern invention, unknown in use even by those who are still children. Tubes as large as eight inches in diameter are now in use in which cartridge boxes are placed, each holding six hundred or more letters, and when the air is exhausted the cartridge is forced through the tubes to the distance sometimes of three miles and more in a few minutes.

In travelling by rail the train is now guided in starting or in stopping on to the right track, which may be one out of forty or fifty, by a pneumatic switch, the switches for the whole number of tracks being under the control of a single operator. The fast-moving train is stopped by an air [Pg 197] brake, and the locomotive bell is rung by touching an air cylinder. The "baggage smashing," a custom more honoured in the breach than in the observance, is prevented by a pneumatic baggage arrangement consisting of an air-containing cylinder, and an arm on which to place the baggage, and which arm is then quickly raised by the cylinder piston and is automatically swung around by a cam action carrying the baggage out of or into the car.

Bridge building has been so facilitated by the use of pneumatic machines for raising heavy loads of stone and iron, and for riveting and hammering, and other air tools, aided by the development in the art of quick transportation, that a firm of bridge builders in America can build a splendid bridge in Africa within a hundred days after the contract has been entered upon.

Ship building is hastened by these same air drilling and riveting machines.

The propelling of cars, road vehicles, boats, balloons, and even ships, by explosive gases and compressed air is an extensive art in itself, yet still in its infancy, and will be more fully described in the chapter on carrying machines.

The realm of Art has received a notable advancement by the use of a little blow-pipe or atomiser by which the pigments forming the background on beautiful vases are blown with just that graduated force desired by the operator to produce the most exquisitely smooth and blended effects, while the varying colours are made to melt imperceptibly into one another as delicately as the mingled shade and coloured sunlight fall on a forest brook.

But to enumerate the industrial arts to which air and other pneumatic machines have been adapted would be to catalogue them all. Mention is made of others in chapters in which those special arts are treated. [Pg 198]

[Pg 199]

CHAPTER XIII.

ART OF HEATING, VENTILATING, COOKING, REFRIGERATION AND LIGHTING.

That Prometheus stole fire from heaven to give it to man is perhaps as authentic an account of the invention of fire as has been given. It is also reported that he brought it to earth in a hollow tube. If a small stick or twig had then been dipped into the divine fire the suggestion of the modern match may be supposed to have been made.

But men went on to reproduce the fire in the old way by rubbing pieces of wood together, or using the flint, the steel and the tinder until 1680, when Godfrey Hanckwitz of London, learning of the recent discovery of phosphorus and its nature, and inspired by the Promethean idea, wrapped the phosphorus in folds of brown paper, rubbed it until it took fire, and then ignited thereat one end of a stick which he had dipped in sulphur; and this is commonly known as the first invented match. There followed the production of a somewhat different form of match, sticks first dipped in sulphur, and then in a composition of chlorate potash, sulphur, colophony, gum of sugar, and cinnabar for coloring. These were arranged in boxes, and were accompanied by a vial containing sulphuric acid, into which the match was dipped and thereby instantly ignited. These were called chemical matches and were sold at first for the high price of fifteen shillings a box. [Pg 200]

They were too costly for common use, and so our fathers went on to the nineteenth century using the flint, the steel and the tinder, and depending on the coal kept alive upon their own or their neighbour's hearth.

Prometheus, however, did reappear about 1820-25, when a match bearing the name "Promethean" was invented. It consisted of a roll of paper treated with sugar and chlorate of potash and a small cell containing sulphuric acid. This cell was broken by a pair of pliers and the acid ignited the composition by contact therewith.

It was not until 1827-29 that John Walker, chemist, at Stockton-upon-Tees, improved upon the idea of Prometheus and Hanckwitz of giving fire to men in a hollow tube. He used folded sanded paper—it may have been a tube—and through this he drew a stick coated with chlorate of potash and phosphorus. This successful match was named "Lucifer," whose other name was Phosphor, the Morning Star, and the King of the Western Land. Faraday, to whom also was given Promethean inspiration, procured some of Walker's matches and brought them to public notice.

In many respects the mode of their manufacture has been improved, but in principle of composition and ignition they remain the same as Walker's to-day. In 1845, Schrotter of Vienna discovered amorphous or allotropic phosphorus, which rendered the manufacture of matches less dangerous to health and property. Tons of chemicals and hundreds of pine trees are used yearly in the making of matches, and many hundreds of millions of them are daily consumed.

But this vast number of matches could not be supplied had it not been for the invention of machines for making and packing them. [Pg 201] Thus in 1842 Reuben Partridge of America patented a machine for making splints. Others for making splints and the matches separately, quickly followed. Together with these came match dipping and match box machines. The splint machines were for slitting a block of wood of the proper height downward nearly the whole way into match splints, leaving their butts in the solid wood. These were square and known as block matches. Other mechanisms cut and divided the block into strips, which were then dipped at one end, dried and tied in bundles. By other means, a swing blade, for instance, the matches were all severed from the block. Matches are made round by one machine by pressing the block against a plate having circular perforations, and the interspaces are beveled so as to form cutting edges.

Poririer, a Frenchman, invented a machine for making match boxes of pasteboard. Suitable sized rectangular pieces of pasteboard rounded at the angles for making the body of the box are first cut, then these pieces are introduced into the machine, where by the single blow of a plunger they are forced into a matrix or die and pressed, and receive by this single motion their complete and final shape. The lid is made in the same way.

By one modern invention matches after they are cut are fed into a machine at the rate of one hundred thousand an hour, on to a horizontal table, each match separated from the other by a thin partition. They are thus laid in rows, one row over another, and while being laid, the matches are pushed out a little way beyond the edge of the table, a distance far enough to expose their ends and to permit them to be dipped. When a number of these rows are completed they are [Pg 202] clamped together in a bundle and then dipped—first, into a vessel of hot sulphur, and then into one of phosphorus, or other equivalent ingredients may be used or added. After the dipping they are subjected to a drying process and then boxed. Processes differ, but all are performed by machinery.

In many factories where phosphorus is used without great care workmen have been greatly affected thereby. The fumes of the phosphorus attack the teeth, especially when decayed, and penetrate to the jaw, causing its gradual destruction, but this has been avoided by proper precautions.

The greatly-increased facility of kindling a fire by matches gave an impetus to the invention of *cooking and heating stoves*. Of course stoves, generically speaking, are not a production of the nineteenth century. The Romans had their *laconicum* or heating stove, which from its name was an invention from Laconia. It probably was made in most cases of brick or marble, but might have been of beaten iron, was cylindrical in shape, with an open cupola at the top, and was heated by the flames of the *hypocaust* beneath. The *hypocaust* was a hot-air furnace built in the basement or cellar of the house and from which the heat was conducted by flues to the bath rooms and other apartments. The Chinese ages ago heated their hollow tiled floors by underground furnace fires. We know of the *athanor* of the alchemists of the middle ages. Knight calls it the "original base-burning furnace." A furnace of iron or earthenware was provided on one side with an open stack or tower which opened at the bottom into the furnace, and which stack was kept filled with charcoal, or other fuel, which fed itself automatically into the furnace as the fuel on the bed thereof burned away. Watt introduced an arrangement on the same principle in his steam boiler [Pg 203] furnace in 1767, and thousands of stoves are now constructed within England and the United States also embodying the same principle.

The earthenware and soapstone stoves of continental Europe were used long before the present century.

In Ben Franklin's time in the American Colonies there was not much of a demand for stoves outside of the largest cities, where wood was getting a little scarce and high, but the philosopher not only deemed it proper to invent an improvement in chimneys to prevent their smoking and to better heat the room, but also devised an improved form of stove, and both inventions have been in constant use unto this day. Franklin invented and introduced his celebrated stove, which he called the Pennsylvania Fire Place, in 1745, having all the advantages of a cheerful open fireplace, and a heat producer; and which consisted of an iron stove with an open front set well into the room, in which front part the fire was kindled, and the products of combustion conducted up a flue, and thence under a false back and up the chimney. Open heat spaces were left between the two flues. Air inlets and dampers were provided. In his description of this stove at that time Franklin also referred to the iron box stoves used by the Dutch, the iron plates extending from the hearths and sides, etc., chimneys making a double fireplace used by the French, and the German stove of iron plates, and so made that the fuel had to be put into it from another room or from the outside of the house. He dwells upon the pleasure of an open fire, and the destruction of this pleasure by the use of the closed stoves. He also describes the discomforts of the fireplace in [Pg 204] cold weather—of the "cold draught nipping one's back and heels"—"scorched before and frozen behind"—the sharp draughts of cold from crevices from which many catch cold and from "whence proceed coughs, catarrhs, toothaches, fevers, pleurisies and many other diseases." Added to the pleasure of seeing the crackling flames, feeling the genial warmth, and the diffusion of a spirit of sociability and hospitality, is the fact of increased purity of the air by reason of the fireplace as a first-class ventilator. Hence it will never be discarded by those who can afford its use; but it alone is inadequate for heating and cooking purposes. It is modernly used as a luxury by those who are able to combine with it other means for heating.

The great question for solution in this art at all times has been how to produce through dwelling houses and larger buildings in cold and damp weather a uniform distribution and circulation of pure heated air. The solution of this question has of course been greatly helped in modern times by a better knowledge of the nature of air and other gases, and the laws which govern their motions and combinations at different temperatures.

The most successful form of heating coal stove of the century has been one that combined in itself the features of base-burning: that is, a covered magazine at the centre or back of the stove open at or near the top of the stove into which the coal is placed, and which then feeds to the bottom of the fire pot as fast as the coal is consumed, a heavy open fire pot placed as low as possible, an ash grate connected with the bottom of the pot which can be shaken and dumped to an ash box beneath without opening the stove, thus preventing the escape of the dust, an [Pg 205] illuminating chamber nearly or entirely surrounding the fire pot, provided with mica windows, through which the fire is reflected and the heat radiated, a chamber above the fire pot and surrounding the fuel chamber and into which the heat and hot gases arise, producing additional radiating surface and permitting the gases to escape through a flue in the chimney, or, leading them first through another chamber to the base of the stove and thence out, and dampers to control and regulate the supply of air to the fuel, and to cut off the escape or control the course of the products of combustion.

The cheerful stove fireplace and stove of Franklin and the French were revived, combined and improved some years ago by Capt. Douglas Galton of the English army for use in barracks, but this stove is also admirably adapted for houses. It consists of an open stove or grate set in or at the front of the fireplace with an air inlet from without, the throat of the fireplace closed and a pipe extending through it from the stove into the chimney. Although a steady flow of heat, desirable regulation of temperature and great economy in the consumption of fuel, by reason of the utilisation of so much of the heat produced, were obtained by the modern stove, yet the necessity of having a stove in nearly every room, the ill-ventilation due to the non-supply of pure outer air to the room, the occasional diffusion of ash dust and noxious gases from the stove, and inability to heat the air along the floor, gave rise to a revival of the hot-air furnace, placed under the floor in the basement or cellar, and many modern and radical improvements therein.

The heat obtained from stoves is effected by radiation—the throwing outward of the waves of heat from its source, while the heat obtained from a hot-air furnace is effected by convection—the moving of a body of air to be heated to the source of heat, and then when heated bodily conveyed to the room to be warmed. Hence in stoves and fireplaces only such obstruction is placed between the fire and the room as will serve to convey away the obnoxious smoke and gases, and the greatest facility is offered for radiation, while in hot-air furnaces, although provision is also made to carry away the smoke and impure gases, yet the radiation is confined as closely as possible to chambers around the fire space, which chambers are protected by impervious linings from the outer air, and into which fresh outdoor air is introduced, then heated and conveyed to different apartments by suitable pipes or flues, and admitted or excluded, as desired, by registers operated by hand levers. [Pg 206]

There are stationary furnaces and portable furnaces; the former class enclose the heating apparatus in walls of brick or other masonry, while in the latter the outer casing and the inner parts are metal structures, separable and removable. In both classes an outer current of pure air is made to course around the fire chamber and around among other flues and chambers through which the products of combustion are carried, so that all heat possible is utilised. Vessels of water are supplied at the most convenient place in one of the hot-air chambers to moisten and temper the air, and dampers are placed in the pipes to regulate and guide the supply of heat to the rooms above.

After Watt had invented his improvements on the steam engine the idea occurred to him of using steam for heating purposes. Accordingly, in 1784, he made a hollow sheet-iron box of plates, and [Pg 207] supplied it with steam from the boiler of the establishment. It had an air-escape cock, and condensed-water-escape pipe; and in 1799 Boulton and Watt constructed a heating apparatus in Lee's factory, Manchester, in which the steam was conducted through cast-iron pipes, which also served as supports to the floor. Patents were also taken out by others in England for steam-heating apparatuses during the latter part of the 18th century.

Heating by the circulation of hot water through pipes was also originated or revived during the 18th century, and a short time before Watt's circulation of steam. It is said that Bonnemain of England, in 1777, desiring to improve the ancient methods of hatching poultry by artificial heat—practised by both ancient and modern Egyptians ages before it became a latter day wonder, and taught the Egyptians by the ostriches—conceived the idea of constructing quite a large incubator building with shelves for the eggs, coops for holding the chickens, and a tube for circulating hot water leading from a boiler below and above each shelf, and through the coops, and back to the boiler. This incubator contains the germs of modern water heaters. In both the steam and water heating systems the band or collection of pipes in each room may be covered with ornamental radiating plates, or otherwise treated or arranged to render them sightly and effective. In one form of the hot-water system, however, the collection of a mass of pipes in the rooms is dispensed with, and the pipes are massed in an air chamber over or adjacent to the furnace, where they are employed to heat a current of air introduced from the outside, and which heated pure air is [Pg 208] conveyed through the house by flues and registers as in the hot-air furnace system.

The hanging of the crane, the turning of the spit, the roasting in ashes and on hot stones, the heating of and the baking in the big "Dutch" ovens, and some other forms of cooking by our forefathers had their pleasures and advantages, and still are appreciated under certain circumstances, and for certain purposes, but are chiefly honoured in memory alone and reverenced by disuse; while the modern cooking stove with its roasting and hot water chambers, its numerous seats over the fire for pots, pans, and kettles, its easy means of controlling and directing the heat, its rotating grate, and, when desired, its rotating fire chamber, for turning the hot fire on top to the bottom, and the cold choked fire to the top, its cleanliness and thorough heat, its economy in the use of fuel, is adopted everywhere, and all the glowing names with which its makers and users christen it fail to exaggerate its qualities when rightly made and used.

It would appear that the field of labour and the number of labourers, chiefly those who toiled with brick and mortar, were greatly reduced when those huge fireplaces were so widely discarded. This must have seemed so especially in those regions where the houses were built up to meet the yearning wants of an outside chimney, but armies of men are engaged in civilised countries in making stoves and furnaces, where three-quarters of a century ago very few were so employed. As in every industrial art old things pass away, but the new things come in greater numbers, demand a greater number of workers, develop new wants, new fields of labour, and the new and increasing supply of consumers refuse to be satisfied with old contrivances. [Pg 209]

In the United States alone there are between four and five hundred stove and furnace foundries, in which about ten thousand people are employed, and more than three million stoves and furnaces produced annually, which require nearly a million tons of iron to make, and the value of which is estimated as at least $100,000,000.

The matter of *ventilation* is such a material part of heating that it cannot escape attention. There can be no successful heating without a circulation of air currents, and fortunately for man in his house no good fire can be had without an outflow of heat and an inflow of cooler air. The more this circulation is prevented the worse the fire and the ventilation.

It seems to many such a simple thing, this change of air—only to keep open the window a little—to have a fireplace, and convenient door. And yet some of the brightest intellects of the century have been engaged in devising means to accomplish the result, and all are not yet agreed as to which is the best way.

How to remove the heated, vitiated air and to supply fresh air while maintaining the same uniform temperature is a problem of long standing. The history of the attempts to heat and ventilate the Houses of Parliament since Wren undertook it in 1660 has justly been said to be history of the Art of Ventilation since that time, as the most eminent scientific authorities in the world have been engaged or consulted in it, and the most exhaustive reports on the subject have been rendered by such men as Gay-Lussac, Sir Humphry Davy, Faraday and Dr. Arnott of England and Gen. Morin of France. The same may be said in regard to the Houses of Congress in the United States Capitol for the past thirty-five years. Prof. Henry, Dr. Billings, the architect, [Pg 210] Clark, of that country, and many other bright inventors and men of ability have given the subject devoted attention. Among the means for creating ventilation are underground tunnels leading to the outer air, with fans in them to force the fresh air in or draw the poor air out, holes in the ceiling, fire places, openings over the doors, openings under the eaves, openings in the window frames, shafts from the floor or basement with fires or gas jets to create an upward draught, floors with screened openings to the outer air, steam engines to work a suction pipe in one place and a blow pipe in another, air boxes communicating with the outer air, screens, hoods, and deflectors at these various openings,—all these, separately or in combination, have been used for the purpose of drawing the vitiated air out and letting the pure air in without creating draughts to chill the sensitive, or overheating to excite the nervous.

There seems to have been as many devices invented to keep a house or building closed up tight while highly heating it, as to ventilate the same and preserve an even, moderate temperature.

The most approved system of ventilation recognises the fact that air is of the same weight and is possessed of the same constituents in one part of a room as at another, and to create a perfect ventilation a complete change and circulation must take place. It therefore creates a draught, arising from the production of a vacuum by a current of heat or by mechanical means, or by some other way, which draws out of a room the used up, vitiated air through outlets at different places, while pure outer air is admitted naturally, or forced in if need be, through numerous small inlets, such outlets and inlets so located and distributed and protected as not to give rise to sensible [Pg 211] draughts on the occupants.

The best system also recognises the fact that all parts of a house, its cellars and attic, its parlours and kitchens, its closets, bathrooms and chambers, should be alike clean and well ventilated, and that if one room is infected all are infected.

The laurels bestowed on inventors are no more worthily bestowed than on those who have invented devices which give to our homes, offices, churches and places of amusement a pure and comfortable atmosphere.

Car Heaters.—The passing away of the good old portable foot stove for warming the feet, especially when away from home, and while travelling, is not to be regretted, although in some instances it was not at first succeeded by superior devices. For a long time after the introduction of steam, railroad cars and carriages, in which any heat at all was used, were heated by a stove in each car—generally kept full of red hot coal or wood—an exceedingly dangerous companion in case of accident. Since 1871 systems have been invented and introduced, the most successful of which consists of utilising the heat of the steam from the locomotive for producing a hot-water circulation through pipes along the floor of each car, and in providing an emergency heater in each car for heating the water when steam from the locomotive is not available.

Grass-burning Stoves.—There are many places in this world where neither wood nor coal abound, or where the same are very scarce, but where waste grass and weeds, waste hay and straw, and similar combustible refuse are found in great abundance. Stoves have been invented especially designed for the economical consumption of such fuel. One requisite is that such light material [Pg 212] should be held in a compressed state while in the stove to prevent a too rapid combustion. Means for so holding the material under compression appear to have been first invented and patented by Hamilton of America in 1874.

Some means besides the sickle and scythe, hoe and plough, were wanted to destroy obnoxious standing grass and weeds. A weed like the Russian thistle, for instance, will defy all usual means for its extermination. A fire chamber has been invented which when drawn over the ground will burn a swath as it advances, and it is provided with means, such as a wide flange on the end of the chamber, which extinguishes the fire and prevents its spreading beyond the path. A similar stove with jets of flame from vapour burners has been used to soften hard asphalt pavement when it is desired to take it up.

The art of heating and cooking by oil, vapour and gas stoves is one that has arisen during the latter half of this century, and has become the subject of a vast number of inventions and extensive industries. Stoves of this character are as efficient and economical as coal stoves, and are in great demand, especially where coal and wood are scarce and high-priced.

Oil stoves as first invented consisted of almost the ordinary lamp, without the glass shade set in the stove and were similar to gas stoves. But these were objectionable on account of the fumes emitted. By later inventions the lamp has been greatly improved. The wick is arranged within tubular sliding cylinders so as to be separated from the other parts of the stove when it is not lit, and better regulating devices adopted, whereby the oil is prevented from spreading from the wick on to the other parts of the stove, which give rise to obnoxious fumes by evaporation and heating. Some recent inventors have dispensed with the wick altogether and the oil is burned practically like vapour. *Gasoline*, and other heavy oily vapours are in many stoves first vapourised by a preliminary heating in a chamber before the gas is ignited for use. These vapours are then conducted by separate jets to different points in the stove where the heat is to be applied. The danger and unpleasant flame and smoke arising from this vapourising in the stove have been obviated by inventions which vapourise the fuel by other means, as by carbonating, or loading the air with the vapour in an elevated chamber and conducting the saturated air to the burners; or by agitation, by means of a quick-acting, small, but powerful fan. [Pg 213]

Sterilising.—The recent scientific discoveries and investigations of injurious bacteria rendered it desirable to purify water by other means than filtering, especially for the treatment of disease-infected localities; and this gave rise to the invention of a system of heat sterilising and filtering the water, in one process, and out of contact with the germ-laden air, thus destroying the bacteria and delivering the water in as pure and wholesome condition as possible. West in 1892 patented such a system.

Electric Heating and Cooking.—Reference has already been made in the Chapter on Electricity to the use of that agent in heating and cooking. The use of the electric current for these purposes has been found to be perfectly practical, and for heating cars especially, where electricity is the motive power, a portion of the current is economically employed.

The art of heating and cooking naturally suggests the other end of the line of temperature —*Refrigeration*. [Pg 214]

A refrigeration by which ordinary ice is artificially produced, perishable food of all kinds preserved for long times, and transported for great distances, which has proved an immense advantage to mankind everywhere and is still daily practised to the gratification and comfort of millions of men, must receive at least a passing notice. The Messrs. E. and F. Carré of France invented successful machines about 1870 for making ice by the rapid absorption and evaporation of heat by the ammonia process. The discoveries and inventions of others in the artificial production of cold by means of volatile liquids, whether for the making of ice or other purposes, constituted a great step in the art of refrigeration.

Vaporisation, absorption, compression or reduction of atmospheric pressure are the principal methods of producing cold. By vaporisation, water, ether, sulphuric acid, ammonia, etc., in assuming the vaporous form change sensible heat to latent heat and produce a degree of cold which freezes an adjacent body of water. The principle of making ice by evaporation and absorption may be illustrated by two examples of the Carré methods:—It is well known what a great attraction sulphuric acid has for water. Water to be frozen is placed in a vessel connected by a pipe to a reservoir containing sulphuric acid. A vacuum is produced in this reservoir by the use of an air pump, while the acid is being constantly stirred. Lessening of the atmospheric pressure upon water causes its evaporation, and as the vapour is quietly absorbed by the sulphuric acid the water is quickly congealed. It is known that ammonia can be condensed into liquid form by pressure or cold, and is absorbed by and soluble in water to an extraordinary degree. A generator containing a strong solution of ammonia is connected by a pipe to an empty receiver immersed in cold water. The ammonia generator is then heated, its vapour driven off and conducted to a jacket around the centre of the receiver and is there condensed by pressure of an air pump. The central cylindrical space in the receiver is now filled with water, and the operation is reversed. The generator is immersed in cold water and pressure on the liquid ammonia removed. The liquid ammonia now passes into the gaseous state, and is conducted to and reabsorbed by the water in the generator. But in this evaporation great cold is produced and the water in the receiver is soon frozen. [Pg 215]

Twining's inventions in the United States in 1853 and 1862 of the compression machine, followed by Pictet of France, and a number of improvements elsewhere have bid fair to displace the absorption method. In dispensing with absorption these machines proceed on the now well-established theory that air and many other gases become heated when compressed; that this heat can then be drawn away, and that when the gas is allowed to re-expand it will absorb a large amount of heat from any solid or fluid with which it is brought in contact, and so freeze it. Accordingly such machines are so constructed that by the operation of a piston, or pistons, in a cylinder, and actuated by steam or other motive power, the air or gas is compressed to the desired temperature, the heat led off and the cold vapour conducted through pipes and around chambers where water is placed and where it is frozen. By the best machines from five hundred to one thousand pounds of ice an hour are produced.

The art of refrigeration and of modern transportation have brought the fruits of the tropics in great abundance to the doors of the dwellers of the north, and from the shores of the Pacific to the Atlantic and across the Atlantic to Europe. A train of refrigerator cars in California laden with delicious assorted fruits, and provided with fan blowers driven by the car axles to force the air through ice chambers, from whence it is distributed by perforated pipes through the fruit chambers, and wherein the temperature is maintained at about 40° Fah., can be landed in New York four days after starting on its journey of 3,000 miles, with the fruits in perfect condition. [Pg 216]

But the public is still excited and wondering over the new king of refrigeration—*liquid air*.

As has been stated, the compression of air to produce cold is a modern discovery applied to practical uses, and prominent among the inventors and discoverers in this line have been Prof. Dewar and Charles E. Tripler.

Air may be compressed and heat generated in the process withdrawn until the temperature of the air is reduced to 312° below zero, at which point the air is visible and to a certain extent assumes a peculiar material form, in which form it can be confined in suitable vessels and used as a refrigerant and as a motor of great power when permitted to re-expand. It is said that it was not so long ago when Prof. Dewar produced the first ounce of liquid air at a cost of $3,000, but that now Mr. Tripler claims that he can produce it by his apparatus for five cents a gallon.

Refrigeration is at present its most natural and obvious use, and it is claimed that eleven gallons of the material when gradually expanded has the refrigerating power of one ton of ice. Its use of [Pg 217] course for all purposes for which cold can be used is thus assured. It is also to be used as a motor in the running of various kinds of engines. It is to be used as a great alleviator of human suffering in lowering and regulating the temperature of hospitals in hot weather, and in surgical operations as a substitute for anæsthetics and cauterising agents.

It was one of the marvellous attractions at the great Paris Exposition of 1900.

Lighting is closely allied to the various subjects herein considered, but consideration of the various modes and kinds of lamps for lighting will be reserved for the Chapter on Furniture for Houses, etc.

[Pg 218]

CHAPTER XIV.

METALLURGY.

"Nigh on the plain, in many cells prepared,
That underneath had veins of liquid fire
Sluiced from the lake, a second multitude
With wondrous art founded the massy ore;
Severing each kind, and scumm'd the bullion dross;
A third as soon had formed within the ground
A various mould, and from the boiling cells
By strange conveyance fill'd each hollow nook;
As in an organ, from one blast of wind,
To many a row of pipes the sound board breathes."

—*Paradise Lost.*

Ever since those perished races of men who left no other record but that engraven in rude emblems on the rocks, or no other signs of their existence but in the broken tools found buried deep among the solid leaves of the crusted earth, ever since Tubal Cain became "an instructor of every artificer in brass and iron," the art of smelting has been known. The stone age flourished with implements furnished ready-made by nature, or needing little shaping for their use, but the ages of metal which followed required the aid of fire directed by the hand of man to provide the tool of iron or bronze.

The Greeks claimed that the discovery of iron was theirs, and was made at the burning of a forest on the mountains of Ida in Crete, about 1500 B. C., when the ore contained in the rocks or soil on which the forest stood was melted, cleansed of its impurities, and then collected and hammered. Archeologists have deprived the Greeks of this gift, and carried back its origin to remoter ages [Pg 219] and localities.

Man first discovered by observation or accident that certain stones were melted or softened by fire, and that the product could be hammered and shaped. They learned by experience that the melting could be done more effectually when the fuel and the ore were mixed and enclosed by a wall of stone; that the fire and heat could be alone started and maintained by blowing air into the fuel—and they constructed a rude bellows for this purpose. Finding that the melted metal sank through the mass of consumed fuel, they constructed a stone hearth on which to receive it. Thus were the first crude furnace and hearth invented.

As to gold, silver and lead, they doubtless were found first in their native state and mixed with other ores and were hammered into the desired shapes with the hardest stone implements.

That copper and tin combined would make bronze was a more complex proceeding and probably followed instead of preceding, as has sometimes been alleged, the making of iron tools. That bronze relics were found apparently of anterior manufacture to any made of iron, was doubtless due to the destruction of the iron by that great consumer—oxygen.

What was very anciently called "brass" was no doubt gold-coloured copper; for what is modernly known as brass was not made until after the discovery of zinc in the 16th century and its combination with copper.

Among the "lost arts" re-discovered in later ages are those which supplied the earliest cities with ornamented vessels of gold and copper, swords of steel that bent and sprung like whalebones, castings that had known no tool to shape their contour and embellishments, and monuments and tablets of steel and brass which excite the wonder and admiration of the best "artificers in brass and iron" of the present day. [Pg 220]

To understand and appreciate the advancements that have been made in metallurgy in the nineteenth century, it is necessary to know, in outline at least, what before had been developed.

The earliest form of a smelting furnace of historic days, such as used by the ancient Egyptians, Hebrews, and probably by the Hindoos and other ancient peoples, and still used in Asia, is thus described by Dr Ure:

"The furnace or bloomary in which the ore is smelted is from 4 to 5 feet high; it is somewhat pear-shaped, being about 5 feet wide at bottom and 1 at top. It is built entirely of clay. There is an opening in front about a foot or more in height which is filled with clay at the commencement, and broken down at the end of each smelting operation. The bellows are usually made of two goatskins with bamboo nozzles, which are inserted into tubes of clay that pass into the furnace. The furnace is filled with charcoal, and a lighted coal being introduced before the nozzle, the mass in the interior is soon kindled. As soon as this is accomplished, a small portion of the ore previously moistened with water to prevent it from running through the charcoal, but without any flux whatever, is laid on top of the coals, and covered with charcoal to fill up the furnace. In this manner ore and fuel are supplied and the bellows urged for three or four hours. When the process is stopped and the temporary wall in front broken down the bloom is removed with a pair of tongs from the bottom of the furnace." [Pg 221]

This smelting was then followed by hammering to further separate the slag, and probably after a reheating to increase the malleability.

It will be noticed that in this earliest process pure carbon was used as a fuel, and a blast of air to keep the fire at a great heat was employed. To what extent this carbon and air blast, and the mixing and remixing with other ingredients, and reheating and rehammering, may have been employed in various instances to modify the conditions and render the metal malleable and more or less like modern steel, is not known, but that an excellent quality of iron resembling modern steel was often produced by this simple mode of manufacture by different peoples, is undoubtedly the fact. Steel after all is iron with a little more carbon in it than in the usual iron in the smelting furnace, to render it harder, and a little less carbon than in cast or moulded iron to render it malleable, and in both conditions was produced from time immemorial, either by accident or design.

It was with such a furnace probably that India produced her keen-edged weapons that would cut a web of gossamer, and Damascus its flashing blades—the synonym of elastic strength.

Africa, when its most barbarous tribes were first discovered, was making various useful articles of iron. Its earliest modes of manufacture were doubtless still followed when Dr Livingstone explored the interior, as they now also are. He thus describes their furnaces and iron: "At every third or fourth village (in the regions near Lake Nyassa) we saw a kiln-looking structure, about 6 feet high and 2½ feet in diameter. It is a clay fire-hardened furnace for smelting iron. No flux is used, whether with specular iron, the yellow hematite, or magnetic ore, and yet capital metal is produced. Native manufactured iron is so good that the natives declare English iron "rotten" in comparison, and specimens of African hoes were pronounced at Birmingham nearly equal to the best Swedish iron." The natives of India, the Hottentots, the early Britons, the Chinese, the savages of North and South America, as discovery or research brought their labours to light, or uncovered the monuments of their earliest life, were shown to be acquainted with similar simple forms of smelting furnaces. [Pg 222]

Early Spain produced a furnace which was adopted by the whole of Europe as fast as it became known. It was the Catalan furnace, so named from the province of Catalonia, where it probably first originated, and it is still so known and extensively used. "It consists of a four-sided cavity or hearth, which is always placed within a building and separated from the main wall thereof by a thinner interior wall, which in part constitutes one side of the furnace. The blast pipe comes through the wall, and enters the fire through a flue which slants downward. The bottom is formed of a refractory stone, which is renewable. The furnace has no chimneys. The blast is produced by means of a fall of water usually from 22 to 27 feet high, through a rectangular tube, into a rectangular cistern below, to whose upper part the blast pipe is connected, the water escaping through a pipe below. This apparatus is exterior to the building, and is said to afford a continuous blast of great regularity; the air, when it passes into the furnace, is, however, saturated with moisture."—*Knight.*

No doubt in such a heat was formed the metal from which was shaped the armour of Don Quixote and his prototypes. [Pg 223]

Bell in his history of Metallurgy tells us that the manufacture of malleable iron must have fallen into decadence in England, especially before the reign of Elizabeth and Charles I., as no furnaces equal even to the Catalan had for a long time been in use; and the architectural iron column found in ancient Delhi, 16 inches in diameter, about 48 feet long and calculated to weigh about 17 tons, could not have been formed by any means known in England in the sixteenth century.

This decadence was in part due to the severe laws enacted against the destruction of forests, and most of the iron was then brought to England from Germany and other countries.

From time immemorial the manufacture of iron and steel has been followed in Germany, and that country yet retains pre-eminence in this art both as to mechanical and chemical processes. It was in the eighteenth century that the celebrated Freiberg Mining Academy was founded, the oldest of all existing mining schools; and based on developing mining and metallurgy on scientific lines, it has stood always on the battle line in the fight of progress.

The early smelting furnaces of Germany resembled the Catalan, and were called the "Stückofen," and in Sweden were known as the "Osmund." In these very pure iron was made.

The art of making cast iron, which differs from the ordinary smelted iron in the fact that it is *melted* and then run into moulds, although known among the ancients more than forty centuries ago, as shown by the castings of bronze and brass described by their writers and recovered from their ruins, appears to have been forgotten long before the darkness of the middle ages gathered. There is no record of its practice from the time the elder Pliny described its former use (40-79 A. [Pg 224] D.), to the sixteenth century. It is stated that then the lost art was re-invented by Ralph Page and Peter Baude of England in 1543—who in that year made cast-iron in Sussex.

The "Stückofen" furnace above referred to was succeeded in Germany by higher ones called the "Flossofen," and these were followed by still higher and larger ones called "Blauofen," so that by the middle of the eighteenth century the furnaces were very capacious, the blast was good, and it had been learned how to supply the furnaces with ore, coal and lime-stone broken into small fragments. The lime was added as a flux, and acted to unite with itself the sand, clay and other impurities to form a slag or scoria. The melted purified iron falling to the bottom was drawn off through a hole tapped in the furnace, and the molten metal ran into channels in a bed of sand called the "Sow and pigs." Hence the name, "pig iron."

The smelting of ore by charcoal in those places where carried on extensively required the use of a vast amount of wood, and denuded the surrounding lands of forests. So great was this loss felt that it gave rise to the prohibitory laws and the decadence in England of the manufacture of iron, already alluded to. This turned the attention of iron smelters to coal as a substitute. Patents were granted in England for its use to several unsuccessful inventors. Finally in 1619 Dud Dudley, a graduate of Oxford University, and to whom succeeded his father's iron furnaces in Worcestershire, obtained a patent and succeeded in producing several tons of iron per week by the use of the pitcoal in a small blast furnace.

This success inflamed the wood owners and the charcoal burners and they destroyed Dudley's [Pg 225] works. He met with other disasters common to worthy inventors and discontinued his efforts to improve the art.

It is said that in 1664 Sir John Winter of England made coke by burning sea coal in closed pots. But this was not followed up, and the use of charcoal and the destruction of the forests went on until 1735, when Abraham Darby of the Coalbrookdale Iron Works at Shropshire, England, commenced to treat the soft pit coal in the same way as wood is treated in producing charcoal. He proposed to burn the coal in a smouldering fire, to expel the sulphur and other impurities existing in the form of phosphorus, hydrogen and oxygen, etc. while saving the carbon. The attempt was successful, and thus *coke* was made. It was found cheaper and superior to either coal or charcoal, and produced a quicker fire and a greater heat. This was a wonderful discovery, and was preserved as a trade secret for a long time. It was referred to as a curiosity in the *Philosophical Transactions* in 1747. In fact it was not introduced in America until a century later, when in 1841 the soft coal abounding around Pittsburgh in Pennsylvania and in the neighbouring regions of Ohio was thus treated. Even its use then was experimental, and did not become a practical art in the United States until about 1860.

With the invention of coke came also the revival of cast iron.

The process of making cast steel was reinvented in England by Benjamin Huntsman of Attercliff, near Sheffield, about 1740. Between that time and 1770 he practised melting small pieces of "blistered" steel (iron bars which had been carbonised by smelting in charcoal) in closed clay [Pg 226] crucibles.

In 1784 Henry Cort of England introduced the puddling process and grooved rolls. Puddling had been invented, but not successfully used before. The term "puddling" originated in the covering of the hearth of stones at the bottom of the furnace with clay, which was made plastic by mixing the clay in a puddle of water; and on which hearth the ore when melted is received. When in this melted condition Cort and others found that the metal was greatly improved by stirring it with a long iron bar called a "rabble," and which was introduced through an opening in the furnace. This stirring admitted air to the mass and the oxygen consumed and expelled the carbon, silicon, and other impurities. The process was subsequently aided by the introduction of pig iron broken into pieces and mixed with hammer-slag, cinder, and ore. The mass is stirred from side to side of the furnace until it comes to a boiling point, when the stirring is increased in quickness and violence until a pasty round mass is collected by the puddler. As showing the value of Cort's discovery and the hard experience inventors sometimes have, Fairbairn states that Cort "expended a fortune of upward of £20,000 in perfecting his invention for puddling iron and rolling it into bars and plates; that he was robbed of the fruits of his discoveries by the villainy of officials in a high department of the government; and that he was ultimately left to starve by the apathy and selfishness of an ungrateful country. His inventions conferred an amount of wealth on the country equivalent to £600,000,000, and have given employment to 600,000 of the working population of our land for the last three or four generations." This process of puddling lasted for about an hour and a half and entailed extremely severe labour on the workman. [Pg 227]

The invention of mechanical puddlers, hereinafter referred to, consisting chiefly of rotating furnaces, were among the beneficent developments of the nineteenth century.

Prior to Cort's time the plastic lump or ball of metal taken from the furnace was generally beaten by hammers, but Cort's grooved rollers pressed out the mass into sheets.

The improvements of the steam engine by Watt greatly extended the manufacture of iron toward the close of the 18th century, as powerful air blasts were obtained by the use of such engines in place of the blowers worked by man, the horse, or the ox.

So far as the art of refining the precious metals is concerned, as well as copper, tin and iron, it had not, previous to this century, proceeded much beyond the methods described in the most ancient writings; and these included the refining in furnaces, pots, and covered crucibles, and alloying, or the mixture and fusion with other metals. Furnaces to hold the crucibles, and made of iron cylinders lined with fire brick, whereby the crucibles were subjected to greater heat, were also known.

The amalgamating process was also known to the ancients, and Vitruvius (B. C. 27) and Pliny (A. D. 79), describe how mercury was used for separating gold from its impurities. Its use at gold and silver mines was renewed extensively in the sixteenth century.

Thus we find that the eighteenth century closed with the knowledge of the smelting furnaces of various kinds, of coke as a fuel in place of charcoal, of furious air blasts driven by steam and other power, of cast iron and cast steel, and of refining, amalgamating, and compounding processes. [Pg 228]

Looking back, now, from the threshold of the nineteenth century over the path we have thus traced, it will be seen that what had been accomplished in metallurgy was the result of the use of ready means tested by prolonged trials, of experiments more or less lucky in fields in which men were groping, of inventions without the knowledge of the real properties of the materials with which inventors were working or of the unvarying laws which govern their operations. They had accomplished much, but it was the work mainly of empirics. The art preceding the nineteenth century compared with what followed is the difference between experience simply, and experience when combined with hard thinking, which is thus stated by Herschel: "Art is the application of knowledge to a practical end. If the knowledge be merely accumulated experience the art is empirical; but if it is experience reasoned upon and brought under general principles it assumes a higher character and becomes a scientific art."

With the developments, discoveries and inventions in the lines of steam, chemistry and electricity, as elsewhere told, the impetus they gave to the exercise of brain force in every field of nature at the outset of the century, and with their practical aid, the art of metallurgy soon began to expand to greater usefulness, and finally to its present wonderful domain.

The subject of metallurgy in this century soon became scientifically treated and its operations classified.

Thus the physical character and metallic constituents of ores received the first consideration; then the proper treatment to which the ores were to be subjected for the purpose of extracting the metal—which are either mechanical or chemical. The mechanical processes designed to separate the ore from its enclosing rock or other superfluous earthy matter called *gangue* became known as *ore dressing* and *ore concentrating*. These included mills with rollers, and stamps operated by gravity, or steam, for breaking up the ore rocks; abrasion apparatus for comminuting the ore by rubbing the pieces of ore under pressure; and smelting, or an equivalent process, for melting the ore and driving off the impurities by heat, etc. The chemical processes are those by which the metal, whatever it may be, is either dissolved or separated from other constituents by either the application to the ore of certain metallic solutions of certain acids, or by the fusion of different ores or metals in substantially the old styles of furnaces; or its precipitation by amalgamating, or by electrolysis—the art of decomposing metals by electricity. [Pg 229]

In the early decades of the century, by the help of chemistry and physics, the nature of heat, carbon, and oxygen, and the great affinity iron has for oxygen, became better known; and particularly how in the making of iron its behaviour is influenced by the presence of carbon and other foreign constituents; also how necessary to its perfect separation was the proper elimination of the oxygen and carbon. The use of manganese and other highly oxidisable metals for this purpose was discovered.

Among the earliest most notable inventions in the century, in the manufacture of iron, was that of Samuel B. Rogers of Glamorganshire, Wales, who invented the iron floor for furnaces with a refractory lining—a great improvement on Cort's sand floor, which gave too much silicon to the iron; and the *hot air blast* by Neilson of Glasgow, Scotland, patented in 1828. The latter consisted in the use of heated air as the blast instead of cold air—whereby ignition of the fuel was quickened, intensity of the heat and the expulsion of oxygen and carbon from the iron increased, and the operation shortened and improved in every way. The patent was infringed and assailed, but finally sustained by the highest courts of England. It produced an immense forward stride in [Pg 230] the amount and quality of iron manufactured.

By the introduction of the hot air blast it became practicable to use the hard anthracite coal as a fuel where such coal abounded; and to use pig iron, scrap iron, and refractory ore and metals with the fuel to produce particular results. Furnaces were enlarged to colossal dimensions, some being a hundred feet high and capable of yielding 80 or 100 tons of metal per day.

The forms of furnaces and means for lining and cooling the hearth and adjacent parts have received great attention.

The discovery that the flame escaping from the throat of the blast furnace was nothing else than burning carbon led Faber du Faur at Wasseralfugen in 1837 to invent the successful and highly valuable method of utilising the unburnt gas from the blast furnace for heating purposes, and to heat the blast itself, and drive the steam engine that blew the blast into the furnace, without the consumption of additional fuel. This also led to the invention of separate gas producers. Bunsen in 1838 made his first experiments at Hesse in collecting the gases from various parts of the furnace, revealing their composition and showing their adaptability for various purposes. Thus, from a scientific knowledge of the constituents of ores and of furnace gases, calculations could be made in advance as to the materials required to make pig iron, cast iron, and steel of particular qualities. [Pg 231]

In the process of puddling difficulty had been experienced in handling the bloom or ball after it was formed in the furnace. A sort of squeezing apparatus, or tongs, called the alligator, had been employed.

In 1840 Henry Burden of America invented and patented a method and means for treating these balls, whereby the same were taken directly from the furnace and passed between two plain converging metal surfaces, by which the balls were gradually but quickly pressed and squeezed into a cylindrical form, while a large portion of the cinders and other foreign impurities were pressed out.

We have described how by Cort's puddling process tremendous labour was imposed on the workmen in stirring the molten metal by hand with "rabbles." A number of mechanical puddlers were invented to take the place of these hand means, but the most important invention in this direction was the revolving puddlers of Beadlestone, patented in 1857 in England, and of Heaton, Allen and Yates, in 1867-68. The most successful, however, was that of Danks of the United States in 1868-69. The Danks rotary puddler is a barrel-shaped, refractory lined vessel, having a chamber and fire grate and rotated by steam, into which pig iron formed by the ordinary blast furnaces, and then pulverised, is placed, with the fuel. Molten metal from the furnace is then run in, which together with the fuel is then subjected to a strong blast. Successive charges may be made, and at the proper time the puddler is rotated, slowly at some stages and faster at others, until the operation is completed. A much more thorough and satisfactory result in the production of a pure malleable iron is thus obtained than is possible by hand puddling. [Pg 232]

But the greatest improvements in puddling, and in the production of steel from iron, and which have produced greater commercial results than any other inventions of the century relating to metallurgy, were the inventions of Henry Bessemer of Hertfordshire, England, from 1855 to 1860. In place of the puddling "rabbles" to stir the molten metal, or *matte*, as it is called, while the air blast enters to oxidise it, he first introduced the molten metal from the furnace into an immense egg-shaped vessel lined with quartzose, and hung in an inclined position on trunnions, or melted the metal in such vessel, and then dividing the air blast into streams forced with great pressure each separate stream through an opening in the bottom of the vessel into the molten mass, thus making each stream of driven air a rabble; and they together blew and lifted the white mass into a huge, surging, sun-bright fountain. The effect of this was to burn out the impurities, silicon, carbon, sulphur, and phosphorus, leaving the mass a pure soft iron. If steel was wanted a small amount of carbon, usually in the form of spiegeleisen, was introduced into the converter before the process was complete.

A. L. Holley of the United States improved the Bessemer apparatus by enabling a greater number of charges to be converted into steel within a given time. [Pg 233]

Sir Henry Bessemer has lived to gain great fortunes by his inventions, to see them afford new fields of labour for armies of men, and to increase the riches of nations, from whom he has received deserved honours.

The Bessemer process led to renewed investigations and discoveries as to heat and its utilisation, the constituents of different metals and their decomposition, and as to the parts played by carbon, silicon, and phosphorus. The carbon introduced by the charge of pig iron in the Bessemer process was at first supposed to be necessary to produce the greatest heat, but this was found to be a mistake; and phosphorus, which had been regarded as a great enemy of iron, to be eliminated in every way, was found to be a valuable constituent, and was retained or added to make phosphorus steel.

The Bessemer process has been modified in various ways: by changing the mode of introducing the blast from the bottom of the converter to the sides thereof, and admitting the blast more slowly at certain stages; by changing the character of the pig iron and fuel to be treated; and by changing the shape and operation of the converters, making them cylindrical and rotary, for instance.

The Bessemer process is now largely used in treating copper. By this method the blowing through the molten metal of a blast of air largely removes sulphur and other impurities.

The principles of reduction by the old style furnaces and methods we have described have been revived and combined with improvements. For instance, the old Catalan style of furnace has been retained to smelt the iron, but in one method the iron is withdrawn before it is reduced [Pg 234] completely and introduced into another furnace, where, mixed with further reducing ingredients, a better result by far is produced with less labour.

It would be a long list that would name the modern discoverers and inventors of the century in the manufacture of iron and steel. But eminent in the list, in addition to Davy and Bessemer, and others already mentioned, are Mushet, Sir L. Bell, Percy, Blomfield, Beasley, Giers and Snellus of England; Martin, Chennot, Du Motay, Pernot and Gruner of France; Lohage, Dr. C. L. Siemens and Höpfer of Germany; Prof Sarnstrom and Akerman of Sweden; Turner of Austria; and Holley, Slade, Blair, Jones, Sellers, Clapp, Griffiths and Eames of the United States.

Some of the new metals discovered in the last century have in this century been combined with iron to make harder steel. Thus we have nickel, chromium, and tungsten steel. Processes for hardening steel, as the "Harveyized" steel, have given rise to a contest between "irresistible" projectiles and "impenetrable" armour plate.

If there are some who regard modern discoveries and inventions in iron and steel as lessening the number of workmen and cheapening the product too much, thus causing trouble due to labour-saving machinery, let them glance, among other great works in the world, at Krupp's at Essen, where on January 1st, 1899, 41,750 persons were employed, and at which works during the previous year 1,199,610 tons of coal and coke were consumed, or about 4000 tons daily. Workers in iron will not be out of employment in the United States, where 16,000,000 tons of [Pg 235] coke are produced annually, 196,405,953 tons of coal mined, 11,000,000 tons of pig iron and about 9,000,000 tons of steel made. The increase of population within the last hundred years bears no comparison with this enormous increase in iron and fuel. It shows that as inventions multiply, so does the demand for their better and cheaper products increase.

As the other metals, gold, silver, copper and lead often occur together, and in the same deposits with iron, the same general modes of treatment to extract them are often applied. These are known as the dry and the wet methods, and electro-reduction.

Ever since Mammon bowed his head in search for gold, every means that the mind of man could suggest to obtain it have been tried, but the devices of this century have been more numerous and more successful than any before. The ancient methods of simply melting and "skimming the bullion dross" have been superseded. Modern methods may be divided into two general classes, the mechanical and the chemical. Of the former methods, when gold was found loose in sand or gravel, washing was the earliest and most universally practised, and was called panning. In this method mercury is often used to take up and secure the fine gold. Rockers like a child's cradle, into which the dirt is shovelled and washed over retaining riffles, were used; coarse-haired blankets and hides; sluices and separators, with or without quicksilver linings to catch the gold; and powerful streams of water worked by compressed air to tear down the banks. Where water could not be obtained the ore and soil were pulverised and dried, and then thrown against the wind or a blast of air, and the heavier gold, falling before the lighter dust, was caught on hides or blankets. For the crushing of the quartz in which gold was found, innumerable inventions in [Pg 236] stamp mills, rollers, crushers, abraders, pulverisers and amalgamators have been invented; and so with roasters, and furnaces, and crucibles to melt the precious metal, separate the remaining impurities and convert it to use.

As to chemical methods for the precious metals, the process of *lixiviation*, or *leaching*, by which the ore is washed out by a solution of potash, or with dilute sulphuric acid, or boiling with concentrated sulphuric acid, is quite modern. About 1889 came out the great cyanide process, also known as the MacArthur-Forrest process (they being the first to obtain patents and introduce the invention), consisting of the use of cyanide potassium in solution, which dissolves the gold, and which is then precipitated by the employment of zinc. This process is best adapted to what are known as free milling or porous ores, where the gold is free and very fine and is attracted readily by mercury.

In 1807, Sir Humphry Davy discovered the metal potassium by subjecting moistened potash to the action of a powerful voltaic battery; the positive pole gave off oxygen and the metallic globules of pure potassium appeared at the negative pole. It is never found uncombined in nature. Now if potassium is heated in cyanogen gas (a gas procured by heating mercury) or obtained on a large scale by the decomposition of yellow prussiate of potash, a white crystalline body very soluble in water, and exceedingly poisonous, is obtained. When gold, for instance, obtained by pulverising the ore, or found free in sand, is treated to such a solution it is dissolved from its surrounding constituents and precipitated by the zinc, as before stated. [Pg 237]

Chlorine is another metal discovered by Scheele in 1774, but not known as an elementary element until so established by Davy's investigations in 1810, when he gave it the name it now bears, from the Greek *chloras*, yellowish green. It is found abundantly in the mineral world in combination with common salt. Now it was found that chlorine is one of the most energetic of bodies, surpassing even oxygen under some circumstances, and that a chlorine solution will readily dissolve gold.

These, the cyanide and chlorination processes, have almost entirely superseded the old washing and amalgamating methods of treating free gold—and the cyanide seems to be now taking the lead.

Alloys.—The art of fusing different metals to make new compounds, although always practised, has been greatly advanced by the discoverers and inventors of the century. As we have seen, amalgamating to extract gold and silver, and the making of bronze from tin and copper were very early followed. One of the most notable and useful of modern inventions or improvements of the kind was that of Isaac Babbitt of Boston in 1839, who in that year obtained patents for what ever since has been known as "babbitting." The great and undesirable friction produced by the rubbing of the ends of journals and shafts in their bearings of the same metal, cast or wrought iron, amounting to one-fifth of the amount of power exerted to turn them, had long been experienced. Lubricants of all kinds had been and are used; but Babbitt's invention was an anti-friction metal. It is composed of tin, antimony, and copper, and although the proportions and ingredients have since been varied, the whole art is still known as babbitting. [Pg 238]

Other successful alloys have been made for gun metal, sheathing of ships, horseshoes, organ pipes, plough shares, roofing, eyelets, projectiles, faucets, and many and various articles of hardware, ornamental ware, and jewelry.

Valuable metals, such as were not always rare or scarce, but very hard to reduce, have been rendered far less in cost of production and more extensive in use by modern processes. Thus, aluminium, an abundant element in rocks and clay, discovered by the German chemist Wöhler, in 1827, a precious metal, so light, bright, and tough, non-oxidizing, harder than zinc, more sonorous than silver, malleable and ductile as iron, and more tenacious, has been brought to the front from an expensive and mere laboratory production to common and useful purposes in all the arts by the processes commencing in 1854 with that of St. Clair Deoville, of France, followed by those of H. Rose, Morin, Castner, Tissier, Hall, and others.

Electro-metallurgy, so far, has chiefly to do with the decomposition of metals by the electric current, and the production of very high temperatures for furnaces, by which the most refractory ores, metals, and other substances may be melted, and results produced not obtainable in any other way. By placing certain mixtures of carbon and sand, or of carbon and clay, between the terminals of a powerful current, a material resembling diamonds, but harder, has been produced. It has been named carbonundrum. The production of diamonds themselves is looked for. Steel wire is now tempered and annealed by electricity, as well as welding done, of which mention further on will be made.

Thus we have seen how the birth of ideas of former generations has given rise in the present age [Pg 239] to children of a larger growth. Arts have grown only as machinery for the accomplishment of their objects has developed, and machinery has waited on the development of the metals composing it. The civilisation of to-day would not have been possible if the successors of Tubal Cain had not been like him, instructors "of every artificer in brass and iron."

[Pg 240]

CHAPTER XV.

METAL WORKING.

We referred in the last chapter to the fact that metal when it came from the melting and puddling furnace was formerly rolled into sheets; but, when the manufacturers and consumers got these sheets then came the severe, laborious work by hand of cutting, hammering, boring, shaping and fitting the parts for use and securing them in place.

It is one of the glories of this century that metal-working tools and machinery have been invented that take the metal from its inception, mould and adapt it to man's will in every situation with an infinite saving of time and labour, and with a perfection and uniformity of operation entirely impossible by hand.

Although the tools for boring holes in wood, such as the gimlet, auger, and the lathe to hold, turn and guide the article to be operated on by the tool, are common in some respects with those for drilling and turning metal, yet, the adaptation to use with metal constitutes a class of metal-working appliances distinct in themselves, and with some exceptions not interchangeable with wood-working utensils. The metal-working tools and machines forming the subject of this chapter are not those which from time immemorial have been used to pierce, hammer, cut, and shape metals, directed by the eye and hand of man, but rather those invented to take the place of the [Pg 241] hand and eye and be operated by other powers.

It needs other than manual power to subdue the metals to the present wants of man, and until those modern motor powers, such as steam, compressed air, gas and electricity, and modern hydraulic machinery, were developed, automatic machine tools to any extent were not invented. So, too, the tools that are designed to operate on hard metal should themselves be of the best metal, and until modern inventors rediscovered the art of making cast steel such tools were not obtainable. The monuments and records of ancient and departed races show that it was known by them how to bore holes in wood, stone and glass by some sharp instruments turned by hand, or it may be by leather cords, as a top is turned.

The lathe, a machine to hold an object, and at the same time revolve it while it is formed by the hand, or cut by a tool, is as old as the art of pottery, and is illustrated in the oldest Egyptian monuments, in which the god Ptah is shown in the act of moulding man upon the throwing wheel. It is a device as necessary to the industrial growth of man as the axe or the spade. Its use by the Egyptians appears to have been confined to pottery, but the ancient Greeks, Chinese, Africans, and Hindoos used lathes, for wood working in which the work was suspended on horizontal supports, and adapted to be rotated by means of a rope and treadle and a spring bar, impelled by the operator as he held the cutting tool on the object. Joseph Holtzapffel in his learned work on *Turning and Mechanical Manipulation*, gives a list of old publications describing lathes for turning both wood and metal. Among these is Hartman Schapper's book published at Frankfort, in 1548. A lathe on which was formed wood screws is described in a work of Jacques Besson, [Pg 242] published at Lyons, France, in 1582.

It is stated that there is on exhibition in the Abbott museum of the Historical Society, New York, a bronze drinking vessel, five inches in diameter, that was exhumed from an ancient tomb in Thebes, and which bears evidence of having been turned on a lathe. It is thought by those skilled in the art that it was not possible to have constructed the works of metal in Solomon's Temple without a turning lathe. One of the earliest published descriptions of a metal turning lathe in its leading features is that found in a book published in London, in 1677-83, by Joseph Moxon, "hydographer" to King Charles II., entitled, *Mechanical Exercises, or the Doctrine of Handy Works*. He therein also described a machine for planing metal. Although there is some evidence that these inventions of the learned gentleman were made and put to some use, yet they were soon forgotten and were not revived until a century later, when, as before intimated, the steam engine had been invented and furnished the power for working them.

Wood-working implements in which the cutting tool was carried by a sliding block were described in the English patents of General Sir Samuel Bentham and Joseph Bramah, in 1793-94. But until this century, and fairly within its borders, man was content generally to use the metal lathe simply as a holding and turning support, while he with such skill and strength as he could command, and with an expenditure of time, labour and patience truly marvellous, held and guided with his hands the cutting tool with which the required form was made upon or from the [Pg 243] slowly turning object before him. The contrivance which was to take the place of the hand and eye of man in holding, applying, directing and impelling a cutting tool to the surface of the metal work was the *slide-rest*. In its modern successful automatic form Henry Maudsley, an engineer in London, is claimed to be the first inventor, in the early part of the century. The leading feature of his form of this device consists of an iron block which constitutes the rest, cut with grooves so as to adapt it to slide upon its iron supports, means to secure the cutting tool solidly to this block, and two screw handles, one to adjust the tool towards and against the object to be cut in the lathe, and the other to slide the rest and tool lengthwise as the work progresses, which latter motion may be given by the hand, or effected automatically by a connection of the screw handle of the slide and the rotating object on the lathe.

A vast variety of inventions and operations have been effected by changes in these main features. Of the value of this invention, Nasmyth, a devoted pupil of Maudsley and himself an eminent engineer and inventor, thus writes:—"It was this holding of a tool by means of an iron hand, and constraining it to move along the surface of the work in so certain a manner, and with such definite and precise motion, which formed the great era in the history of mechanics, inasmuch as we thenceforward became possessed, by its means, of the power of operating alike on the most ponderous or delicate pieces of machinery with a degree of minute precision, of which language cannot convey an adequate idea; and in many cases we have, through its agency, equal facility in carrying on the most perfect workmanship in the interior parts of certain machines where neither [Pg 244] the hand nor the eye can reach, and nevertheless we can give to these parts their required form with a degree of accuracy as if we had the power of transforming our-selves into pigmy workmen, and so apply our labour to the innermost holes and corners of our machinery."

The scope of the lathe, slide-rest and operating tool, by its adaptation to cut out from a vast roll of steel a ponderous gun, or by a change in the size of parts to operate in cutting or drilling the most delicate portions of that most delicate of all mechanisms, a watch, reminds one of that other marvel of mechanical adaptation, the steam hammer, which makes the earth tremble with its mighty blows upon a heated mass of iron, or lightly taps and cracks the soft-shelled nut without the slightest touch of violence upon its enclosed and fragile fruit.

The adaptation of the lathe and slide to wood-working tools will be referred to in the chapter relating to wood-working.

Following the invention of the lathe and the slide-rest, came the *metal-planing* machines. It is stated in Buchanan's *Practical Essays*, published in 1841, that a French engineer in 1751, in constructing the Marly Water Works on the Seine in France, employed a machine for planing out the wrought iron pump-barrels used in that work, and this is thought to be the first instance in which iron was reduced to a plane surface without chipping or filing. But it needed the invention of the slide-rest and its application to metal-turning lathes to suggest and render successful metal-planing machines. These were supplied in England from 1811 to 1840 by the genius of Bramah, Clement, Fox, Roberts, Rennie, Whitworth, Fletcher, and a few others. When it is

considered how many different forms are essential to the completion of metal machines of every [Pg 245]
description, the usefulness of machinery that will produce them with the greatest accuracy and despatch can be imagined. The many modifications of the planing machine have names that indicate to the workman the purpose for which they are adapted—as the *jack*, a small portable machine, quick and handy; the *jim crow*, a machine for planing both ways by reversal of the movement of the bed, and it gets its name because it can "wheel about and turn about and do just so"; the key groove machine, the milling machine with a serrated-faced cutter bar, shaping machine and shaping bar, slotting machine, crank planer, screw cutting, car-wheel turning, bolt and nut screwing, etc.

As to the mutual evolution and important results of these combined inventions, the slide-rest and the planer, we again quote Nasmyth:—

"The first planing machine enabled us to produce the second still better, and that a better still, and then slide rests of the most perfect kind came streaming forth from them, and they again assisted in making better still, so that in a very short time a most important branch of engineering business, namely, tool-making, arose, which had its existence not merely owing to the pre-existing demand for such tools, but in fact raised a demand of its own creating. One has only to go into any of these vast establishments which have sprung up in the last thirty years to find that nine-tenths of all the fine mechanisms in use and in process of production are through the agency, more or less direct, of the *slide rest and planing machine*."

Springing out of these inventions, as from a fruitful soil, came the metal-boring machines, one [Pg 246]
class for turning the outside of cylinders to make them true, and another class for boring and drilling holes through solid metal plates. The principle of the lathe was applied to those machines in which the shaft carrying the cutting or boring tool was held either in a vertical or in a horizontal position.

Now flowed forth, as from some Vulcan's titanic workshop, machines for making bolts, nuts, rivets, screws, chains, staples, car wheels, shafts, etc., and other machines for applying them to the objects with which they were to be used.

The progress of screw-making had been such that in 1840, by the machines then in use for cutting, slotting, shaving, threading, and heading, twenty men and boys were enabled to manufacture 20,000 screws in a day. Thirty-five years later two girls tending two machines were enabled to manufacture 240,000 screws a day. Since then the process has proceeded at even a greater rate. So great is the consumption of screws that it would be utterly impossible to supply the demand by the processes in vogue sixty years ago.

In England's first great International Fair, in 1851, a new world of metallurgical products, implements, processes, and metal-working tools, were among the grand results of the half century's inventions which were exhibited to the assembled nations. The leading exhibitor in the line of self-acting lathes, planing, slotting, drilling and boring machines was J. Whitworth & Co., of Manchester, England. Here were for the first time revealed in a compact form those machines which shaped metal as wood alone had been previously shaped. But another quarter of a century brought still grander results, which were displayed at the Centennial Exhibition at Philadelphia,
in 1876. [Pg 247]

As J. Whitworth & Co. were the leading exhibitors at London in 1851, so were William Sellers & Co., of Philadelphia, the leading exhibitors in the 1876 exhibition. As showing the progress of the century, the official report, made in this class by citizens of other countries than America, set forth that this exhibit of the latter company, "in extent and value, in extraordinary variety and originality, was probably without parallel in the past history of international exhibitions." Language seemed to be inadequate to enable the committee to describe satisfactorily the extreme refinement in every detail, the superior quality of material and workmanship, the mathematical accuracy, the beautiful outlines, the perfection in strength and form, and the scientific skill displayed in the remarkable assemblage of this class of machinery at that exhibition.

An exhibit on that occasion made by Messrs. Hoopes & Townsend of Philadelphia attracted great attention by the fact that the doctrine of the flow of solid metal, so well expounded by that eminent French scientist, M. Tresca, was therein well illustrated. It consisted of a large collection of bolts and screws which had been *cold-punched*, as well as of elevator and carrier chains, the links of which had been so punched. This punching of the cold metal without cutting, boring, drilling, hammering, or otherwise shaping the metal, was indeed a revelation.

So also at this Exhibition was a finer collection of machine-made horseshoes than had ever previously been presented to the world. A better and more intelligent and refined treatment of that noble animal, the horse, and especially in the care of his feet, had sprung up during the last
half century, conspicuously advocated by Mr. Fleming in England, and followed promptly in [Pg 248]
America and elsewhere. Within the last forty years nearly two hundred patents have been taken out in the United States alone for machines for making horseshoes. Prejudices, jealousies and objections of all kinds were raised at first against the machine-made horseshoe, as well as the horseshoe nail, but the horses have won, and the blacksmiths have been benefited despite their early objections. The smiths make larger incomes in buying and applying the machine-made shoes. The shoes are not only hammered into shape on the machine, but there are machines for stamping them out from metal at a single blow; for compressing several thicknesses of raw hide and moulding them in a steel mould, producing a light, elastic shoe, and without calks; furnishing

shoes for defective hoofs, flexible shoes for the relief and cure of contracted or flat feet, shoes formed with a joint at the toe, and light, hard shoes made of aluminium.

Tube Making.—Instead of heating strips of metal and welding the edges together, tubes may now be made seamless by rolling the heated metal around a solid heated rod; or by placing a hot ingot in a die and forcing a mandrel through the ingot. And as to tube and metal bending, there are wonderful machines which bend sheets of metal into great tubes, funnels, ship masts and cylinders.

Welding.—As to welding—the seams, instead of being hammered, are now formed by melting and condensing the edges, or adjoining parts, by the electric current.

Annealing and Tempering.—Steel wire and plates are now tempered and annealed by electricity. It is found that they can be heated to a high temperature more quickly and evenly by the electric current passed through them than by combustion, and the process is much used in making clock [Pg 249] and watch springs.

One way of hardening plates, especially armour plates, by what is called the Harveyized process, is by embedding the face of the plate in carbon, protecting the back and sides with sand, heating to about the melting point of cast iron, and then hardening the face by chilling, or otherwise.

Coating with Metal.—Although covering metal with metal has been practised from the earliest times, accomplished by heating and hammering, it was not until this century that electro-plating, and plating by chemical processes, as by dipping the metal into certain chemical solutions, and by the use of automatic machinery, were adopted. It was in the early part of the century that Volta discovered that in the voltaic battery certain metallic salts were reduced to their elements and deposited at the negative pole; and that Wollaston demonstrated how a silver plate in bath of sulphate of copper through which a current was passed became covered with copper. Then in 1838, Spencer applied these principles in making casts, and Jacobi in Russia shortly after electro-gilded a dome of a cathedral in St. Petersburg. Space will not permit the enumeration of the vast variety of processes and machines for coating and gilding that have since followed.

Metal Founding.—The treatment of metal after it flows from the furnaces, or is poured from the crucibles into moulds, by the operations of facing, drying, covering, casting and stripping, has given rise to a multitude of machines and methods for casting a great variety of objects. The most interesting inventions in this class have for their object the chilling, or chill hardening, of the [Pg 250] outer surfaces of articles which are subject to the most and hardest wear, as axle boxes, hammers, anvils, etc., which is effected by exposing the red-hot metal to a blast of cold air, or by introducing a piece of iron into a mould containing the molten metal.

In casting steel ingots, in order to produce a uniform compact structure, Giers of England invented "soaking pits of sand" into which the ingot from the mould is placed and then covered, so that the heat radiating outward re-heats the exterior, and the ingot is then rolled without re-heating.

Sheet Metal Ware.—Important improvements have been made in this line. Wonderful machines have been made which, receiving within them a piece of flat metal, will, by a single blow of a plunger in a die, stamp out a metal can or box with tightly closed seams, and all ready for the cover, which is made in another similar machine; or by which an endless chain of cans are carried into a machine and there automatically soldered at their seams; and another which solders the heads on filled cans as fast as they can be fed into the machine.

Metal Personal Ware.—Buckles, clasps, hooks and eyelets, shanked buttons, and similar objects are now stamped up and out, without more manual labour than is necessary to supply the machines with the metal, and to take care of the completed articles.

Wire Working.—Not only unsightly but useful barbed wire fences, and the most ornamental wire work and netting for many purposes, such as fences, screens, cages, etc., are now made by ingenious machines, and not by hand tools.

In stepping into some one of the great modern works where varied industries are carried on under one general management, one cannot help realising the vast difference between old [Pg 251] systems and the new. In one portion of the establishment the crude ores are received and smelted and treated, with a small force and with ease, until the polished metal is complete and ready for manipulation in the manufacture of a hundred different objects. In another part ponderous or smaller lathes and planing machines are turning forth many varied forms; in quiet corners the boring, drilling, and riveting machines are doing their work without the clang of hammers; in another, an apparently young student is conducting the scientific operation of coating or gilding metals; in another, girls may be seen with light machines, stamping, or burnishing, or assembling the different parts of finished metal ware; and the motive power of all this is the silent but all-powerful electric current received from the smooth-running dynamo giant who works with vast but unseen energy in a den by himself, not a smoky or a dingy den, but light, clean, polished, and beautiful as the workshop of a god.

[Pg 252]

CHAPTER XVI.

ORDNANCE, ARMS AND EXPLOSIVES.

Although the progress in the invention of fire-arms of all descriptions seems slow during the ages preceding the 19th century, yet it will be found on investigation that no art progressed faster. No other art was spurred to activity by such strong incentives, and none received the same encouragement and reward for its development. The art of war was the trade of kings and princes, and princely was the reward to the subject who was the first to invent the most destructive weapon. Under such high patronage most of the ideas and principles of ordnance now prevailing were discovered or suggested, but were embodied for the most part in rude and inefficient contrivances.

The art waited for its success on the development of other arts, and on the mental expansion and freedom giving rise to scientific investigation and results.

The cannon and musket themselves became the greatest instruments for the advancement of the new civilisation, however much it was intended otherwise by their kingly proprietors, and the new civilisation returned the compliment through its trained intellects by giving to war its present destructive efficiency.

To this efficiency, great as the paradox may seem, Peace holds what quiet fields it has, or will have, until most men learn to love peace and hate the arts of war. [Pg 253]

As to the Chinese is given the credit for the invention of gunpowder, so they must also be regarded as the first to throw projectiles by its means. But their inventions in these directions may be classed as fireworks, and have no material bearing on the modern art of Ordnance. It is supposed that the word "cannon," is derived from the same root as "cane," originally signifying a hollow reed; and that these hollow reeds or similar tubes closed at one end were used to fire rockets by powder.

It is also stated that the practice existed among the Chinese as early as 969 A. D. of tying rockets to their arrows to propel them to greater distances, as well as for incendiary purposes.

This basic idea had percolated from China through India to the Moors and Arabs, and in the course of a few centuries had developed into a crude artillery used by the Moors in the siege of Cordova in 1280. The Spaniards, thus learning the use of the cannon, turned the lesson upon their instructors, when under Ferdinand IV. they took Gibraltar from the Moors in 1309. Then the knowledge of artillery soon spread throughout Europe. The French used it at the siege of Puy Guillaume in 1338, and the English had three small guns at Crecy in 1346. These antique guns were made by welding longitudinal bars of iron together and binding them by iron rings shrunk on while hot. Being shaped internally and externally like an apothecary's mortar, they were called mortars or bombards. Some were breech-loaders, having a removable chamber at the breech into which the charge of powder was inserted behind the ball. The balls were stone. These early cannon, bombards, and mortars were mounted on heavy solid wooden frames and moved [Pg 254] with great difficulty from place to place. Then in the fifteenth century they commenced to make wrought-iron cannon, and hollow projectiles, containing a bursting charge of powder to be exploded by a fuse lit before the shell was fired. In the next century cannon were cast.

The Hindoos, when their acquaintance was made by the Europeans, were as far advanced as the latter in cannon and fire-arms. One cannon was found at Bejapoor, in India, cast of bronze, bearing date 1548, and called the "Master of the Field," which weighed 89,600 pounds, and others of similar size of later dates. Great cast bronze guns of about the same weight as the Hindoo guns were also produced at St. Petersburg, Russia, in the sixteenth century.

Many and strange were the names given by Europeans to their cannon in the fifteenth and sixteenth centuries to denote their size and the weight of the ball they carried: such as the Assick, the Bombard, the Basilisk, the cannon Royal, or Carthoun, the Culverin, Demi-culverin, Falcon, Siren, Serpentine, etc.

The bombards in the fifteenth century were made so large and heavy, especially in France, that they could not be moved without being taken apart.

When the heavy, unwieldy bombards with stone balls were used, artillery was mostly confined to castles, towns, forts, and ships. When used in the field they were dragged about by many yokes of oxen. But in the latter part of the fifteenth century, when France under Louis XI. had learned to cast lighter brass cannon, to mount them on carriages that could be drawn by four or six horses, and which carriages had trunnions in which the cannon were swung so as to be elevated or depressed, and cast-iron projectiles were used instead of stones, field artillery took its rise, and [Pg 255] by its use the maps of the world were changed. Thus with their artillery the French under Charles VIII., the successor of Louis XI., conquered Italy.

In the sixteenth century Europe was busy in adopting these and other changes. Cannon were made of all sizes and calibres, but were not arranged in battle with much precision. Case shot were invented in Germany but not brought into general use. Shells were invented by the Italians and fired from mortars, but their mode of construction was preserved in great secrecy. The early breech-loaders had been discarded, as it was not known how to make the breech gas-tight, and the explosions rendered the guns more dangerous to their users than to the enemy.

In the seventeenth century Holland began to make useful mortar shells and hand grenades. Maurice and Henry Frederick of Nassau, and Gustave Adolphus, made many improvements in the sizes and construction of cannon. In 1674, Coehorn, an officer in the service of the Prince of Orange, invented the celebrated mortar which bears his name, and the use of which has continued to the present time. The Dutch also invented the howitzer, a short gun in which the projectiles could be introduced by hand. About the same time Comminges of France invented mortars which threw projectiles weighing 550 pounds. In this part of that century also great improvements were made under Louis XIV. Limbers, by which the front part of the gun carriage was made separable from the cannon part and provided with the ammunition chest; the prolonge, a cord and hook by which the gun part could be moved around by hand; and the elevating screw, [Pg 256] by which the muzzle of the gun could be raised or depressed,—were invented.

In the early part of the eighteenth century it was thought by artillerists in England that the longer the gun the farther it would carry. One, called "Queen Ann's Pocket Piece" still preserved at Dover, is twenty-five feet long and carries a ball only twenty-five pounds in weight. It was only after repeated experiments that it was learned that the shorter guns carried the projectile the greatest distance.

The greatest improvements in the eighteenth century were made by Gribeauval, the celebrated French artillerist, about 1765. He had guns made of such material and of such size as to adapt them to the different services to which they were to be put, as field, siege, garrison, and sea coast. He gave greater mobility to the system by introducing six-pound howitzers, and making gun carriages lighter; he introduced the system of fixed ammunition, separate compartments in the gun carriages for the projectiles, and the charges of powder in paper or cloth bags or cylinders; improved the construction of the elevating screw, adapted the tangent scale, formed the artillery into horse batteries, and devised new equipments and a new system of tactics.

It was with Gribeauval's improved system that "Citizen Bonaparte, young artillery officer," took Toulon; with which the same young "bronze artillery officer" let go his great guns in the Cul-de-Sac Dauphin against the church of St. Roch; on the Port Royal; at the Theatre de la Republique; "and the thing we specifically call French Revolution is blown into space by it, and became a thing that was."

It was with this system that this same young officer won his first brilliant victories in Italy. When [Pg 257] the fruit of these victories had been lost during his absence he reappeared with his favorite artillery, and on the threshold of the century, in May 1800, as "First Consul of the Republic" re-achieved at Marengo the supremacy of France over Austria.

As to *small arms*, as before suggested, they doubtless had their origin in the practice of the Chinese in throwing fire balls from bamboo barrels by the explosion of light charges of powder, as illustrated to this day in what are known as "Roman Candles." Fire-crackers and grenades were also known to the Chinese and the Greeks.

Among ancient fire-arms the principal ones were the arquebus, also bombardelle, and the blunderbuss. They were invented in the fourteenth century but were not much used until the fifteenth century. These guns for the most part were so heavy that they had to be rested on some object to be fired. The soldiers carried a sort of tripod for this purpose. The gun was fired by a slow-burning cord, a live coal, a lit stick, or a long rod heated at one end, and called a match. The blunderbuss was invented in Holland. It was a large, short, funnel-shaped muzzle-loader, and loaded with nails, slugs, etc. The injuries and hardships suffered by the men who used it, rather than by the enemy, rendered its name significant. Among the earliest fire-arms of this period one was invented which was a breech-loader and revolver. The breech had four chambers and was rotated by hand on an arbour parallel to the barrel. The extent of its use is not learned. To ignite the powder the "wheel-lock" and "snap-haunce" were invented by the Germans in the sixteenth century. The wheel lock consisted of a furrowed wheel and was turned by the trigger and chain against a fixed piece of iron on the stock to excite sparks which fell on to the priming. The snap- [Pg 258] haunce, a straight piece of furrowed steel, superseded the wheel-lock. The sixteenth century had got well started before the English could be induced to give up the cross-bow and arrow, and adopt the musket. After they had introduced the musket with the snap-haunce and wooden ramrod, it became known, in the time of Queen Elizabeth, as the "Brown Bess."

The "old flint-lock" was quite a modern invention, not appearing until the seventeenth century. It was a bright idea to fix a piece of flint into the cock and arrange it to strike a steel cap on the priming pan when the trigger was fired; and it superseded the old match, wheel-lock, and snap-haunce. The flint-lock was used by armies well into the nineteenth century, and is still in private use in remote localities. As the arquebus succeeded the bow and arrow, so the musket, a smooth and single-barrel muzzle-loader with a flint-lock and a wooden ramrod, succeeded the arquebus. Rifles, which were the old flint-lock muskets with their barrels provided with spiral grooves to give the bullet a rotary motion and cause it to keep one point constantly in front during its flight, is claimed as the invention of Augustin Kutler of Germany in 1520, and also of Koster of Birmingham, England, about 1620. Muskets with straight grooves are said to have been used in the fifteenth century.

The rifle with a long barrel and its flint-lock was a favourite weapon of the American settler. It was made in America, and he fought the Indian wars and the war of the Revolution with it.

It would not do to conclude this sketch of antique cannon and fire-arms without referring to Puckle's celebrated English patent No. 418, of May 15, 1718, for "A Defence." The patent starts [Pg 259] out with the motto:

> "Defending King George, your Country, and Lawes,
> Is defending Yourselves and Protestant Cause."

It proceeds to describe a "Portable Gun or Machine" having a single barrel, with a set of removable chambers which are charged with bullets before they are placed in the gun, a handle to turn the chambers to bring each chamber in line with the barrel, a tripod on which the gun is mounted and on which it is to be turned, a screw for elevating and turning the gun in different directions, a set of square chambers "for shooting square bullets against Turks," a set of round chambers "for shooting round bullets against the Christians;" and separate drawings show the square bullets for the Turks and the round bullets for the Christians. History is silent as to whether Mr. Puckle's patent was put in practice, but it contained the germs of some modern inventions.

Among the first inventions of the century was a very important one made by a clergyman, the Rev. Mr. Forsyth, a Scotchman, who in 1803 invented the percussion principle in fire-arms. In 1807 he patented in England detonating powder and pellets which were used for artillery. About 1808 General Shrapnel of the English army invented the celebrated shell known by his name. It then consisted of a comparatively thin shell filled with bullets, having a fuse lit by the firing of the gun, and adapted to explode the shell in front of the object fired at. This fuse was superseded by one invented by General Bormann of Belgium, which greatly added to the value of case shot. [Pg 260]

In 1814 Joshua Shaw of England invented the percussion cap. Thus, by the invention of the percussion principle by Forsyth, and that little copper cylinder of Shaw, having a flake of fulminating powder inside and adapted to fit the nipple of a gun and be exploded by the fall of the hammer, was sounded the death knell of the old flint-locks with which the greatest battles of the world had been and were at that time being fought. The advantages gained by the cap were the certain and instantaneous fire, the saving in time, power, and powder obtained by making smaller the orifice through which the ignition was introduced, and the protection from moisture given by the covering cap. And yet so slow is the growth of inventions sometimes that all Europe continued to make the flint-locks for many years after the percussion cap was invented; and General Scott, in the war between the United States and Mexico in 1847, declined to give the army the percussion cap musket. The cap suggested the necessity and invention of machines for making them quickly and in great quantities.

The celebrated "Colt's" revolver was invented by Colonel Samuel Colt of the United States, in 1835. He continued to improve it, and in 1851 exhibited it at the World's Fair, London, where it excited great surprise and attention. Since then the revolver has become a great weapon in both private and public warfare. The next great inventions in small arms were the readoption and improvement of the breech-loader, the making of metallic cartridges, the magazine gun, smokeless powder and other explosives, to which further reference will be made.

To return to cannons:—In 1812 Colonel Bomford, an American officer, invented what is called the "Columbiad," a kind of cannon best adapted for sea-coast purposes. They are long-chambered pieces, combining certain qualities of the gun, howitzer and mortar, and capable of projecting shells and solid shot with heavy charges of powder at high angles of elevation, and peculiarly adapted to defend narrow channels and sea-coast defences. A similar gun was invented by General Paixhans of the French army in 1822. The adoption of the Paixhans long-chambered guns, designed to throw heavy shells horizontally as well as at a slight elevation and as easily as solid shot, was attended with great results. Used by the French in 1832, in the quick victorious siege of Antwerp, by the allies at Sebastopol, where the whole Russian fleet was destroyed in about an hour, and in the fight of the Kearsarge and the doomed Alabama off Cherbourg in the American civil war, it forced inventors in the different countries to devise new and better armour for the defence of ships. This was followed by guns of still greater penetrative power. Then as another result effected by these greater guns came the passing away of the old-fashioned brick and stone forts as a means of defence. [Pg 261]

In an interesting address by Major Clarence E. Dutton of the Ordnance Department, U.S.A., at the Centennial Patent Congress at Washington in 1891, he thus stated what the fundamental improvements were that have characterised the modern ordnance during the century:

1. The regulation and control of the action of gunpowder in such a manner as to exert less strain upon the gun, and to impart more energy to the projectile.

2. To so construct the gun as to transfer a portion of the strain from the interior parts of the walls which had borne too much of it, to the exterior parts which had borne too little, thus nearly equalising the strain throughout the entire thickness of the walls. [Pg 262]

3. To provide a metal which should be at once stronger and safer than any which had been used before.

In the United States General Rodman, "one of the pioneers of armed science," commenced about 1847 a series of investigations and experiments on the power and action of gunpowder and the strains received by every part of the gun by the exploding gases, of very great importance; and in this matter he was assisted greatly by Dr. W. E. Woodbridge, who invented an ingenious apparatus termed a "piezometer," or a pressure measurer, by which the pressure of the gases at the various parts of the gun was determined with mathematical certainty.

Dr. Woodbridge also added greatly to the success of rifled cannon. The success in rifling small arms, by which an elongated ball is made to retain the same end foremost during its flight, led again to the attempts of rifling cannon for the same purpose, which were finally successful. But this success was due not to the spiral grooves in the cannon bore, but in attachments to the ball compelling it to follow the course of the grooves and giving it the proper initial movement. The trouble with these attachments was that they were either stripped off, or stripped away, by the gun spirals. Woodbridge in 1850 overcame the difficulty by inventing an improved *sabot*, consisting of a ring composed of metal softer than the projectile or cannon, fixed on the inner end of the projectile and grooved at its rear end, so that when the gun is fired and the ball driven forward these grooves expand, acting valvularly to fill the grooves in the gun, thus preventing the [Pg 263]
escape of the gases, while the ring at the same time is forced forward on to the shell so tightly and forcibly that the projectile is invariably given a rotary motion and made to advance strictly in the line of axis of the bore, and in the same line during the course of its flight. This invention in principle has been followed ever since, although other forms have been given the sabot, and it is due to this invention that modern rifled cannon have been so wonderfully accurate in range and efficient in the penetrating and destructive power both on sea and land.

Woodbridge also invented the *wire-wound cannon*, and a machine for winding the wire upon the gun, thus giving the breach part, especially, immense strength.

In England, among the first notable and greater inventors in ordnance during the latter half of the century, a period which embraces the reduction to practice of the most wonderful and successful inventions in weapons of war which the world had up to that time seen, are Lancaster, who invented the elliptical bore; Sir William Armstrong, who, commencing in 1885, constructed a gun built of wrought-iron bars twisted into coils and applied over a steel core and bound by one or more wrought-iron rings, all applied at white heat and shrunk on by contraction due to cooling, by which method smooth-bore, muzzle-loading cannon of immense calibre, one weighing one hundred tons, were made. They were followed by Armstrong, inventor of breech-loaders; Blakely, inventor of cannon made of steel tubes and an outer jacket of cast iron; and Sir Joseph Whitworth, inventor of most powerful steel cannon and compressed steel projectiles. [Pg 264]

In Germany, Friedrich Krupp at Essen, Prussia, invented and introduced such improvements in breech-loading cannon as revolutionised the manufacture of that species of ordnance, and established the foundation of the greatest ordnance works in the world. The first of his great breech-loading steel guns was exhibited at the Paris Exhibition in 1867. A Krupp gun finished at Essen in the 70's was then the largest steel gun the world had ever seen. It weighed seventy-two tons, and was thirty-two feet long. The charge consisted of 385 pounds of powder, the shell weighed 1,660 pounds, having a bursting charge of powder of 22 pounds, and a velocity of 1,640 feet per second. It was estimated that if the gun were fired at an angle of 43° the shell would be carried a distance of fifteen miles. It was in the Krupp guns, and also in the Armstrong breech-loaders, that a simple feature was for the first time introduced which proved of immense importance in giving great additional expansive force to the explosion of the powder. This was an increase in the size of the powder chamber so as to allow a vacant space in it unfilled with powder.

In the United States, Rodman, commencing in 1847, and Dahlgren in 1850, and Parrott in 1860, invented and introduced some noticeable improvements in cast-iron, smooth-bore, and rifled cannon.

In France General Paixhans and Colonel Treuille de Beaulieu improved the shells and ordnance.

The latest improvements in cannon indicate that the old smooth-bore muzzle-loader guns are to be entirely superseded by breech-loaders, just as in small arms the muzzle-loading musket has given way to the breech-loading rifle.

A single lever is now employed, a single turn of which will close or open the breech, and when [Pg 265]
opened expel the shell by the same movement. Formerly breech-loaders were confined to the heaviest ordnance; now they are a part of the lightest field pieces.

As to the operation of those immense guns above referred to, which constitute principally sea-coast defences and the heavy armament for forts, gun carriages have been invented whereby the huge guns are quickly raised from behind immense embrasures by pneumatic or hydraulic cylinders, quickly fired (the range having been before accurately ascertained) and then as quickly lowered out of sight, the latter movement being aided by the recoil action of the gun.

It is essential that the full force of the gases of explosion shall be exerted against the base of the projectile, and therefore all escape of such gases be prevented. To this end valuable improvements in *gas checks* have been made,—one kind consisting of an annular canvas sack containing asbestos and tallow placed between the front face of the breech block and a mushroom-shaped piece, against which the explosion impinges.

As among projectiles and shells for cannon those have been invented which are loaded with dynamite or other high explosive, a new class of *Compressed air ordnance* has been started, in which air or gas is used for the propelling power in place of powder, whereby the chances of exploding such shells in the bore of the gun are greatly lessened.

The construction of metals, both for cannon to resist most intense explosives and for plates to resist the penetration of the best projectiles, have received great attention. They are matters pertaining to metallurgy, and are treated of under that head. The strife still continues between [Pg 266] impenetrable armour plate and irresistible projectiles. Within the last decade or so shells have been invented with the design simply to shatter or fracture the plate by which the way is broken for subsequent shots. Other shells have been invented carrying a high explosive and capable of penetrating armour plates of great thickness, and exploding after such penetration has taken place.

A great accompaniment to artillery is "The Range Finder," a telescopic apparatus for ascertaining accurately the location and distance of objects to be fired at.

Returning to *small arms*,—at the time percussion caps were invented in England, 1803-1814, John H. Hall of the United States invented a breech-loading rifle. It was in substance an ordinary musket cut in two at the breech, with the rear piece connected by a hinge and trunnion to the front piece, the bore of the two pieces being in line when clamped, and the ball and cartridge inserted when the chamber was thrown up. A large number were at once manufactured and used in the U.S. Army. A smaller size, called *carbines*, were used by the mounted troops. After about twenty years' use these guns began to be regarded as dangerous in some respects, and their manufacture and use stopped, although the carbines continued in use to some extent in the cavalry. A breech-loading rifle was also invented by Colonel Pauly of France in 1812, and improved by Dreyse in 1835; also in Norway in 1838, and in a few years adopted by Sweden as superior to all muzzle-loading arms. About 1841 the celebrated "Needle Gun" was invented in Prussia, and its superiority over all muzzle-loaders was demonstrated in 1848 in the first Schleswig-Holstein war.

Cartridges, in which the ball and powder were secured together in one package, were old in artillery, as has been shown, but their use for small arms is a later invention. *Metallic* cartridges, made of sheet metal with a fulminate cap in one end and a rim on the end of the shell by which it could be extracted after the explosion, were invented by numerous persons in Europe and America during the evolution of the breech-loader. Combined metal case and paper patented in England in 1816, and numerous wholly metallic cartridge shells were patented in England, France, and United States between 1840 and 1860. M. Lefaucheux of France, in the later period, devised a metal *gas check* cartridge which was a great advance.

A number of inventors in the United States besides Hall had produced breech-loading small arms before the Civil War of 1861, but with the exception of Colt's revolver and Sharp's carbine, the latter used by the cavalry to a small extent, none were first adopted in that great conflict. Later, the Henry or Winchester breech-loading rifle and the Spencer magazine gun were introduced and did good service. But the whole known system of breech-loading small arms was officially condemned by the U.S. Military authorities previous to that war. The absence of machines to make a suitable cartridge in large quantities and vast immediate necessities compelled the authorities to ignore the tested Prussian and Swedish breech-loaders and those of their own countrymen and to ransack Europe for muskets of ancient pattern. These were worked by the soldiers under the ancient tactics, of load, ram, charge and fire, until a stray bullet struck the ramrod, or the discharge of a few rammed cartridges so over-heated the musket as to thereby dispense with the soldier and his gun for further service in that field. However, private individuals and companies continued to invent and improve, and the civil war in America revolutionised the systems of warfare and its weapons. The wooden walls of the navies disappeared as a defence after the conflict between the Monitor and the Merrimac, and muzzle-loading muskets became things of the past.

Torpedoes, both stationary and movable, then became a successful weapon of warfare. Soon after that war, and when the United States had adopted the Springfield breech-loading rifle, the works at Springfield were equipped with nearly forty different machines, each for making a separate part of a gun in great quantities. Many of these had been invented by Thomas Blanchard forty years before. That great inventor of labour-saving machinery had then designed machines for the shaping and making of gun stocks and for forming the accompanying parts. Blanchard was a contemporary of Hall, and Hall, to perfect his breech-loader, was the first to invent machines for making its various parts. His was the first interchangeable system in the making of small arms.

Army officers had come to regard "the gun as only the casket while the cartridge is the jewel;" and to this end J. G. Gill at the U.S. Arsenal at Frankford, Philadelphia, devised a series of cartridge-making machines which ranked among the highest triumphs of American invention.

The single breech-loader is now being succeeded by the magazine gun, by which a supply of cartridges in a chamber is automatically fed into the barrel. The Springfield, has been remodelled as a magazine loader. Among later types of repeating rifles, known from the names of their inventors, are the "Krag-Jorgensen," and the "Mauser," and the crack of these is heard around the world. Modern rifles are rendered more deadly by the fact that they can be loaded and fired in a recumbent position, and with smokeless powder, by which the soldier and his location remain concealed from his foe.

The recoil of the gun in both large and small arms is now utilised to expel the fired cartridge shell, and to withdraw a fresh one from its magazine and place it in position in the chamber. *Compressed air and explosive gases* have been used for the same purpose. A small *electric battery* has been placed in the stock to explode the cartridge when the trigger is pulled.

Sporting guns have kept pace with other small arms in improvements, and among modern forms are those which discharge in alternative succession the two barrels by a single trigger. Revolvers have been improved and the Smith and Wesson is known throughout the world.

The idea of *Machine Guns*, or *Mitrailleuses*, was not a new one, as we have seen from Puckle's celebrated patent of 1718. Also history mentions a gun composed of four breech-loading tubes of small calibre, placed on a two-wheeled cart used in Flanders as early as 1347, and of four-tubed guns used by the Scotch during the civil war in 1644. The machine gun invented by Dr. Gatling of the United States during the Civil War and subsequently perfected, has become a part of the armament of every civilised nation. The object of the gun is to combine in one piece the destructive effect of a great many, and to throw a continuous hail of projectiles. The gun is mounted on a tripod; the cartridges are contained in a hopper mounted on the breech of the gun and are fed from locks into the barrels (which are usually five or ten in number) as the locks and barrels are revolved by a hand crank. As the handle is turned the cartridges are first given a forward motion, which thrusts them into the barrels, closes the breech and fires the cartridges in succession, and then a backward motion which extracts the empty shells. The gun weighs one hundred pounds and firing may be kept up with a ten-barreled gun at one thousand shots a minute. [Pg 270]

The *Hotchkiss* revolving cannon is another celebrated American production named from its inventor, and constructed to throw heavier projectiles than the Gatling. It also has revolving barrels and great solidity in the breech mechanism. It has been found to be of great service in resisting the attacks of torpedo boats. It is adapted to fire long-range shells with great rapidity and powerful effect, and is exceedingly efficient in defence of ditches and entrenchments.

Explosives.—The desire to make the most effective explosives for gunnery led to their invention not only for that purpose but for the more peaceful pursuit of blasting. *Gun Cotton*, that mixture of nitric acid and cotton, made by Schönbein in 1846, and experimented with for a long time as a substitute for gunpowder in cannon and small arms and finally discarded for that purpose, is now being again revived, but used chiefly for blasting. This was followed by the discovery of nitro-glycerine, a still more powerful explosive agent—too powerful and uncontrollable for guns as originally made. They did not supersede gunpowder, but smokeless powders have come, containing nitro-cellulose, or nitro-glycerine rendered plastic, coherent and homogeneous, and converted into rods or grains of free running powder, to aid the breech-loaders and magazine guns, while the high explosives, gun-cotton, nitro-glycerine, dynamite, dualine, etc., have become the favorite agencies for those fearful offensive and defensive weapons, the *Torpedoes*. From about the time of the discovery of gunpowder, stationary and floating chambers and mines of powder, to be discharged in early times by fuses (later by percussion or electricity), have existed, but modern inventions have rendered them of more fearful importance than was ever dreamed of before this century. The latest invention in this class is the *submarine torpedo boat*, which, moving rapidly towards an enemy's vessel, suddenly disappears from sight beneath the water, and strikes the vessel at its lowest or most vulnerable point. [Pg 271]

To the inquiry as to whether all this vast array of modern implements of destruction is to lessen the destruction of human life, shorten war, mitigate its horrors and tend toward peace, there can be but one answer. All these desirable results have been accomplished whenever the new inventions of importance have been used. "Warlike Tribes" have been put to flight so easily by civilised armies in modern times that such tribes have been doubted as possessing their boasted or even natural courage. Nations with a glorious past as to bravery but with a poor armament have gone down suddenly before smaller forces armed with modern ordnance. The results would have been reversed, and the derision would have proceeded from the other side, if the conditions had been reversed, and those tribes and brave peoples been armed with the best weapons and the knowledge of their use. The courage of the majority of men on the battle-field is begot of confidence and enthusiasm, but this confidence and enthusiasm, however great the cause, soon fail, and discretion becomes the better part of valour, if men find that their weapons are weak and useless against vastly superior arms of the enemy. The slaughter and destruction in a few hours with modern weapons may not be more terrible than could be inflicted with the old arms by far greater forces at close quarters in a greater length of time in the past, but the end comes sooner; and the prolongation of the struggle with renewed sacrifices of life, and the long continued and exhausting campaigns, giving rise to diseases more destructive than shot or shell, are thereby greatly lessened, if not altogether avoided. [Pg 272]

[Pg 273]

CHAPTER XVII.

PAPER AND PRINTING.

Paper-making.—"The art preservative of all arts"—itself must have means of preservation, and hence the art of paper-making precedes the art of printing.

It was Pliny who wrote, at the beginning of the Christian era, that "All the usages of civilised life depend in a remarkable degree upon the employment of paper. At all events the remembrance of past events."

Naturally to the Chinese, the Hindoo, and the Egyptian, we go with inquiries as to origin, and find that as to both arts they were making the most delicate paper from wood and vegetable fibres and printing with great nicety, long before Europeans had even learned to use papyrus or parchment, or had conceived the idea of type.

So far as we know the wasp alone preceded the ancient Orientals in the making of paper. Its gray shingled house made in layers, worked up into paper by a master hand from decayed wood, pulped, and glutinised, waterproofed, with internal tiers of chambers, a fortress, a home, and an airy habitation, is still beyond the power of human invention to reproduce.

Papyrus—the paper of the Egyptians: Not only their paper, but its pith one of their articles of food, and its outer portions material for paper, boxes, baskets, boats, mats, medicines, cloths and other articles of merchandise.

Once one of the fruits of the Nile, now no longer growing there. On its fragile leaves were recorded and preserved the ancient literatures—the records of dynasties—the songs of the Hebrew prophets—the early annals of Greece and Rome—the vast, lost tomes of Alexandria. Those which were fortunately preserved and transferred to more enduring forms now constitute the greater part of all we have of the writings of those departed ages.

In making paper from papyrus, the inner portion next to the pith was separated into thin leaves; these were laid in two or more layers, moistened and pressed together to form a leaf; two or more leaves united at their edges if desired, or end to end, beaten smooth with a mallet, polished with a piece of iron or shell, the ends, or sides, or both, of the sheet sometimes neatly ornamented, and then rolled on a wooden cylinder. The Romans and other ancient nations imported most of their papyrus from Egypt, although raising it to considerable extent in their own swamps.

In the seventh century, the Saracens conquered Egypt and carried back therefrom, papyrus, and the knowledge of how to make paper from it to Europe.

Parchment manufactured from the skins of young calves, kids, lambs, sheep, and goats, was an early rival of papyrus, and was known and used in Europe before papyrus was there introduced.

The softening of vegetable and woody fibre of various kinds, flax and raw cotton and rags, and reducing it into pulp, drying, beating, and rolling it into paper, seem to have been suggested to Europe by the introduction of papyrus, for we learn of the first appearance of such paper by the Arabians, Saracens, Spaniards and the French along through the eighth, ninth, and tenth and eleventh centuries. Papyrus does not, however, appear to have been superseded until the twelfth century.

Public documents are still extant written in the twelfth century on paper made from flax and rags; and paper mills began to put in an appearance in Germany in the fourteenth century, in which the fibre was reduced to pulp by stampers. England began to make paper in the next century. Pulping the fibre by softening it in water and beating the same had then been practised for four centuries. Rollers in the mills for rolling the pulp into sheets were introduced in the fifteenth century, and paper makers began to distinguish their goods from those made by others by water marks impressed in the pulp sheets. The jug and the pot was one favourite water mark in that century, succeeded by a fool's cap, which name has since adhered to paper of a certain size, with or without the cap. So far was the making of paper advanced in Europe that about 1640 wall paper began to be made as a substitute for tapestry; although as to this fashion the Chinese were still ahead some indefinite number of centuries.

Holland was far advanced in paper-making in the seventeenth century. The revolution of 1688 having seriously interrupted the art in England, that country imported paper from Holland during that period amounting to £100,000. It was a native of Holland, Rittenhouse, who introduced paper-making in America and erected a mill near Philadelphia in the early years of the eighteenth century, and there made paper from linen rags.

The Dutch also had substituted cylinders armed with blades in place of stampers and used their windmills to run them. The Germans and French experimented with wood and straw.

In the latter part of the eighteenth century some manufacturers in Europe had learned to make white paper from white rags, and as good in quality, and some think better, than is made at the present day. The essentials of paper making by hand from rags and raw vegetable fibres, the soaking of fibres in water and boiling them in lyes, the beating, rolling, smoothing, sizing and polishing of the paper, were then known and practised. But the best paper was then a dear commodity. The art of bleaching coloured stock was unknown, and white paper was made alone from stock that came white into the mill. The processes were nearly all hand operations. "Beating" was pounding in a mortar. The pulp was laid by hand upon moulds made of parallel strands of coarse brass wire; and the making of the pulp by grinding wood and treating it chemically to soften it was experimental.

The nineteenth century produced a revolution. It introduced the use of modern machinery, and modern chemical processes, by which all known varieties and sizes of paper, of all colours, as well as paper vessels, are made daily in immense quantities in all civilised countries, from all sorts of fibrous materials.

Knight, in his *Mechanical Dictionary*, gives a list of nearly 400 different materials for paper making that had been used or suggested, for the most part within the century and up to twenty years ago, and the number has since increased.

The modern revolution commenced in 1799, when Louis Robert, an employee of François Didot of Essones, France, invented and patented the first machine for making paper in a long, wide, continuous web. The French government in 1800 granted him a reward of 8,000 francs. The machine was then exhibited in England and there tested with success. It was there that Messrs. [Pg 277] Fourdrinier, a wealthy stationery firm, purchased the patents, expended £60,000 for improvements on the machine, and first gave to the world its practical benefits. This expenditure bankrupted them, as the machines were not at once remunerative, and parliament refused to grant them pecuniary assistance. Gamble, Donkin, Koops, the Fourdriniers, Dickenson, and Wilkes, were the first inventors to improve the Robert machine, and to give it that form which in many essential features remains to-day. They, together with later inventors, gave to the world a new system of paper making.

By 1872 two hundred and ninety-nine Fourdrinier machines were running in the United States alone. In the improved Fourdrinier machine or system, rags, or wood, or straw are ground or otherwise reduced to pulp, and then the pulp, when properly soaked and drained, is dumped into a regulating box, passing under a copper gate to regulate the amount and depth of feed, then carried along through strainers, screeners or dressers, to free the mass from clots and reduce it to the proper fineness, over an endless wire apron, spread evenly over this apron by a shaking motion, subjected to the action of a suction box by which the water is drawn off by air-suction pumps, carried between cloth-covered rollers which press and cohere it, carried on to a moving long felt blanket to further free it from moisture, and which continues to hold the sheet of pulp in form; then with the blanket through press rolls adjustable to a desired pressure and provided with means to remove therefrom adhering pulp and to arrest the progress of the paper if necessary; then through another set of compression rollers, when the condensed and matted [Pg 278] pulp, now paper, is carried on to a second blanket, passed through a series of steam cylinders, where the web is partially dried, and again compressed, thence through another series of rollers and drying cylinders, which still further dry and stretch it, and now, finally completed, the sheet is wound on a receiving cylinder. The number of rollers and cylinders and the position and the length of the process to fully dry, compact, stretch and finish the sheet, may be, and are, varied greatly. If it is desired to impress on or into the paper water marks, letters, words, or ornamental matter, the paper in its moist stage, after it passes through the suction boxes, is passed under a "dandy" or fancy scrolled roll provided on its surface with the desired design. When it is desired to give it a smooth, glossy surface, the paper, after its completion, is passed through animal sizing material, and then between drying and smoothing rollers. Or this sizing may be applied to the pulp at the outset of the operation. Colouring material, when desired, is applied to the pulp, before pressing. By the use of machines under this system, a vast amount of material, cast-off rags, etc., before regarded as waste, was utilised for paper making.

The modern discoveries of the chemists of the century as to the nature of fibres, best modes and materials for reducing them to pulp, and bleaching processes, have brought the art of paper making from wood and other fibrous materials to its present high and prosperous condition.

What are known as the soda-pulp and the sulphite processes are examples of this. The latter and other acid processes were not successful until cement-lined digesters were invented to withstand their corroding action. But now it is only necessary to have a convenient forest of almost any kind [Pg 279] of wood to justify the establishment of a paper mill.

It was the scarcity of rags, especially of linen rags, that forced inventors to find other paper-producing materials.

It would be impossible and uninteresting in a work of this character to enumerate the mechanical details constituting the improvements of the century in paper-making machinery of all kinds. Thousands of patents have been granted for such inventions. With one modern Fourdrinier machine, and a few beating engines, a small paper mill will now turn out daily as much paper as could be made by twelve mills a hundred years ago.

In moulding pulp into articles of manufacture, satisfactory machines have been invented, not only for the mere forming them into shape, but for water-proofing and indurating the same. From the making of a ponderous paper car wheel to a lady's delicate work basket, success has been attained.

Paper bag machines, machines for making *paper boxes*, applying and staying corners of such boxes, for making *cell cases* used in packing eggs and fruit, and for wrapping fruit; machines for affixing various forms of labels and addresses, are among the wonders of modern inventions relating to paper. It is wonderful how art and ingenuity united about thirty years ago to produce attractive *wall papers*. Previous to that time they were dull and conventional in appearance. Now beautiful designs are rolled out from machines.

Printing.—We have already seen how paper making and printing grew up together an indefinite number of centuries ago in the Far East. Both block printing and movable types were the [Pg 280] production of the Chinese, with which on their little pages of many-coloured paper they printed myriads of volumes of their strange literature in stranger characters during centuries when Europeans were painfully inscribing their thoughts with the stylus and crude pens upon papyrus and the dried skins of animals.

But the European and his descendants delight to honour most the early inventors of their own countries. Italy refers with pride to the printing from blocks practised by the Venetians, and at Ravenna, from 1280 to 1300; from type at Subiaco in the Roman territory in 1465, and to the first

Roman book printed in 1470; the Dutch to Laurens Coster, whom they allege invented movable type in 1423. Some of the Dutch have doubted this, and pin their faith on Jacob Bellaert, as the first printer, and Gerard Leeu, his workman, who made the types at Haarlem, in 1483. The Germans rely with confidence on John Guttenberg, who at Strasburg, as early as 1436, had wooden blocks, and wooden movable types, and who, two or three years after, printed several works; on the partnership of Faust and Guttenberg in 1450 at Mentz, and their Bible in Latin printed in 1456 on vellum with types imitating manuscript in form, and illustrated by hand; and, finally, on Peter Schoeffer of Gernsheim, who then made matrices in which were cast the letters singly, and who thereby so pleased his master, Faust, that the latter gave him his daughter, Christina, in marriage.

From Germany the art spread to Paris and thence to England. About 1474 Caxton was printing his black-letter books in England. Spain followed, and it is stated that in 1500 there were two hundred printing offices in Europe. The religious and political turmoils in Germany in the [Pg 281] sixteenth century gave an immense impetus to printing there. The printing press was the handmaid of the Reformation. In America the first printing press was set up in Mexico in 1536, and in Lima, Brazil, in 1586. In 1639, nineteen years after the landing of the Pilgrims on the bleak rock at Plymouth, they set up a printing press at Cambridge, Mass.

The art of printing soon resolved itself into two classes: first, *composition*, the arranging of the type in the proper order into words and pages; and second, *press work*; the taking of impressions from the types, or from casts of types in plates—being a *facsimile* of a type bed. This was *stereotyping*—the invention of William Ged, of Edinburgh, in 1731.

Types soon came to be made everywhere of uniform height; that of England and America being 92-100 of an inch, and became universally classified by names according to their sizes, as pica, small pica, long primer, minion, nonpareil, etc.

After movable types came the invention of *Presses*. The earliest were composed of a wooden frame on which were placed the simple screw and a lever to force a plate down upon a sheet of paper placed on the bed of type which had been set in the press, with a spring to automatically raise the screw and plate after the delivery of the impression. This was invented by Blaew of Amsterdam in 1620. Such, also, was the Ramage press, and on such a one Benjamin Franklin worked at his trade as a printer, both in America and in London. His London press, on which he worked in 1725, was carried to the United States, and is now on exhibition in Washington. This was substantially the state of the art at the beginning of the century. [Pg 282]

Then Earl Stanhope in England invented a press entirely of iron, and the power consisted of the combination of a toggle joint and lever. The first American improvement was invented by George Clymer, of Philadelphia, in 1817, the power being an improved lever consisting of three simple levers of the second order. This was superseded by the "Washington" press invented by Samuel Rust in 1829. It has as essential parts the toggle joint and lever, and in the frame work, as in the Stanhope, type bed, rails on which the bed was moved in and out, means to move the bed, the platen, the tympan on which the sheet is placed, the frisket, a perforated sheet of paper, to preserve the printed sheet, an inking roller and frame. In this was subsequently introduced an automatic device for inking the roller, as it was moved back from over the bed of type on to an inking table. This, substantially, has been the hand press ever since.

With one of these hand-presses and the aid of two men about two hundred and fifty sheets an hour could be printed on one side. The increase in the circulation of newspapers before the opening of the 19th century demanded greater rapidity of production and turned the attention of inventors to the construction of power or machine presses. Like the paper-making machine, the power press was conceived in the last decade of the eighteenth century, and like that art was also not developed until the nineteenth century. William Nicholson of England is believed to have been the first inventor of a machine printing press. He obtained an English patent for it in 1720. The type were to be placed on the face of one cylinder, which was designed to be in gear, revolved with, and press upon another cylinder covered with soft leather, the type cylinder to be [Pg 283] inked by a third cylinder to which the inking apparatus, was applied, and the paper to be printed by being passed between the type and the impression cylinder. These ideas were incorporated into the best printing machines that have since been made. But the first successful machine printing press was the invention of two Saxons, König and Bauer, in 1813, who introduced their ideas from Germany, constructed the machine in London, and on which on the 28th of November, 1814, an issue of the *London Times* was printed. The *Times* announced to its readers that day that they were for the first time perusing a paper printed upon a machine driven by steam power. What a union of mighty forces was heralded in this simple announcement! The union of the steam engine, the printing press, and a great and powerful journal! An Archimedean lever had been found at last with which to move the world.

The production of printed sheets per hour over the hand-press was at once quadrupled, and very shortly 1800 sheets per hour were printed. This machine was of that class known as cylinder presses. In this machine ordinary type was used, and the type-form was flat and passed beneath a large impression cylinder on which the paper was held by tapes. The type-form was reciprocated beneath an inking apparatus and the paper cylinder alternately. The inking apparatus consisted of a series of rollers, to the first of which the ink was ejected from a trough and distributed to the others. In 1815 Cowper patented in England electrotype plates to be affixed to a cylinder. Applegath and Cowper improved the König machine in the matter of the ink distributing rollers, and in the adaptation of four printing cylinders to the reciprocating type bed, whereby, with [Pg 284] some other minor changes, 5000 impressions on one side were produced per hour. Again Applegath greatly changed the arrangement of cylinders and multiplied their number, and the number of the other parts, so that in 1848 the sheets printed on one side were first 8000 and then 12,000 an hour.

In the United States, Daniel Treadwell of Boston invented the first power printing machine in 1822. Two of these machines were at that time set up in New York city. It was a flat bed press and was long used in Washington in printing for the government. David Bruce of New York, in 1838, invented the first successful type-casting machine, which, when shortly afterward it was perfected, became the model for type-casting machines for Europe and America. Previous to that time type were generally made by casting them in hand-moulds—the metal being poured in with a spoon.

Robert Hoe, an English inventor, went to New York in 1803, and turned his attention to the making of printing presses. His son, Richard March Hoe, inherited his father's inventive genius. While in England in 1837-1840, obtaining a patent on and introducing a circular saw, he became interested in the printing presses of the London Times. Returning home, he invented and perfected a rotary machine which received the name of the "Lightning Press." It first had four and then ten cylinders arranged in a circle. As finally completed, it printed from a continuous roll of paper several miles in length, and on both sides at the same time, cutting off and folding ready for delivery, 15,000 to 20,000 newspapers an hour, the paper being drawn through the press at the rate of 1,000 feet in a minute. Before it was in this final, completed shape, it was adopted by [Pg 285] the *London Times*. John Walter of London in the meantime invented a machine of a similar class. He also used a sheet of paper miles long. It was first damped, passed through blotting rolls, and then to the printing cylinders. It gave out 11,000 perfected sheets, or 22,000 impressions an hour, and as each sheet was printed, it was cut by a knife on the cylinder, and the sheets piled on the paper boards. It was adopted by the London *Times* and the New York *Times*.

A German press at Augsburg, and the Campbell presses of the United States, have also become celebrated as web perfecting presses, in which the web is printed, the sheets cut, associated, folded, and delivered at high speed. One of the latest quadruple stereotype perfecting presses made by Hoe & Co. of New York has a running capacity of 48,000 papers per hour. On another, a New York paper has turned off nearly six hundred thousand copies in a single day, requiring for their printing ninety-four tons of paper. Among other celebrated inventors of printing presses in the United States were Isaac Adams, Taylor, Gordon, Potter, Hawkins, Bullock, Cottrell, Campbell, Babcock, and Firm.

Mail-marking Machines, in which provision is made for holding the printing mechanism out of operative position in case a letter is not in position to be stamped; address-printing machines, including machines for printing addresses by means of a stencil; machines for automatically setting and distributing the type, including those in which the individual types are caused to enter the proper receptacle by means of nicks in the type, which engage corresponding projections on a stationary guard plate, and automatic type justifying machines. All such have [Pg 286] been invented, developed, and perfected in the last half century.

Another invention which has added wonderfully to push the century along, is the *Typewriter*. It has long been said that "The pen is mightier than the sword," but from present indications, it is proper to add that the typewriter is mightier than the pen.

A machine in which movable types are caused to yield impressions on paper to form letters by means of key levers operated by hand, has been one of slow growth from its conception to its present practical and successful form.

Some one suggested the idea in England in a patent in 1714. The idea rested until 1840, when a French inventor revived it in a patent. At the same time patents began to come out in England and the United States; and about forty patents in each of these two countries were granted from that time until 1875. Since that date about 1400 patents more have been issued in the United States, and a large number in other countries. It was, however, only that year and before 1880, that the first popular commercially successful machines were made and introduced.

The leading generic idea of all subsequent successful devices of this kind was clearly set forth in the patent of S. W. Francis of the United States in 1857. This feature is the arranging of a row of hammers in a circle so that when put in motion they will all strike the same place, which is the centre of that circle. The arrangement of a row of pivoted hammers or type levers, each operated by a separate key lever to strike an inked ribbon in front of a sheet of paper, means to automatically move the carriage carrying the paper roll from right to left as the letters are [Pg 287] successfully printed, leaving a space between each letter and word, and sounding a signal when the end of a line is reached, so that the carriage may be returned to its former position—all these and some other minor but necessary operations may seem simple enough when stated, but their accomplishment required the careful study of many inventors for years.

One of the most modern of typewriters has a single electro-magnet to actuate all the type bars of a set, and to throw each type from its normal position to the printing centre. By an extremely light touch given to each key lever the circuit is closed and causes the lever to strike without the necessity of pressing the key down its whole extent and releasing it before the next key strikes. By this device, the operator is relieved of fatigue, as his fingers may glide quickly from one key to another, the printing is made uniform, and far greater speed attained by reason of the quick and delicate action. Mr. Thaddeus Cahill of Washington appears to be the first to have invented the most successful of this type of machines.

Book-binding Machinery is another new production of the century. It may be that the old hand methods would give to a book a stronger binding than is found on most books to-day, but the modern public demands and has obtained machinery that will take the loose sheets and bind them ready for delivery, at the rate of ten or fifteen thousand volumes a day.

The "quaint and curious volumes of forgotten lore," the Latin folios in oak or ivory boards with brass clasps, or bound in velvet, or in crimson satin, ornamented with finest needlework or precious stones, or the more humble beech boards, and calf and sheep skins with metal edges [Pg 288] and iron clasps, in all of which the sheets were stoutly sewed together and glued, when glue was known, to the covers, are now but relics of the past. Machinery came to the front quite rapidly after 1825, at which time cloth had been introduced as cheaper than leather, and as cheap and a more enduring binder than paper. The processes in book-binding are enumerated as follows; and for each process a machine has been invented within the last sixty years to do the work:

Folding the sheets;
Gathering the consecutive sheets;
Rolling the backs of folded sheets;
Saw cutting the backs for the combs;
Sewing;
Rounding the back of the sewed sheets.
Edge cutting;
Binding, securing the books to the sides, covering with muslin, leather or paper. Tooling and lettering.
Edge gilting.

One of the best modern illustrations of human thought and complicated manual operations contained in automatic machinery is the *Linotype*.

It is a great step from the humble invention of Schoeffer five hundred and fifty years ago of cast movable type to that of another German, Mergenthaler, in 1890-92.

The Linotype (a line of type) was pronounced by the *London Engineering* "as the most remarkable machine of this century." It was the outcome of twelve years of continuous experiment and invention, and the expenditure of more than a million dollars. A brief description of this invention is given in the report of the United States commissioner of patents for 1895 as follows: "In the present Mergenthaler construction there is a magazine containing a series of [Pg 289] tubes for the letter or character moulds, each of which moulds is provided with a single character. There are a number of duplicates of each character, and the moulds containing the same character are all arranged in one tube. The machine is provided with a series of finger keys, which, when pressed like the keys of a typewriter, cause the letter moulds to assemble in a line in their proper order for print. A line mould and a melting pot are then brought into proper relation to the assembled line of letter moulds and a cast is taken, called the linotype, which represents the entire line, a column wide, of the matter to be printed. The letter moulds are then automatically returned to their proper magazine tube. The Mergenthaler machine is largely in use in the principal newspaper offices, with the result that a single operator does at least the work of four average compositors."

Mr Rogers obtained a United States patent, September 23, 1890, for a machine for casting lines of type, the principal feature of which is that the letter moulds are strung on wires secured on a hinged frame. "When the frame is in one position, the letter moulds are released by the keys, slide down the wires by gravity and are assembled in line at the casting point. After the cast is taken, the lower ends of the guide wires are elevated, which causes the letter moulds to slide back on the wires to their original position, when the operation is repeated for the next line." Operated by a single person, the Mergenthaler produces and assembles linotypes ready for the press or stereotyping table at the rate of from 3,600 to 7,000 ems (type characters) per hour. It permits the face or style of type to be changed at will and it permits the operator to read and [Pg 290] correct his matter as he proceeds.

To the aid of the ordinary printing press came *electrotyping*, stenographic colour printing, engraving, and smaller job and card presses, all entirely new creations within the century, and of infinite variety, each in itself forming a new class in typographic art, and a valuable addition to the marvellous transformation.

The introduction of the linotype and other modern machines into printing offices has without doubt many times reduced and displaced manual labour, and caused at those times at least temporary suffering among employees. But statistics do not show that as a whole there are fewer printers in the land. On the contrary, the force seems to increase, just as the number of printing establishments increase, with the multiplication of new inventions. As in other arts, the distress caused by the displacement of hand-labour by machinery is local and temporary. The whole art rests for its development on the demand for reading matter, and the demand never seems to let up. It increases as fast as the means of the consumers increase for procuring it. One hundred years ago a decent private library, consisting of a hundred or so volumes, one or two weekly newspapers, and an occasional periodical, was the badge and possession alone of the wealthy few. Now nearly every reading citizen of every village has piled up in some corner of his house a better supply than that, of bound or unbound literature, and of a far superior quality. Besides the tons of reading matter of all kinds turned out daily by the city presses, every village wants its own paper and its town library, and every one of its business men has recourse to the typewriter [Pg 291] and the printer for his letters, his cards, and his advertisements.

To supply the present demand for printed matter with the implements of a hundred years ago, it would be necessary to draw upon and exhaust the supply of labourers in nearly every other occupation. Printing would become the one universal profession.

The roar of the guns at Waterloo and the click of the first power printing press in London were nearly simultaneous. The military Colossus then tumbled, and the Press began to lead mankind. Wars still continue, and will, until men are civilised; but the vanguard of civilisation are the printers, and not the warriors. The marvellous glory of the nineteenth century has proceeded from the intelligence of the people, awakened, stimulated, and guided by the press. But the press itself, and its servitors and messengers, speeding on the wings of electricity, are the children of the inventors.

These inventions have made the book and the newspaper the poor man's University. They are mirrors which throw into his humble home reflections of the scenes of busy life everywhere. By them knowledge is spread, thought aroused, and universal education established.

[Pg 292]

CHAPTER XVIII.

TEXTILES.

Spinning:—A bunch of combed fibre fixed in the forked end of a stick called a distaff, held under the left arm, while with the right forefinger and thumb the housewife or maiden deftly drew out and twisted a thread of yarn of the fibre and wound it upon a stick called a spindle, was the art of spinning that came down to Europe from Ancient Egypt or India without a change through all the centuries to at least the middle of the fourteenth century, and in England to the time of Henry VIII. Then the spinning wheel was introduced, which is said to have also been long in use in India. By the use of the wheel the spindle was no longer held in the hand, but, set upon a frame and connected by a cord or belt to the wheel, was made to whirl by turning the wheel by hand, or by a treadle. The spindle was connected to the bunch of cotton by a cord, or by a single roving of cotton or wool attached to the spindle, which was held between the finger and thumb, and as the spindle revolved the thread was drawn out and twisted and wound by the spindle upon itself.

In the cloth of the ancient East the warp and weft were both of cotton. In England the warp was linen and the weft was cotton. The warp was made by the cloth and linen manufacturers, and the weft yarns furnished by the woman spinsters throughout the country. By both these methods only a single thread at a time was spun. The principle of the spinning operation, the drawing out and [Pg 293] twisting a thread or cord from a bunch or roll of fibre, has remained the same through all time.

The light and delicate work, the pure and soft material, and the beauty and usefulness of raiments produced, have all through time made woman the natural goddess, the priestess, the patroness, and the votary of this art. The object of all modern machinery, however complicated or wonderful, has simply been to increase the speed and efficiency of the ancient mode of operation and to multiply its results. The loom, that antique frame on which the threads were laid in one direction to form the warp, and crossed by the yarns in the opposite direction, carried through the warp by the shuttle thrown by hand, to form the woof, or weft, comprised a device as old as, if not older than, the distaff and spindle.

The ancient and isolated races of Mexico had also learned the art of spinning and weaving. When the Spaniards first entered that country they found the natives clothed in cotton, woven plain, or in many colours.

After forty centuries of unchanged life, it occurred to John Kay of Bury, England, that the weaving process might be improved. In 1733 he had succeeded in inventing the picker motion, "picker peg," or "fly." This consisted of mechanical means for throwing the shuttle across the web by a sudden jerk of a bar—one at each side—operated by pulling a cord. He could thus throw the shuttle farther and quicker than by hand—make wider cloth, and do as much work in the same time as two men had done before. This improvement put weaving ahead of spinning, and the weavers were continually calling on the spindlers for more weft yarns. This set the wits of [Pg 294] inventors at work to better the spinning means.

At the same time that Kay was struggling with his invention of the flying shuttle, another poor man, but with less success, had conceived another idea, as to spinning. John Wyatt of Lichfield thought it would be a good thing to draw out the sliver of cotton or wool between two sets of rollers, one end of the sliver being held and fed by one set of rollers, while the opposite end was being drawn by the other set of rollers moving at a greater speed. His invention, although not then used, was patented in 1738 by Lewis Paul, who in time won a fortune by it, while Wyatt died poor, and it was claimed that Paul and not Wyatt was the true inventor.

About 1764 a little accident occurring in the home of James Hargreaves, an English weaver of Blackburn, suggested to that observant person an invention that was as important as that of Kay.

He was studying hard how to get up a machine to meet the weavers' demands for cotton yarns. One day while Hargreaves was spinning, surrounded by his children, one of them upset the spinning wheel, probably in a children's frolic, and after it fell and while lying in a horizontal position, with the spindle in a vertical position, and the wheel and the spindle still running, the idea flashed into Hargreaves' mind that a number of spindles might be placed upright and run from the same power. Thus prompted he commenced work, working in secret and at odd hours, and finally, after two or three years, completed a crude machine, which he called the spinning jenny, some say after his wife, and others that the name came from "gin," the common abbreviated name of an engine. This machine had eight or ten spindles driven by cords or belts [Pg 295] from the same wheel, and operated by hand or foot. The rovings at one end were attached to the spindles and their opposite portions held together and drawn out by a clasp held in the hand. When the thread yarn was drawn out sufficiently it was wound upon the spindles by a reverse movement of the wheel. Thus finally were means provided to supply the demand for the weft yarns. One person with one of Hargreaves' machines could in the same time spin as much as twenty or thirty persons with their wheels. But those who were to be most benefited by the invention were the most alarmed, for fear of the destruction of their business, and they arose in their wrath, and demolished Hargreaves' labours. It was a hard time for inventors. The law of England then was that patents were invalid if the invention was made known before the patent was applied for, and part of the public insisted on demolishing the invention if it was so made known, so that to avoid the law and the lawless the harassed inventors kept and worked their inventions in secret as long as they could. Hargreaves fled to Nottingham, where works were soon started with his spinning jennys. The ideas of Kay, Wyatt and Hargreaves are said to have been anticipated in Italy. There were makers of cloths at Florence, and also in Spain and the Netherlands, who were far in advance of the English and French in this art, but the descriptions of machinery employed by them are too vague and scanty to sustain the allegation.

And now the long ice age of hand working was breaking up, and the age of machine production was fast setting in. Hargreaves was in the midst of his troubles and his early triumphs, in 1765- [Pg 296] 1769, when Richard Arkwright entered the field. Arkwright, first a barber, and then a travelling buyer of hair, and finally a knight, learned, as he travelled through Lancashire, Lichfield, Blackburn and Nottingham, of the inventions and labours of Wyatt, Kay and Hargreaves. Possessed as he was of some mechanical skill and inventive genius, and realising that the harvest was ripe and the labourers few, entered the field of inventions, and with the help of Kay, revived the old ideas of John Wyatt and Lewis Paul of spinning by rollers, which had now slumbered for thirty years. Kay and Arkwright constructed a working model, and on this Arkwright by hard pushing and hard work obtained capital, and improved, completed and patented his machine. The machine was first used by him in a mill erected at Nottingham and worked by horses; then at Cromford, and in this mill the power used to drive the spinning machine was a water wheel. His invention was therefore given the name of the *water* frame, which it retained long after steam had been substituted for water as the driving power. It was also named the *throstle*, from the fact that it gave a humming or singing sound while at work; but it is commonly known as the *drawing* frame. Arkwright patented useful improvements. He had to contend with mobs and with the courts, which combined to destroy his machines and his patent, but he finally succeeded in establishing mills, and in earning from the Government, manufacturers, and the public a great and well-merited munificence.

It is a remarkable coincidence that Watt's steam engine patent and Arkwright's first patent for his spinning machine were issued in the same year——1769. The new era of invention was [Pg 297] dawning fast.

Then, in 1776, came Samuel Crompton of Bolton, who invented a combination of the jenny of Hargreaves and the roller water frame of Arkwright, and to distinguish his invention from the others he named it the "mule." The mule was a carriage on wheels to which the spindles were attached. When the mule was drawn out one way on its frame the rovings were drawn from bobbins through rollers on a stationary frame, stretched and twisted into threads, and then as the mule was run back the spun threads were wound on spools on the spindles. The mule entirely superseded the use of the jenny. Notwithstanding the advantage in names the mule did more delicate work than the jenny. It avoided the continuous stretch on the thread of the jenny by first completing the thread and then winding it. Crompton's mule was moved back and forth by hand. Roberts subsequently made it self-acting. Next, followed in England the Rev. Edward Cartwright, who, turning his attention to *looms*, invented the first loom run by machinery, the *first power loom*, 1784-85. Then the rioters turned on him, and he experienced the same attentions received by Hargreaves and Arkwright. The ignorance of ages died in this branch of human progress, as it often dies in others, with a violent wrench. But the age of steam had at last come, and with it the spinning machine, the power loom, the printing press, and the discovery among men of the powers of the mind, their freedom to exercise such powers, and their right to possess the fruits of their labours.

The completed inventions of Arkwright and others, combined with Watt's steam engine, revolutionised trade, and resulted in the establishment of mills and factories. A thousand spindles [Pg 298] whirled where one hummed before. The factory life which drew the women and girls from their country homes to heated, and closely occupied, ill ventilated buildings within town limits, was, however, not regarded as an improvement in the matter of health; and it was a long time before mills were constructed and operated with the view to the correction of this evil.

The great increase in demand for cotton produced by these machine inventions could not have been met had it not been for Eli Whitney's invention of the saw gin in America in 1793. The cleaning of the seed from the cotton accomplished by this machine produced as great a revolution in the culture of cotton in America as the inventions of Arkwright and others accomplished in spinning and weaving in England. America had also learned of Arkwright's machinery. Samuel Slater, a former employee of Arkwright, introduced it to Rhode Island in 1789, and built a great cotton mill there in 1793. Others followed in Massachusetts. Within twenty years after the introduction of Arkwright's machines in the United States there were a hundred mills there with a hundred thousand spindles.

As has been said, it was customary for weavers to make the warp on their looms at one place, and the spinners to furnish the yarns for the weft from their homes, and even after the spinning machines were invented the spinning and weaving were done at separate places. It remained for Francis C. Lowell of Boston, who had been studying the art of spinning and weaving in England and Scotland and the inventions of Arkwright and Crompton, to establish in 1813 at Waltham, Mass., with the aid of Paul Moody, machinist, the first factory in the world wherein were [Pg 299] combined under one roof all the processes for converting cotton into cloth.

The task of the century in this art has been to greatly extend the dominion of machinery in the treatment of cotton and wool in all stages, from the reception of the raw material at the door of the factory to its final completion in the form of the choicest cloth, and to increase the capacity of machines sufficiently to meet an ever-increasing and enormous consumption. There are from twenty to forty separate and distinct operations performed both in spinning and weaving and the completion of a piece of cloth from cotton or wool, and nearly all of these operations are accomplished by machinery.

The century's improvements and inventions in machines for treating and spinning cotton comprise machines for first opening and tearing the matted mass apart as it is taken from the bales, then cleaning, carding, drawing, roving, stretching, spinning, winding, doubling, dressing, warping, weaving, etc. Formerly, the opening machines were simply cylinders armed with spikes, to which the cotton was led through nipping rollers, and then delivered in a loose, fluffy condition. When such a machine was associated with a blowing machine to blow out the dust and cleanse the fibre, the loose and scattered condition in which the cotton was left gave rise to a great danger from fire, and destructive fires often occurred. The object of the later opening machinery is to confine the cotton within a casing in its passage through the machine, during which passage it is thoroughly stretched, beaten and blown and then rolled into a continuous sheet or lap. At the same time, by nice devices, it is evened, that is, freed from all knots, and [Pg 300] made of uniform thickness, while a certain quantity only of cotton of known weight is allowed to pass through to constitute the required lap. Finally the lap is wound upon a roller, which when filled is removed to the carder. Although the cotton is now a white, soft, clean, downy sheet, still the fibres cross each other in every direction, and they require to be straightened and laid parallel before the spinning. This is done by carding. Paul, Hargreaves, Robert Peel, and Arkwright had worked in constructing a machine to take the place of hand carding, and it was finally reduced by Arkwright, towards the close of the 18th century, to its present form and principle.

But to make those narrow, ribbon-like, clean, long lines of rolled cotton, known as slivers, by machinery with greater precision and uniformity than is possible by hand, and with a thousand times greater rapidity, has been the work of many inventors at different times and in different countries. The machine cards are cylinders clothed with leather and provided with separate sets of slender, sharp, bent fingers. The different cards are arranged to move past each other in opposite directions, so as to catch and disentangle the fibres. Flat, overhead stationary cards are also used through which the cotton is carried. As one operation of carding is not sufficient for most purposes the cotton is subjected to one or more successive cardings. So ingenious is the structure in some of its parts that as the stream of cotton passes on, any existing knots do not fail to excite the attention of the machine, which at once arrests them and holds them until disentangled. In connection with the cards, combers and strippers are used to assist in further cleaning and straightening the fibre, which is finally removed from the cards and the combs by [Pg 301] the doffer. The cotton is stripped from the doffer by the doffer knife and in the form of delicate, flat narrow ribbons, which are drawn through a small funnel to consolidate them, and finally delivered in a coiled form into a tall tin can. The material is then carried to a drawing frame, which takes the spongy slivers, and, carrying them through successive sets of rollers moving at increased speed, elongates, equalises, straightens and "doubles" them, and finally condenses them into two or more rolls by passing the same through a trumpet-shaped funnel. As the yarns still need to be twisted, they are passed through a roving frame similar to a drawing frame. An ingenious device connected with the winding of the roving yarns upon bobbins may be here noted. Formerly the bobbins on which the yarns were wound increased in speed as they were filled, thus endangering and often breaking the thread, and at all times increasing the tension. In 1823 Asa Arnold of Rhode Island invented "a differential motion" by which the velocity of the bobbin is kept uniform. The roving having been reduced to proper size for the intended number of yarns, now goes to the spinning machine, to still further draw out the threads and give to them a more uniform twist and tenuity. The spinning machine is simply an improved form of Crompton's mule, already described.

Great as have been the improvements in many matters in spindle structure, the drawing, the stretching and the twisting still remain fundamentally the same in principle as in the singing throstle of Arkwright and the steady mule of Crompton. And yet so great and rapid has been the

[Pg 302]

advancement of inventions as to details and to meet the great demand, that the machinery of half a century ago has been almost entirely discarded and supplanted by different types. A great improvement on the spinning frame of the 18th century is the ring frame invented by Jenks. In this the spindles, arranged vertically in the frame, are driven by bands from a central cylinder, and project through apertures in a horizontal bar. A flanged ridge around each aperture forms a ring and affords a track for a little steel hoop called a traveller, which is sprung over the ring. The traveller guides the thread on to the spool. As the spindles revolve, the thread passing through the traveller revolves it rapidly, and the horizontal bar rising and falling has the effect of winding the yarn alternately and regularly upon the spools.

The bobbins of the spindle frame were found not large enough to contain a sufficient amount of yarn to permit of a long continuous operation when the warp came to be applied, and besides there were occasional defects in the thread which could not be detected until it broke, if the yarn was used directly from the bobbins. So to save much time and trouble spooling machines were invented which wind the yarn from the bobbins holding 1200 to 1800 yards, to large spools, each holding 18,000 to 20,000 yards; and then by passing the yarn through fine slots in guides which lead to the spool, lumps or weak places, which would break the yarns at the guide, could at once be discovered and the yarn retied firmly, so that there would be no further breaking in the warper. After the yarn is finally spooled it is found that its surface is still rough and covered with fuzz. It is desirable, therefore, that it shall be smoothed out and be given somewhat of a lustre before weaving. These final operations are performed by the warping and dressing machines. In [Pg 303] the warping machine the threads are drawn between rollers, the tension of which can be regulated, and then through a "reed," a comb-shaped device which separates the threads, and then finally wound upon a large cylinder. In this machine a device is also arranged which operates to stop the machine at once if any thread is broken. When the cylinder is filled it is then taken to the dresser, which in its modern and useful form is known as the "slusher," by which the yarns are drawn through hot starch, the superfluous starch squeezed out, and the yarns, kept separated all the time, dried by passing them around large drying cylinders, or through a closed box heated by steam pipes, and then wound upon the loom beam or cylinder.

In weaving, as in spinning, however advanced, complicated and improved the means may be beyond the hand methods and simple looms of past ages, the general principles in the process are still the same. These means, generally and broadly speaking, consist of a frame for two sets of threads, a roller, called the warp beam, for receiving and holding the threads which form the warp, a cloth beam upon which the cloth is wound as it is woven, the warp threads, being first laid parallel, carried from the warp beam and attached to the cloth beam; means called heddles, which with their moving frames constitute "a harness," consisting of a set of vertical strings or rods having central loops through which the threads are passed, two or more sets of which receive alternate threads, and by the reciprocation of which the threads are separated into sets, *decussated*, forming between them what is called a shed through which the shuttle is thrown; means for throwing the shuttle; and means, called the batten, lay or lathe, for forcing or packing [Pg 304] the weft tight into the angle formed by the opened warp and so rendering the fabric tight and compact, and then the motive power for turning the cloth beam and winding the cloth as fast as completed. It is along these lines that the inventors have wrought their marvellous changes from hand to power looms.

Prior to 1800, in the weaving of figures into cloths, it was customary to employ boys to pull the cords in the loom harness in order to arrange the coloured threads in their relative positions. In that year appeared at the front Joseph Marie Jacquard, a French mechanician and native of Lyons, whose parents were weavers, a prolific inventor in his youth, a wayward wanderer after fortune and a wife, a soldier in the Revolution, losing a son fighting by his side, eking out a poor living with his wife's help at straw weaving, finally employed by a silk manufacturer, and while thus engaged, producing that loom which has ever since been known by his name. This loom was personally inspected by Napoleon, who rewarded the inventor with honours and a pension. It was then demolished by a mob and its inventor reviled, but it afterward became the pride of Lyons and the means of its renown and wealth in the weaving of silks of rich designs.

The leading feature of the Jacquard loom consists of a chain of perforated pattern cards made to pass over a drum, through which cards certain needles pass, causing certain threads of the warp to rise and fall, according to the holes in the cards, and thus admitting at certain places in the warp coloured weft threads thrown by the shuttle, and reproducing the pattern which is perforated in the cards. The Jacquard device could be applied to any loom, and it worked a [Pg 305] revolution in the manufacture of figured goods. The complexity and expensiveness of Jacquard's loom were greatly reduced by subsequent improvements. In 1854 M. Bonelli constructed an electric loom in which the cards of the Jacquard apparatus are superseded by an endless band of tin-foiled paper, which serves as an electrical conductor to operate the warp thread needles, which before had each been actuated by a spiral spring. The Jacquard loom was also greatly improved by the English inventors, Barlow, Taylor, Martain and others.

Radcliffe and Johnson, also of England, had invented and introduced the machines for dressing the yarns in one operation before the weaving; Horrocks and Marsland of Stockport greatly improved the adaptation of steam to the driving of looms, and Roberts of Manchester made striking advances in their mechanical parts and in bringing them to their present state of wonderful efficiency.

In America, in 1836, George Crompton of Taunton, Massachusetts, commenced a series of inventions in power looms for the manufacture of fancy woollen goods, and in the details of such looms generally, particularly in increasing the speed of the shuttle, which vastly increased the production of such goods and gave to his looms a world-wide reputation.

E. B. Bigelow of Massachusetts in 1848 invented a power loom, which was exhibited at the Exhibition at London in 1851, and astonished the world by his exhibition of carpets superior to any woven by hand. By the later improvements, and the aid of steam power, a single American Bigelow carpet loom can turn out now one hundred yards of Brussels carpet in a day, far superior in quality to any carpet which could possibly be made by hand, when a man toiled painfully to [Pg 306] produce five yards a day. Mr. Bigelow was also a pioneer inventor of power machines for weaving coach lace, and cotton checks and ginghams. James Lyall of New York invented a power loom applicable either to the weaving of very wide and heavy fabrics, such as jute canvas for the foundation of floor oil cloth, or to fabrics made of the finest and most delicate yarns.

It would be interesting, if space permitted, to describe the great variety of machines that have been invented for dressing, finishing and treating cloths after they are woven: The *teasling* machine, by which the nap of woollen cloth is raised; the cloth *drying* machine, with heated rollers, over which the cloth is passed to drive off the moisture acquired in dyeing, washing, etc., the cloth *printing*, *figuring*, *colouring* and *embossing* machines, with engraved cylinders; cloth pressing and *creasing* machines, and the *cloth* cutting machines for cutting the cloth into strips of all lengths, or for cutting piles of cloth in a single operation into parts of garments corresponding to the prearranged pattern; machines for making *felt* cloth, and stamping or moulding different articles of apparel from felt, etc., etc.

For the making of ribbons and other kind of narrow ware, the needle power loom has been invented, in which the fine weft thread is carried through the web by a needle instead of a shuttle. This adaptation of the needle to looms has placed ribbons within the reach of the poor as well as the rich girl.

What a comparison between the work of the virtuous Penelopes and the weavers of a century ago and to-day! Then with her wheel, and by walking to and from it as the yarn was drawn out, and wound up, a maiden could spin twelve skeins of thread in ten hours, producing a thread a little [Pg 307] more than three miles in length, while the length of her walk to and fro was about five miles. Now one Penelope can attend to six or eight hundred spindles, each of which spins five thousand yards of thread a day, or, with the eight hundred spindles, four million yards, or nearly twenty-one hundred miles of thread in a day, while she need not walk at all.

It was when the weaver threw the shuttle through the warp by hand that Job's exclamation, "My days are like a weaver's shuttle" was an appropriate text on the brevity of human life. It may be just as appropriate now, but far more striking, when it is realised that machines now throw the shuttle one hundred and eighty times a minute, or three times a second. Flying as fast as it does, when the shuttle becomes exhausted of yarn a late invention presents a new bobbin and a new supply of yarn to the shuttle without stopping the machine.

As to *knitting*, the century has seen the day pass when all hosiery was knit by hand. First, machines were invented for knitting the leg or the foot of the stocking, which were then joined by hand, and then came machines that made the stocking complete. The social industry so quietly but slowly followed by the good women in their chimney corners with their knitting needles, by which a woman might possibly knit a pair a day, was succeeded a quarter of a century ago by machines, twelve of which could be attended to by a boy, which would knit and complete five thousand pairs a week. Such a machine commences with the stocking at the top, knits down, widening and narrowing, changes the stitch as it goes on to the heel, shapes the heel, and finishes at the end of the toe, all one thread, and then it recommences the operation and goes on [Pg 308] with another and another. Fancy stockings, with numerous colours blended, are so knit, and if the yarn holds out a mile of stockings may be thus knit, without a break and without an attendant. By these machines the astounding result was reached of making the stockings at the cost of one-sixth of a mill per pair.

The wonderful reduction in the cost of all kinds of textile fabrics due to the perfection of spinning and loom mechanisms, and its power to meet the resulting enormous increase in demand, has enabled the poor of to-day to be clad better and with a far greater variety of apparel than it was possible for the rich a hundred years ago; and the increased consumption and demand have brought into these fields of labour, and into other fields of labour created by these, great armies of men and women, notwithstanding the labour-saving devices.

The wants of the world can no longer be supplied by skilled hand labour. And it is better that machines do the skilled labour, if the product is increased while made better and cheaper, and the number of labourers in the end increased by the development and demands of the art.

Among the recent devices is one which dispenses with the expensive and skilful work by hand of drawing the warp threads into the eyes of the heddles and through the reed of the loom.

Cane-backed and bottomed chairs and lounges only a few years ago were a luxury of the rich and made slowly by hand. Now the open mesh cane fabric, having diagonal strands, and other varieties, are made rapidly by machinery. Turkish carpets are woven, and floors the world over are carpeted with those rich materials the sight of which would have astonished the ordinary [Pg 309] beholder a half century ago. Matting is woven; wire, cane, straw, spun glass; in fact, everything that can be woven by hand into useful articles now finds its especially constructed machine for weaving it.

CHAPTER XIX.

GARMENTS.

"Man is a tool-using animal. Weak in himself, and of small stature, he stands on a basis, at most for the flattest-soled, of some half square foot, insecurely enough; has to straddle out his legs lest the very wind supplant him. Feeblest of bipeds! Three quintals are a crushing load for him; the steer of the meadow tosses him aloft, like a waste rag. Nevertheless he can use tools, can devise tools; with these the granite mountain melts into light dust before him; he kneads glowing iron as if it were paste; seas are his smooth highway, winds and fire his unwearying steeds. Nowhere do you find him without tools; without tools he is nothing, with tools he is all.... Man is a tool-using animal, of which truth, clothes are but one example."—*Sartor Resartus.*

In looking through the records of man's achievements to find the beginnings of inventions, we discover the glimmering of a change in the form of the immemorial needle, in an English patent granted to Charles F. Weisenthal, June 24, 1775. It was a needle with a centrally located eye, and with both ends pointed, designed for embroidery work by hand, and the object of the two points was to prevent the turning of the needle end for end after its passage through the cloth. But it was not until the 19th century that the idea was reduced to practice in sewing machines. [Pg 311]

To Thomas Saint, a cabinet maker by trade, of Greenhills Rents, in the Parish of St. Sepulchre, Middlesex County, England, the world is indebted for the first clear conception of a sewing machine. Saint's attention was attracted to the slow way of sewing boots and shoes and other leather work, so he determined to improve the method. He took out a patent September 17, 1790, and although the germs of some of the leading parts of the modern sewing machine are there described, it does not appear that his patent was applied to practice. In fact, it slumbered in the archives of the British patent office for two generations, and after the leading sewing machines of the century had been invented and introduced, before it was rediscovered, and its contents appreciated in the light of more recent developments. Probably Saint's machine, if constructed in accordance with his plans, would not have done much good work, certainly not with woven cloth, as he proposed to employ a hooked needle to carry a loop through the material, which would have been snarled by the cloth threads; but from his drawings and description it is clearly established that he was first to conceive of a vertically reciprocating needle for forming a seam from a continuous thread drawn from a spool; a seam in which each loop is locked, or enchained with a subsequent loop, to form what is known as the chain, or single thread stitch; and a horizontal sliding plate, to support the material to be sewed, and by which the material was also moved sideways after each stitch.

May 30, 1804, John Duncan received an English patent for "tamboring on cloth." He proposed to employ a series of hooked needles attached in a straight line to a horizontal bar, which, when [Pg 312] threaded, were first thrust forward and their hooked ends carried through the cloth, where each needle hook was supplied with a thread by a thread carrier. Then the motion of the bar was reversed, which drew the thread back through the cloth in the form of loops, and through the loops first formed, thus producing a chain stitch. The cloth was automatically shifted to correspond to the pattern to be produced, and thus was chain stitch embroidery first manufactured. From this point of time successful embroidery machines were made.

In 1807 another Englishman patented a machine for making a sort of rope matting, in which he describes two eye-pointed, thread-carrying, perforating needles, each held in a reciprocating needle bar, and designed to unite several small ropes laid parallel, by a reciprocating movement.

A German publication, the *Kunst* and *Generbe Blatt*, for 1817, and *Karmarsch's History of Technology*, made mention of a sewing machine invented by one Mr. Joseph Madersperger of Vienna, formerly from Kuefstein in the Tyrol, and for which he received royal letters patent in 1814. From these descriptions it appears Madersperger used a needle pointed at both ends, and the eye in the centre, invented many years before by Weisenthal, as above stated, which was moved vertically up and down, piercing alternately the top and bottom of the stuff, and which carried a short thread, enough to make about one hundred and thirty stitches, which machine was driven by a crank and handle, on which sewing was made of many different shaped forms, by slight changes, and which sewed with far greater accuracy and rapidity than hand work. The [Pg 313] inventor was striving to simplify the machine, but to what extent it had been used or had been improved, or what finally became of it, does not appear. Yet it is a bit of evidence showing that Germany came next to England in the earlier ideas, conceptions of, and struggles after a sewing machine.

France then entered the list, and it was in 1830 that Barthelmy Thimonnier there produced and patented a sewing machine, which he continued to improve and to further patent in 1848 and in 1850 in France, England, and the United States. The Thimonnier resembled in some prominent respects the machine that had been described in the Saint patent, but unlike Saint's, it was reduced to successful practice, and possessed some points in common with more modern machines. These were the flat cloth plate, vertical post, overhung arm, vertically reciprocating needle, and continuous thread. The crochet or barbed needle was worked by a treadle, and upon pushing the needle down through the cloth, it there caught a thread from a carrier, carried the loop to and laid it upon the upper surface of the cloth. Again descending, it brought up another loop, enchained it with the one last made, making a chain stitch, consisting of a series of loops on the upper side.

Thimonnier made quite a large number of machines, constructed mostly of wood, and which were used to make army clothing at Paris. They were best adapted to work on leather and in embroidering. They were so far successful as to arouse the jealousy and fear of the workmen and working women, and, as in the case of Hargreaves, Jacquard, and others, a mob broke into his shop, destroyed his machines, ruined his business, and he died penniless in 1857. [Pg 314]

In the meantime an English patent, No. 8948, of May 4, 1841, had been issued to Newton and Archbold for a machine for embroidering the backs of gloves, having an eye-pointed needle, worked by a vibrating lever, and adapted to carry a thread through the back of the glove, held on a frame—the frame and glove moving together after each stitch.

The germs of inventions often develop and fructify simultaneously in distant places, without, so far as any one can ascertain, the slightest mutual knowledge or co-operation on the part of the separate inventors. Between 1832 and 1834, while Thimonnier was in the midst of his early struggles in Paris, Walter Hunt was inventing a sewing machine in New York, which he completed at that time and on which he sewed one or two garments. But as it was experimental in form, and Hunt was full of other inventions and schemes, he put it aside, and it probably would never have been heard of had not Elias Howe of Massachusetts, ten years after Hunt had abandoned his invention, but without knowledge of Hunt's efforts, made the first practical successful sewing machine for commercial purposes the world had ever seen, obtained his patent, and made claims therein which covered not only his special form of improvements, but Hunt's old device as well.

Howe's patent was issued September 10, 1846. In that he claimed to be the first and original inventor of "A sewing machine, constructed and operated to form a seam, substantially as described."

Also "The combination of a needle and a shuttle, or equivalent, and holding surfaces, constructed and operating substantially as described."

Also "The combination of holding surfaces with a baster plate or equivalent, constructed and [Pg 315] operating substantially as described."

Also "A grooved and eye-pointed needle, constructed and adapted for rapid machine sewing substantially as described."

When the machine commenced to be a practical success this patent was infringed, and when Howe sued upon it a few years after its issue, it woke up Hunt and all other alleged prior inventors; and all prior patents and publications the world over, relating to sewing machines, were raked up to defeat Howe's claims.

But the courts, after long deliberation, held that although, so far as Hunt was concerned he had without doubt made a machine in many respects like Howe's machine, that it had a curved, eye-pointed needle similar to Howe's operated by a vibrating arm and going through the cloth, a shuttle carrying the thread that passed through the loop made by the needle thread, thus making a lock stitch by drawing it up to one side of the cloth, and that this machine did, to a certain extent, sew, yet that it ended in an experiment, was laid aside, destroyed, and never perfected nor used so as to give to the public the knowledge and benefit of a completed invention, and was not therefore an anticipation in the eye of the law of Howe's completed, more successful and patented machine.

Public successful use is the fact in many cases which alone establishes the title of an inventor, when all other tests fail. And this is right in one sense, as the laws of all countries in respect to protection by patents for inventions are based upon the primary condition of benefit to society. This benefit is not derived from the inventor who hides his completed invention for years in his [Pg 316] closet, or throws it on a dust heap. As to previous patents and publications, some were not published before Howe's inventions were made, and others were insufficient in showing substantially the same machine and mode of operation. And as to prior use abroad, it was not regarded under the law of his country as competent evidence.

Seldom have the lives of great inventors presented a more striking example of the vicissitudes, the despair, and the final triumphs of fortune, which are commonly their lot, than is shown in the case of Howe. A machinist with a wife and children to support, his health too feeble to earn hardly a scanty living, he watches his faithful wife ply her constant needle, and wonders why a machine cannot be made to do the work. The idea cannot be put aside, and with such poor aids as he can command he commences his task.

At last, amid the trials of bitter poverty, he brings his invention to that stage in which he induces a friend to advance some money, by the promise of a share in the future patent, and thereby gains a temporary home for his family and a garret for his workshop. Day after day and night after night he labours, and finally, in April, 1845, the rather crude machine is completed, and two woollen suits of clothing are sewed thereon, one for a friend, and one for himself.

Then came the effort to make more machines and place them on the market. People admired the machines as a curiosity, but none were induced to buy them or help him pecuniarily. Finally, in September, 1846, he obtained his patent, but by that time his best friends had become [Pg 317] discouraged, and he was compelled to return with his family to his father's house in Cambridge, Mass. To earn his bread he sought and found employment on a railway locomotive. By some means his brother sold one of his machines to Mr. William Thomas, a corset maker of London, and Howe was induced to go there to make stays, and his machines. He took his wife and children with him. The arrangement made with his employer was not such as to enable him to keep his family there, and he soon sent them home.

Unable to sell his machines, he was soon reduced to want. He pawned his patent and his last machine, and procured money to return to New York, where he arrived penniless in 1849. He then learned that his wife was dying of consumption at Cambridge. He was compelled to wait until money could be sent him to pay his passage home, and reached there just before his wife's death.

He then learned that during his absence his patent and machine had attracted attention, that others had taken the matter up, added their improvements to his machines, and that many in various places were being made and sold which were infringements of his patent. A great demand for sewing machines had sprung up. He induced friends to again help him. Suits were commenced which, although bitterly fought for six years, were finally successful.

Now fortune turned her smiling face upon him. Medals and diplomas, the Cross of the Legion of Honour, and millions of money became his. When the great civil war broke out in 1861, he entered the army as a private soldier, and advanced the money to pay the regiment to which he belonged, when the Government paymaster had been long delayed. His life was saddened by the fact that his wife had not lived to share his fortune. He died in Brooklyn, New York, October 3, [Pg 318] 1867, in the midst of life, riches, and honour, at the comparatively early age of forty-eight.

In referring to the early inventors of sewing machines in America who entered the field about the same time with Howe, mention should be made of J. J. Greenough and George Corliss, who had machines patented respectively in 1842 and 1843, for sewing leather, with double pointed needles; and the running stitch sewing machine used for basting, made and patented by B. W. Bean in 1843. About this time, both in England and America, machines had been devised for sewing lengths of calico and other cloths together, previous to bleaching, dyeing or printing. The edges of the cloths were first crimped or fluted and then sewed by a running stitch.

The decade of 1849-1859, immediately following the development of the Howe machine, was the greatest in the century for producing those successful sewing machines which were the foundation of the art, established a new industrial epoch, and converted Hood's "Song of the Shirt" into a lament commemorative of the miseries of a slavish but dying industry.

It was during that decade that, in the United States, Batcheller invented the perpetual feed for moving the cloth horizontally under and past the needle. In Howe's the cloth could be sewed but a certain distance at a time, and then the machine must be readjusted for a new length. Then Blodgett and Lerow imparted to the eye-pointed needle what is called the "dip motion,"—the needle being made to descend completely through the material, then to rise a little to form a loop; the shuttle then entered the loop, the needle descended again a short distance, while the [Pg 319] shuttle passed through the loop of the needle thread, and then the needle was raised above the cloth.

It was then that Allen B. Wilson invented the still more famous "four-motion feed" for feeding the cloth forward. He employed a bar having saw like teeth on one edge which projected up through a slotted plate and engaged the cloth. He then first moved the bar forward carrying the cloth; second, dropped the bar; third, moved it back under the plate; and fourth, raised it to its first position to again engage the cloth. These motions were so timed with the movement of the needle and so quickly done that the cloth was carried forward while the needle was raised, the passage and quick action of the needle was not interfered with, and the feeding and the sewing seem to be simultaneous. The intermittent grasp and feed of the cloth were hardly perceptible, and yet it permitted the cloth to be turned to make a curved seam. Wilson also invented the rotating hook which catches the loop of the upper thread, and drops a disk bobbin through it to form the stitch. The shuttle was thus dispensed with, and an entirely new departure was made in the art. These with other improvements made up the celebrated "Wheeler and Wilson" machine.

Now also appeared "the Singer," consisting chiefly of the invention of T. M. Singer. He improved the operation of the needle bar, devised a roughened feed wheel, as a substitute for Wilson's serrated bar, introduced a spring presser foot, alongside the needle, to hold the work down in proper position while permitting it to be moved forward or in any other direction. A "friction pad" was also placed between the cloth seam and the spool, to prevent the thread from kinking or [Pg 320] twisting under the point of the descending needle. He was the first to give the shuttle an additional forward movement after it had once stopped, to draw the stitch tight,—such operation being taken while the feed moved the cloth in the reverse direction, and while, the needle completed its upward motion, so that the two threads were simultaneously drawn, and finally a spring guide upon the shuttle to control the slack of the thread, and prevent its catching by the needle.

By reason of these improvements it is thought by many that Singer was the first to furnish the people with a successful operating and practical sewing machine. At any rate, the world at last so highly appreciated his machines, that it lifted him from poverty to an estate which was valued at between eight and ten millions of dollars at the time of his death in 1875. Singer was also the first to invent the "ruffler," a machine for ruffling or gathering cloth, and a device which laid an embroidering thread upon the surface of the cloth under the needle thread.

The "Grover and Baker" another celebrated American machine, was invented by William O. Grover and William E. Baker in 1851. By certain changes they made in the thread carrier and connections, they were enabled to make a double looped stitch. This required more thread, but the stitch made was unexcelled in strength.

And so the work went on, from step to step, and from the completion of one machine after another, until when the Centennial Exhibition came to be held in Philadelphia in 1876, a fine array of excellent sewing machines was had, from the United States, principally, but also those of inventors and manufacturers in Great Britain, Canada, France, Germany, Belgium, Sweden and Denmark. [Pg 321]

Up to that time about twenty-two hundred patents had been granted in the United States, all of which, with the exception of a very few, were for inventions made within the preceding quarter of a century. And during the last quarter of the century about five thousand more United States patents have been issued for devices in this art. This number includes many, of course, to inventors of other countries. When it is remembered that these patents were issued only after an examination in each case as to its novelty, and although slight as may have been the changes or additions, yet substantially different they must have been in nearly all respects, it may to some extent be realized how great and incessant has been the exercise of invention in this useful class of machines.

On this point of the exercise of invention in sewing machines, as well as on some others growing out of the subject, Knight, writing in his *Mechanical Dictionary*, about twenty years ago, remarks: "If required to name the three subjects on which the most extraordinary versatility of invention has been expended, the answer would be without hesitation, the *sewing machine*, *reaping machine* and *breech-loading firearm*. Each of these has thousands of patents, and although each is the growth of the last forty years, it is only during the last twenty-five years that they have filled any notable place in the world. It was then only by a combination of talents that any of these three important inventions was enabled to achieve remarkable success. The sewing machine previous to 1851, made without the admirable division of labour which is a feature in all well conducted factories, was hard to make, and comparatively hard to run. The system of *assembling*, first introduced in the artillery service of France by General Gribeauval in 1765 and brought to proximate perfection by Colonel Colt in the manufacture of the revolver at Hartford, Connecticut, has economised material and time, improved the quality as well as cheapened the product. There is to-day, and in fact has been for some years, more actual invention in the special machines for *making* sewing machines than in the machines themselves. The assembling system, that is, making the component parts of an article in distinct pieces of pattern, so as to be interchangeable, and the putting them together, is the only system of order. How else should the Providence Tool Company execute their order for 600,000 rifles for the Turkish Government? How otherwise could the Champion Harvesting Machine Company of Springfield, Ohio, turn out an equipped machine every four minutes each working day of ten hours? Or, to draw the illustration from the subject in hand, how by any other than the nicest arrangement of detail can the Singer Sewing Machine Company make 6,000 machines per week at Elizabethport, New Jersey?" [Pg 322]

When sewing machines were so far completed as to be easily run by a hand crank, or treadle, the application of power to run them singly, or in series, and to run machines of a larger and more powerful description, soon naturally followed—so that garment-making factories of all kinds, whether of cloth or leather, have been established in many countries—in which steam or electric power is utilised as the motor, and thus human strain and labour saved, while the amount of production is increased. [Pg 323]

No radical changes in the principle or mode of operation of sewing machines have been made in the last twenty-five years; but the efforts of inventors have been directed to improve the previously established types, and to devise attachments of all kinds, by the aid of which anything that can be sewed, can be sewed upon a machine. Tucking, ruffling, braiding, cording, hemming, turning, plaiting, gaging, and other attachment devices are numerous. Inventors have rivalled one another in originating new forms of stitches. About seventy-five distinct stitches have been devised, each of which must of course be produced by a change in mechanism.

When sewing machines were in their infancy, and confined to sewing straight seams and other plain sewing, it was predicted that it was not possible to take from the hands of women the making of fine embroidery from intricate patterns, or the working of button-holes, and the destruction of the quilting party was not apprehended. Nor was it expected that human hands could be dispensed with in the cutting out of garments. And yet these things have followed. Machines, by a beautiful but complex system of needles, working to some extent on the Jacquard system of perforated card boards, and by the help of pneumatic or electrical power, will work out on most delicate cloths embroidery of exquisite patterns.

The button-hole machines will take the garment, cut the button-hole at the desired point, and either, as in one class of machines, by moving the fabric about the stitch-forming mechanism, or, as in another class, moving the stitch-forming mechanism about the button-hole, complete the delicate task in the nicest and most effective manner. [Pg 324]

Quilting machines have their own bees, consisting of a guide which regulates the spaces between the seams, and adjusts them to any width, and a single needle, or gang of needles, the latter under the control of cams which force the needles to quilt certain desired patterns.

And as to cutting, it is only necessary to place the number of pieces of fabric desired to be cut in cutting dies, or upon a table, and over them an "over-board" cutter, which comprises a reciprocating band-saw, or a rotary knife, all quick, keen and delicate, in an apparatus guided by hand, in order to produce in the operation a great pile of the parts formerly so slowly produced, one at a time, by scissors or shears.

If men were contented with that single useful garment of some savages, a blanket with a slit cut in it for the passage of the head and neck, not only would a vast portion of the joys and sorrows of social philosophy have been avoided, but an immense strain and trouble on the part of inventors of the century would have been obviated.

But man's propensity for wearing clothes has led to the invention of every variety of tools for making them faster, cheaper, and better.

No machine has yet been invented that will take the place of the deft fingers of women in certain lines of ornamentation, as in final completion and trimming of their hats. The airy and erratic demands of fashion are too nimble to be supplied by the slow processes of machinery, although the crude ground-work, the frame, has been shaped, moulded and sewed by machines; and women themselves have invented and patented *bonnet frames* and *patterns*. [Pg 325]

But no such difficulty in invention has occurred in *hat-making* for men. From the treating and cutting of the raw material, from the outer bound edge, and the band about the body, to the tip of the crown, a machine may be found for performing each separate step. Especially is this the case with the hard felt and the high silk hats.

Seventy-five years ago the making of hats was by hand processes. Now in all hat factories machines are employed, and the ingenuity displayed in the construction of some of them is marvellous. It is exceedingly difficult to find many of the old hand implements existing even as relics.

Wool and fur each has its special machines for turning it into a hat. The operations of cleaning and preparing the material, felting the fur, when fur is used, shaping the hat body, and then the brim, washing, dying, hardening and stiffening it, stretching, smoothing, finishing, sizing, lining, trimming, all are now done by machines devised for each special purpose. A description of these processes would be interesting, but even in an abbreviated form would fill a book.

The wonderful things done in the manufacture of boots and shoes and rubber goods will be referred to in subsequent chapters.

Although it was old from time immemorial to colour cotton goods, and the calico power printing cylinder was invented and introduced into England in the latter part of the 18th century and began to turn out at once immense quantities of decorated calicoes and chintz, yet *figured* woven goods were a novelty sixty years ago.

In 1834, Mr. Bonjeau, a prominent wool manufacturer in Sedan, France, and an *élève* of the Polytechnic School, conceived the idea of modifying the plain cloths, universally made, by the [Pg 326] union of different tints and patterns. This he was enabled to do by the Jacquard loom. The manufacture of fancy woven cloths, cassimeres, worsted coatings, etc., of great beauty, combined with strength of fabrication, followed in all civilised countries, but their universal adoption as wearing apparel was due in part to the lessening of the expense in the making them into garments by the sewing machine.

As to the effect of modern inventions on wearing apparel, it is not apparent that they were necessary to supply the wardrobes of the rich. The Solomons and the Queen of Sheba of ancient days, and all their small and great successors in the halls of Fortune, have had their rich robes, their purple and their fine linen, whether made in one way or another; but modern inventions have banished the day when the poor man's hard labour of a long day will not suffice to bring his wife a yard of cheapest cloth. Toil, then, as hard as he and his poor wife and children might, their united labours would hardly suffice to clothe them in more than the poorly-dressed skins of animals and the coarsest of homespun wool.

Now, cottons and calicoes are made and sold at a profit for three cents a yard; and the poorest woman in the land may appear in neat, comfortable and tasteful dress, the entire cost of material and labor of which need not exceed fifty cents. The comfort, respectability and dignity of a large family, which depend so much on clothes, may be ensured at the cost of a few dollars.

And as to the condition of the sewing woman, trying and poor as it is in many instances, yet she can earn more money with less physical exhaustion than under the old system. [Pg 327]

The epoch of good clothes for the people, with all that it means in the fight upward from degradation, began in this century, and it was due to the inventions which have been above outlined.

CHAPTER XX.

INDUSTRIAL MACHINES.

One invention engenders another, or co-operates with another. None lives, or stands, or dies, alone.

So, in the humble but extensive art of *broom-making*, men and women worked along through ages binding with their hands the supple twigs of trees or bushes, or of corn, by thongs, or cords, or wire, upon the rudely-formed collar of a hand-smoothed stick, until the modern lathe and hollow mandrel armed with cutters, the power-driven shuttle, and the sewing machine, were invented.

The lathe and mandrel to hold the stick while it was cut was used before, but it was long within the century that a hollow mandrel was first invented, which was provided internally with cutting bevelled knives, and into which the stick was placed, carried through longitudinally, and during its passage cut smooth and finished. As broom corn became the chief product from which brooms are made, it became desirable to have a machine, after the corn had been scraped of its seed, to size and prepare the stems in regular lengths for the various sizes of brooms, and accordingly such a machine was invented. Then a machine was needed and invented to wind the corn-brush with the cord or wire and tie it in a round bunch, preparatory to flattening and sewing it.

Then followed different forms of broom-sewing machines. Among the pioneers was one which received the round bunch between two compressing jaws, and pressed it flat. While so held a needle with its coarse thread was forced through the broom above the binding and the cord twined around it. Then a shuttle, also carrying a stout thread, was thrown over the cord, the needle receded and was then forced through the broom again *under* the binding cord. Thus in conjunction with the shuttle the stitches were formed alternately above and below the binding twine, the holding jaws being raised intermittently for that purpose. As each stitch was formed the machine fed the broom along laterally and intermittently. By another ingenious device the cord was tied and cut, when the sewing was completed.

It is only by such machines which treat the entire article from the first to the last step, that the immense number of brooms now necessary to supply the market are made. True it is that at first labour was displaced. At one time seventeen skilled workmen would manufacture five hundred dozen brooms per week.

They had reduced the force of earlier times by making larger quantities by better processes. Then when the broom-sewing machines and other inventions got fairly to work, nine men would turn out twelve hundred dozen brooms per week. Thus, while the force was reduced nearly one-half, the quantity of product was more than doubled. But as the cost of labour decreased and the product increased, the product became more plentiful and cheaper, the demand and use became greater, more broom-corn was raised, more broom-factories started, and soon the temporary displacement of labour was succeeded by a permanent increase in manufacture and in labourers, an increase in their wages, and an improvement in their condition.

Useful and extensive as is its use, the broom does not compare in variety and wide application to the *brush*. The human body, cloth, leather, metals, wood and grains, everything that needs rubbing, cleaning, painting and polishing, meets the acquaintance of the brush. Nearly a hundred species of brushes might be enumerated, each having an especial construction for a particular use.

Although the majority of brushes are still made by hand, yet a few most ingenious machines have been made which greatly facilitate and speed the operation, and many mechanical appliances have been invented in aid of hand-work. These machines and appliances, together with those which cut, turn, bore, smooth, and polish the handles and backs, to which the brush part is secured, have greatly changed and improved the art of brush-making during the last fifty years.

The first machine which attracted general attention was invented by Oscar D. and E. C. Woodbury of New York, and patented in 1870. As in hand-making and before subjected to the action of the machine, the bristles are sorted as to length and color. A brush-back, bored with holes by a gang of bits, which holes do not extend, however, all the way through the back, is placed in the machine under a cone-jointed plunger, adapted to enter the hole in the brush-back. A comb-shaped slitted plate in the machine has then each slit filled with bristles, sufficient in number to form a single tuft. When the machine is started, the bristles in a slit are forced out therefrom through a twisted guideway, which forms them into a round tuft, and which is laid horizontally beneath a plunger, which, descending, first doubles the tuft, and as the plunger continues to descend, forces the double end down into the hole. The plunger is supplied with a wire from a reel, turns as it descends, and twists the wire around the lower end of the tuft, the wire being directed in that way by a spiral groove within the plunger. The continuing action of the plunger is such as to screw the wire into the back. The wire is cut when the rotary plunger commences its descent, and when the tuft is thus secured the plunger ascends, the block is moved for another hole, and another set of bristles is presented for manipulation. Brushes with 70 holes can be turned out by this machine at the rate of one a minute.

Another most ingenious machine for this purpose is that of Kennedy, Diss, and Cannan, patented in the United States in 1892. In this, brush blocks of varying sizes, but of the same pattern, are bored by the same machine which receives the bristles, and the tufts are inserted as fast as the holes are bored. Both machines are automatic in operation.

Street-sweeping machines began to appear about 1831 in England, shortly after in France, and then in cities in other countries.

The simplest form and most effective sweeper comprises a large cylinder armed with spiral rows of splints and hung diagonally on the under side and across a frame having two or four wheels. This cylinder is connected by bevelled gearing with the wheels, and in revolving throws the dirt from the street into a ridge on one side thereof, where it is swept into heaps by hand sweepers, and is then carted off. King of the United States was the inventor.

A more recent improvement consists in the use of pneumatic means for removing the dust that is caused by the use of revolving brooms or brushes, such removal being effected by means of a hood that covers the area of the street beneath the body of the machine, and incloses an air exhaust, the sweepings being drawn through the exhaust mechanism and deposited in a receptacle for the purpose, or in some instances deposited in a furnace carried by the machine and there burned. [Pg 332]

In cities having hard, smooth, paved streets and sufficient municipal funds, the most effective, but most expensive way, has been found to keep a large force of men constantly at work with hoes, shovels, brooms, bags and carts, removing the dirt as fast as it accumulates.

Abrading Machines.

One of the most striking inventions of the century is the application of the sand-blast to industrial and artistic purposes.

For ages the sands of the desert and wild mountain plains, lifted and driven by the whirling winds, had sheared and polished the edges and faces of rocks, and cut them into fantastic shapes, and the sands of the shore, tossed by the winds of the sea, had long scratched and bleared the windows of the fisherman's hut, before it occurred to the mind of man that here were a force and an agent which could be harnessed into his service.

It was due finally to the inventive genius of B. F. Tilghman of Philadelphia, Pa., who, in 1870, patented a process by which common sand, powdered quartz, emery, or other comminuted sharp cutting material, may be blown or driven with such force upon the surface of the hardest materials, as to cut, clean, engrave, and otherwise abrade them, in the most wonderful and satisfactory manner. [Pg 333]

Diamonds are abraded; glass depolished, or engraved, or bored; metal castings cleaned; lithographic zinc plates grained; silverware frosted; stone and glass for jewelry shaped and figured; the inscriptions and ornaments of monuments and tombstones cut thereon; engravings and photographs copied; steel files cleaned and sharpened, and stones and marble carved into forms of beauty with more exactness and in far less time than by the chisel of the artisan.

The gist of the process is the employment of a jet of sand or other hard abrading material, driven at a high velocity by a blast of air or steam, under a certain pressure, in accordance with the character of the work to be done. The sand is placed in a box-like receptacle into which the air or steam is forced, and the sand flowing into the same chamber is driven through a narrow slit or slits in the form of a thin sheet, directly on to the object to be abraded.

By one method the surface of the object is first coated with tinfoil on which the artist traces his design, and this is then coated with melted transparent wax. Then when the wax is hardened it is cut away along the lines already indicated, and seen through the wax. The object now is subjected to the blast, and as the sand will not penetrate a softened material sufficient to abrade a surface beneath, the exposed portions alone will be cut away. The sand after it strikes is carried off by a blast to some receptacle, from which it is returned to its former place for further use. Other means may be used in the place of a slitted box, as a small or larger blow-pipe; but the driving of the sand, or similar abrading material, with great force by the steam or air blast, is the essential feature of the process. [Pg 334]

Emery, that variety of the mineral corundum, consisting of crystalline alumina, resembling in appearance dark, fine-grained iron ore, ranking next to the diamond in hardness, and a sister of the sapphire and the ruby, has long been used as an abradant. The Eastern nations have used corundum for this purpose for ages. Turkey and Greece once had a monopoly of it. Knight says: "The corundum stone used by the Hindoos and Chinese is composed of corundum powdered, two parts; lac resin, one part. The two are intimately mixed in an earthen vessel, kneaded and flattened, shaped and polished. A hole in the stone for the axis is made by a heated copper rod."

However ancient the use of artificial stones for grinding and polishing, nevertheless it is true that the solid emery wheel in the form that has made it generally useful, in machines known as *emery grinders*, is a modern invention, and of American origin.

In the manufacture of such machines great attention and the highest scientific skill has been paid, first, to the material composing the wheel, and to the cementing substances by which the emery is compacted and bound in the strongest manner, to prevent bursting when driven at great speed; secondly, to the construction of machines and wheels of a composition varying from the finest to the coarsest; and thirdly, to the proper balancing of the wheels in the machines, an operation of great nicety, in order that the wheel may be used on delicate tools, when driven at [Pg 335] high speed, without producing uneven work, marking the objects, or endangering the breaking, or bursting of the wheel.

Such machines, when properly constructed, although not adapted to take the place of the file, other steel-cutting tools, and the grindstone for many purposes, yet have very extensively displaced those tools for cutting edges, and the grinding and polishing of hardened metals, by reason chiefly of their greater convenience, speed, and general adaptability. Not only tools of all sizes are ground and polished, but ploughshares, stove and wrought-iron plates, iron castings, the inner surfaces of hollow ironware, the bearings of spindles, arbours, and the surfaces of steel, chilled or cast-iron rolls, etc.

In the great class of Industrial Mechanics, no machines of the century have contributed more to the comfort and cleanliness of mankind than those by which wearing apparel in its vast quantities is washed and ironed more thoroughly, speedily, and satisfactorily in every way than is possible by the old hand systems. When it is remembered how under the old system such a large part of humanity, and this the weaker part, devoted such immense time and labour to the universal washing and ironing days, the invention of these machines and appliances must be regarded as among the great labour-saving blessings of the century.

True, the individual washerwoman and washerman, and ironers, have by no means disappeared, and are still in evidence everywhere, yet the universal and general devotion of one-half the human race to the wash-tub and ironing-table for two or more days in the week is no longer necessary. And even for the individual worker, the convenient appliances and helps that have been invented have greatly relieved the occupation of pain and drudgery. [Pg 336]

Among modern devices in the laundry, worked by hand, is, first, the *washing-machine*, in which the principle is adapted of rolling over or kneading the clothes. By moving a lever by hand up and down, the clothes are thoroughly rubbed, squeezed and lifted at each stroke. Then comes the *wringer*, a common form of which consists of two parallel rolls of vulcanized and otherwise specially treated rubber, fitted to shafts which, by an arrangement of cog-wheels, gearing and springs in the framework at the ends of rolls, and a crank handle, are made to roll on each other. The clothes are passed between the rollers, the springs permit the rollers to yield and part more or less, according to the thickness of the clothes.

Then the old-fashioned, or the new-fashioned mangle is brought into play. The old-style mangle had a box, weighted with stone, which was reciprocated on rollers, and was run back and forth upon the clothes spread upon a polished table beneath. One of the more modern styles is on the principle of the wringer above described, or a series of rollers arranged around a central drum, and each having a rubber spring attached, by which means the clothes are not subjected to undue pressure at one or two points, as in the first mentioned kind.

Starch is also applied by a similar machine. The cloth is dipped into a body of starch, or the same is applied by hand, and then the superfluous starch squeezed out as the clothes are passed through the rollers.

But for hotels and other large institutions washing is now done by steam-power machinery.

It is an attractive sight to step into a modern laundry, operated with the latest machinery on the largest scale. The first thing necessary in many localities is to clarify the water. This is done by [Pg 337] attaching to the service pipe tanks filled with filtering material, through which the water flows before reaching the boiler. The driving engine and shafting are compactly placed at one end or side of the room, with boilers and kettles conveniently adjacent. The water and clothes are supplied to the washing-machine, and operated by the engine. Steam may be used in addition to the engine to keep it boiling hot, or steam may be substituted entirely for the water.

The machine may be one of several types selected especially for the particular class of goods to be washed. There is the dash-wheel, constructed on the principle of the cylinder churn; the outer case being stationary and the revolving dash-wheel water-tight, or perforated, which is the preferred form for collars and cuffs. In place of the dash-wheel cylinders are sometimes used, having from sixty to seventy revolutions a minute. Another form has vibrating arms or beaters, giving between four hundred and five hundred strokes a minute, and by which the clothes are squeezed between rubbing corrugated boards. The rubbing boards also roll the clothes over and over until they are thoroughly washed. In another form a rotating cylinder for the clothes is provided with an arrangement of pipes by which either steam, water or blueing can be introduced as desired, into the cylinder, through its hollow journals, so that the clothes can be washed, rinsed, and blued without removal from the machine.

Another type has perforated, reciprocating pistons, between which the clothes are alternately squeezed and released, a supply of fresh water being constantly introduced through one of the hollow cylinder journals, while the used water is discharged through the opposite journal; and in [Pg 338] still another the clothes are placed in a perforated cylinder within an outer casing, and propeller blades, assisted by other spiral blades, force a continuous current of water through the clothes.

In ironing, hollow polishing rolls of various sizes are used, heated either by steam or gas. The articles to be ironed are placed in proper position upon a table and carried under and in contact with the rolls. Or the goods are ironed between a heated cylinder and a revolving drum covered with felting, and the polishing effected by the cylinder revolving faster than the drum. Ingenious forms of hand-operated ironing machines for turning over and ironing the edges of collars, and other articles, are in successful use.

[Pg 339]

CHAPTER XXI.

WOOD-WORKING.

In surveying the wonderful road along which have travelled the toiling inventors, until the splendid fields of the present century have been reached, the mind indulges in contrasts and reverts to the far gone period of man's deprivations, when man, the animal, was fighting for food and shelter.

"Poor naked wretches, wheresoe'er you are,
That bide the pelting of this pitiless storm,
How shall your houseless heads and unfed sides,
Your loop'd and window'd raggedness, defend you
From seasons such as these?"

—*King Lear III, IV.*

When the implements of labour and the weapons of war were chiefly made of stone, or bronze, or iron, such periods became the "age" of stone, or bronze, or iron; and we sometimes hear of the ages of steam, steel and electricity. But the age of wood has always existed, wherever forests abounded. It was, doubtless, the earliest "age" in the industries of man, but is not likely to be the latest, as the class of inventions we are about to consider, although giving complete dominion to man over the forests, are hastening their destruction.

As in every other class of inventions, there had been inventions in the class of wood-working through the ages preceding this century, in tools, implements and machines; but not until near the close of the eighteenth century had there been much of a break in the universal toil by hand. [Pg 340] The implements produced were, for the most part, the result of the slow growth of experience and mechanical skill, rather than the product of inventive genius.

True, the turning-lathe, the axe, the hammer, the chisel, the saw, the auger, the plane, the screw, and cutting and other wood-shaping instruments in simple forms existed in abundance. The Egyptians used their saws of bronze. The Greeks deified their supposed inventor of the saw, Talus, or Perdix, and they claimed Theodore of Lamos as the inventor of the turning-lathe; although the main idea of pivoting an object between two supports, so that it could be turned while the hands were free to apply a tool to its shaping, was old in the potter's wheel of the Egyptians, which was turned while the vessel resting upon it was shaped and ornamented by the hand and tools. It appears also to have been known by the Hindoos and the Africans.

Pliny refers to the curled chips raised by the plane, and Ansonius refers to mills driven by the waters of the Moselle for sawing marble into slabs. Early records mention saw-mills run by water-power in the thirteenth century in France, Germany and Norway; and Sweden had them in the next century. Holland had them one hundred years at least before they were introduced into England.

Fearful of the entire destruction of the forests by the wood used in the manufacture of iron, and incited by the opposition and jealousy of hand sawyers, England passed some rigid laws on the subject in the sixteenth and seventeenth centuries, which, although preserving the forests, gave for a long time the almost exclusive manufacture of iron and lumber to Germany and Holland. Even as late as 1768, a saw-mill, built at Limehouse, under the encouragement of the Society of Arts, by James Stansfield, was destroyed by a mob. [Pg 341] Saw-mills designed to be run by water-power had been introduced into the American colonies by the Dutch more than a century before they made their appearance in England. William Penn found that they had long been at work on the Delaware when he reached its shores in 1682.

It was nothing indigenous to the climate or race that rendered the Americans inventors. The early colonists, drawn from the most civilised countries of Europe, carried to the new world knowledge of the latest and best appliances known to their respective countries in the various arts. With three thousand miles of water between them and the source of such appliances, and between them and the source of arbitrary power and laws to hamper efforts and enterprise, with stern necessity on every hand prompting them to avail themselves of every means to meet their daily wants, all known inventions were put to use, and brains were constantly exercised in devising new means to aid, or take the place of, manual labour, which was scarce. Surrounded, too, by vast forests, from which their houses, their churches and their schools must be constructed, these pioneers naturally turned their thoughts toward wood-working machinery. The attention to this art necessarily created interest in and developed other arts. Thus constant devotion to pursuits strenuously demanding labour-saving devices evolved a race of keen inventors and mechanics. So that when Watt had developed his wonderful application of steam to industrial purposes, America was ready to substitute steam for water-power in the running of saw-mills. [Pg 342]

Steam saw-mills commenced to buzz with the opening of the century.

As to the relation of that humble machine, the saw-mill, to the progress of civilisation, it was once said: "The axe produces the log hut, but not until the saw-mill is introduced do framed dwellings and villages arise; it is civilisation's pioneer machine; the precursor of the carpenter, wheelwright and turner, the painter, the joiner, and legions of other professions. Progress is unknown where it is not. Its comparative absence in the Southern American continent was not the least cause of the trifling advancement made there during three centuries and a half. Surrounded by forests of the most valuable and variegated timber, with water-power in mountain streams, equally neglected, the masses of the people lived in shanties and mud hovels, not more commodious than those of the aborigines, nor more durable than the annual structures of birds. Wherever man has not fixed and comfortable homes, he is, as regards civilisation, stationary; improvement under such circumstances has never taken place, nor can it."

Miller, in England, in 1777, had described in his patent a circular saw, and Hatton, in 1776, had vaguely described a planing machine; but the inception of the marvellous growth in wood-working machinery in the nineteenth century occurred in England during the last decade of the eighteenth. It was due to the splendid efforts of General Samuel Bentham, and of Bramah and Branch, both as to metal-working and wood-working machinery.

General Bentham, a brother of the celebrated jurist, Jeremy Bentham, had his attention drawn to the slow, laborious, and crude methods of working in wood, while making a tour of Europe, and [Pg 343] especially in Russia, and engaged in inspecting the art of ship-building in those countries, in behalf of the British Admiralty. On his return, 1791-1792, he converted his home into a shop for making wood-working machines. These included "Planing, moulding, rabbeting, grooving, mortising, and sawing, both in coarse and fine work, in curved, winding, and transverse directions, and shaping wood in complicated forms."

Of the amount of bills presented to and paid for by the Admiralty for these machines, General Bentham received about £20,000.

These machines were developed and in use just as the new century approached. Thus, with the exception of the saw-mill, it may be again said that prior to this century the means mankind had to aid them in their work in metals and in wood were confined to hand tools, and these were for the most part of a simple and crude description.

The ground-work now being laid, the century advanced into a region of invention in tools and machinery for wood-working of every description, far beyond the wildest dreams of all former carpenters and joiners. Not only were the machines themselves invented, but they gave rise in turn to a host of inventions in metal-working for making them.

In the same line of inventions there appeared in the first decade of the century one of the most ingenious of men, and a most fitting type of that great class of Yankee inventors who have carved their way to renown with all implements, from the jack-knife to the electrically-driven universal shaping machine.

Thomas Blanchard, born in Massachusetts in 1788, while a boy, was accustomed to astonish his companions by the miniature wind-wheels and water-wheels that he whittled out with his knife. [Pg 344] While attending the parties of young people who gathered on winter evenings at different homes in the country to pare apples, the idea of a paring machine occurred to him, and when only thirteen years of age, he invented and made the first apple-paring machine, with which more apples could be pared in a given time than any twelve of his girl acquaintances could pare with a knife.

At eighteen, while working in a shop, driving the heads down on tacks, on an anvil, with a hammer, he invented the first tack-forming machine, which, when perfected by him, made five hundred tacks a minute, and which has never since been improved in principle. He improved the steam engine, and invented one of the first envelope machines. He made the first metal lathe for cutting out the butts of gun-barrels. But his greatest triumphs were in wood-working machinery.

Challenged to make a machine that would make a gun stock, always before that time regarded an impossible task, its every part being so irregular in form, he secluded himself in his workshop for six months, and after constant labour and experiments he at the end of that time had produced a machine that more than astonished the entire world, and which worked a revolution in the making of all irregular forms from wood. This was in 1819. This machine would not only make a perfect gun-stock, but shoe lasts, and ships' tackle-blocks, axe-handles, and a multitude of irregular-shaped blocks which before had always required the most expert hand operatives to produce. This machine became the subject of parliamentary inquiry on the part of England, and so great were the doubts concerning it, that successive commissions were appointed to examine [Pg 345] and report upon it. Finally the English government ordered eight or ten of such machines for the making of gun-stocks for its army, and paid Blanchard about $40,000 for them. He was once jestingly asked at the navy department at Washington if he could turn a seventy-four? He at once replied, "Yes, if you will furnish me the block." Of course infringers appeared, but he maintained his rights and title as first and original inventor after the most searching trials in court.

The generic idea of Blanchard's lathe for turning irregular forms consists in the use of a pattern of the device which is to be shaped from the rough material, placing such pattern in a lathe, alongside of the rough block, and having a guide wheel which has an arm having cutters, and which guide follows all the lines of the pattern, and which cutters, extending to the rough material, chip it away to the depth and in the direction imparted by the pattern lines to the guide, thus producing from the rough block a perfect representation of the pattern.

In the midst of his studies in the construction of his inventions Blanchard's attention was drawn to the operations of a boring worm upon an old oak log. Closely examining and watching the same by the aid of a microscope, he gained valuable ideas from the work of his humble teacher, which he incorporated into his new cutting and boring machines.

His series of machines in gun-making were designed to make and shape automatically every part of the gun, whether of wood or metal. His machines, and subsequent improvements by others, for boring, mortising and turning, display wonderful ingenuity. A modern mortising machine, for instance, is adapted to quickly and accurately cut a square or oblong hole to any desired depth, [Pg 346] width, and length by cutting blades; to automatically reciprocate the cutters both vertically and horizontally in order to cut the mortise, both as to length and depth, at one time, and to automatically withdraw the cutters when they have finished cutting the mortise. They are provided with simple means for setting and feeding the cutters to do this work, and while giving the cutters a positive action, ample clearance is provided for the removal of the chips as fast as they are cut.

From what such inventions will produce in the way of complicated and ornamental workmanship we may conclude that it is a law of invention that whatever can be made by hand may be made by a machine, and made better.

Carving Machines made their appearance early in the century. In 1800 a Mr. Watt of London produced one, on which he carved medallions and figures in ivory and ebony. Also subsequently, John Hawkins of the same city, and a Mr. Cheverton, invented machines for the same purpose. Another Englishman, Braithwaite, in 1840, invented a most attractive carving process in which, instead of cutting tools, he employed *burning* as his agent. Heated casts of previously carved models were pressed into or on to wet wood, and the charcoal surfaces then brushed off with hard brushes.

After Blanchard's turning-lathes and boring apparatus, appeared machines in which a series of cutters were employed, guided by a tracing lever attached to a carved model, and actuating the cutter to reproduce on material placed upon an adjusting table a copy of the model.

Machines have been invented which consist of hard iron or steel rollers on the surface of which [Pg 347] are cut beautiful patterns, and between which wood previously softened by steam is passed, and designs thus impressed thereon. A similar process of embossing, was devised in Paris and called Xyloplasty, by which steam-softened wood is compressed in carved moulds, which give it bas-relief impressions.

But in the carving of wood by hand, a beautiful art, which has been revived within the past generation, there are touches of sentiment, taste and human toil, which, like the touches of the painter and the master of music, appeal to cultivated minds in a higher than mechanical sense. The mills of the modern gods, the inventors, grind with exceeding and exact fineness, but the work of a human hand upon a manufactured article still appeals to human sympathy.

The bending of wood when heated by fire or steam had been known and practised to a limited extent, but Blanchard invented a *clamping machine*, to which improvements have been added, and by which ship timbers, furniture, ploughs, piano frames, carriage bows, stair and house banisters and balusters, wheel rims, staves, etc., etc., are bent to the desired forms, and without breaking. Bending to a certain extent does not weaken wood, but stretching the same has been found to impair and destroy its strength.

The principal problems which the inventors of the century have solved in the class of wood-working have been the adaptation to rapid-working machinery of the saw and other blades, to sever; the plane to smooth, the auger, the bit and the gimlet to bore, the hammer to drive, and a combination of all or a part of these to shape and finish the completed article. [Pg 348]

It was a great step from the reciprocating hand saw, worked painfully by one or two men, to the band saw, invented by a London mechanic, William Newbury, in 1808. This was an endless steel belt serrated on one edge, mounted on pulleys, and driven continuously by the power of steam through the hardest and the heaviest work. Pliable, to conform to the faces of the wheels over which it is carried, it will bend with all the sinuosities of long timber, no time is lost in its operation, and no labour of human hands is necessary to guide it or the object on which it works.

At the Vienna Exposition in 1873, the first mammoth saw of this description was exhibited. The saw itself was made by the celebrated firm of Perin & Co., of Paris, upon machinery the drawings of which were made by Mr. Van Pelt of New York, and constructed by Richards, Loudon and Kelly of Philadelphia. The saw was fifty-five feet long, and sawed planks from a pine log three feet thick, at the rate of sixty superficial feet per minute. The difficulty of securing a perfectly reliable weld in the endless steel band was overcome by M. Perin, who received at the Paris Exhibition in 1867 the Grand Cross of the Legion of Honour. Now gangs of such saws may be found in America and elsewhere, and circular saws have also been added. Saws that both cut, form, and *plane* the boards at the same time are now known.

Boring tools, both for hand and machinery, demanded improvement. Formerly augers and similar boring tools had merely a curved sharpened end and a concavity to hold the chips, and the whole tool had to be withdrawn to empty the chips. It was known as a *pod* auger. In 1809, L'Hommedieu, a Frenchman, invented an auger with two pods and cutting lips, a central screw and a twisted shank. About the same time Lilley of Connecticut made a twisted auger, and these screw-form, twisted, cutting tools of various kinds, with their cutting lips, and by which the shavings or chips were withdrawn continuously from the hole as the cutting proceeded, became so improved in the United States that they were known as the American augers and bits. The planing machines of General Bentham were improved by Bramah, and he and Maudsley also greatly improved other wood-working machines and tools in England—1802-1810. [Pg 349]

We have before, in the chapter on metal-working, shown the importance of the *slide-rest*, *planer* and *lathe*, *when combined*, and which also are extensively adapted to wood-working. In Bramah's machine, a vertical spindle carried at its lower extremity a horizontal wheel having twenty-eight cutter blades, followed by a plane also attached to a wheel. A board was by these means perfectly trimmed and smoothed from end to end, as it was carried against the cutters by suitable moving means. William Woodworth of New York, in 1828, patented a celebrated planing machine which became so popular and its use was regarded so necessary in the wood-working trades, that the patent was looked upon as an odious monopoly. It consisted of a combination of rollers armed with cutters, attached to a horizontal shaft revolving at a great speed, and of means for feeding the boards to the cutters. With Bentham's, Bramah's, Blanchard's, and Woodworth's ideas for a basis, those innumerable improvements have been made in machinery, by which wood is converted with almost lightning rapidity into all the forms in which we see it, whether ornamental or useful, in modern homes and other structures. [Pg 350]

Some machines are known as "Universal Wood Workers." In these a single machine is provided with various tools, and adapted to perform a great variety of work by shifting the position of the material and the tools. The following operations can be performed on such a machine:—Planing, bevelling, tapering, tenoning, tongueing and grooving (grooves straight, circular or angular), making of joints, twisting and a number of other operations.

The later invention by Stow of Philadelphia of a *flexible* shaft, made up of a series of coils of steel wire, given a leather covering, and to which can be attached augers, bits, or metal drills, the tool applied to its work from any direction, and its direction varied while at work, has excited great attention.

Shingles are as old in the art as the framework of buildings. Rome was roofed with shingles for centuries, made of oak or pine.

Tiles, plain and fancy, and slates, have to a certain extent superseded wood shingling, but the wood will always be used where it can be found in plenty, as machines will now turn them out complete faster than they can be hauled away. A shingle is a thin piece of wood, thicker at one end than at the other, having parallel sides, about three times as long as it is wide, having generally smooth surfaces and edges. All these features are now given to the shingle by modern machines.

A great log is rolled into a mill at one end and soon comes out at the other in bundles of shingles; the logs sawed into blocks, the blocks split or sawed again into shingle sizes, tapered, planed in the direction of the grain of the wood, the complete shingles collected and bound in bundles, each operation by a special machine, or by a series of mechanisms. [Pg 351]

Veneering, that art of covering cheap or ordinary wood with a thin covering of more ornamental and valuable wood, known from the days of the Egyptians, has been vastly extended by modern machinery. The practice, however, so emphatically denounced centuries ago by Pliny, as "the monstrous invention of paint and dyes applied to the woods or veneers, to imitate other woods," has yet its practitioners and admirers.

T. M. Brunel, in 1805-1808, devised a set of circular saws run by a steam engine, which cut sheets of rosewood and mahogany, one-fourteenth of an inch thick, with great speed and accuracy. Since that day the veneer planing machine, for delicately smoothing the sheets, the straightening machine, for straightening scrolls that have been cut from logs, the polishing machines for giving the sheets their bright and glossy appearance, the pressing machine for applying them to the surfaces to which they are to be attached, the hammering machine for forcing out superfluous glue from between a veneer and the piece to which it is applied; all of these and numerous modifications of the same have been invented, and resulted in placing in the homes everywhere many beautiful ornamental articles of furniture, which before the very rich only could afford to have.

Special forms of machinery for making various articles of wood are about as numerous as the articles themselves.

We appear before the house and know before entering that its doors and sills, clapboards and window frames, its sashes and blinds, its cornices, its embrasures and pillars, and shingles, each or all have had a special machine invented for its manufacture. We enter the house and find it is so with objects within—the flooring may be adorned with the beautiful art of marquetry and parquetry, wood mosaic work, the wainscoting and the frescoes and ceilings, the stairs and staircases, its carved and ornamental supporting frames and balusters, the charming mantel frames around the hospitable fireplaces, and every article of furniture we see in which wood is a [Pg 352] part. So, too, it is with every useful wooden implement and article within and without the house,—the trays, the buckets, the barrels, the tubs, the clothes-pins, the broom-handles, the mops, the ironing and bread boards; and outside the house, the fences, railings and posts—many of these objects entirely unknown to the poor of former generations, uncommon with the rich, and the machinery for making them unknown to all.

It was a noble array of woodwork and machinery with which the nations surprised and greeted the world, at each of its notable international Expositions during the century. Each occasion surpassed its predecessor in the beauty of construction of the machines displayed and efficiency of their work. The names of the members of this array were hard and uncouth, such as the axe, the adze, and the bit, the auger, bark-cutting and grinding machines, blind-slat boring, and tenoning, dovetail, mortising, matching and planing, wood splitting, turning, wheeling and planing, wood-bending, rim-boring dowelling, felly-jointing, etc., etc. These names and the clamour of the machines were painful to the ear, but to the thoughtful, they were converted into sweeter music, when reflection brought to mind the hard toil of human hands they had saved, the before unknown comforts and blessings of civilisation they had brought and were bringing to the human race, and the enduring forms of beauty they had produced. [Pg 353]

To the invention of wood-working machinery we are also indebted for the awakening of interest in the qualities of wood for a vast number of artistic purposes. It was a revelation, at the great Philadelphia Exposition of 1876, to behold the specimens of different woods from all the forests of the earth, selected and assembled to display their wonderful grain and other qualities, and showing how well nature was storing up for us in its silent shades those growths which were waiting the genius of invention to convert into forms of use and beauty for every home.

[Pg 354]

CHAPTER XXII.

FURNITURE.

So far as machinery is concerned for converting wood into furniture, the same has been anticipated in the previous chapter, but much remains to be said about the articles of furniture themselves.

Although from ancient days the most ancient countries provided by hand elaborate and beautiful articles of furniture of many descriptions, yet it has been left for modern advances in machinery and kindred arts to yield that universal supply of convenient and ornamental furniture which now prevails.

The Egyptians used chairs and tables of a more modern form than the Greeks or Romans, who lolled about on couches even at their meals; but the Egyptians did not have the convenient section tables built in sliding sections, which permit the table to be enlarged to accommodate an increased number of guests. And now recently this modern form of table has been improved, by arranging the sections and leaves so that when the sections are slid out the leaves are automatically raised and placed in position, which is done either by lazy-tongs mechanism, or by a series of parallel links: Tables constructed with folding detachable and adjustable legs, tables constructed for special purposes as sewing machines, and typewriting machine tables, by which the machine head may be dropped beneath the table top when not in use; tables combined with [Pg 355] desks wherein the table part may be slid into the desk part when not in use and the sliding cover pulled down to cover and lock from sight both the table and desk; surgical tables, adapted to be raised or lowered at either end or at either side and to be extended; "knock down" tables, adapted to be taken all apart for shipment or storage; tables combined with chairs to be folded down by the side of the chair when not in use; and many other useful forms have been added to the list.

Much ingenuity has been displayed in the construction of desks, to save and economise space. Mention has been made of a combined folding desk and extensible table. Another form is an arrangement of desk drawers, whereby when one drawer is locked or unlocked all the rest are locked or unlocked automatically. Whatever shape or function anyone desires in a desk may be met, except, perhaps, the performance of the actual work of the occupant.

In the matter of *beds*, the principal developments have been due to the advancement of wood-working machinery, and the manufacture of iron, steel, and brass. The old-fashioned ponderous bedsteads, put together by heavy screws, have given way to those mortised and tenoned, joined and matched, and by which they can easily be put up and taken down; and to iron and brass bedsteads, which are both ornamental and more healthful. No bed may be without an inexpensive steel spring frame or mattress for the support of the bedding. Folding beds made to economise space, and when folded upright become an ornamental bureau; and invalid bedsteads, designed for shifting the position of the invalid, are among the many modern improvements. [Pg 356]

Kitchen Utensils.—A vast amount of drudgery in the kitchen has been relieved by the convenient inventions in labor-saving appliances: coffee and spice mills, can-openers, stationary washtubs, stopper extractors, superseding the old style of hand-corkscrews where large numbers of bottles are to be uncorked; refrigerators and provision safes, attaching and lifting devices and convenient culinary dishes and utensils of great variety.

Curtains, *shades* and *screens* have been wonderfully improved and their use made widely possible by modern inventions and new adaptation of old methods. Wood, cotton, silk, paper, combined or uncombined with other materials, in many novel ways unknown to our ancestors, have rendered these articles available in thousands of homes where their use was unknown and impossible a century ago. Among the most convenient attachments to shades is the spring roller, invented by Hartshorn of America, in 1864, whereby the shade is automatically rolled upon its stick to raise or lower it.

Window screens for the purpose of excluding flies, mosquitoes, and other insects, while freely admitting the air, are now made extensible and adjustable in different ways to fit different sizes of windows. Curtains and shades are provided with neat and most attractive supporting rods, to which they are attached by brass or wooden rings, and provided with easily manipulated devices to raise and securely hold them in any desired position.

The art of steaming wood and bending it, by iron pattern forms adjustable to the forms desired, as particularly devised in principle by Blanchard in America in 1828-1840, referred to in Wood-working, has produced great changes in the art of furniture making, especially in chairs. A [Pg 357] particularly interesting illustration of the results of this art occurred in Austria. About forty years ago the manufacture in Germany and Austria of furniture by machinery, especially of bent wood-ware, became well established there; and by the time of the Vienna Exposition in 1873, factories on a most extensive scale for the construction of bed furniture were in operation among the vast mountain beech forests of Moravia and Hungary. The greatest of these works were located in Great Urgroez, Hungary, and Bisritz, Moravia, with twenty or more auxiliary establishments. Between five and six thousand work people were employed, the greater part of whom were females, and it was necessary to use steam and water motors, to the extent of many hundred horse power.

The forests were felled, and the tree-tops removed and made into charcoal for use in the glass works of Bohemia. The trunks were hauled to the mills and sawed into planks of suitable thickness by gang-saws. The planks in turn were cut with circular saws into square pieces for turning, and then the pieces turned and cut on lathes, to give them the size required and the rounded shape; the pieces then steamed while in their green state for twenty-four hours in suitable boilers, then taken out and bent to the desired shape on a cast-iron frame by hand, then subjected, with the desired pattern, to the pattern-turning table, and cut; then kept locked in the pattern's iron embrace until the pieces were dried and permanently set in shape, then clamped to a bench, filed, rasped, stained, and French polished by the deft hands of the women; then assembled in proper position in frames of the form of the chair or other article to be made, their [Pg 358] contact surface sawed to fit at the joints, and then finally the parts glued together and further secured by the addition of a few screws or balls.

Chairs, lounges and lighter furniture were thus made from bent pieces of wood with very few joints, having a neat and attractive appearance, and possessing great strength. The art has spread to other forests and other countries, and the turned, bent, highly polished and beautiful furniture of this generation would have been but a dream of beauty to the householder of a century ago.

Children's chairs are made so that the seat may be raised or lowered, or the chair converted into a perambulator. Dentist's chairs have been developed until it is only necessary for the operator to turn a valve governing a fluid, generally oil, under pressure to raise or lower the chair and the patient. In the more agreeable situation at the theatre or concert one may hang his hat on the bottom of the chair, upturned to afford access to it through a crowded row, and turning down the chair, sit with pleasure, as the curtain is rolled up by compressed air, or electricity, at the touch of a button.

To the unthinking and unobserving, the subject of *bottle stoppers* is not entrancing, but those acquainted with the art know with what long, continuous, earnest efforts, thousands of inventors have sought for the best and cheapest bottle stopper to take the place of corks—the enormous demand for which was exhausting the supply and rendering their price almost prohibitive.

One of the most successful types is a stopper of rubber combined with a metal disk, and hung by a wire on the neck of the bottle, so that the stopper can be used over and over again; another [Pg 359] form composed of glass, or porcelain, and cork; another is a thin disk of cork placed in a thin metal cap which is crimped over a shoulder on the neck of the bottle, and still another is a thin disk of pasteboard adapted for milk bottles and pressed tightly within a rim on the inside of the neck of the bottle.

In this connection should be mentioned that self-sealing fruit jar, known from its inventor as "Mason's fruit jar," which came into such universal use—that combination of screw cap, screw-threaded jar-neck and the rubber ring, or gasket, on which the cap was screwed so tightly as to seal the jar hermetically.

In lamplighting, what a wonderful change from the old oil lamps of former ages! The modern lamp may be said to be an improved means of grace, as it will hold out much longer, and shed a far more attractive light for the sinner, whose return, by its genial light, is, even to the end, so greatly desired.

The discovery of petroleum and its introduction as a light produced a revolution in the construction of lamps. Wicks were not discarded, but changed in shape from round to flat, and owing to the coarseness and disagreeable odour of coal oil, especially in its early unrefined days, devices first had for their object the easy feeding of the wick, and perfect combustion. To this end the burner portion through which the wick passed was perforated at its base to create a proper draft, and later the cap over the base was also perforated. But with refined oil the disagreeable odour continued. It was found that this was mainly due to the fact that both in lamps and stoves the oil would ooze out of the wick on to the adjacent parts of the lamps or stove, and when the wick was lit the heat would burn or heat the oil and thus produce the odour. Inventors therefore [Pg 360] contrived to separate the oil reservoir and wick part when the lamp or stove were not in use; and finally, in stoves, to dispense with the wick altogether. As wickless oil stoves are now in successful use the wickless lamp may be expected to follow.

The lamp, however, that throws all others into the shade is that odourless, heatless, magic, mellow, tempered light of electricity, that springs out from the little filament, in its hermetically sealed glass cage, and shines with unsurpassed loveliness on all those fortunate enough to possess it.

[Pg 361]

CHAPTER XXIII.

LEATHER.

It is interesting to speculate how prehistoric man came to use the skin of the beasts of the field for warmth and shelter. Originally no doubt, and for untold centuries, the use was confined to the hairy, undressed, fresh, or dried skins, known as pelts. Then came the use of better tools. The garments have perished, but the tools of stone and of bronze survived, which, when compared with those employed among the earliest historic tribes of men, were found to be adapted to cut and strip the hairy covering from the bodies of animals, and clean, pound, scrape and otherwise adapt them to use.

And ever since the story of man began to be preserved in lasting records from farthest Oriental to the northernmost limits of Europe and America, memorials of the early implements of labour in the preparation of hides for human wear have been found. The aborigines knew how to sharpen bones of the animals they killed to scrape, clean, soften or roughen their skins. They knew how to sweat, dry, and smoke the skins, and this crude seasoning process was the forerunner of modern tanning. But leather as we know it now, that soft, flexible, insoluble combination of the gelatine and fibrine of the skin with tannic acid, producing a durable and imputrescible article, that will withstand decay from the joint attack of moisture, warmth and air, was unknown to the earlier [Pg 362] races of men, for its production was due to thorough tanning, and thorough tanning was a later art.

When men were skin-dressed animals they knew little or nothing of tanning. Tannic acid is found in nearly every plant that grows, and its combination with the fresh skins spread or thrown thereon, may have given rise to the observation of the beneficial result and subsequent practice. But whether discovered by chance, accident or experience, or invented from necessity, the art of tanning should have rendered the name of the discoverer immortal. The earliest records, however, describe the art, but not the inventor.

From the time the Hebrews covered the altars of their tabernacles with rams' skins dyed red, as recorded in Exodus; when they and the Egyptians worked their leather, currying and stretching it with their knives, awls, stones, and other implements, making leather water buckets, resembling very much those now made by machinery, covering their harps and shields with leather, ornamental and embossed; from the days of the early Africans, famous for their yellow, red and black morocco; from the days of the old national dress of the Persians with their leather trousers, aprons, helmets, belts and shirts; from the time that the ancient Scythians utilised the skins of their enemies, and Herodotus described the beauty and other good qualities of the human hide; from the early days of that peculiar fine and agreeable leather of the Russians, fragrant with the oil of the birch; from the days of the white leather of the Hungarians, the olive-tanned leather of the Saracens; from the time of the celebrated Cordovan leather of the Spaniards; from the [Pg 363] ancient cold periods of the Esquimaux and the Scandinavians, who, clad in the warm skins of the Arctic bears, stretched tough-tanned sealskin over the frame work of their boats; from the time of the introduction of the art of the leather worker to the naked Briton, down to almost the nineteenth century, substantially the same hand tools, hard hand labour, and the old elbow lubricant were known and practised.

Hand tools have improved, of course, as other arts in wood and iron making have developed, but the operations are about the same. There were and must be fleshing knives to scrape from off the hide the adherent flesh and lime,—for this the hide is placed over the convex edge of an inclined beam and the work is called beaming; the curriers' knife for removing the hair; skiving, or the cutting off the rough edges and fleshy parts on the border of the hide; shaving and flattening; the cutting away of the inequalities left after skiving; *stoning*, the rubbing of the leather by a scouring stone to render it smooth; *slicking*, to remove the water and grease; or to smooth and polish, by a rectangular sharpened stone, steel or glass tool; *whitening*, to shave off thin strips of the flesh, leaving the leather thinner, whiter and more pliable; *stuffing*, to soften the scraped and pounded hides and make them porous; *graining*, the giving to the hair or grain side a granular appearance by rubbing with a grooved or roughened piece of wood; *bruising* or boarding to make the leather supple and pliable by bringing the two flesh sides together and rubbing with a graining board; *scouring*, by aid of a stream of water to whiten the leather by rubbing with a slicking stone or steel.

The inventions of the century consist in labour-saving machinery for these purposes, new tanning [Pg 364]
and dressing processes, and innumerable machines for making special articles of leather.

As before stated, the epoch of modern machinery commenced with the practical application of water power to other than grinding mills, and of steam in place of water, contemporaneously with the invention of spinning and weaving machinery in the last half of the eighteenth century. These got fairly to work at the beginning of the century, and the uses of machinery spread to the treatment of leather. John Bull was the appropriate name of the man who first patented a scraping machine in England, about 1780, and Joseph Weeks the next one, some years later.

One of the earliest machines of the century was the hide mill, which, after the hand tools had scraped and stoned, shaved and hardened the hides, was used to rub and dub them, and soften and swell them for tanning. Pegged rollers were the earliest form for this purpose, and later corrugated rollers and power-worked hammers were employed. Hundreds of hides could be softened daily by these means.

Then came ingenious machines to take the place of the previous operations of the hand tools,—the fleshing machine, in one form of which the hides are placed on a curved bed, and the fleshy parts scraped off or removed by revolving glass blades, or by curved teeth of steel and wood in a roller under which a table is given a to-and-fro movement; tanning apparatus of a great variety, by which hides, after they are thoroughly washed and softened, and the pores opened by swelling, are subjected to movements in the tanning liquor vats, such as rocking or oscillating,
rotary, or vertical; or treated by an air exhaust, known as the vacuum process; in all of which the [Pg 365]
object is to thoroughly impregnate in the shortest time all the interstices and pores of the skin with the tannic acid, by which the fibrous and gelatinous matter is made to combine to form leather, and by which process, also, the hide is greatly increased in weight.

Reel machines are then employed to transfer the hides from one vat to another, thus subjecting them to liquors of increasing strength. Soaking in vats formerly occupied twelve or eighteen months, but under the new methods the time has been greatly reduced. And now since 1880, the chemists are pushing aside the vegetable processes, and substituting mineral processes, by which tanning is still further shortened and cheapened. The new processes depend chiefly on the use of chromium compounds.

Then came scouring machines, in which a rapidly revolving stiff brush is used to scour the grain or hair side, removing the superfluous colouring matter, called the bloom, and softening and cleansing the hide; the slicking or polishing machines to clean, stretch and smooth the leather by glass, stone, or copper blades on a rapidly-moving belt carried over pulleys; whitening, buffing, skiving, fleshing and shaving machines, all for cutting off certain portions and inequalities of the leather, and reducing its thickness.

In one form of this class of machines an oscillating pendulum lever is employed, carrying at its end a revolving cylinder having thirty or more spiral blades. The pendulum swings to and fro at the rate of ninety movements a minute, while the cylinder rolls over the leather at the rate of
2780 revolutions per minute. Scarfing, skiving, chamfering, bevelling, feather-edging, appear to [Pg 366]
be synonymous terms for a variety of machines for cutting the edges of leather obliquely, for the purpose chiefly of making lap seams, scarf-joints, and reducing the thickness and stiffness of leather at those and certain other points.

Then there are leather-splitting machines, consisting of one or more rollers and a pressure bar, which draw and press the leather against a horizontally arranged and adjustable knife, which nicely splits the leather in two parts, and thus doubles the quantity. This thin split leather is much used in making a cheap quality of boots and shoes and other articles.

There are also corrugating, creasing, fluting, pebbling, piercing and punching machines; machines for grinding the bark and also for grinding the leather; machines for gluing sections of leather together, and machines for sewing them; machines for rounding flat strips of leather, for the making of whips and tubes; machines for scalloping the edges; and a very ingenious machine for assorting leather strips or strings according to their size or thickness.

The most important improvements of the century in leather working relate to the manufacture of boots and shoes. It could well be said of boots and shoes, especially those made for the great mass of humanity, before the modern improvements in means and processes had been invented: "Their feet through faithless leather met the dirt."

It is true that in the eighteenth century, both in Europe and America, the art of leather and boot and shoe making had so far advanced that good durable foot wear was produced by long and tedious processes of tanning, and by careful making up of the leather into boots and shoes by
hand; the knife, the awl, the waxed thread, the nails and hammer and other hand tools of the [Pg 367]
character above referred to being employed. But the process was a tedious and costly one and

the articles produced were beyond the limits of the poor man's purse. Hence the wooden shoes, and those made of coarse hide and dressed and undressed skins, and of coarse cloth, mixed or unmixed with leather.

In 1809, David Mead Randolph of England patented machinery for riveting soles and heels to the uppers instead of sewing them together.

The celebrated civil engineer, Isambard M. Brunel, shortly thereafter added several machines of his own invention to Randolph's method, and he established a large manufactory for the making chiefly of army shoes. The various separate processes performed by his machines involved the cutting out of the leather, hardening it by rolling, securing the welt on to the inner sole by small nails, and studding the outer sole with larger nails. Divisions of men were employed to work each separate step, and the shoes were passed from one process to another until complete.

Large quantities of shoes were made at reduced prices, but complaints were made as to the nails penetrating into the shoe and hurting the feet. The demand for army shoes fell off, and the system was abandoned; but it had incited invention in the direction of machine-made shoes and the day of exclusive hand labour was doomed.

About 1818 Joseph Walker of Hopkinston, Massachusetts invented the wooden peg. Making and applying pegs by hand was too slow work, and machines were at once contrived for making them. As one invention necessitates and begets others, so special forms of machines for sawing and working up wood into pegs were devised.

Such machinery was for first sawing the selected log of wood into slices across the grain a little thicker than the length of a peg and cutting out knots in the wood; then planing the head of the block smooth; grooving the block with a V-shaped cutting tool; splitting the pegs apart, and then bleaching, drying, polishing and winnowing them.

It took forty or fifty years to perfect these and kindred machines, but at the end of that time there was a factory at Burlington, Vermont, which from four cords of wood, made every day four hundred bushels of shoe pegs.

About 1858 B. F. Sturtevant of Massachusetts made a great improvement in this line. He was a very poor man, getting a living by pegging on the soles of a few pair of shoes each day. He devised a pegging machine, and out of his scanty earnings and at odd hours, with much pain and labour, and by borrowing money, he finally completed it. The machine made what was called "peg wood," a long ribbon strip of seasoned wood, sharpened on one edge and designed to be fed into the machine for pegging shoes. The shoes were punctured by awls driven by machinery, and then as the peg strip was carried to it the machine severed the strip into chisel-edged pegs, and peg-driving mechanism drove them into the holes. Nine hundred pegs a minute were driven. It soon almost supplanted all other peg-driving machines, and after the machines were quite generally introduced, there were made in one year alone in New England fifty-five million pairs of boots and shoes pegged by the Sturtevant machines.

Other forms of pegs followed, such as the metal screw pegs, and machines to cut them off from a continuous spiral wire from which they were made. Lasts on which the shoes were made had been manufactured by the hundred thousand on the wood-turning lathes invented by Blanchard, described in the chapter on Wood-Working.

In 1858 also, about the same time the Sturtevant pegging machine was introduced, the shoe-sewing machine was developed. The McKay Shoe-Sewing Machine Co. of Massachusetts after an expenditure of $130,000, and three years' time in experiments, were enabled to put their machines in practical operation. The pegging machines and sewing machines worked a revolution in shoemaking.

A revolution in the art of shoemaking thus started was followed up by wondrous machines invented to meet every part of the manufacture. Lasting machines for drawing and fitting the leather over lasts, in which the outer edges of the leather are drawn over the bottom of the last and tacked thereto by the hands and fingers of the machine instead of those of the human hand, were invented.

Indenting machines:—The welt is known as that strip of leather around the shoe between the upper and the sole, and machines were invented for cutting and placing this, indenting it for the purpose of rendering it flexible and separating the stitches, all a work until recently entirely done by hand. Machines for twining the seams in the uppers, and forming the scallops; machines especially adapted to the making of the heel, as heel trimming and compressing, rounding and polishing, and for nailing the finished heel to the boot or shoe; machines for treating the sole in every way, rolling it, in place of the good old way of pounding it on a lap stone; trimming, rounding, smoothing, and polishing it; machines for cutting out gores; machines for marking the uppers so that at one operation every shoe will be stamped by its size, number, name of manufacture, number of case, and any other convenient symbols; machines for setting the buttons and eyelets; all these are simply members in the long line of inventions in this art.

The old style of boot has given way to the modern shoe and gaiter, but for the benefit of those who still wear them, special machines for shaping the leg, called boot trees, have been contrived.

So far had the art advanced that twenty years ago one workingman with much of this improved machinery combined in one machine called the "bootmaker," could make three hundred pairs of boots or shoes a day. Upward of three thousand such machines were then at work throughout the world; and one hundred and fifty million pairs of boots were then being made annually thereon. Now the number of machines and pairs of boots and shoes has been quadrupled.

And the world is having its feet clothed far more extensively, better and at less cost than was ever possible by the hand system. The number of workers in the art, both men and women, has vastly increased instead of being diminished, while their wages have greatly advanced over the old rates.

As an illustration of how rapidly modern enterprise and invention proceeds in Yankeeland, it has been related that some years ago in Massachusetts, after many of these shoe-making machines had got into use, a factory which was turning out 2400 pairs of shoes every day was completely destroyed by fire on a Wednesday night. On Thursday the manufacturer hired a neighbouring building and set carpenters at work fitting it up. On Friday he ordered a new and complete outfit [Pg 371] of machinery from Boston; on Saturday the machinery arrived and the men set it up; on Monday work was started, and on Tuesday the manufacturer was filling his orders to the full number of 2400 pairs a day.

There are very many people in the world who still prefer the hand-made shoe, and there is nothing to prevent the world generally from going back to that system if they choose; but St. Crispin's gentle art has blossomed into a vaster field of blessings for mankind under the fruitful impetus of invention than if left to vegetate under the simple processes of primitive man.

Horses, no less than man, have shared in the improvement in leather manufacture. The harnesses of the farmer's and labouring man's horses a century ago, when they were fortunate enough to own horses, were of the crudest description. Ropes, cords, coarse bands of leather were the common provisions. Now the strength and cheapness of harnesses enable the poor man to equip his horse with a working suit impossible to have been produced a hundred years ago.

To the beautiful effects produced by the use of modern embossing machines on paper and wood have been added many charming patterns in *embossed* leather. Books and leather cases, saddlery and household ornamentation of various descriptions have been either moulded into forms of beauty, or stamped or rolled by cameo and intaglio designs cut into the surface of fast-moving cylinders.

The leather manufactures have become so vastly important and valuable in some countries, especially in the United States—second, almost to agricultural products—that it would be very [Pg 372] interesting to extend the description to many processes and machines, and to facts displaying the enormous traffic in leather, now necessarily omitted for want of space.

[Pg 373]

CHAPTER XXIV.

MINERALS—WELLS.

Dost thou hear the hammer of Thor,
Wielded in his gloves of iron?

As with leather, so with stone, the hand tools and hard labour have not changed in principle since the ancient days. The hammer for breaking, the lever for lifting, the saw for cutting, rubbing-stones and irons for smoothing and polishing, sand and water for the same purpose, the mallet and chisel, and other implements for ornamenting, the square, the level, and the plumb for their respective purposes, all are as old as the art of building.

And as for buildings and sculpture of stone and marble made by hand tools, we have yet to excel the pyramids, the Parthenon of Athens, which "Earth proudly wears as the best gem upon her zone," the palaces, coliseums, and aqueducts of Rome, the grand and polished tombs of India, the exquisite halls of the Alhambra, and the Gothic cathedrals.

But the time came when human blood and toil became too dear to be the possession solely of the rulers and the wealthy, and to be used alone to perpetuate and commemorate riches, power and glory.

Close on the expansion of men's minds came the expansion of steam and the development of modern inventions. The first application of the steam engine in fields of human labour was the drawing of water from the coal mines of England; then in drawing the coal itself. [Pg 374]

It was only a step for the steam engine into a new field of labour when General Bentham introduced his system of wood-sawing machinery in 1800; and from sawing wood to sawing stone was only one more step. We find that taken in 1803 in Pennsylvania, when Oliver Evans of Philadelphia drove with a high-pressure steam engine, "twelve saws in heavy frames, sawing at the rate of one hundred feet of marble in twelve hours." How long would it have taken hand sawyers of marble at ancient Paros and Naxos to have done the same?

Stone-cutting machines of other forms than sawing then followed.

It was desired to divide large blocks generally at the quarries to facilitate transportation. Machines for this purpose are called stone-channelling machines. They consist of a gang of chisels bound together and set on a framework which travels on a track adjacent to the stone to be cut, and so arranged that the cutters may be set to the stone at desired angles, moved automatically forward and back in the grooves they are cutting, be fed in or out, raised or lowered, detached, and otherwise manipulated in the operation.

Other stone-cutting machines had for their objects the cutting and moulding the edges of tables, mantels and slabs; and the cutting of circular and other curved work. In the later style of machine the cutter fixed on the end of a spindle is guided in the desired directions on the surface of the stone by a pointer, which, attached to the cutter spindle, moves in the grooves of a pattern also connected to the rotating support carrying the cutter.

Other forms of most ingenious stone-dressing and carving machines have been devised for [Pg 375] cutting mouldings, and ornamental figures and devices, in accordance with a model or pattern fixed to the under side of the table which carries the stone or marble to be dressed; and in which, by means of a guide moving in the pattern, the diamond cutter or cutters, carried in a circular frame above the work and adjusted to its surface, are moved in the varying directions determined by the pattern. A stream of water is directed on the stone to clear it of the dust during the operations. The carving of stone by machinery is now a sister branch of wood carving. Monuments, ornamentation, and intricate forms of figures and characters are wrought with great accuracy by cutting and dressing tools guided by the patterns, or directed by the hand of the operator.

For the dressing of the faces of grindstones, special forms of cutting machines have been devised.

It was a slow and tedious task to drill holes through stone by hand tools; and it was indeed a revolution in this branch of the art when steam engines were employed to rotate a rod armed at its end with diamond or other cutters against the hardest stone. This mode of drilling also effected a revolution in the art of blasting. Then, neither height, nor depth, nor thickness of the stone could prevent the progress of the drill rod. Tunnels through mountain walls, and wells through solid quartz are cut to the depth of thousands of feet.

One instance is related of the wonderful efficiency on a smaller scale of such a machine: The immense columns of the State Capitol at Columbus, Ohio, were considered too heavy for the foundation on which they rested. The American Diamond Rock Boring Company of Providence, Rhode Island, bored out a twenty-four inch core from each of the great pillars, and thus relieved [Pg 376] the danger.

In the most economical and successful stone drills *compressed air* is employed as the motive power to drive the drills, which may be used singly or in gangs, and which may be adjusted against the rock or quarry in any direction. When in position and ready for work a few moments will suffice to bore the holes, apply the explosive and blast the ledge. The cleaning away of submarine ledges in harbours, such as the great work at Hell Gate in the harbour of New York, has thus been effected.

Crushing:—Among the most useful inventions relating to stone working are machines for crushing stones and ores, and assorting them. The old way of hammering by hand was first succeeded by powerful stamp hammers worked by steam. Both methods of course are still followed, but they demand too great an expenditure of force and time.

About a third of a century ago, Eli Whitney Blake of New Haven, Connecticut, was a pioneer inventor of a new and most successful type of stone breaking machine, which ever since has been known as the "Blake Crusher." This crusher consists of two ponderous upright jaws, one fixed and the other movable, between which the stones or ores to be crushed are fed. Each of the jaws is lined with the hardest kind of chilled steel. The movable jaw is inclined from its lower end from the fixed jaw and at its upper end is pivoted to swing on a heavy round iron bar. The movable jaw is forced toward the fixed jaw by two opposite toggle levers set, in one form of the crusher, at their inner ends in steel bearings of a vertical vibrating, rocking lever, one of the toggles bearing at its outer end against the movable jaw and the outer toggle against a solid frame-work. The [Pg 377] rocking lever is operated through a crank by a steam engine, and as it is vibrated, the toggle joint forces the lever end of the movable jaw towards the fixed jaw with immense force, breaking the hardest stone like an eggshell.

The setting of the movable jaw at an incline enables the large stone to be first cracked, the movable jaw then opens, and as the stone falls lower between the more contracted jaws, it is broken finer, until it is finally crushed or pulverized and falls through at the bottom. The movable jaw is adjustable and can be set to crush stones to a certain size.

As the rock drill made a revolution in blasting and tunnelling, so the Blake crusher revolutionised the art of road making. "Road metal," as the supply of broken stones for roads is now called, is the fruit of the crusher. Hundreds of tons of stone per day can be crushed to just the size desired, and the machine may be moved from place to place where most convenient to use.

Other crushers have been invented, formed on the principle of abrasion. The stones, or ore, fall between two great revolving disks, having corrugated steel faces, which are set the desired distance apart, and between which the stones are crushed by the rubbing action. In this style of machine the principle of a gradual breaking from a coarse to a finer grade, is maintained by setting the disks farther apart at the centre where the stone enters, and nearer together at their peripheries where the broken stone is discharged. Large smooth or corrugated rollers, conical disks, concentric rollers armed with teeth of varying sizes, and yet so arranged as to preserve the feature of the narrowing throat at the bottom or place of discharge, have also been devised and extensively used. [Pg 378]

A long line of inventions has appeared especially adapted to break up and separate coal into different sizes. To view the various monstrous heaps of assorted coals at the mouth of a coal mine creates an impression that some great witch had imposed on a poor victim the gigantic and seemingly impossible task of breaking and assorting a vast heap of coal into these separate piles within a certain time—a task which also seems to have been miraculously and successfully performed within such an exceedingly short time as to either satisfy or confuse the presiding evil genius.

Modern civilisation has been developed mostly from steam and coal, and they have been to each other as strong brothers, growing more and more mutually dependent to meet the demands made upon them.

The mining of coal, and its subsequent treatment for burning, before the invention of the steam engine, were long, painful, and laborious tasks, and the steam engine could never have had its modern wants supplied if its power had not been used to supplement, with a hundredfold increased effect, the labour of human hands.

It being impracticable to carry steam or the steam engine to the bottom of the mine for work there, compressed air is there employed, which is compressed by a steam engine up at the mouth. By this compressed air operated in a cylinder to drive a piston, and a connecting rod and a pick, a massive steel pick attached to the rod may be driven in any direction against the wall of coal at the rate of from ninety to one hundred and twenty blows per minute; and at the same time the discharged compressed, cold, pure, fresh air flows into and through the mine, affording ventilation when and where most needed. [Pg 379]

In addition to these great drills, more recent inventors have brought out small machines for single operators, worked by the electric motor.

After the coal is lifted out, broken and assorted, it needs to be washed free of the adhering dust and dirt; and for this purpose machines are provided, as well as for screening, loading and weighing. The operations of breaking, assorting and washing are often combined in one machine, while an intermediate hand process for separating the pieces of slate from the coal may be employed; but additional automatic means for separating the coal and slate are provided, consisting in forcing with great power water through the coal as it falls into a chamber, which carries the lighter slate to the top of the chamber, where it is at once drawn off.

The chief of machines with *ores* is the *ore mill*, which not only breaks up the ore but grinds or pulverises it.

Some chemical and other processes for reducing ores have been referred to in the Chapter on Metallurgy.

Other mechanical processes consist of *separators* of various descriptions—a prominent one of which acts on the principal of centrifugal force. The crushed material from a spout being led to the centre of a rapidly rotating disk is thrown off by centrifugal force; and as the lighter portions are thrown farther from the disk, and the heavier portions nearer to the same, the material is automatically assorted as to size and weight. As the disk revolves these assorted portions fall through properly graded apertures into separate channels of a circular trough, from whence they are swept out by brushes secured to a support revolving with the disk. [Pg 380]

Many forms of ore washing machines have been invented to treat the ore after it has been reduced to powder. These are known by various names, as jiggers, rifflers, concentrators, washing frames, etc. A stream of water is directed on, into, and through the mass of pulverised ore and dirt, the dirt and kindred materials, lighter than the ore, are raised and floated towards the top of the receptacle and carried away, while the ore settles.

This operation is frequently carried on in connection with amalgamated surfaces over which the metal is passed to still further attract and concentrate the ore. An endless apron travelling over cylinders is sometimes employed, composed of slats the surface of each of which is coated with an amalgam, and on this belt the powdered ore is spread thinly and carried forward. The vibrations of the belt tend to shake and distribute the ore particles, the amalgam attracts them, the refuse is thrown off as the belt passes down over the cylinder, while the ore particles are retained and brushed off into a proper receptacle. *Amalgamators* themselves form a large class of inventions. They are known as electric, lead, mercury, plate, vacuum, vapour, etc.

By the help of these and a vast number of other kindred inventions, the business of mining in all its branches has been revolutionised and transformed, even within the last half century. With the vast increase in the output of coal, and of ores, and the incalculable saving of hand labour, the number of operators has been increased in the same proportion, their wages increased, their hours of labour shortened, and their comforts multiplied in variety and quantity, with a diminished cost. The whole business of mining has been raised from ceaseless darkness and [Pg 381] drudgery to light and dignity. Opportunity has been created for miners to become men of standing in the community in which they live; and means provided for educating their children and for obtaining comfortable homes adorned with the refinements of civilisation.

Well boring is an ancient art—known to the Egyptians and the Chinese. Wells were coeval with Abraham when his servant had the celebrated interview with Rebecca. "Jacob's well at Sychar—the ancient Shechim—has been visited by travellers in all ages and has been minutely described. It is nine feet in diameter and one hundred and five feet deep, made entirely through rock. When visited by Maundrel it contained fifteen feet of water."—*Knight.* Some kind of a drill must have been used to have cut so great a depth through rock. The Chinese method of boring wells from time immemorial has been by the use of a sharp chisel-like piece of hard iron on the end of a heavy iron and wood frame weighing four or five hundred pounds, lifted by a lever and turned by a rattan cord operated by hand, and by which wells from fifteen hundred to eighteen hundred feet in depth and five or six inches in diameter have been bored.

This method has lately been improved by attaching the chisel part, which is made very heavy, to a rope of peculiar manufacture, which gives the chisel a turn as it strikes, combined with an air pump to suck up from the hole the accumulating dirt and water.

Artesian wells appear to have first been known in Europe in the province of Artois, France, in the thirteenth century. Hence their name. The previous state of the art in Egypt, China and elsewhere was not then known. [Pg 382]

Other modern inventions in well-making machinery have consisted in innumerable devices to supplant manual labour and to meet new conditions.

Coal Oil:—Reichenbach, the German chemist, discovered paraffine. Young, soon after, in 1850, patented paraffine oil made from coal. These discoveries, added to the long observed fact of coal oil floating on streams in Pennsylvania and elsewhere, led to the search for its natural source. The discovery of the reservoirs of petroleum in Pennsylvania in 1855-1860, and subsequently of gas, which nature had concealed for so long a time, gave a great impetus to inventions to obtain and control these riches. With earth-augurs, drills, and drill cleaning and clearing and "fishing" apparatus, and devices for creating a new flow of oil, and tubing, new forms of packing, etc., inventors created a new industry.

Colonel E. Drake sank the first oil well in Pennsylvania in 1859. Since then, 125,000 oil wells have been drilled in that and neighbouring localities. The world has seldom seen such excitement, except in California on the discovery of gold, as attended the coal oil discovery. The first wells sunk gushed thousands of barrels a day. Farmers and other labouring men went to bed poor and woke up rich. Rocky wildernesses and barren fields suddenly became Eldorados. The burning rivers of oil were a reflection of the golden treasures which flowed into the hands and pockets of thousands as from a perpetual fountain touched by some great magician's wand.

Old methods of boring wells were too slow, and although the underlying principle was the same, the new methods and means invented enabled wells to be bored with one-tenth the labour, in one-tenth the time, and at one-tenth the cost. Many great cities and plains and deserts have been provided with these wells owing to the ease with which they can now be sunk. [Pg 383]

Another ingenious method of sinking wells was invented by Colonel N. W. Greene at Cortland, New York, in 1862. It became known as the "driven well," and consisted of a pointed tube provided with holes above the pointed end, and an inclosed tube to prevent the passage of sand or gravel through the holes in the outer tube. When the pointed tube was driven until water was reached the inner tube was withdrawn and a pump mechanism inserted. This well, so simple, so cheap and effective, has been used in all countries by thousands of farmers on dry plains and by soldiers in many desert lands. With these and modern forms of artesian wells the deserts have literally been made to blossom as the rose.

[Pg 384]

CHAPTER XXV.

HOROLOGY AND INSTRUMENTS OF PRECISION.

"Time measures all things, but I measure it."

So far as we at present know there were four forms of time-measuring instruments known to antiquity—the sun-dial, the clepsydra or water clock, the hour-glass, and the graduated candle.

The sun-dial, by which time was measured by the shadow cast from a pin, rod or pillar upon a graduated horizontal plate—the graduations consisting of twelve equal parts, in which the hours of the day were divided, were, both as to the instrument and the division of the day into hours, invented by the Babylonians or other Oriental race, set up on the plains of Chaldea, constructed by the Chinese and Hindoos—put into various forms by these nations, and adapted, but unimproved, by the learned Greeks and conquering Romans. It appears to have been unknown to the Assyrians and Egyptians, or if known, its knowledge confined to their wise men, as it does not appear in any of their monuments.

The clepsydra, an instrument by which in its earliest form a portion of time was measured by the escape of water from a small orifice in the bottom of a shell or vase, or by which the empty vase, placed in another vessel filled with water, was gradually filled through the orifice and which sank within a certain time, is supposed by many to have preceded the invention of the sun-dial. At any [Pg 385] rate they were used contemporaneously by the same peoples.

In its later form, when the day and night were each divided into twelve hours, the vessel was correspondingly graduated, and a float raised by the inflowing water impelled a pointer attached to the float against the graduations.

Plato, it is said, contrived a bell so connected with the pointer that it was struck at each hour of the night. But the best of ancient clepsydras was invented by Ctesibius of Alexandria about the middle of the third century B. C. He was the pupil of Archimedes, and adopting his master's idea of geared wheels, he mounted a toothed wheel on a shaft extending through the vessel and carrying at one end outside of the vessel a pointer adapted to move around the face of a dial graduated with the 24 hours. The vertical toothed rod or rack, adapted to be raised or lowered by a float in a vessel gradually filled with water, engaged a pinion fixed on another horizontal shaft, which pinion in turn engaged the larger wheel. It was not difficult to proportion the parts and control the supply of water to make the point complete its circuit regularly. Then the same inventor dispensed with the wheel, rack, and pinion, and substituted a cord to which a float was attached, passing the cord over a grooved pulley and securing a weight at its other end. The pulley was fixed on the shaft which carried the hour hand. The float was a counterbalance to the weight, and as it was lifted by the water the weight stretched the cord and turned the pulley, which caused the pointer to move on the dial and indicate the hour. The water thus acted as an escapement to control the motive power. In one form the water dropped on wheels which had [Pg 386] their motion communicated to a small statue that gradually rose and pointed with a rod to the hour upon the dial.

Thus the essential parts of a clock—an escapement, which is a device to control the power in a clock or watch so that it shall act intermittently on the time index, a motive power, which was then water or a weight, a dial to display the hours, and an index to point them out—were invented at this early age. But the art advanced practically no further for many centuries.

The hour-glass is too familiar to need description.

The incense sticks of the Chinese, the combustion of which proceeded so slowly and regularly as to render them available for time measures, were the precursors of the graduated candles.

With the ungraduated sun-dial the Greeks fixed their times for bathing and eating. When the shadow was six feet long it was time to bathe, when twice that length it was time to sup. The clepsydra became in Greece a useful instrument to enforce the law in restricting loquacious orators and lawyers to reasonable limits in their addresses. And in Rome the sun-dials, the clepsydras and the hour-glass were used for the same purpose, and more generally than in Greece, to regulate the hours of business and pleasure.

The graduated candles are chiefly notable as to their use, if not invention, by Alfred the Great in about 883. They were 12 inches long, divided into 12 parts, of which three would burn in one hour. In use they were shielded from the wind by thin pieces of horn, and thus the "horn lantern" originated. With them he divided the day into three equal parts, one for religion, one for public [Pg 387] affairs, and one for rest and recreation.

Useful clocks of wondrous make were described in the annals of the middle ages, especially in Germany, made by monks and others for Kings, monasteries and churches. The old Saxon and Teutonic words *cligga*, and *glocke*, signifying the striking of a bell, and from which the name clock is derived, indicates the early combination of striking and time-keeping mechanism. The records are scant as to the particulars of inventions in horology during the middle ages and down to the sixteenth century, but we know that weights, and trains of wheels and springs, and some say pendulums, were used in clockwork, and that the tones of hourly bells floated forth from the dim religious light of old cathedrals. They all appear to have involved in different forms the principle of the old clepsydra, using either weights or water as the motive power to drive a set of wheels and to move a pointer over the face of a dial.

Henry de Vick of France about 1370 constructed a celebrated clock for Charles V., the first nearest approach to modern weight clocks. The weight was used to unwind a cord from a barrel. The barrel was connected to a ratchet and there were combined therewith a train of toothed wheels and pinions, an escapement consisting of a crown wheel controlled by two pallets, which in turn were operated alternately by two weights on a balanced rod. An hour hand was carried by a shaft of the great wheel, and a dial plate divided into hours. This was a great advance, as a more accurate division of time was had by improving the isochronous properties of the vibrating escapement. But the world was still wanting a time-keeper to record smaller portions of the day than the hour and a more accurate machine than Vick's. [Pg 388]

Two hundred years, nearly, elapsed before the next important advance in horology. By this time great astronomers like Tycho Brahe and Valherius had divided the time-recording dials into minutes and seconds.

About 1525 Jacob Zech of Prague invented the fusee, which was re-invented and improved by the celebrated Dr. Hooke, 125 years later.

Small portable clocks, the progenitors of the modern watch, commenced to appear about 1500. It was then that Peter Hele of Nuremberg substituted for weights as the motive power a ribbon of steel, which he wound around a central spindle, connecting one end to a train of wheels to which it gave motion as it unwound.

Then followed the famous observation of the swinging lamp by the then young Galileo, about 1582, while lounging in the cathedral of Pisa. The isochronism of the vibrations of the pendulum inferred from this observation was not published or put to practical application in clocks for nearly sixty years afterward. In 1639 Galileo, then old and blind, dictated to his son one of his books in which he discussed the isochronal properties of oscillating bodies, and their adaptation as time measures. He and others had used the pendulum for dividing time, but moved it by hand and counted its vibrations. But Huygens, the great Dutch scientist, about 1556 was the first to explain the principles and properties of the pendulum as a time measurer and to apply it most successfully to clocks. His application of it was to the old clock of Vick's.

The seventeenth century thus opened up a new era in clock and watch making. The investigations, discoveries, and inventions of Huygens and other Dutch clock-makers, of Dr. Hooke and David Ramsey of England, Hautefeuille of France, and a few others placed the art of clock and watch making on the scientific basis on which it has ever since rested. [Pg 389]

The pendulum and watch-springs needed to have their movements controlled and balanced by better escapements. Huygens thought that the pendulum should be long and swing in a cycloidal course, but Dr. Hooke found the better way to produce perfect isochronous movements was to cause the pendulum to swing in short arcs, which he accomplished by his invention of the anchor escapement.

The fusee which Dr. Hooke re-invented consists of a conical spirally-grooved pulley, around which a chain is wound, and which is connected at one end to a barrel, in which the main actuating spring is tightly coiled. The fusee is thus interposed between the wheel train and the spring to equalise the power of the latter.

To Dr. Hooke must also be credited the invention of that delicate but efficient device, the hair-spring balance for watches. His inventions in this line were directed to the best means of utilising and controlling the force of springs, his motto being "*ut tensio sic vis*," (as the tension is so is the force.) Repeating watches to strike the hours, half-hours and quarters, made their appearance in the seventeenth century. In the next century Arnold made one for George III., as small as an English sixpence. This repeated the hours, halves and quarters, and in it for the first time in the art a jewel was used as a bearing for the arbors, and this particular one was a ruby made into a minute cylinder.

After the discovery and practical application of weights, springs, wheels, levers and escapements to time mechanisms, subsequent inventions, numerous as they have been, have consisted chiefly, not in the discovery of new principles, but in new methods in the application of old ones. Prior to the eighteenth century, however, clocks were cumbrous and expensive, and the watches rightly regarded as costly toys; and as to their accuracy in time-measuring, the cheaper ones were hardly as satisfactory as the ancient sun-dials. [Pg 390]

With the coming of the machine inventions and the new industrial and social ideas of the eighteenth century came an almost sudden new appreciation of the value of time. Hours, minutes and seconds began to be carefully prized, both by the trades and professions, and the demand from the common people for accurate time records became great. This demand it has been the office of the nineteenth century to supply, and to place clocks and watches within the reach of the poor as well as the rich. While thus lessening the cost of time-keepers their value has been enhanced by increasing their accuracy and durability.

Among the other ideas for which the eighteenth century was famous in watch-making was that of dispensing with the key for winding, thus saving the losing of keys and preventing access of dust, an idea which, however, was perfected only in the last half of the nineteenth century.

The eighteenth century was chiefly distinguished by its scientific improvements in time-keepers, to adapt them for astronomical observations and for use at sea, in not only accurately determining the time, but the degrees of longitude. Chronometers were invented, distinguished from watches and clocks, by means by which the fluctuation of the parts caused by the variations in temperature are obviated or compensated. In clocks what are known as the mercurial and gridiron pendulums were invented respectively toward the close of the eighteenth century by Graham and Harrison, and the latter also subsequently invented the expanding and contracting balance wheel for watches. The principle in these appliances is the employment of two different metals which expand unequally, and thus maintain an uniformity of operation. [Pg 391]

The Dutch, with Huygens in the lead, were long among the leading clock-makers. Germany ranked next. It was in the seventeenth century that a wonderful industry in clock-making there commenced, which lasted for two centuries. The Black Forest region of South Germany became a famous locality for the manufacture of cheap wooden clocks. The system adopted was a minute division of labour. From fourteen to twenty thousand hands twenty years ago were employed in the Schwarzwald district. Labour-saving machines were ignored almost entirely. The annual production finally reached nearly two million clocks, of the value of about five million dollars.

Switzerland in watch-making followed precisely the example of Germany in clock-making. It commenced there in the seventeenth and culminated in the nineteenth century. Many thousands of its population were engaged in the business and it flourished under the fostering care of the government—by the establishment of astronomical observations for testing the adjustment of the best watches, the giving of prizes, and the establishment and encouragement of schools of horology conducted on thorough scientific methods. A quarter of a century ago it was estimated that in Switzerland 40,000 persons out of a population of 150,000 were engaged in watch-making, and that the annual production sometimes reached 1,600,000 completed movements. The whole world was their market. The United States alone was in 1875 importing 134,000 watches annually from that country. [Pg 392]

As in Germany, so one characteristic of the Swiss system was a minute sub-division of the labour. Individuals and entire families had certain parts only to make. It is said that the Swiss watch passed through the hands of one hundred and thirty different workmen before it was put upon the market. The use of machines was also, as in Germany, ignored. By this national devotion to a single trade and its sub-division of labour, the successful production of complicated watches became great and their prices comparatively low.

The United States in the commencement of its career and at the opening of the century had no clocks or watches of its own manufacture. But it soon followed the example of Germany and Switzerland and established cheap clock manufactories, first of wood, and then of metal, which became famous and of world-wide use. But it could make no headway against the cheap labour of Europe in watch-making, and the country was flooded with watches of all qualities, principally from Switzerland and England. Finally, at the half-way mark in the century, the inquiry arose among Americans, why could not the system of the minute sub-division of human labour followed in watch-making countries so cheaply and profitably, be accomplished by machinery? The field was open, the prize was great, and the government stood ready to grant exclusive patents to every inventor who would devise a new and useful machine. The problem was great, as the fields abroad had been filled for generations by skilled artisans who had reduced the complicated mechanism of watch-making to a fine art. Fortunately the habit had been established in America in several of the leading industries, principally in that of fire-arms, of fabricating separate machinery for the independent making of numerous parts of the same implement, whereby uniformity and interchangeability were established. Under such a practice, which was known as the American system, a duplicate of the smallest part of a complicated machine, lost or worn out thousands of miles from the factory, could soon be furnished by simply sending the number or name of such required part to the manufacturer, or to the nearest dealer in such machines. [Pg 393]

With such encouragement and example the scheme of watch-making was commenced. Soon large factories were built, and by the time of the Centennial Exhibition in 1876, the American Watch Company of Waltham, Massachusetts, were enabled to present an exhibit of watch movements made by machinery, which astonished the world. Other great companies in different parts of the country soon followed with the same general system. Machines, working with the apparent intelligence and facility of human minds and hands, and with greater mathematical accuracy than was possible with the hands, appeared:—for cutting out the finest teeth from blank wheels stamped out from steel or brass; for making and cutting the smallest, finest threaded screws by the thousands per hour and with greatest uniformity and accuracy; for jewel-making; for cutting and polishing by diamonds, or sapphire-armed tools, the rough, unpolished diamond and ruby, crysolite, garnet, or aqua-marine, and for boring, finishing and setting the same; for the formation of the most delicate pins or arbors; for the making of the escapements, including forks, pallets, rollers, and scape wheels; for making springs and balances, including the main-springs and hair-springs; for making and setting the stem-winding parts; for making the cases, and engraving the same, etc. The list would be too long to simply name all the ingenious machines there exhibited and subsequently invented for every important operation. [Pg 394]

It was the aim of these manufacturers to locate every great factory in some quiet and attractive spot, free from the dust of town, and city, and divide it into many departments, from the blacksmithing to the packing and transportation of the completed article; and to conduct every department with the best mechanical and mathematical skill that money and brains could provide.

The same system was followed with equal success in producing the first-class pocket-chronometer for the nicest work to which chronometers can be put.

Thus with every watch and its every part made the exact duplicate of its fellow, uniformity in time-keeping has been established; and the simile of Pope is no longer so correct, "'Tis with our judgments as our watches, none go just alike, yet each believes his own." A simple statement of this system illustrates with greater force than an entire volume the revolution the nineteenth century has produced in the useful art of horology. And yet the story should not omit reference to the application of the electric system to clocks, whereby clocks at distant points of a city or country are connected, automatically corrected and set to standard time from a central observatory or other time station. [Pg 395]

Great as were the advances in horology during the seventeenth and eighteenth centuries, the number of inventions that have been made in the nineteenth century is evidenced by the fact that in the United States alone about 4,000 patents have been granted since 1800, which, however, represent not only American inventors but very many of other countries.

Registering Devices.—Devices for recording fares and money have employed the keenest wits of many inventors and is an art of quite recent origin. Attention was first directed to fare registers in public vehicles, the object of which is to accurately report to the proper office of the company at the end of a trip, or of the day, the number of passengers carried and the fares received. Portable registers, to be carried by the conductor and operated in front of the passenger have been almost universally succeeded by stationary ones set up at one end of the vehicle in open view of all the passengers and operated by a strap and lever by the conductor. These fare registers have been called "A mechanical conscience for street car conductors."

Cash Registers, intended to compel honesty on the part of retail salesmen, are required to be operated by them, and when the proper lever, or levers, or it may be a crank handle, is or are touched, the machine automatically records the amount of the sale, the amount of change given, and the total amount of all the sales and money received and paid out.

Voting Machines—designed to overcome the difficulties, expenditure of time, and the commission of errors and frauds experienced in the reading and counting of votes—have received great attention from inventors, and are not yet in a satisfactory condition. The problem involves the dispensing of printing the ballots, the prevention of fraudulent deposition of ballots, the [Pg 396] automatic correct counting of the same, and a display of the result as soon as the balloting is closed.

Successful electrical devices have been made for recording the votes of a great number of persons in a large assembly by the touch of an "aye" or "nay" button at the seat of the voter and the recording of the same on paper at a central desk.

The invention and extensive use of bicycles, automobiles, etc., have given rise to the invention of *cyclometers*, which are small devices connected to some part of the vehicle to indicate to the rider or driver the rate at which he is riding, and the number of miles ridden.

Speed Indicators.—Many municipalities having adopted ordinances limiting the rate of speed for street and steam cars, bicycles, automobiles, and other vehicles, a want was created, which has been met, for devices to indicate to the passengers, drivers or conductors the rate at which the vehicle is travelling, and to sound an alarm in case of excess of speed, so that brakes can be applied and the speed reduced. Or to relieve persons of anxiety and trouble in this respect, ingenious devices have been contrived which automatically reduce the speed when the prescribed limit has been exceeded.

Weighing Scales and Machines.—"Just balances and just weights" have been required from the day of the declaration, "a false weight is an abomination unto the Lord." And therefore strict accuracy must always be the measure of merit of a weighing machine. To this standard the inventions of the century in weighing scales have come. Until this century the ordinary balance with equal even arms suspended from a central point, and each carrying means for suspending [Pg 397] articles to be weighed, or compared in weights, and the later steelyard with its unequal arms, with its graduated long arms and a sliding weight and holding pan, were the principal forms of weighing machines. Platform scales were described in an English patent to one Salman in 1796, but their use is not recorded. The compound lever scale on the principle of the steelyard, but arranged to be used with a platform, was invented and came into use in the United States about 1831. Thaddeus and Erastus Fairbanks of St. Johnsbury, Vermont, were the inventors, and it was found to meet the want of farmers in weighing hemp, hay, etc., by more convenient means than the ordinary steelyard. They converted the steelyard into platform scales. The leading characteristics of such machines are, first, a convenient platform nicely balanced on knife edges of steel levers, and second, a graduated horizontal beam, a sliding weight thereon connected by an upright rod at one end to the beam, and at its opposite end to the balance frame beneath the platform.

The modification in size and adaptation of this machine for the weighing of different commodities amounted to some 400 different varieties—running from the delicately-constructed apparatus for weighing the fraction of a grain, to the ponderous machines for weighing and recording the loaded freight car of fifty or sixty tons, or the canal-boat or other vessel with its load of five or six hundred tons. The adaptation of a balance platform on which to place a light load, or to drive thereon with heavy loads, whether of horses, steam, or water vehicles, was a great blessing to mankind. No wonder that they were soon sold all over the world, and that monarchs and people [Pg 398] hastened to heap honors on the inventors.

Spring weighing scales have recently been invented, which will accurately and automatically show not only the weight but the total price of the goods weighed, the price per unit being known and fixed.

In the weighing of large masses of coarse material, such as grain, coal, cotton seed, and the like, machines have been constructed which automatically weigh such materials and at the same time register the weight.

Previous to this century no method was known, except the exercise of good judgment in the light of experience, of accurately testing the strength of materials. Wood and metals were used in unnecessarily cumbrous forms for the purpose to which they were put, in order to ensure safety, or else the strength of the parts failed where it was most needed.

The idea of testing the tensile, transverse, and cubical resisting strength of materials has been applied to many other objects than beams and bars of wood and metals; to belts, cloths, cables, wires, fibres, paper, twine, yarn, cement, and to liquids. Kiraldy, Kennedy, and others of England, Thomasset of France, Riehle of Germany, and Fairbanks, Thurston and Emery of the United States, are among the noted inventors of such machines.

In the Emery system of machines, consisting of scales, gages, and dynamometers, the power exerted on the material tested is transmitted from the load to an indicating device by means of liquid acting on diaphragms. The same principle is employed in his weighing machines. [Pg 399]

By one of these hydraulic testing machines the tensile strength of forged links has been ascertained by the exertion of a power amounting to over 700,000 pounds before breaking a link, the chain breaking with a loud report.

The most delicate materials are tested by the same machine—the tensile strength of a horsehair, some of which are found to stand the strain of one and two pounds. Eggs and nuts are cracked without being crushed, and the power exerted and the strain endured automatically recorded. Steel beams and rods have been subjected to a strain of a million pounds before breaking.

Governments, municipalities, and the people generally are thus provided with means by which they can proceed with the greatest confidence in the safe and economical construction and completion of their buildings and public works.

[Pg 400]

CHAPTER XXVI.

MUSIC, ACOUSTICS, OPTICS, FINE ARTS.

Neither the historic nor prehistoric records find man without musical instruments of some sort. They are as old as religion, and have been found wherever evidence of religious rites of any description have been found, as they constituted part of the instrumentalities of such rites. They are found as relics of worship and the dance, ages after the worshippers and the dancers have become part of the earth's strata. They have been found wherever the earliest civilisations have been discovered; and they appear to have been regarded as desirable and necessary as the weapons and the labour implements of those civilisations. They abounded in China, in India, and in Egypt before the lyre of Apollo was invented, or the charming harp of Orpheus was conceived.

There was little melody according to modern standards, but the musical instruments, like all other inventions, the fruit of the brain of man, were slowly evolved as he wanted them, and to meet the conditions surrounding him.

There were the conch shell trumpet, the stone, bone, wood and metal dance rattles, the beaks of birds, and the horns and teeth of beasts, for the same rattling purpose. The simple reed pipes, the hollow wooden drums, the skin drum-heads, the stretched strings of fibre and of tendons, the flutes, the harps, the guitars, the psalteries, and hundreds of other forms of musical instruments, [Pg 401] varied as the skill and fancy of man varied, and in accordance with their taste and wants, along the entire gamut of noises and rude melodies. The ancient races had the instruments, but their voices, except as they existed in the traditions of their gods, were not harmonious.

As modern wants and tastes developed and music became a science the demands of the nineteenth century were met by a Helmholtz, who discovered and explained the laws of harmony, and by many ingenious manufacturers, who so revolutionised the pianoforte action, and the action of musical instruments constructed on these principles, that their predecessors would hardly be recognised as prototypes.

The story of the piano, that queen of musical instruments, involves the whole history of the art of music. Its evolution from the ancient harp, gleaned by man from the wind, "that grand old harper, who smote his thunder harp of pines," is too long a story to here recite in detail. It must suffice to say, it started with the harp, in its simplest form, composed of a frame with animal tendons stretched tight thereon and twanged by the fingers. Then followed strings of varied length, size, and tension, to obtain different tones, soon accompanied by an instrument called the plectrum—a bone or ivory stick with which to vibrate the strings, to save the fingers. This was the harp of the Egyptians, and of Jubal, "the father of all such as handle the harp and the organ," and half-brother of Tubal Cain, the great teacher "of every artificer in brass and iron." Then the harp was laid prostrate, its strings stretched over a sounding board, and each held and adapted to be tightened by pegs, and played upon by little hammers having soft pellets or corks at their [Pg 402] ends. This was the psaltery and the dulcimer of the Assyrians and the Hebrews.

The Greeks derived their musical instruments from the Egyptians, and the Romans borrowed theirs from the Greeks, but neither the Greeks nor the Romans invented any.

Then, after fourteen or fifteen centuries, we find the harp, both in a horizontal and an upright position, with its strings played upon by keys. This was the *clavicitherium*. In the sixteenth century came the virginal, and the spinet, those soft, tinkling instruments favoured by Queen Elizabeth and Queen Mary, and which, recently brought from obscurity, have been made to revive the ancient Elizabethan melodies, to the delight of modern hearers. These were followed in the seventeenth century by the clavichord, the favourite instrument of Bach. Then appeared the harpsichord, a still nearer approach to the piano, having a hand or knee-worked pedal, and on which Mozart and Handel and Haydn brought out their grand productions. The ancient Italian cembello was another spinet.

Thus, through the centuries these instruments had slowly grown. By 1711 in Italy, under the inventive genius of Bartolommeo Cristofori of Florence, they had culminated in the modern piano. The piano as devised by him differed from the instruments preceding it chiefly in this, that in the latter the strings were vibrated by striking and pulling on them by pieces of quills attached to levers and operated by keys, whereas, in the piano there were applied hammers in place of quills.

In the 1876 exhibition at Philadelphia, a piano The Greeks derived their musical instruments from the Egyptians, and the Romans borrowed theirs from the Greeks, but neither the Greeks nor the Romans invented any.

Then, after fourteen or fifteen centuries, we find the harp, both in a horizontal and an upright position, with its strings played upon by keys. This was the clavicitherium. In the sixteenth century came the virginal, and the spinet, those soft, tinkling instruments favoured by Queen Elizabeth and Queen Mary, and which, recently brought from obscurity, have been made to revive the ancient Elizabethan melodies, to the delight of modern hearers. These were followed in the seventeenth century by the clavichord, the favourite instrument of Bach. Then appeared the harpsichord, a still nearer approach to the piano, having a hand or knee-worked pedal, and on which Mozart and Handel and Haydn brought out their grand productions. The ancient Italian cembello was another spinet.

Thus, through the centuries these instruments had slowly grown. By 1711 in Italy, under the inventive genius of Bartolommeo Cristofori of Florence, they had culminated in the modern piano. The piano as devised by him differed from the instruments preceding it chiefly in this, that in the latter the strings were vibrated by striking and pulling on them by pieces of quills attached to levers and operated by keys, whereas, in the piano there were applied hammers in place of quills.

In the 1876 exhibition at Philadelphia, a piano was displayed which had been made by Johannes [Pg 403] Christian Schreiber of Germany in 1741.

Then in the latter part of the eighteenth century Broadwood and Clementi of London and Erard of Strasburg and Petzold of Paris commenced the manufacture of their fine instruments. Erard particularly made many improvements in that and in the nineteenth century in the piano, its hammers and keys, and Southwell of Dublin in the dampers.

By them and the Collards of London, Bechstein of Berlin, and Chickering, Steinway, Weber, Schomacher, Decker and Knabe of America, was the piano "ripened after the lapse of more than 2,000 years into the perfectness of the magnificent instruments of modern times, with their better materials, more exact appliances, finer adjustments, greater strength of parts, increase of compass and power, elastic responsiveness of touch, enlarged sonority, satisfying delicacy, and singing character in tone."

A piano comprises five principal parts: first, the framing; second, the sounding board; third, the stringing; fourth, the key mechanism, or action, and fifth, the ornamental case. To supply these several parts separate classes of skilled artisans have arisen, the forests have been ransacked for their choicest woods, the mines have been made to yield their choicest stores, and the forge to weld its finest work. Science has given to music the ardent devotion of a lover, and resolved a confused mass of more or less pleasant noises into liquid harmonies. In 1862 appeared Helmholtz's great work on the "Law and Tones and the Theory of Music." He it was who invented the method of analysing sound. By the use of hollow bodies called *resonators* he found that every sound as it generally occurs in nature and as it is produced by most of our musical instruments, [Pg 404] or the human voice, is not a single simple sound, but a compound of several tones of different intensity and pitch; all of which different tones combined are heard as one; and that the difference of quality or *timbre* of the sounds of different musical instruments resides in the different composition of these sounds; that different compound sounds contain the same fundamental tone but differently mixed with other tones. He explained how these fundamental and compound tones might be fully developed to produce either harmonious or dissonant sensations. His researches were carried farther and added to by Prof. Mayer of New Jersey. These theories were practically applied in the pianos produced by the celebrated firm of Steinway and Sons of New York; and their inventions and improvements in the iron framing, in laying of strings in relation to the centre of the sounding-board, in "resonators" in upright frames, and in other features, from 1866 to 1876, produced a revolution in the art of piano making.

If the piano is properly the queen of musical instruments, the organ may be rightly regarded, as it has been named, "King in the realm of music." It is an instrument, the notes of which are produced by the rush of air through pipes of different lengths, the air being supplied by bellows or other means, and controlled by valves which are operated by keys, and by which the supply of air is admitted or cut off.

The earliest description appears to be that in the "Spiritalia" of Hero of Alexandria (150-200 B. C.) and Ctesibius of Alexandria was the inventor. A series of pipes of varying lengths were filled by an air-pump which was operated by a wind-mill. Organs were again originated in the early Christian centuries; and a Greek epigram of the fourth century refers to one as provided with [Pg 405] "reeds of a new species agitated by blasts of wind that rush from a leathern cavern beneath their roots, while a robust mortal, running with swift fingers over the concordant keys, makes them smoothly dance and emit harmonious sounds."

The same in principle to-day, but more complicated in structure, "yet of easy control under the hands of experts, fertile in varied symphonious effects, giving with equal and satisfying success the gentlest and most sympathetic tones as well as complete and sublimely full utterances of musical inspiration."

The improvements of the century have consisted in adding a great variety of stops; in connections and couplers of the great keyboard and pipes; in the pedal part; in the construction of the pipes and wind chests; and principally in the adaptation of steam, water, air, and electricity, in place of the muscles of men, as powers in furnishing the supply of air. Some of the great organs of the century, having three or four thousand pipes, with all the modern improvements, and combining great power with the utmost brilliancy and delicacy of utterance, and with a blended effect which is grand, solemn and most impressive, render indeed this noble instrument the "king" in the realm of music.

In the report of 1895 of the United States Commissioner of patents it is stated that "the *autoharp* has been developed within the past few years, having bars arranged transversely across the strings and provided with dampers which, when depressed, silence all the strings except those producing the desired chords. [Pg 406]

"An ingenious musical instrument of the class having keyboards like the piano or organ has been recently invented. All keyboard instruments in ordinary use produce tones that are only approximately correct in pitch, because these must be limited in number to twelve, to the octave, while the tones of the violin are absolute or untempered. The improved instrument produces untempered tones without requiring extraordinary variations from the usual arrangement of the keys."

Self-playing musical instruments have been known for more than forty years, but it is within the past twenty-five years that devices have been invented for controlling tones by pneumatic or electrical appliances to produce expressions. Examples of the later of these three kinds of musical instruments may be found in the United States patents of Zimmermann in 1882, Tanaka, 1890, and Gally, 1879.

The science of *acoustics* and its practical applications have greatly advanced, chiefly due to the researches of Helmholtz, referred to above.

When the nature and laws of the waves of sound became fully known a great field of inventions was opened. Then came the telephone, phonograph, graphophone and gramophone.

The telephone depends upon a combination of electricity and the waves of the human voice. The phonograph and its modifications depend alone on sound waves—the recording of the waves from one vibrating membrane and their exact reproduction on another vibrating membrane.

The acoustic properties of churches and other buildings were improved by the adaptation of banks of fine wires to prevent the re-echoing of sounds. *Auricular tubes* adapted to be applied to the ears and concealed by the hair, and other forms of aural instruments, were devised. [Pg 407]

The *Megaphone* of Edison appeared, consisting of two large funnels having elastic conducting tubes from their apices to the aural orifice. Conversation in moderate tones has been heard and understood by their use at a distance of one and a half miles. The megaphone has been found very useful in speaking to large outdoor crowds.

But let us go back a little: In 1845, Chas. Bourseuil of France published the idea that the vibrations of speech uttered against a diaphragm might break or make an electric contact, and the electric pulsations thereby produced might set another diaphragm vibrating which should produce the transmitted sound waves. In 1857, another Frenchman, Leon Scott, patented in France his *Phonautograph*—an instrument consisting of a large barrel-like mouth-piece into which words were spoken, a membrane therein against which the voice vibrations were received, a stylus attached to this vibrating membrane, and a rotating cylinder covered with blackened paper, against which the stylus bore and on which it recorded the sound waves in exact form received on the vibrating diaphragm. Then came the researches and publications of Helmholtz and König on acoustic science, 1862-1866. Then young Philip Reis of Frankfort, Germany, attempted to put all these theories into an apparatus to reproduce speech, but did not quite succeed. Then in 1874-1875, Bell took up the matter, and at the Philadelphia exhibition, 1876, astonished the world by the revelations of the telephone. In April, 1877, Charles Cros, a Frenchman, in a communication to the Academy of Sciences in Paris, after describing an apparatus like the Scott phonautograph, set forth how traced undulating lines of voice vibrations [Pg 408] might be reproduced in intaglio or in relief, and reproduced upon a vibrating membrane by a pointed stylus attached thereto and following the line of the original pulsations. The communication seems to have been pigeon-holed, and not read in open session until December, 1877, and until after Thomas A. Edison had actually completed and used his phonograph in the United States. Cros rested on the suggestion. Edison, without knowing of Cros' suggestion, was first to make and actually use the same invention. Edison's cylinder, on which the sounds were recorded and from which they were reproduced, was covered by tin foil. A great advance was made by Dr Chichester A. Bell and Mr. C. S. Tainter, who in 1886 patented in the United States means of cutting or engraving the sound waves in a solid body. The solid body they employed was a thin pasteboard cylinder covered with wax. This apparatus they called the *graphophone*. Two years thereafter, Mr. Emile Berliner of Washington had invented the *gramophone*, which consists in etching on a metallic plate the record of voice waves. He has termed his invention, "the art of etching the human voice." He prepares a polished metal plate, generally zinc, with an extremely thin coating of film or fatty milk, which dries upon and adheres to the plate. The stylus penetrates this film, meeting from it the slightest possible resistance, and traces thereon the message. The record plate is then subjected to a particularly constituted acid bath, which, entering the groove or grooves formed by the stylus, cuts or etches the same into the plate. The groove thus formed may be deepened by another acid solution. When thus produced, as many copies of the record as desired may be made by the electrotyper or print plater. [Pg 409]

The public is now familiar with the different forms of this wonderful instrument, and like the telephone, they no longer seem marvellous. Yet it is only within the age of a youth or a maiden when the allegations or predictions that the human voice would soon be carried over the land, and reproduced across a continent, or be preserved or engraven on tablets and reproduced at pleasure anywhere, in this or any subsequent generation, were themselves regarded as strange messages of dreamers and madmen.

Optical Instruments.—There were practical inventions in optical instruments long before this century. Achromatic and other lenses were known, and the microscope, the telescope and spectacles.

The inventive genius of this century in the field of optics has not eclipsed the telescope and microscope of former ages. They were the fruits of the efforts of many ages and of many minds, although Hans Lippersheim of Holland in 1608 appears to have made the first successful instrument "for seeing things at a distance." Galileo soon thereafter greatly improved and increased its capacity, and was the first to direct it towards the heavens. And as to the microscope, Dr. Lieberkulm, of Berlin, in 1740, made the first successful solar microscope. As well known, it consisted essentially of two lenses and a mirror, by which the sun's rays are reflected on the first lens, concentrated on the object and further magnified by the second lens.

The depths of the stars and the minutest mote that floats in the sun beam reflect the glory of those inventions. [Pg 410]

The invention of John Dolland of London, about 1758, of the achromatic lens should be borne in mind in connection with telescopes, microscopes, etc. He it was who invented the combination of two lenses, one concave and the other convex, one of flint glass and the other of crown glass, which, refracting in contrary ways, neutralised the dispersion of colour rays and produced a clear, colourless light.

Many improvements and discoveries in optics and optical instruments have been made during the century, due to the researches of such scientists as Arago, Brewster, Young, Fresnel, Airy, Hamilton, Lloyd, Cauchy and others, and of the labours of the army of skilled experts and mechanicians who have followed their lead.

Sir David Brewster, born in Scotland in 1781, made (1810-1840) many improvements in the construction of the microscope and telescope, invented the kaleidoscope, introduced in the stereoscope the principles and leading features which those beautiful instruments still embody, and rendered it popular among scientists and artists.

It is said that Prof. Eliot of Edinburgh in 1834 was the first to conceive of the idea of a stereoscope, by which two different pictures of the same object, taken by photography, to correspond to the two different positions of an object as viewed by the two eyes, are combined into one view by two reflecting mirrors set at an angle of about 45°, and conveying to the eyes a single reflection of the object as a solid body. But Sir Charles Wheaton in 1838 constructed the first instrument, and in 1849 Brewster introduced the present form of lenticular lenses.

Brewster also demonstrated the utility of dioptric lenses, and zones in lighthouse illumination; and in which field Faraday and Tyndall also subsequently worked with the addition of electrical appliances. The labours of these three men have illuminated the wildest waters of the sea and preserved a thousand fleets of commerce and of war from awful shipwreck. [Pg 411]

As illustrating the difficulties sometimes encountered in introducing an invention into use, the American Journal of Chemistry some years ago related that the Abbé Moigno, in introducing the stereoscope to the savants of France, first took it to Arago, but Arago had a defect of vision which made him see double, and he could only see in it a medley of four pictures; then the Abbé went to Savart, but unfortunately Savart had but one eye and was quite incapable of appreciating the thing. Then Becquerel was next visited, but he was nearly blind and could see nothing in the new optical toy. Not discouraged, the Abbé then called upon Puillet of the Conservatoire des Arts et Metiers. Puillet was much interested, but he was troubled with a squint which presented to his anxious gaze but a blurred mixture of images. Lastly Brot was tried. Brot believed in the corpuscular theory of light, and was opposed to the undulatory theory, and the good Abbé not being able to assure him that the instrument did not contradict his theory, Brot refused to have anything to do with it. In spite, however, of the physical disabilities of scientists, the stereoscope finally made its way in France.

Besides increasing the power of the eye to discover the secrets and beauties of nature, modern invention has turned upon the eye itself and displayed the wonders existing there, behind its dark glass doors. It was Helmholtz who in 1851 described his *Ophthalmoscope*. He arranged a candle so that its rays of light, falling on an inclined reflector, were thrown through the pupil of the patient's eye, whose retina reflected the image received on the retina back to the mirror where it could be viewed by the observer. This image was the background of the eye, and its delicate [Pg 412] blood vessels and tissues could thus be observed. This instrument was improved and it gave rise to the contrivance of many delicate surgical instruments for operating on the eye.

The *Spectroscope* is an instrument by which the colours of the solar rays are separated and viewed, as well as those of other incandescent bodies. By it, not only the elements of the heavenly bodies have been determined, but remarkable results have been had in analysing well-known metals and discovering new ones. Its powers and its principles have been so developed during the century by the discoveries, inventions and investigations of Herschel, Wollaston, Fraunhofer, Bronsen and Kirchoff, Steinheil, Tyndall, Huggins, Draper and others, that spectrum analysis has grown from the separation of light into its colours by the prism of Newton, to what Dr. Huggins has aptly termed "a new sense."

We have further referred to this wonderful discovery in the Chapter on Chemistry.

The inventions and improvements in optical instruments gave rise to great advances in the making of lenses, based on scientific principles, and not resting alone on hard work and experience. Alvan Clark a son of America, and Prof. Ernst Abbe of Germany, have within the last third of the century produced a revolution in the manufacture of lenses, and thereby extended the realms of knowledge to new worlds of matter in the heavens and on earth. [Pg 413]

Solarmeter.—In 1895 a United States patent was granted to Mr. Bechler for an instrument called a solarmeter. It is designed for taking observations of heavenly bodies and recording mechanically the parts of the astronomical triangle used in navigation and like work. Its chief purpose is to determine the position of the compass error of a ship at sea independently of the visibility of the sea horizon. If the horizon is clouded, and the sun or a known star is visible, a ship's position can still be determined by the solarmeter.

Instruments for Measuring the Position and Distances of Unseen Objects.—Some of the latest of such instruments will enable one to see and shoot at an object around a corner, or at least out of sight. Thus a United States patent was granted to Fiske in 1889, wherein it is set forth that by stationing observers at points distant from a gun, which points are at the extremities of a known base line, and which command a view of the area within the range of the gun, the observers discover the position and range of the object by triangulation and set certain pointers. By means of electrical connection between those pointers and pointers at the gun station based on the system of the Wheatstone bridge, the latter pointers, or the guns themselves serving as pointers, may be placed in position to indicate the line of fire. By a nice arrangement of mirror and lenses attached to a firearm the same object may be accomplished. Similar apparatuses in which the reflectory surfaces of mirrors mounted on an elevated frame-work, and known as *Polemoscopes* and *Altiscopes* and *Range-Finders*, have also been invented, and used with artillery. But such devices may be profitably used for more peaceful and amusing purposes. [Pg 414]

Born with the ear attuned to music and the eye to observe beauty, the hand of Art was to trace and make permanent the fleeting forms which melody and the eye impressed upon the soul of man.

In fact modern science has demonstrated that tones and colours are inseparable. Bell and Tainter with their *photophone* have converted the undulatory waves of light into the sweetest music. Reversing the process, beautiful flashes of light have been produced from musical vibrations by the *phonophote* of M. Coulon and the *phonoscope* of Henry Edmunds.

Entrancing as the story is, we can only here allude to a few of those discoveries and inventions that have become the handmaidens of the art which guided the chisel of Phidias and inspired the brush of Raphael.

Photography.—The art of producing permanent images of the "human face divine," natural scenes, and other objects, by the agency of light, is due more to the discoveries of the chemist than to the inventions of the mechanic; and to the chemists of this century. At the same time a mechanical invention of old times became a necessary appliance in the reduction of the theories of the chemists to practice:—The *Camera Obscura*, that dark box in which a mirror is placed, provided also with a piece of ground glass or white cardboard paper, and having a projecting part at one end in which a lens is placed, whereby when the lens part is directed to an object an image of the same is thrown by the rays of light focused by the lens upon the mirror, and reflected by the mirror to the glass or paper board, was invented by Roger Bacon about 1297, or by Alberta in 1437, described by Leonardo da Vinci in 1500 as an imitation of the structure of the eye, again by Baptista Porta in 1589, and remodelled by Sir Isaac Newton in 1700. Until the 19th century it was used only in the taking of sketches and scenes on or from the card or glass on which the reflection was thrown. [Pg 415]

Celebrated chemists such as Sheele of the 18th century, and Ritter, Wollaston, Sir Humphry Davy, Young, Gay-Lussac, Thenard, and others in the early part of the 19th century, began to turn their attention to the chemical and molecular changes which the sunlight and its separate rays effected in certain substances, and especially upon certain compounds of silver. In sensitising the receiving paper, glass, or metal with such a compound it must necessarily be protected from exposure to sunlight, and this fact, together with the desire to sensitise the image produced by the camera, not only suggested but seemed to render that instrument indispensable to photography. Nevertheless the experiments of chemists fell short of the high mark, and it was reserved for an artist to unite the efforts of the sun and the chemists in a successful instrument.

It was Louis Jacques Mandé Daguerre, born at Corneilles, France, in 1789, and who died in 1851, who was the first to reduce to practice the invention called after his name. He was a brilliant scene painter, and especially successful in painting panoramas. In 1822, assisted by Bouton, he had invented the *diorama*, by which coloured lights representing the various changes of the day and season were thrown upon the canvasses in his beautiful panoramas of Rome, London, Naples and other great cities. Several years previous to 1839 he and Joseph N. Niepce, learning of the efforts of chemists in that line, began independently, and then together, to develop the art of obtaining permanent copies of objects produced by the chemical action of the sun. Niepce died [Pg 416] while they were thus engaged. Daguerre prosecuted his researches alone, and toward the close of 1838 his success was such that he made known his invention to Arago, and Arago announced it in an eloquent and enthusiastic address to the French Academy of Sciences in January 1839. It at once excited great attention, which was heightened by the pictures produced by the new process. The French Government, in consideration of the details of the invention and its improvements being made public and on request of Daguerre, granted him an annuity and one also to Niepce's son.

At first only pictures of natural objects were taken; but in learning of Daguerre's process Dr. John William Draper of New York, a native of England and adopted son of America, the brilliant author of *The Intellectual Development of Europe*, and other great works, in the same year, 1839, took portraits of persons by photography, and he was the first to do this. Draper was also the first in America to reveal the wonders of the spectroscope; and he was first to show that each colour of the spectrum had its own peculiar chemical effect. This was in 1847.

The sun was now fairly harnessed in the service of man in the new great art of Photography. Natural philosophers, chemists, inventors, mechanics, all now pressed forward, and still press forward to improve the art, to establish new growths from the old art, and extend its domains. Those domains have the generic term of *Photo-Processes*. Daguerreotypy, while the father of them all, is now hardly practised as Daguerre practised it, and has become a small subordinate sub-division of the great class. Yet more faithful likenesses are not yet produced than by this now old process. Among the children of the Photo-Process family are the *Calotype*, *Ambrotype*, [Pg 417] *Ferreotype*, *Collodion* and *Silver Printing*, *Carbon Printing*, *Heliotype*, *Heliogravure*, *Photoengraving* (relief intaglio-Woodburytype), *Photolithography*; *Alberttype*; *Photozincograph*, *Photogelatine-printing*; *Photomicrography* (to depict microscopic objects), *Kinetographs*, and *Photosculpture*. A world of mechanical contrivances have been invented:—*Octnometers*, *Baths*, *Burnishing tools*, *Cameras and Camera stands*, *Magazine and Roll holders*; *Dark rooms* and *Focussing devices*, *Heaters* and *Driers*; *Exposure Meters*, etc. etc.

The *Kinetograph*, for taking a series of pictures of rapidly moving objects, and by which the living object, person or persons, are made to appear moving before us as they moved when the picture was taken, is a marvellous invention; and yet simple when the process is understood. Photography and printing have combined to revolutionise the art of illustration. Exact copies of an original, whether of a painting or a photograph, are now produced on paper with all the original shades and colours. The long-sought-for problem of photographing in colours has in a measure been solved. The "three *colour processes*" is the name given to the new offspring of the inventors which reproduces by the camera the natural colours of objects.

The scientists Maxwell Young and Helmholtz established the theory that the three colours, red, green, and blue, were the primary colours, and from a mixture of these, secondary colours are produced. Henry Collen in 1865 laid down the lines on which the practical reduction should take place; and within the last decade F. E. Ives of Philadelphia has invented the *Photochromoscope* for producing pictures in their natural colours. The process consists in blending in one picture [Pg 418] the separate photographic views taken on separate negative plates, each sensitised to receive one of the primary colours, which are then exposed and blended simultaneously in a triple camera.

Plates and films and many other articles and processes have helped to establish the Art of Photography on its new basis.

Among the minor inventions relating to Art, mention may be made of that very useful article the lead *pencil*, which all have employed so much time in sharpening to the detriment of time and clean hands. Within a decade, pencils in which the lead or crayon is covered instead of with wood, with slitted, perforated or creased paper, spirally rolled thereon, and on which by unrolling a portion at a time a new point is exposed; or that other style in which a number of short, sharpened marking leads, or crayons, are arranged in series and adapted to be projected one after the other as fast as worn away.

In Painting modern inventions and discoveries have simply added to the instrumentalities of genius but have created no royal road to the art made glorious by Titian and Raphael. It has given to the artists, through its chemists, a world of new colours, and through its mechanics new and convenient appliances.

Air Brushes have proved a great help by which the paint or other colouring matter is sprayed in heavy, light, or almost invisible showers to produce backgrounds by the force of air blown upon the pigments held in drops at the end of a fine spraying tube. Made of larger proportions, this brush has been used for fresco painting, and for painting large objects, such as buildings, which [Pg 419] it admits of doing with great rapidity.

A description of modern methods of applying colours to porcelain and pottery is given in the chapter treating of those subjects.

Telegraphic pictures:—Perhaps it is appropriate in closing this chapter that reference be made to that process by which the likeness of the distant reader may be taken telegraphically. A picture in relief is first made by the swelled gelatine or other process; a tracing point is then moved in the lines across the undulating surface of the pictures, and the movements of this tracer are imparted by suitable electrical apparatus to a cutter or engraving tool at the opposite end of the line and there reproduced upon a suitable substance.

CHAPTER XXVII.

SAFES AND LOCKS.

Prior to the century safes were not constructed to withstand the test of intense heat. Efforts were numerous, however, to render them safe against the entrance of thieves, but the ingenuity of the thieves advanced more rapidly than the ingenuity of safe-makers. And the race between these two classes of inventors still continues. For with the exercise of a vast amount of ingenuity in intricate locks, aided by all the advancement of science as to the nature of metals, their tough manufacture and their resistance to explosives, thieves still manage to break in and steal. The only sure protection against burglars at the close of the nineteenth century appears to consist of what it was at the close of any previous century—the preponderance of physical force and the best weapons. Among the latest inventions are electrical connections with the safe, whereby tampering therewith alarms one or more watchmen at a near station.

A classification of safes embraces, *Fire-proof*, *Burglar-proof*, *Safe Bolt Works*, *Express and Deposit Safes and Boxes*, *Circular Doors*, *Pressure Mechanism*, and *Water and Air Protective Devices*.

The attention of the earliest inventors of the century were directed toward making safes fire-proof. In England the first patent granted for a fire-proof safe was to Richard Scott in 1801. It had two casings, an inner and outer one, including the door, and the interspace was filled in with [Pg 421] charcoal, or wood, and treated with a solution of alkaline salt.

This idea of interspacing filled in with non-combustible material has been generally followed ever since. The particular inventions in that line consist in the discovery and appliance of new lining materials, variations in the form of the interspacing, and new methods in the construction of the casings, and the selection of the best metals for such construction.

In 1834 William Marr of England patented a lining for a double metallic chest, filled with non-combustible materials such as mica, or talc clay, lime, and graphite. Asbestos commenced to be used about the same time.

The great fire in New York City in 1835, destroying hundreds of millions of dollars' worth of property of every description, gave a great impetus to the invention of fire-proof safes in America.

B. G. Wilder there patented in 1843 his celebrated safe, now extensively used throughout the world. It consisted of a double box of wrought-iron plates strengthened at the edges with bar iron, with a bar across the middle; and as a filling for the interspaces he used hydrated gypsum, hydraulic cement, plaster of paris, steatite, alum, and the dried residuum of soda water.

Herring was another American who invented celebrated safes, made with a boiler-iron exterior, a hardened steel inner safe, with the interior filled with a casting of franklinite around rods of soft steel. Thus the earth, air and water were ransacked for lining materials, in some cases more for the purpose of obtaining a patent than to accomplish any real advance in the art. Water itself was [Pg 422] introduced as a lining, made to flow through the safes, sometimes from the city mains, and so retained that when the temperature in case of fire reached 212° F. it became steam; and an arrangement for introducing steam in place of water was contrived. Among other lining materials found suitable were soapstone, alumina, ammonia, copperas, starch, Epsom salts, and gypsum, paper, pulp, and alum, and a mixture of various other materials.

After safes were produced that would come out of fiery furnaces where they had been buried for days without even the smell of fire or smoke upon their contents, inventors commenced to direct their attention to burglar-proof safes.

Chubb, in 1835, patented a process of rendering wooden safes burglar proof by lining them with steel, or case-hardened iron plate. Newton in 1853 produced one made of an outer shell of cast iron, an interior network of wrought iron rods, and fluid iron poured between these, so that a compound mass was formed of different degrees of resistance to turn aside the burglar's tools. Chubb again, in 1857, and in subsequent years, and Chartwood, Glocker, and Thompson and Tann and others in England invented new forms to prevent the insertion of wedges and the drilling by tools. Hall and Marvin of the United States also invented safes for the same purpose. Hall had thick steel plates dovetailed together; and angle irons tenoned at the corners. Marvin's safe was globeshaped, to present no salient points for the action of tools, made of chrome steel, mounted in this shape on a platform, or enclosed in a fire-proof safe. Herring also invented a safe in which he hinged and grooved the doors with double casings, and which he hung with a lever-hinge, provided the doors with separate locks and packed all the joints with rubber to prevent the operation of the air pump—which had become a dangerous device of burglars with which to introduce explosives to blow open the doors. [Pg 423]

Still later and more elaborate means have been used to frustrate the burglars. Electricity has been converted into an automatic warder to guard the castle and the safe and to give an alarm to convenient stations when the locks or doors are meddled with and the proper manipulation not used. Express safes for railroad cars have been made of parts telescoped or crowded together by hydraulic power, requiring heavy machinery for locking and unlocking, and this machinery is located in machine shops along the route and not accessible to burglars.

About 1815 inventors commenced to produce devices to show with certainty if a lock had been tampered with. The keyhole was closed by a revolving metallic curtain, and paper was secured over the keyhole. As a further means of detection photographs of some irregular object are made, one of which is placed over the keyhole and the other is retained. This prevents the substitution of one piece of paper for another piece without detection. A large number of patents have been taken out on glass coverings for locks which have to be broken before the lock can be turned. These are called seal locks.

Locks of various kinds, consisting at least of the two general features of a bolt and a key to move the bolt, have existed from very ancient days. The Egyptians, the Hebrews and the Chinese, and Oriental nations generally had locks and keys of ponderous size. Isaiah speaks of the key of the house of David; and Homer writes sonorously of the lock in the house of Penelope with its brazen key, the respondent wards, the flying bars and valves which, [Pg 424]

"Loud as a bull makes hills and valley ring,
So roared the lock when it released the spring."

The castles, churches and convents of the middle ages had their often highly ornamental locks and their warders to guard and open them. Later, locks were invented with complex wards. These are carved pieces of metal in the lock which fit into clefts or grooves in the key and prevent the lock from being opened except by its own proper key.

As early as 1650 the Dutch had invented the Letter lock, the progenitor of the modern permutation lock, consisting of a lock the bolt of which is surrounded by several rings on which were cut the letters of the alphabet, which by a prearrangement on the part of the owner were made to spell a certain word or number of words before the lock could be opened. Carew, in verses written in 1621, refers to one of these locks as follows:—

"As doth a lock that goes with letters; for, till every one be known,
The lock's as fast as though you had found none."

The art had also advanced in the eighteenth century to the use of *tumblers* in locks, the lever or latch or plate which falls into a notch of the bolt and prevents it from being shot until it has been raised or released by the action of the key. Barron in England in 1778 obtained a patent for such a lock.

Joseph Bramah, who has before been referred to in connection with the hydraulic press he invented, also in 1784 invented and patented in England a lock which obtained a world-wide reputation and a century's extensive use. It was the first, or among the first of locks which troubled modern burglars' picks. Its leading features were a key with longitudinal slots, a barrel enclosing a spring, plates, called sliders, notched unequally and resting against the spring, a plate with a central perforation and slits leading therefrom to engage the notches of the slides simultaneously and allow the frame to be turned by the key so as to actuate the bolt. Chubb and Hobbs of England made important improvements in tumbler locks, which for a long time were regarded as unpickable. [Pg 425]

Most important advances have been made during the century in *Combination* or *Permutation Locks* and *Time Locks*. For a long time permutation or combination locks consisted of modifications of one general principle, and that was the Dutch letter lock already referred to, or the wheel lock, composed of a series of disks with letters around their edges. The interior arrangement is such as to prevent the bolt being shot until a series of letters were in line, forming a combination known only to the operator. Time locks are constructed on the principle of clockwork, so that they cannot be opened even with the proper key until a regulated interval of time has elapsed.

Among the most celebrated combination and time locks of the century are those known as the Yale locks, chiefly the inventions of Louis Yale, Jr., of Philadelphia. The Yale double dial lock is a double combination bank or safe lock having two dials, each operating its own set of tumblers and bolts, so that two persons, each in possession of his own combination, must be present at a certain time in order to unlock it. If this double security is not desired, one person alone may be possessed of both combinations, or the combinations may be set as one. In their time locks a safe can be set so as to not only render it impossible to unlock except at a predetermined time each day, but the arrangement is such that on intervening Sundays the time mechanism will entirely prevent the operation of the lock or the opening of the door on that day. [Pg 426]

Another feature of the lock is the thin, flat keys with bevel-edged notchings, or with longitudinal sinuous corrugations to fit a narrow slit of a cylinder lock. To make locks for use with the corrugated keys machines of as great ingenuity as the locks were devised. In such a lock the keyhole, which is a little very narrow slit, is formed sinuously to correspond to the sinuosities of the key. No other key will fit it, nor can it be picked by a tool, as the tool must be an exact duplicate of the key in order to enter and move in the keyhole.

Of late years numerous locks have been invented for the special uses to which they are to be applied. Thus, one type of lock is that for safety deposit vaults and boxes, in which a primary key in the keeping of a janitor operates alone the tumblers or guard mechanism to set the lock, while the box owner may use a secondary key to completely unlock the box or vault.

Master, or secondary key locks, are now in common use in hotels and apartment-houses, by which the key of the door held by a guest will unlock only his door, but the master key held by the manager or janitor will unlock all the doors. This saves the duplication and multiplicity of a vast number of extra keys.

The value of a simple, cheap, safe, effective lock in a place where its advantages are appreciated by all classes of people everywhere is illustrated in the application of the modern rotary registering lock to the single article of mail bags. Formerly it was not unusual that losses by theft of mail matter were due in part to the extraction of a portion of the mail matter by unlocking or removing the lock and then restoring it in place. [Pg 427]

The United States, with its 76,000,000 of people, found it necessary to use in its mail service hundreds of thousands of mail pouches, having locks for securing packages of valuable matter. But these locks are of such character that it is impossible for anyone to break into the bag and conceal the evidence of his crime. The unfortunate thief is reduced to the necessity of stealing the whole pouch. Losses under this system have grown so small "as to be almost incapable of mathematical calculation."

Safe and convenient locks for so very many purposes are now so common, even to prevent the unauthorised use of an umbrella, or the unfriendly taking away of a bicycle or other vehicle, that notwithstanding the nineteenth century dynamite with which burglars still continue to blow open the best constructed safes and vaults, still a universal sense of greater security in such matters is beginning to manifest itself; and not only the loss of valuables by fire and theft is becoming the exception, but the temptation to steal is being gradually removed.

[Pg 428]

CHAPTER XXVIII.

CARRYING MACHINES.

The reflecting observer delights occasionally to shift the scenes of the present stage and bring to the front the processions of the past. That famous triumphal one, for instance, of Ptolemy of Philadelphus, at Alexandria, about 270 B. C., then in the midst of his power and glory, in which there were chariots and cumbrous wagons drawn by elephants and goats, antelopes, oryxes, buffaloes, ostriches, gnus and zebras; then a tribe of the Scythians, when with many scores of oxen they were shifting their light, big round houses, made of felt cloth and mounted on road carts, to a new camping place; next a wild, mad dash of the Roman charioteers around the amphitheatre, or a triumphal march with chariots of carved ivory bearing aloft the ensigns of victory; and now an army of the ancient Britons driving through these same charioteers of Cæsar with their own rude chariots, having sharp hooks and crooked iron blades extending from their axles; now a "Lady's Chair" of the fourteenth century—the state carriage of the time—with a long, wooden-roofed and windowed body, having a door at each end, resting on a cumbrous frame without springs, and the axles united rigidly to a long reach; next comes a line of imposing clumsy state coaches of the sixteenth century, with bodies provided with pillars to support the roof, and adorned with curtains of cloth and leather, but still destitute of springs; and here in [Pg 429] stately approach comes a line of more curious and more comfortable "royal coaches" of the seventeenth century, when springs were for the first time introduced; and now rumbles forward a line of those famous old English stage coaches originated in the seventeenth century, which were two days flying from Oxford to London, a distance of fifty-five miles; but a scene in the next century shows these ponderous vehicles greatly improved, and the modern English stage mail-coaches of Palmer in line. Referring to Palmer's coaches, Knight says: "Palmer, according to De Quincey, was twice as great a man as Galileo, because he not only invented mail-coaches (of more general practical utility than Jupiter's satellites), but married the daughter of a duke, and succeeded in getting the post-office to use them. This revolutionised the whole business." The coaches were built with steel springs, windows of great strength and lightness combined, boots for the baggage, seats for a few outside passengers, and a guard with a grand uniform, to protect the mail and stand for the dignity of his majesty's government.

By the system of changing horses frequently great speed was attained, and the distance from Edinburgh to London, 400 miles, was made in 40 hours. Other lines of coaches, arranged to carry double the number of passengers outside than in, fourteen to six, were made heavier, and took the road more leisurely.

The carts and conveyances of the poor were cumbrous, heavy contrivances, without springs, mostly two-wheel, heavy carts.

The middle classes at that time were not seen riding in coaches of their own, but generally on horseback, as the coaches of the rich were too expensive, and the conveyances of the poor were too rude in construction, and too painful in operation. [Pg 430]

Let the observer now pass to the largest and most varied exhibition of the best types of modern vehicles of every description that the world had ever seen, the International Exhibition at Philadelphia in 1876, and behold what wonderful changes art, science, invention, and mechanical skill had wrought in this domain. Here were the carriages of the rich, constructed of the finest and most appropriate woods that science and experience had found best adapted for the various parts, requiring the combination of strength and lightness, the best steel for the springs, embodying in themselves a world of invention and discovery, and splendid finish and polish in all parts unknown to former generations.

Here, too, were found vehicles of a great variety for the comfort and convenience of every family, from the smallest to the largest means.

The farmer and the truckman were especially provided for. One establishment making an exhibition at that time, employed some six hundred or seven hundred hands, four hundred horse-power of steam, turning out sixty wagons a day, or one in every ten minutes of each working day in the year.

Here England showed her victoria, her broughams, landaus, phætons, sporting-carts, wagonettes, drays and dog-carts; Canada her splendid sleighs; France her superb barouches, carriages, double-top sociables, the celebrated Collinge patent axle-trees and springs; Germany the best carriage axles, springs and gears; Russia its famous low-wheeled fast-running carriages; Norway its carryalls, or sulkies, and sleighs strongly built, and made of wood from those vast forests that ever abound in strength and beauty. One ancient sleigh there was, demurely standing [Pg 431] by its modern companions, said to have been built in 1625, and it was still good. America stood foremost in carriage wheels of best materials and beautiful workmanship, bent rims, turned and finished spokes, mortised hubs, steel tires, business and farm wagons, carts and baby carriages. Each trade and field of labour had its own especially adapted complete and finished vehicle. There were hay wagons and hearses; beer wagons and ice carts; doctors' buggies, express wagons, drays, package delivery wagons; peddlers' wagons with all the shelves and compartments of a miniature store, skeleton wagons, and sportsmen's, and light and graceful two and four "wheelers." Beautiful displays of bent and polished woods, a splendid array of artistic, elegant, and useful harnesses, and all the traps that go to make modern means of conveyance by animal power so cheap, convenient, strong and attractive that civilisation seemed to have reached a stop in principles of construction of vehicles and in their materials, and since contents itself in improving details.

To this century is due the development of that class of carriages, the generic term for which is *Velocipedes*—a word which would imply a vehicle propelled by the feet, although it has been applied to vehicles propelled by the hands and steered by the feet. This name originated with the French, and several Frenchmen patented velocipedes from 1800 to 1821.

Tricycles having three wheels, propelled by the hands and steered with the feet, were also invented in the early part of the century.

The term *Bicycle* does not appear to have been used until about 1869. [Pg 432]

Although such structures had been referred to in publications before, yet the modern bicycle appears to have been first practically constructed in Germany. In 1816 Baron von Drais of Manheim made a vehicle consisting of two wheels arranged one before the other, and connected by a bar, the forward wheel axled in a fork which was swiveled to the front end of the bar and had handles to guide the machine, with a seat on the bar midway between the two wheels, and arranged so that the driver should bestride the bar. But there was no support for the rider's feet, and the vehicle was propelled by thrusting his feet alternately against the ground. This machine was called the "Draisine" and undoubtedly was the progenitor of the modern bicycle. Denis Johnson patented in England in 1818 a similar vehicle which he named the "Pedestrian Curricle." Another style was called the "Dandy Horse." Another form was that of Gompertz in England in 1821, who contrived a segmental rack connected with a frame over the front wheel and engaging a pinion on the wheel axle. With some improvements added by others, the vehicle came into quite extensive and popular use in some of the cities in Europe and America. It was also named the "Dandy" and the "Hobby Horse." Treadles were subsequently applied, but after a time the machine fell into disuse and was apparently forgotten. In 1863, however, the idea was revived by a Frenchman, Michaux, who added the crank to the front wheel axle of the "Draisine" (also called the "célérifèré.") In 1866 Pierre Lallement of France, having adapted the idea of the crank and pedal movement and obtained a patent, went to America, where after two years of public indifference the machine suddenly sprung into favour. In 1869 a popular wave in its favour also [Pg 433] spread over part of Europe, and all classes of people were riding it.

But the wheels had hard tires, the roads and many of the streets were not smooth, the vehicle got the name of the "bone-breaker" and its use ceased. During the few years following some new styles of frames were invented. Thus some very high wheels, with a small wheel in front, or one behind, wheels with levers in addition to the crank, etc., and then for a time the art rested again.

Some one then recalled the fact that McMillan, a Scotchman, about 1838-1841, had used two low wheels like the "Draisine" with a driving gear, and that Dalzell, also of Scotland, had in 1845 made a similar machine. Parts of these old machines were found and the wheel reconstructed. Then in the seventies the entire field was thrown open to women by the invention in England of the "drop frame," which removed completely the difficulty as to arrangement of the skirts and thus doubled the interest in and desire for a comfortable riding machine. But they were still, to a great degree, "bone-breakers."

Then J. B. Dunlop, a veterinary surgeon of Belfast, Ireland, in order to meet the complaints of his son that the wheel was too hard, thought of the *pneumatic rubber tire*, and applied it with great success. This was a very notable and original re-invention. A re-invention, because a man "born before his time" had invented and patented the pneumatic tire more than forty years before. It was not wanted then and everybody had forgotten it. This man was Robert William Thomson, a civil engineer of Adelphi, Middlesex county, England. In 1845 he obtained a patent in England, and shortly after in the United States. In both patents he describes how he proposed to make a [Pg 434] tire for all kinds of vehicles consisting of a hollow rubber tube, with an inner mixed canvas and rubber lining, a tube and a screw cup by which to inflate it, and several ways for preventing punctures. To obviate the bad results of punctures he proposed also to make his tire in sectional compartments, so that if one compartment was punctured the others would still hold good. He also proposed to use vulcanised rubber, thus utilising the then very recent discovery of Goodyear of mixing sulphur with soft rubber, and to apply the same to the canvas lining.

And, now, when the last decade of the century had been reached, and after a century's hard work by the inventors, the present wonderful vehicle, known as the "safety bicycle," had obtained a successful and permanent foothold among the vehicles of mankind. Proper proportions, low wheels, chain-gearing, treadles, pedals and cranks, cushion and pneumatic tires, drop frames, steel spokes like a spider's web, ball-bearings for the crank and axle parts, a spring-supported cushioned seat which could be raised or lowered, adjustable handles, and the clearest-brained scientific mechanics to construct all parts from the best materials and with mathematical exactness—all this has been done. To these accomplishments have been added a great variety of tires to prevent wear and puncturing, among which are *self-healing* tires, having a lining of viscous or plastic rubber to close up automatically the air holes. Many ways of clamping the tire to the rim have been contrived. So have brakes of various descriptions, some consisting of disks on the driving shaft, brought into frictional contact by a touch of the toe on the pedal, as a substitute for those applied to the surface of the tire, known as "spoon brakes"; saddles, speed- [Pg 435] gearings, men's machines in which by the removal of the upper bar the machine is converted into one for the use of women; the substitution of the direct action, consisting of beveled gearing for the sprocket chain, etc., etc.

The ideas of William Thomson as to pneumatic and cushioned tires are now, after a lapse of fifty years, generally adopted. Even sportsmen were glad to seize upon them, and wheels of sulkies, provided with the pneumatic tires, have enabled them to lower the record of trotting horses. Their use on many other vehicles has accomplished his objects, "of lessening the power required to draw carriages, rendering the motion easier, and diminishing the noise."

It is impossible to overlook the fact in connection with this subject that the processes and machinery especially invented to make the various parts of a bicycle are as wonderful as the wheel itself. Counting the spokes there are, it is estimated, more than 300 different parts in such a wheel. The best and latest inventions and discoveries in the making of metals, wood, rubber and leather have been drawn upon in supplying these useful carriers. And what a revolution they have produced in the making of good roads, the saving of time, the dispatch of business, and more than all else, in the increase of the pleasure, the health and the amusement of mankind!

It was quite natural that when the rubber cushion and pneumatic tires rounded the pleasure of easy and noiseless riding in vehicles that *Motor vehicles* should be revived and improved. So we have the *Automobiles* in great variety. Invention has been and is still being greatly exercised as to the best motive power, in the adaption of electric motors, oil and gasoline or vapour engines, [Pg 436] springs and air pumps, in attempts to reduce the number of complicated parts, and to render less strenuous the mental and muscular strain of the operator.

Traction Engines.—The old road engines that antedated the locomotives are being revived, and new ideas springing from other arts are being incorporated in these useful machines to render them more available than in former generations. Many of the principles and features of motor vehicles, but on a heavier scale, are being introduced to adapt them to the drawing of far heavier loads. Late devices comprise a spring link between the power and the traction wheel to prevent too sudden a start, and permit a yielding motion; steering devices by which the power of the engine is used to steer the machine; and application of convenient and easily-worked brakes.

An example of a modern traction engine may be found attached to one or more heavy cars adapted for street work, and on which may be found apparatus for making the mixed materials of which the roadbed is to be constructed, and all of which is moved along as the road or street surface is completed. When these fine roads become the possession of a country light traction engines for passenger traffic will be found largely supplanting the horse and the steam railroad engines.

Brakes, railway and electric, have already been referred to in the proper chapters. In the latest system of railroading greater attention has been paid to the lives and limbs of those employed as workmen on the trains, especially to those of brakemen. And if corporations have been slow to adopt such merciful devices, legislatures have stepped in to help the matter. One great source of accidents in this respect has been due to the necessity of the brakemen entering between the cars while they are in motion to couple them by hand. This is now being abolished by *automatic couplers*, by which, when the locking means have been withdrawn from connection or thrown up, they will be so held until the cars meet again, when the locking parts on the respective cars will be automatically thrown and locked, as easily and on the same principle as the hand of one man may clasp the hand of another. [Pg 437]

The comfort of passengers and the safety of freight have also been greatly increased by the invention of *Buffers* on railroad cars and trains to prevent sudden and violent concussion. Fluid pressure car buffers, in which a constant supply of fluid under pressure is provided by a pump or train pipe connected to the engine is one of a great variety.

Another notable improvement in this line is the splendid vestibule trains, in which the cars are connected to one another by enclosed passages and which at their meeting ends are provided with yieldingly supported door-like frames engaging one another by frictional contact, usually, whereby the shock and rocking of cars are prevented in starting and stopping, and their oscillation reduced to a minimum.

As collisions and accidents cannot always be prevented, car frames are now built in which the frames are trussed, and made of rolled steel plates, angles, and channels, whereby a car body of great resistance to telescoping or crushing is obtained.

[Pg 438]

CHAPTER XXIX.

SHIPS AND SHIP-BUILDING.

"Far as the breeze can bear, the billows foam,
Survey our empire, and behold our home."

"Ships are but boards," soliloquised the crafty Shylock, and were this still true, yet this present period has seen wonderful changes in construction.

The high castellated bows and sterns and long prows of *The Great Harry*, of the seventeenth century, and its successors in the eighteenth, with some moderation of cumbersome matter, gave way to lighter, speedier forms, first appearing in the quick-gliding Yankee clippers, during the first decade of the nineteenth century.

Eminent naval architects have regarded the proportions of Noah's ark, 300 cubits long, 50 cubits broad and 30 cubits high, in which the length was six times the breadth, and the depth three-fifths of the breadth, as the best combination of the elements of strength, capacity and stability.

Even that most modern mercantile vessel known as the "whale-back" with its nearly flat bottom, vertical sides, arched top or deck, skegged or spoon-shaped at bow and stern, straight deck lines, the upper deck cabins and steering gear raised on hollow turrets, with machinery and cargo in the main hull, has not departed much from the safe rule of proportions of its ancient prototype.

But in other respects the ideas of Noah and of the Phœnicians, the best of ancient ship-builders, as well as the Northmen, the Dutch, the French, and the English, the best ship-builders of later centuries, were decidedly improved upon by the Americans, who, as above intimated, were revolutionizing the art and building the finest vessels in the early part of the century, and these rivalled in speed the steam vessels for some years after steamships were ploughing the rivers and the ocean. [Pg 439]

Discarding the lofty decks fore and aft and ponderous topsides, the principal characteristics of the American "clippers" were their fine sharp lines, built long and low, broad of beam before the centre, sharp above the water, and deep aft. A typical vessel of this sort was the clipper ship *Great Republic*, built by Donald McKay of Boston during the first half of the century. She was 325 feet long, 53 feet wide, 37 feet deep, with a capacity of about 4000 tons. She had four masts, each provided with a lightning rod. A single suit of her sails consisted of 15,563 yards of canvas. Her keel rose for 60 feet forward, gradually curved into the arc of a circle as it blended with the stern. Vessels of her type ran seventeen and eighteen miles an hour at a time when steam vessels were making only twelve or fourteen miles an hour, the latter speed being one which it was predicted by naval engineers could not with safety be exceeded with ocean steamships.

These vessels directed the attention of ship-builders to two prominent features, the shape of the bow and the length of the vessel. For the old convex form of bow and stern, the principal of an elongated wedge was substituted, the wedge slightly hollowed on its face, by which the waters were more easily parted and thrown aside. [Pg 440]

A departure was early made in the matter of strengthening the "ribs of oak" to better meet the strains from the rough seas. In 1810 Sir Robert Seppings, surveyor of the English navy, devised and introduced the system of diagonal bracing. This was an arrangement of timbers crossing the ribs on the inside of the ship at angles of about 45°, and braced by diagonals and struts.

Of course the great and leading event of the nineteenth century in the matter of inventions relating to ships was the introduction of steam as the motive power. Of this we have treated in the chapter on steam engineering. The giant, steam, demanded and received the obeisance of every art before devoting his inexhaustible strength to their service. Systems of wood-working and metal manufacture must be revolutionised to give him room to work, and to withstand the strokes of his mighty arm. Lord Dundas at the beginning of the century had an iron boat built for the Forth and Clyde Canal, which was propelled by steam.

But the departure from the adage that "ships are but boards" did not take place, however, until about 1829-30, when the substitution of iron for wood in the construction of vessels had passed beyond the experimental stage. In those years the firm of John Laird of Birkenhead began the building of practical iron vessels, and he was followed soon by Sir William Fairbairn at Manchester, and Randolph, Elder & Co., and the Fairfield Works on the Clyde.

The advantage of iron over wood in strength, and in power to withstand tremendous shocks, was early illustrated in the *Great Britain* built about 1844, the first large, successful, seagoing vessel constructed. Not long thereafter this same vessel lay helpless upon the coast of Ireland, driven [Pg 441] there by a great storm, and beaten by the tremendous waves of the Atlantic with a force that would have in a few hours or days broken up and pulverised a "ship of boards," and yet the *Great Britain* lay there several weeks, was finally brought off, and again restored to successful service.

Wood and iron both have their peculiar advantages and disadvantages. Wood is not only lighter, but easily procured and worked, and cheaper, in many small and private ship-yards where an iron frame and parts would be difficult and expensive to produce. It is thought that as to the fouling of ships' bottoms a wooden hull covered with copper fouls less, and consequently impedes the speed less; that the damage done by shocks or the penetration of shot is not so great or difficult to repair, and that the danger of variation of the compass by reason of local attraction of the metal is less.

But the advantages of iron and steel far outnumber those of wood. Its strength, its adaptability for all sizes and forms and lines, its increased cheapness, its resistance to shot penetration, its durability, and now its easy procurement, constitute qualities which have established iron ship-building as a great new and modern art. In this modern revolution in iron-clad ships, their adaptation to naval warfare was due to the genius of John Ericsson, and dates practically from the celebrated battle between the iron-clads the *Merrimac* and the *Monitor* in Hampton Roads on the Virginia coast in the Civil war in America in April, 1862.

Although the tendency at first in building iron and steel vessels, especially for the navy, was towards an entire metal structure, later experience resulted in a more composite style, using [Pg 442] wood in some parts, where found best adapted by its capacity of lightness, non-absorption of heat and less electrical conductivity, etc., and at the same time protecting such interior portions by an iron shell or frame-work.

One great improvement in ship-building, whether in wood or metal, thought of and practised to some extent in former times, but after all a child of this century, is the building of the hull and hold in compartments, water-tight, and sometimes fire-proof, so that in case of a leakage or a fire in one or more compartments, the fire or water may be confined there and the extension of the danger to the entire ship prevented.

In the matter of *Marine Propulsion*, when the steam engine was made a practical and useful servant by Watt, and men began to think of driving boats and ships with it, the problem was how to adapt it to use with propelling means already known. Paddle-wheels and other wheels to move boats in place of oars had been suggested, and to some extent used from time to time, since the days of the Romans; and they were among the first devices used in steam vessels. Their whirl may still be heard on many waters. Learned men saw no reason why the screw of Archimedes should not be used for the same purpose, and the idea was occasionally advocated by French and English philosophers from at least 1680, by Franklin and Watt less than a century later, and finally, in 1794, Lyttleton of England obtained a patent for his "aquatic propeller," consisting of threads formed on a cylinder and revolving in a frame at the head, stern, or side of a vessel.

Other means had been also suggested prior to 1800, and by the same set of philosophers, and [Pg 443] experimentally used by practical builders, such as steam-pumps for receiving the water forward, or amidships, and forcing it out astern, thus creating a propulsive movement. The latter part of the eighteenth century teemed with these suggestions and experiments, but it remained for the nineteenth to see their embodiment and adaptation to successful commercial use.

The earliest, most successful demonstrations of screw propellers and paddle wheels in steam vessels in the century were the construction and use of a boat with twin screws by Col. John Stevens of Hoboken, N. J., in 1804 and the paddle-wheel steamboat trial of Fulton on the Hudson in 1807.

But it was left to John Ericsson, that great Swedish inventor, going to England in 1826 with his brain full of ideas as to steam and solar engines, to first perfect the screw-propeller. He there patented in 1836 his celebrated propeller, consisting of several blades or segments of a screw, and based on such correct principles of twist that they were at once adopted and applied to steam vessels.

In 1837-1839 the knowledge of his inventions had preceded him to America, where his propeller was at once introduced and used in the vessels *Frances B. Ogden* and the *Robert E. Stockton* (the latter built by the Lairds of Birkenhead and launched in 1837). In 1839 or 1840 Ericsson went to America, and in 1841 he was engaged in the construction of the U.S. ship of war *Princeton*, the first naval screw warship built having propelling machinery under the water line and out of reach of shot.

The idea that steamships could not be safely run at a greater speed than ten or twelve miles an hour was now abandoned. [Pg 444]

Twice Ericsson revolutionised the naval construction of the world by his inventions in America: first by the introduction of his screw-propeller in the *Princeton*; and second, by building the iron-clad *Monitor*.

Since Ericsson's day other inventors have made themselves also famous by giving new twists to the tail of this famous fish and new forms to its iron-ribbed body.

Pneumatic Propellers operated by the expulsion of air or gas against the surrounding body of water, and chain-propellers, consisting of a revolving chain provided with paddles or floats, have also been invented and tested, with more or less successful results.

A great warship as she lies in some one of the vast modern ship-yards of the world, resting securely on her long steel backbone, from which great ribs of steel rise and curve on either side and far overhead, like a monstrous skeleton of some huge animal that the sea alone can produce, clothed with a skin, also of steel; her huge interior, lined at bottom with an armoured deck that stretches across the entire breadth of the vessel, and built upon this deck, capacious steel compartments enclosing the engines and boilers, the coal, the magazines, the electric plant for supplying power to various motors for lighting the ship and for furnishing the current to powerful search-lights; having compartments for the sick, the apothecary shop, and the surgeon's hospital, the men's and the officers' quarters; above these the conning tower and the armoured pilot-house, then the great guns interspersed among these various parts, looking like the sunken eyes, or protruding like the bony prominences of some awful sea monster, is a structure that gives one an idea of the immense departure which has occurred during the last half century, not only from the wooden walls of the navies of all the past, but from all its mechanical arts. [Pg 445]

What a great ocean liner contains and what the contributions are to modern ship-building from other modern arts is set forth in the following extract from *McClure's Magazine* for September, 1900, in describing the *Deutschland*. "The *Deutschland*, for instance has a complete refrigerating plant, four hospitals, a safety deposit vault for the immense quantities of gold and silver which pass between the banks of Europe and America, eight kitchens, a complete post-office with German and American clerks, thirty electrical motors, thirty-six pumps, most of them of American and English make, no fewer than seventy-two steam engines, a complete drug store, a complete fire department, with pumps, hose and other fire-fighting machinery, a library, 2600 electric lights, two barber shops, room for an orchestra and brass band, a telegraph system, a telephone system, a complete printing establishment, a photographic dark room, a cigar store, an electric fire-alarm system, and a special refrigerator for flowers."

We have seen, in treating of safes and locks, how burglars keep pace with the latest inventions to protect property by the use of dynamite and nitro-glycerine explosions. The reverse of this practice prevails when those policemen of the seas, the *torpedo boats*, guard the treasures of the shore. It is there the defenders are armed with the irresistible explosives. These explosives are either planted in harbours and discharged by electricity from the shore, or carried by very swift armoured boats, or by boats capable of being submerged, directed, and propelled by mechanisms contained there and controlled from the shore, or from another vessel; or by boats containing all instrumentalities, crew, and commander, and capable of submerging and raising itself, and of attacking and exploding the torpedo when and where desired. The latter are now considered as the most formidable and efficient class of destroyers. [Pg 446]

No matter how staunch, sound and grand in dimensions man may build his ships, old Neptune can still toss them. But Franklin, a century and a half ago, called attention to his experiments of oiling his locks when in a tempestuous mood, and thus rendering the temper of the Old Man of the Sea as placid as a summer pond. Ships that had become unmanageable were thus enabled, by spreading oil on the waves from the windward side, to be brought under control, and dangerous surfs subdued, so that boats could land. Franklin's idea of pouring oil on the troubled waters has been revived during the last quarter of the century and various means for doing it vigorously patented. The means have varied in many instances, but chiefly consist of bags and other receptacles to hold and distribute the oil upon the surrounding water with economy and uniformity.

At the close of the century the world was still waiting for the successful *Air-ship*.

A few successful experiments in balloon navigation by the aid of small engines of different forms have been made since 1855. Some believe that Count Zeppelin, an officer of the German army has solved the great problem, especially since the ascent of his ship made on July 2, 1900, at Lake Constance.

It has been asserted that no vessel has yet been made to successfully fly unless made on the balloon principle, and Count Zeppelin's boat is on that principle. According to the description of Eugen Wolf, an aeronaut who took part in the ascent referred to and who published an account of [Pg 447] the same in the November number of *McClure's*, 1900, it is not composed of one balloon, but of a row of them, and these are not exposed when inflated to every breeze that blows, but enclosed and combined in an enormous cylindrical shell, 420 feet in length, about 38 feet in diameter, with a volume of 14,780 cubic yards and with ends pointed like a cigar. This shell is a framework made up of aluminium trellis work, and divided into seventeen compartments, each having its own gas bag. The frame is further strengthened and the balloons stayed by a network of aluminium wire, and the entire frame covered with a soft ramie fibre. Over this is placed a water-tight covering of pegamoid, and the lower part covered with light silk. An air space of two feet is left between the cover and the balloons. Beneath the balloons extends a walking bridge 226 feet long, and from this bridge is suspended two aluminium cars, at front and rear of the centre, adapted to hold all the operative machinery and the operator and other passengers.

The balloons, provided with proper valves, served to lift the structure; large four-winged screws, one on each side of the ship, their shafts mounted on a light framework extending from the body of the ship, and driven backward and forward by two light benzine engines, one on each car, constituted the propelling force. Dirigibility (steering) was provided for by an apparatus consisting of a double pair of rudders, one pair forward and one aft, reaching out like great fins, and controlled by light metal cords from the cars. A ballast of water was carried in a [Pg 448]
compartment under each car. To give the ship an upward or a downward movement the plane on which the ship rests was provided with a weight adapted to slip back and forth on a cable underneath the balloon shell. When the weight was far aft the tip of the ship was upward and the movement was upward, when at the forward end the movement was downward, and when at the centre the ship was poised and travelled in a horizontal plane. The trip was made over the lake on a quiet evening. A distance of three and three-quarter miles, at a height of 1300 feet, was made in seventeen minutes. Evolutions from a straight course were accomplished. The ship was lowered to the lake, on which it settled easily and rode smoothly.

The other great plan of air navigation receiving the attention of scientists and aeronauts is the aeroplane system. Although the cohesive force of the air is so exceedingly small that it cannot be relied upon as a sufficient resisting medium through which propulsion may be accomplished alone by a counter-resisting agent like propeller blades, yet it is known what weight the air has and it has been ascertained what expanse of a thin plane is necessary without other means to support the weight of a man in the air.

To this idea must be added the means of flight, of starting and maintaining a stable flight and of directing its course. Careful observation of the manner of the flight of large heavy birds, especially in starting, has led to some successful experiments. They do not rise at once, but require an initiative force for soaring which they obtain by running on the ground before spreading their wings. The action of the wings in folding and unfolding for maintaining the flight [Pg 449]
and controlling its direction, is then to be noted.

It is along these lines that inventions in this system are now working. An initiative mechanism to start the ship along the earth or water, to raise it at an angle, to spread planes of sufficient extent to support the weight of the machine and its operators on the body of the air column, light engines to give the wing-planes an opening and closing action, rudders to steer by, means for maintaining equilibrium, and means when landing to float upon the water or roll upon the land, these are the principal problems that navigators of the great seas above us are now at work upon.

[Pg 450]

CHAPTER XXX.

ILLUMINATING GAS.

> "How wonderful that sunbeams absorbed by vegetation in the primordial ages of the earth and buried in its depths as vegetable fossils through immeasurable eras of time, until system upon system of slowly formed rocks have been piled above, should come forth at last, at the disenchanting touch of science, and turn the light of civilised man into day."—*Prof. E. L. Youmans.*

> "The invention of artificial light has extended the available term of human life, by giving the night to man's use; it has, by the social intercourse it encourages, polished his manners and refined his tastes, and perhaps as much as anything else, has aided his intellectual progress."—*Draper.*

If one desires to know what the condition of cities, towns and peoples was before the nineteenth century had lightened and enlightened them, let him step into some poor country town in some out-of-the-way region (and such may yet be found) at night, pick his way along rough pavements, and no pavements, by the light of a smoky lamp placed here and there at corners, and of weeping lamps and limp candles in the windows of shops and houses, and meet people armed with tin lanterns throwing a dubious light across the pathways. Let him be prepared to be assailed by the odours of undrained gutters, ditches, and roads called streets, and escape, if he can, stumbling [Pg 451] and falling into them. Let him take care also that he avoid in the darkness the drippings from the overhanging eaves or windows, and falling upon the slippery steps of the dim doorway he may be about to enter. Within, let him overlook, if he can, in the hospitable reception, the dim and smoky atmosphere, and observe that the brightest and best as well as the most cheerful illuminant flashes from the wide open fireplace. Occasionally a glowing grate might be met. The eighteenth century did have its glowing grates, and its still more glowing furnaces of coal in which the ore was melted and by the light of which the castings were made.

It is very strange that year after year for successive generations men saw the hard black coal break under the influence of heat and burst into flames which lit up every corner, without learning, beyond sundry accidents and experiments, that this *gast*, or *geest*, or *spirit*, or *vapour*, or *gas*, as it was variously called, could be led away from its source, ignited at a distance, and made to give light and heat at other places than just where it was generated.

Thus Dr. Clayton, Dean of Kildare, Ireland, in 1688 distilled gas from coal and lit and burned it, and told his learned friend, the Hon. Robert Boyle, about it, who announced it with interest to the Royal Society, and again it finds mention in the *Philosophical Transactions* fifty years later. Then, in 1726, Dr. Hales told how many cubic inches of gas a certain number of grains of coal would produce. Then Bishop Watson in 1750 passed some gas through water and carried it in pipes from one place to another; and then Lord Dundonald in 1786 built some ovens, distilled coal and tar, burned the gas, and got a patent. In the same year, Dr. Rickel of Würzburg lighted his [Pg 452] laboratory with gas made by the dry distillation of bones; but all these were experiments. Finally, William Murdock, the owner of large workshops at Redruth, in Cornwall, a practical man and mechanic, and a keen observer, using soft coal to a large extent in his shops, tried with success in 1792 to collect the escaping gas and with it lit up the shops. Whether he continued steadily to so use the gas or only at intervals, at any rate it seems to have been experimental and failed to attract attention. It appears that he repeated the experiment at the celebrated steam engine works of Boulton and Watt at Soho, near Birmingham, in 1798, and again illuminated the works in 1802, on occasion of a peace jubilee.

In the meantime, in 1801, Le Bon, a Frenchman at Paris, had succeeded in making illuminating gas from wood, lit his house therewith, and proposed to light the whole city of Paris.

Thus it may be said that illuminating gas and the new century were born together—the former preceding the latter a little and lighting the way.

Then in 1803 the English periodicals began to take the matter up and discuss the whole subject. One magazine objected to its use in houses on the ground that the curtains and furniture would be ruined by the saturation produced by the oxygen and hydrogen, and that the curtains would have to be wrung out the next morning after the illumination. There doubtless was good cause for objection to the smoky, unpleasant smelling light then produced.

In America in 1806 David Melville of Newport, Rhode Island, lighted with gas his own house and the street in front of it. In 1813 he took out a patent and lighted several factories. In 1817 his process was applied to Beaver Tail Lighthouse on the Atlantic coast—the first use of illuminating [Pg 453] gas in lighthouses. Coal oil and electricity have since been found better illuminants for this purpose.

Murdoch, Winser, Clegg and others continued to illuminate the public works and buildings of England. Westminster Bridge and the Houses of Parliament were lighted in 1813, and the streets of London in 1815. Paris was lighted in 1820, and the largest American cities from 1816 to 1825. But it required the work of the chemists as well as the mechanics to produce the best gas. The rod of Science had touched the rock again and from the earth had sprung another servant with power to serve mankind, and waited the skilled brain and hand to direct its course.

Produced almost entirely from bituminous coal, it was found to be composed chiefly of carbon, oxygen and hydrogen; but various other gases were mixed therewith. To determine the proper proportions of these gases, to know which should be increased or wholly or partly eliminated, required the careful labours of patient chemists. They taught also how the gas should be distilled, condensed, cleaned, scrubbed, confined in retorts, and its flow measured and controlled.

Fortunately the latter part of the eighteenth century and the early part of the nineteenth had produced chemists whose investigations and discoveries paved the way for success in this revolution in the world of light. Priestley had discovered oxygen. Dalton had divided matter into atoms, and shown that in its every form, whether solid, liquid, or gaseous, these atoms had their own independent, characteristic, unalterable weight, and that gases diffused themselves in certain proportions. [Pg 454]

Berthollet, Graham, and a host of others in England, France, and Germany, advanced the art. The highest skilled mechanics, like Clegg of England, supplied the apparatus. He it was who invented a gas purifier, liquid gas meter, and other useful contrivances.

As the character of the gas as an illuminator depends on the quantity of hydro-carbon, or olefiant elements it contains, great efforts were made to invent processes and means of carbureting it.

The manufacture of gas was revolutionised by the invention of water gas. The main principle of this process is the mixture of hydrogen with the vapour of some hydro-carbon: Hydrogen burns with very little light and the purpose of the hydro-carbon is to increase the brilliancy of the flame. The hydrogen gas is so obtained by the decomposition of water, effected by passing steam through highly heated coals.

Patents began to be taken out in this line in England in 1823-24; by Donovan in 1830; Geo. Lowe in 1832, and White in 1847. But in England water gas could not compete with coal gas in cheapness. On the contrary, in America, especially after the petroleum wells were opened up, and nature supplied the hydro-carbon in roaring wells and fountains, water gas came to the front.

The leading invention there in this line was that of T. S. C. Lowe of Morristown, Pennsylvania, in 1873. In Lowe's process anthracite coal might be used, which was raised in a suitable retort to a great heat, then superheated steam admitted over this hot bed and decomposed into hydrogen and carbonic oxide; then a small stream of naphtha or crude petroleum was thrown upon the surface of the burning coal, and from these decompositions and mixtures a rich olefiant product [Pg 455] and other light-giving gases were produced.

The Franklin Institute of Philadelphia in 1886 awarded Lowe, or his representatives, a grand medal of honour, his being the invention exhibited that year which in their opinion contributed most to the welfare of mankind.

A number of inventors have followed in the direction set by Lowe. The largest part of gas manufacture, which has become so extensive, embodies the basic idea of the Lowe process.

The competition set up by the electricians, especially in the production of the beautiful incandescent light for indoor illumination, has spurred inventors of gas processes to renewed efforts—much to the benefit of that great multitude who sit in darkness until corporations furnish them with light.

It was found by Siemens, the great German inventor of modern gas regenerative furnace systems, that the quality of the gas was much improved, and a greater intensity of light obtained, by heating the gases and air before combustion—a plan particularly adapted in lighting large spaces.

To describe in detail the large number of inventions relating to the manufacture of gas would require a huge volume—the generators, carburetors, retorts, mixers, purifiers, metres, scrubbers, holders, condensers, governors, indicators, registers, chargers, pressure regulators, etc., etc.

It was a great convenience outside of towns and cities, where gas mains could not be laid, to have domestic plants and portable gas apparatus, worked on the same principles, but in miniature form, adapted to a single house, but the exercise of great ingenuity was required to render such adaptation successful. [Pg 456]

In the use of liquid illuminants, which need a wick to feed them, the *Argand burner*—that arrangement of concentric tubes between which the wick is confined—although invented by Argand in 1784, yet has occupied a vast field of usefulness in connection with the lamps of the nineteenth century.

A dangerous but very extensively used illuminating liquid before coal oil was discovered was camphene, distilled from turpentine. It gave a good light but was not a safe domestic companion.

Great attention has recently been paid to the production of *acetylene* gas, produced by the reaction between *calcium carbide* and water. The making of the calcium carbide by the decomposition of mixed pulverised lime and coal by the use of a powerful electric battery, is a preliminary step in the production of this gas, and was a subsequent discovery.

The electric light, acetylene, magnesium, and other modern sources of light, although they may be more brilliant and intense than coal gas, cannot compete in cheapness of production with the latter. Thus far illuminating coal gas is still the queen of artificial lights.

After gas was fairly started in lighting streets and buildings its adaptation to lamps followed; and among the most noted of gas lamps is that of Von Welsbach, who combined a bunsen gas flame and a glass chimney with a "*mantle*" located therein. This mantle is a gauze-like structure made of refractory quartz, or of certain oxides, which when heated by the gas flame produce an incandescent glow of intense brilliancy, with a reduced consumption of gas.

[Pg 457]

CHAPTER XXXI.

BRICK, POTTERY, GLASS, PLASTICS.

When the nineteenth century dawned, men were making brick in the same way for the most part that they were fifty centuries before. It is recorded in the eleventh chapter of Genesis that when "the whole earth was of one language and one speech, it came to pass as they journeyed from the east that they found a plain in the land of Shinar; and they dwelt there, and they said to one another, Go to, let us make brick and burn them thoroughly, And they had brick for stone, and slime had they for mortar." Then commenced the building of Babel. Who taught the trade to the brick-makers of Shinar?

The journey from the east continued, and with it went brick making to Greece and Rome, across the continent of Europe, across the English channel, until the brick work of Cæsar, stamped by the trade mark of his legions, was found on the banks of the Thames, and through the fields of Caerleon and York.

Alfred the Great encouraged the trade, and the manufacture flourished finely under Henry VIII., Elizabeth and Charles I.

As to Pottery:—Could we only know who among the peoples of the earth first discovered, used, or invented fire, we might know who were the first makers of baked earthenware. Doubtless the art of pottery arose before men learned to bake the plastic clay, in that groping time when men, [Pg 458] kneading the soft clay with their fingers, or imprinting their footsteps in the yielding surface and learning that the sun's heat stiffened and dried those forms into durability, applied the discovery to the making of crude vessels, as children unto this day make dishes from the tenacious mud. But the artificial burning of the vessels was no doubt a later imitation of Nature.

Alongside the rudest and earliest chipped stone implements have been found the hollow clay dish for holding fire, or food, or water. "As the fragment of a speech or song, a waking or a sleeping vision, the dream of a vanished hand, a draught of water from a familiar spring, the almost perished fragrance of a pressed flower call back the singer, the loved and lost, the loved and won, the home of childhood, or the parting hour, so in the same manner there linger in this crowning decade of the crowning century bits of ancient ingenuity which recall to a whole people the fragrance and beauty of its past." *Prof. O. T. Mason.* The same gifted writer, adds: "Who has not read, with almost breaking heart, the story of Palissy, the Huguenot potter? But what have our witnesses to say of that long line of humble creatures that conjured out of prophetic clay, without wheels or furnace, forms and decorations of imperishable beauty, which are now being copied in glorified material in the best factories of the world? In ceramic as well as textile art the first inventors were women. They quarried the clay, manipulated it, constructed and decorated the ware, burned it in a rude furnace and wore it out in a hundred uses."

From the early dawn of human history to its present noonday civilisation the progress of man may be traced in his pottery. Before printing was an art, he inscribed on it his literature. Poets [Pg 459] and painters have adorned it; and in its manufacture have been embodied through all ages the choicest discoveries of the chemist, the inventor and the mechanic.

It would be pleasant to trace the history of pottery from at least the time of Homer, who draws a metaphor from the potter seated before his wheel and twirling it with both hands, as he shapes the plastic clay upon it; to dwell upon the clay tablets and many-coloured vases, covered with Egyptian scenes and history; to re-excite wonder over the arts of China, in her porcelain, the production of its delicacy and bright colours wrapped in such mystery, and stagnant for so many ages, but revived and rejuvenated in Japan; to recall to mind the styles and composition of the Phœnician vases with mythological legends burned immortally therein; the splendid work of the Greek potteries; to lift the Samian enwreathed bowl, "filled with Samian wine"; to look upon the Roman pottery, statues and statuettes of Rome's earlier and better days; the celebrated *Faience* (enamelled pottery) at its home in Faenza, Italy, and from the hands of its master, Luca della Robia; to trace the history of the rare Italian majolica; to tread with light steps the bright tiles of the Saracens; to rehearse the story of Bernard Palissy, the father of the beautiful French enamelled ware; to bring to view the splendid old ware of Nuremberg, the raised white figures on the deep blue plaques of Florence, the honest Delft ware of Holland; and finally to relate the revolution in the production of pottery throughout all Europe caused by the discoveries and inventions of Wedgwood of England in the eighteenth century. All this would be interesting, but we must hasten on to the equally splendid and more practical works of the busy nineteenth [Pg 460] century, in which many toilsome methods of the past have been superseded by labour-saving contrivances.

The application of machinery to the manufacture of brick began to receive attention during the latter part of the eighteenth century, after Watt had harnessed steam, and a few patents were issued in England and America at that time for such machinery of that character, but little was practically done.

The operations in *brickmaking*, to the accomplishment of which by machines the inventors of the nineteenth century have devoted great talent, relate:

First, to the preparation of the clay.—In ancient Egypt, in places where water abounded, it appears that the clay was lifted from the bottoms of ponds and lakes on the end of poles, was formed into bricks, then sun-dried, modernly called *adobes*. The clay for making these required a stiffening material. For this straw was used, mixed with the clay; and stubble was also used in the different courses. Hence the old metaphor of worthlessness of "bricks without straw," but of course in burning, and in modern processes of pressing unburnt bricks, straw is no longer used. Sand should abound in the clay in a certain proportion, or be mixed therewith, otherwise the clay, whether burned or unburned, will crumble. Stones, gravel and sticks must be removed, otherwise the contraction of the clay and expansion of the stones on burning, produce a weak and crumbling structure.

Brick clay generally is coloured by the oxide of iron, and in proportion as this abounds the burned brick is of a lighter or a deeper red. It may be desired to add colouring matter or mix different forms of clay, or add sand or other ingredients. Clay treated by hand was for ages kneaded as [Pg 461] dough is kneaded, by the hand or feet, and the clay was often long subjected, sometimes for years, to exposure to the air, frost and sun to disintegrate and ripen it. As the clay must be first disintegrated, ground or pulverised, as grain is first ground to flour to make and mould the bread, so the use of a grinding mill was long ago suggested. The first machine used to do all this work goes by the humble name of *pug mill*.

Many ages ago the Chilians of South America hung two ponderous solid wood or stone wheels on an axis turned by a vertical shaft and operated by animal power; the wheels were made to run round on a deep basin in which ores, or stones, or grain were placed to be crushed. This Chilian mill, in principle, was adopted a century or so ago in Europe to the grinding of clay. The pug mill has assumed many different forms in this age; and separate preliminary mills, consisting of rollers of different forms for grinding, alone are often used before the mixing operation. In one modern form the pug mill consists of an inverted conical-shaped cylinder provided with a set of interior revolving blades arranged horizontally, and below this a spiral arrangement of blades on a vertical axis, by which the clay is thoroughly cut up and crushed against the surrounding walls of the mill, in the meantime softened with water or steam if desired, and mixed with sand if necessary, and when thus ground and tempered is finally pressed down through the lower opening of the cylinder and directly into suitable brick moulds beneath.

Second.—The next operation is for moulding and pressing the brick. To take the place of that ancient and still used mode of filling a mould of a certain size by the hands with a lump of soft [Pg 462] clay, scraping off the surplus, and then dumping the mould upon a drying floor, a great variety of machines have been invented.

In some the pug mill is arranged horizontally to feed out the clay in the form of a long horizontal slab, which is cut up into proper lengths to form the bricks. Some machines are in the form of a large horizontal revolving wheel, having the moulds arranged in its top face, each mould charged with clay as the wheel presents it under the discharging spout of the grinding mill, and then the clay is pressed by pistons or plungers worked by a rocking beam, and adapted to descend and fit into the mould at stated intervals; or the moulds, carried in a circular direction, may have movable bottom plates, which may be pressed upwards successively by pistons attached to them and raised by inclines on which they travel, forcing the clay against a large circular top plate, and in the last part of the movement carrying the pressed brick through an aperture to the top of the plate, where it is met by and carried away on an endless apron.

In some machines two great wheels mesh together, one carrying the moulds in its face, and the other the presser plate plungers, working in the former, the bricks being finally forced out on to a moving belt by the action of cam followers, or by other means.

In others the moulds are passed, each beneath a gravity-descending or cam-forced plunger, the clay being thus stamped by impact into form; or in other forms the clay in the moulds may be subjected to successive pressure from the cam-operated pistons arranged horizontally and on a line with the discharging belt. [Pg 463]

Third, the drying and burning of the brick.—The old methods were painfully slow and tedious. A long time was occupied in seasoning the clay, and then after the bricks were moulded, another long time was necessary to dry them, and a final lengthy period was employed to burn them in crude kilns. These old methods were too slow for modern wants. But they still are in vogue alongside of modern inventions, as in all ages the use of old arts and implements have continued along by the side of later inventions and discoveries.

No useful contrivances are suddenly or apparently ever entirely supplanted. The implements of the stone age are still found in use by some whose environment has deprived them of the knowledge of or desire to use better tools. The single ox pulling the crooked stick plough, or other similar ancient earth stirrer, and Ruth with her sickle and sheaves, may be found not far from the steam plough and the automatic binder.

But the use of antiquated machinery is not followed by those who lead the procession in this industrial age. Consequently other means than the slow processes of nature to dry brick and other ceramics, and the crude kilns are giving way to modern heat distributing structures.

Air and heat are driven by fans through chambers, in which the brick are openly piled on cars, the surplus heat and steam from an engine-room being often used for this purpose, and the cars so laden are slowly pushed on the tracks through heated chambers. Passages and pipes and chimneys for heat and air controlled by valves are provided, and the waste moisture drawn off through bottom drains or up chimneys, the draft of which is increased by a hot blast, or blasts of [Pg 464] heated air are driven in one direction through a chamber while the brick are moved through in the opposite direction, or a series of drying chambers are separated from each other by iron folding-doors, the temperature increasing as cars are moved on tracks from one chamber to another.

Dr. Hoffmann of Berlin invented different forms of drying and burning chambers which attracted great attention. In his kiln the bricks are stacked in an *annular* chamber, and the fire made to progress from one section of the chamber to another, burning the brick as the heat advances; and as fast as one section of green brick is dried, or burned, it is withdrawn, and a green section presented. Austria introduced most successful and thorough systems of drying brick about 1870. In some great kilns fires are never allowed to cease. One kiln had been kept thus heated for fifteen years. Thus great quantities of green brick can at any time be pushed into the kiln on tracks, and when burned pushed out, and thus the process may go on continuously day and night.

To return to pottery: As before stated, Wedgwood of England revolutionised the art of pottery in the eighteenth century. He was aided by Flaxman. Before their time all earthenware pottery was what is now called "soft pottery." That is, it was unglazed, simply baked clay; *lustrous* or *semi-glazed* and *enamelled* having a harder surface. Wedgwood invented the hard porcelain surface, and very many beautiful designs. To improve such earthenware and to best decorate it, are the objects around which modern inventions have mostly clustered.

The "*regenerative*" principle of heating above referred to employed in some kilns, and so successfully incorporated in the regenerators invented since 1850 by Siemens, Frank, Boetius, [Pg 465] Bicheroux, Pousard and others, consisting in using the intensely hot wasted gases from laboratories or combustion chambers to heat the incoming air, and carrying the mingled products of combustion into chambers and passages to heat, dry or burn materials placed therein, has been of great service in the production of modern pottery; not only in a great saving in the amount of fuel, but in reduction in loss of pieces of ware spoiled in the firing.

The old method of burning wood, or soft coal, or charcoal at the bottom of a small old-fashioned cylindrical fire brick kiln attended to by hand, and heating the articles of pottery arranged on shelves in the chamber above, is done away with to a great extent in large manufactories for the making of stone and earthenware—although still followed in many porcelain kilns.

Inventions in the line of pottery kilns have received the aid of woman. Susan Frackelton of the United States invented a portable kiln for firing pottery and porcelain, for which she obtained a patent in 1886.

As in drying clay for brick, so in drying clay for porcelain and pottery generally, great improvements have been made in the drying of the clay, and other materials to be mixed therewith. A great step was taken to aid drying by the invention of the *filter press*, in which the materials, after they are mixed and while still wet, are subjected to such pressure that all surplus water is removed and all air squeezed out, by which the inclosure of air bubbles in the clay is prevented.

[Pg 466] Despairing of excelling the China porcelain, although French investigators having alleged their discovery of such methods, modern inventors have contented themselves in inventing new methods and compositions. Charles Aoisseau, the potter of Tours, born in 1796, rediscovered and revived the art of Palissy. About 1842, Thomas Battam of England invented the method of imitating marble and other statuary by a composition of silica, alumina, soda, and traces of lime, magnesia, and iron, reducing it to liquid form and pouring it into plaster moulds, forming the figure or group. His plaster casts soon became famous. In the use of materials the aid of chemists was had in finding the proper ingredients to fuse with sand to produce the best forms of common and fine *Faience*.

Porcelain Moulding, and its accompanying ornamentation and the use of apparatus for moulding by compression and by exhaustion of the air has become since that time a great industry.

Porcelain Colours.—Chemists also aided in discovering what metallic ingredients could best be used when mixed with the clay and sand to produce the desired colours. As soon as a new metal was discovered, it was tested to find, among other things, what vitrifiable colour it would produce. In the production of metallic glazes, the oxides generally are employed. The colours are usually applied to ware when it is in its unglazed or *biscuit* form. In the *biscuit* or *bisque* form pottery is bibulous, the prepared glaze sinks into its pores and when burned forms a vitreous coating.

The application of oil colours and designs to ware before baking by the "bat" system of printing originated in the eighteenth and was perfected in the nineteenth century. It consists of impressing oil pictures on a bat of glue and then pressing the bat on to the porous unbaked clay [Pg 467] or porcelain which transferred the colours. This was another revolution in the art.

One manner for ages of applying colours to ware is first to reduce the mixture to a liquid form, called "slip," and then, if the Chinese method is followed, to dip the colour up on the end of a hollow bamboo rod, which end is covered with wire gauze, then by blowing through the rod the colour was sprayed or deposited on the ware. Another method is the use of a brush and comb. The brush being dipped into the coloured matter, the comb is passed over the brush in such manner as to cause the paint to spatter the object with fine drops or particles. A very recent method, by which the beautiful background and blended colours of the celebrated Rookwood pottery of Cincinnati, Ohio, have become distinguished, consists in laying the colour upon the ware in a cloud or sheet of almost imperceptible mist by the use of an air atomiser blown by the operator. By the use of this simple instrument, the laying on a single colour, or the delicate blending and shadings of two or more colours in very beautiful effects is easily produced.

This use of the atomiser commenced in 1884, and was claimed as the invention of a lady, Miss Laura Fry, who obtained a patent for thus blowing the atomised spray colouring matter on pottery in 1889; but it was held by the courts that she was anticipated by experiments of others, and by descriptions in previous patents of the spraying of paint on other objects by compressed air apparatus known as the air brush. However, this introduction of the use of the atomiser caused quite a revolution in the art of applying colours to pottery in the forming of backgrounds. [Pg 468]

Enamelled ware is no longer confined to pottery. About 1878 Niedringhaus in the United States began to enamel sheet iron by the application of glaze and iron oxide, giving such articles a granite appearance; and since then metallic cooking vessels, bath tubs, etc., have been converted in appearance into the finest earthenware and porcelain, and far more durable, beautiful and useful than the plain metal alone for such purposes.

When we remember that for many centuries, wood and pewter, and to some extent crude earthenware, were the materials from which the dishes of the great bulk of the human family were made, as well as their table and mantel ornaments, and compare them in character and plenteousness with the table and other ware of even the poorest character of to-day, we can appreciate how much has been done in this direction to help the human family by modern inventions.

Artificial Stone.—The world as yet has not so far exhausted its supply of stone and marble as to compel a resort to artificial productions on a great scale, and yet to meet the demands of those localities wherein the natural supplies of good building stones and marble are very scarce, necessitating when used a long and expensive transportation, methods have been adopted by which, at comparatively small cost, fine imitations of the best stones and marbles have been produced, having all the durable and artistic qualities of the originals, as for the most part, they are composed of the same materials as the stone and marbles themselves.

The characteristic backgrounds, the veins and shadowings, and the soft colours of various marbles have been quite successfully imitated by treating dehydrated gypsum with various [Pg 469] colouring solutions. Sand stones have been moulded or pressed from the same ingredients, and with either smooth or undressed faces. When necessary the mixture is coloured, to resemble precisely the original stones.

One of the improvements in the manufacture and use of modern *cements* and artificial stones consists in their application to the making of streets and sidewalks. Neat, smooth, hard, beautiful pavements are now taking the place everywhere of the unsatisfactory gravel, wood, and brick pavements of former days. We know that the Romans and other ancient peoples had their hydraulic cements, and the plaster on some of their walls stands to-day to attest its good quality. Modern inventors have turned their attention in recent years to the production of machines to grind, crush, mix and set the materials, and to apply them to large wall surfaces, in place of hand labour. *Ready-made plaster* of a fine quality is now manufactured in great quantities. It needs only the addition of a little water to reduce it to a condition for use; and a machine operated by compressed air may be had for spreading it quickly over the lath work of wood or sheet metal, slats, or over rough cement ceilings and walls.

Glass.—The Sister of Pottery is Glass. It may have been an accidental discovery, occurring when men made fire upon a sandy knoll or beach, that fire could melt and fuse sand and ashes, or sand and lime, or sand and soda or some other alkali, and with which may also have been mixed some particles of iron, or lead, or manganese, or alumina to produce that hard, lustrous, vitreous, brittle article that we call *glass*.

But who invented the method of blowing the viscid mass into form on the end of a hollow tube? [Pg 470] Who invented the scissors and shears for cutting and trimming it when soft? Or the use of the diamond, or its dust, for polishing it when hard? History is silent on these points. The tablets of the most ancient days of Egypt, yet recovered, show glass blowers at work at their trade—and the names of the first and original inventors are buried in oblivion. Each age has handed down to us from many countries specimens of glass ware which will compare favourably in beauty and finish with any that can be made to-day.

Yet with the knowledge of making glass of the finest description existing for centuries, it is strange that its manufacture was not extended to supply the wants of mankind, to which its use now seems so indispensable. And yet as late as the sixteenth and seventeenth centuries glass windows were found only in the houses of the wealthy, in the churches and palaces, and glass mirrors were unknown except to the rich, as curiosities, and as aids to the scientists in the early days of telescopy. Poor people used oiled paper, isinglass, thinly shaved leather, resembling parchment, and thin sheets of soft pale crystalised stone known as talc, and soapstone.

The nineteenth century has been characterised as the scientific century of glass, and the term commercial, may well be added to that designation.

Its commercial importance and the advancement in its manufacture during the first half of the century is illustrated in the fact that the Crystal Palace of the London Industrial Exhibition of 1851, although containing nearly 900,000 square feet of glass, was furnished by a single firm, Messrs. Chance & Co. of London, without materially delaying their other orders. In addition to [Pg 471] scientific discoveries, the manufacture of glass in England received a great impetus by the removal of onerous excise duties which had been imposed on its manufacture.

The principal improvements in the art of glass-making effected during the nineteenth century may be summarised as follows:

First, Materials.—By the investigations of chemists and practical trials it was learned what particular effect was produced by the old ingredients employed, and it was found that the colours and qualities of glass, such as clearness, strength, tenacity, purity, etc., could be greatly modified and improved by the addition to the sand of certain new ingredients. By analysis it was learned what different metallic oxides should be employed to produce different colours. This knowledge before was either preserved in secrecy, or accidentally or empirically practised, or unknown. Thus it was learned and established that lime hardens the glass and adds to its lustre; that the use of ordinary ingredients, the silicates of lime, magnesia, iron, soda and potash, in their impure form, will produce the coarser kinds of glass, such as that of which green bottles are made; that silicates of soda and lime give the common window glass and French plate; that the beautiful varieties of Bohemian glass are chiefly a silicate of potash and lime; that crystal or flint glass, so called because formerly pulverised flints were used in making it, can be made of a suitable combination of potassia plumbic silicate; that the plumbic oxide greatly increases its transparency, brilliancy, and refractive power; that *paste*—that form of glass from which imitations of diamonds are cut, may be produced by adding a large proportion of the oxide of [Pg 472] lead; that by the addition of a trace of ferric oxide or uranic acid the yellow topaz can be had; that by substituting cobaltic oxide the brilliant blue sapphire is produced; that cuperic oxide will give the emerald, gold oxide the ruby, manganic oxide the royal purple, and a mixture of cobaltic and manganic oxides the rich black onyx.

Professor Faraday as early as 1824 had noticed a change in colour gradually produced in glass containing oxide of manganese by exposure to the rays of the sun. This observation induced an American gentleman, Mr. Thomas Gaffield, a merchant of Boston, to further experiment in this direction. His experiments commenced in 1863, and he subjected eighty different kinds of glass, coloured and uncoloured, and manufactured in many different countries, to this exposure of the sun's rays. He found that not only glass having manganese as an element, but nearly every species of glass, was so affected, some in shorter and some in longer times; that this discoloration was not due to the heat rays of the sun, but to its actinic rays; and that the original colour of the glass could be reproduced by reheating the same.

Mr. Gaffield also extended his experiments to ascertain the power of different coloured glasses to transmit the actinic or chemical rays, and found that blue would transmit the most and red and orange the least.

Others proceeded on lines of investigation in ascertaining the best materials to be employed in glass-making in producing the clearest and most permanent uncoloured light; the best coloured lights for desired purposes; glasses having the best effects on the growth of plants; and the best class for refracting, dispersing and transmitting both natural lights and those great modern [Pg 473] artificial lights, gas and electricity.

Another illustration of modern scientific investigation and success in glass-making materials is seen at the celebrated German glass works at Jena under the management of Professors Ernst Abbe and Dr. Schott, commenced in 1881. They, too, found that many substances had each its own peculiar effect in the refraction and dispersion of light, and introduced no fewer than twenty-eight new substances in glass making. Their special work was the production of glass for the finest scientific and optical purposes, and the highest grades of commercial glass. They have originated over one hundred new kinds of glass. Their lenses for telescopes and microscopes and photographic cameras, and glass and prisms, and for all chemical and other scientific work, have a worldwide reputation.

So that in materials of composition the old days in which there were substantially but two varieties of glass—the old-fashioned standard crown, and flint glass—have passed away.

Methods.—The revolution in the production of glass has been greatly aided also by new methods of treatment of the old as well as the new materials. For instance, the application of the Siemens regenerative furnace, already alluded to in referring to pottery, in place of old-fashioned kilns, and by which the amount of smoke is greatly diminished, fuel saved, and the colour of the glass improved. Pots are used containing the materials to be melted and not heated in the presence of the burning fuel, but by the heated gases in separate compartments.

Another process is that of M. de la Bastie, added to by others, of toughening glass by plunging it [Pg 474] while hot and pasty and after it has been shaped, annealed, and reheated, into a bath of grease, whereby the rapid cooling and the grease changes its molecular condition so that it is less dense, resists breaking to a greater degree, and presents no sharp edges when broken.

Another process is that of making plate glass by the cylinder process—rolling it into large sheets.

Other processes are those for producing hollow ware by pressing in moulds; for decorating; for surface enamelling of sheet glass whereby beautiful lace patterns are transferred from the woven or netted fabric itself by using it as a stencil to distribute upon the surface the pulverised enamel, which is afterwards burned on; of producing *iridescent* glass in which is exhibited the lights and shadows of delicate soap bubble colours by the throwing against the surface of hydrochloric acid under pressure, or the fumes of other materials volatilised in a reheating furnace.

Then there is Dode's process for platinising glass, by which a reflecting mirror is produced without silvering or otherwise coating its back, by first applying a thin coating of platinic choride mixed with an oil to the surface of the glass and heating the same, by which the mirror reflects from its front face. The platinum film is so thin that the pencil and hand of a draughtsman may be seen through it, the object to be copied being seen by reflection.

Again there is the process of making *glass wool or silk*—which is glass drawn out into such extremely fine threads that it may be used for all purposes of silk threads in the making of fabrics for decorative purposes and in some more useful purposes, such as the filtration of water and other liquids. [Pg 475]

We have already had occasion to refer to Tilghman's sand blast in describing pneumatic apparatus. In glass manufacture the process is used in etching on glass designs of every kind, both simple and intricate. The sand forced by steam, or by compressed air on the exposed portions of the glass on which the design rests, will cut the same deeply, or most delicately, as the hand and eye of the operator may direct.

Machines.—In addition to the new styles of furnaces, moulds and melting, and rolling mills to which we have alluded, mention may be made of annealing and cooling ovens, by which latter the glass is greatly improved by being allowed to gradually cool. A large number of instruments have been invented for special purposes, such as for making the beautiful expensive cut glass, which is flint glass ground by wheels of iron, stone, and emery into the desired designs, while water is being applied, and then polished by wheels of wood, and pumice, or rottenstone; for grinding and polishing glass for lenses; and for polishing and finishing plate glass; for applying glass lining to metal pipes, tubes, etc.; for the delicate engraving of glass by small revolving copper disks, varying in size from the diameter of a cent down to one-fifteenth of an inch, cutting the finest blade of grass, a tiny bud, the downy wing of an insect, or the faint shadow of an exquisite eyebrow.

Cameo cutting and incrustation; porcelain electroplating and moulding apparatus, and apparatus for making porcelain plates before drying and burning, may be added to the list.

It would be a much longer list to enumerate the various objects made of glass unknown or not in common use in former generations. The reader must call to mind or imagine any article which he [Pg 476] thinks desirable to be made from or covered with this lustrous indestructible material, or any practicable form of instrument for the transmission of light, and it is quite likely he will find it already at hand in shops or instruments in factories ready for its making.

Rubber—Goodyear.

The rubber tree, whether in India with its immense trunk towering above all its fellows and wearing a lofty crown, hundreds of feet in circumference, of mixed green and yellow blossoms; or in South America, more slender and shorter but still beautiful in clustered leaves and flowers on its long, loosely pendent branches; or in Africa, still more slender and growing as a giant creeper upon the highest trees along the water courses, hiding its struggling support and festooning the whole forest with its glossy dark green leaves, sweetly scented, pure white, star-like flowers, and its orange-like fruit—yields from its veins a milk which man has converted into one of the most useful articles of the century.

The modes of treating this milky juice varies among the natives of the several countries where the trees abound. In Africa they cut or strip the bark, and as the milk oozes out the natives catch and smear it thickly over their limbs and bodies, and when it dries pull it off and cut it into blocks for transportation. In Brazil the juice is collected in clay vessels and smoked and dried in a smouldering fire of palm nuts, which gives the material its dark brown appearance. They mould the softened rubber over clay patterns in the form of shoes, jars, vases, tubes, etc., and as they [Pg 477] are sticky they carry them separated on poles to the large towns and sea ports and sell them in this condition. It was some such articles that first attracted the attention of Europeans, who during the eighteenth century called the attention of their countrymen to them.

It was in 1736 that La Condamine described rubber to the French Academy. He afterward resided in the valley of the Amazon ten years, and then he and MM. Herissent, Macquer, and Grossat, again by their writings and experiments interested the scientific and commercial world in the matter.

In 1770 Dr. Priestley published the fact that this rubber had become notable for rubbing out pencil marks, bits of it being sold for a high price for that purpose. About 1797, some Englishman began to make water-proof varnish from it, and to take out patents for the same. This was as far as the art had advanced in caoutchouc, or rubber, in the eighteenth century.

In 1819 Mr. Mackintosh, of Glasgow, began experimenting with the oil of naphtha obtained from gas works as a solvent for India rubber; and so successfully that he made a water-proof varnish which was applied to fabrics, took out his patent in England in 1823, and thus was started the celebrated "Mackintoshes."

In 1825 Thomas C. Wales, a merchant of Boston, conceived the idea of sending American boot and shoe lasts to Brazil for use in place of their clay models. This soon resulted in sending great quantities of rubber overshoes to Europe and America.

The importation of rubber and the manufacture of water-proof garments and articles therefrom now rapidly increased in those countries. But nothing that could be done would prevent the [Pg 478] rubber from getting soft in summer and hard and brittle in the winter. Something was needed to render the rubber insensible to the changes of temperature.

For fifty years, ever since the manufacturers and inventors of Europe and America had learned of the water-proof character of rubber, they had been striving to find something to overcome this difficulty. Finally it became the lot of one man to supply the want. His name was Charles Goodyear.

Born with the century, in New Haven, Connecticut, and receiving but a public school education, he engaged with his father in the hardware business in Philadelphia. This proving a failure, he, in 1830, turned his attention to the improvement of rubber goods. He became almost a fanatic on the subject—going from place to place clad in rubber fabrics, talking about it to merchants, mechanics, scientists, chemists, anybody that would listen, making his experiments constantly; deeply in debt on account of his own and his father's business failures, thrown into jail for debt for months, continuing his experiments there with philosophical, good-natured persistence; out of jail steeped to his lips in poverty; his family suffering for the necessaries of life; selling the school books of his children for material to continue his work, and taking a patent in 1835 for a rubber cement, which did not help him much. Finding that nitric acid improved the quality of the rubber by removing its adhesiveness, he introduced this process, which met with great favour, was applied generally to the manufacture of overshoes, and helped his condition. But his trials and troubles continued. Finally one Nathaniel Haywood suggested the use of sulphurous acid gas, [Pg 479] and this was found an improvement; but still the rubber would get hard in winter, and although not so soft in summer, yet the odour was offensive. Yet by the use of this improvement he was enabled to raise more money to get Haywood a patent for it, while he became its owner. In the midst of his further troubles, and while experimenting with the sulphur mixed with rubber he found by accidental burning or partly melting of the two together on a stove, that the part in which the sulphur was embedded was hard and inelastic, and that the part least impregnated with the sulphur was proportionately softer and more elastic. At last the great secret was discovered!

And now at this later day, when $50,000,000 worth of rubber goods are made annually in the United States alone, the whole immense business is still divided into but two classes—hard and soft—hard or vulcanized like that called "ebonite," or soft, it may be, as a delicate wafer. And these qualities depend on and vary as a greater or less amount of sulphur is used, as described in the patents of Goodyear, commencing with his French patent of 1844.

Then of course the pirates began their attacks, and he was kept poor in defending his patents, and died comparatively so in 1860; but happy in his great discovery. He had received, however, the whole world's honours—the great council medal at the Nations Fair in London in 1851 the Cross of the Legion of Honour by Napoleon III., and lesser tributes from other nations.

It can be imagined the riches that flowed into the laps of Goodyear's successors; the wide field opened for new inventions in machines and processes; and the vast added comforts to mankind resulting from Goodyear's introduction of a new and useful material to man.—A material which, [Pg 480] takes its place and stands in line with wood, and leather, and glass, and iron, and steel!

But rubber and steel as we now know them are not the only new fabrics given to mankind by the inventors of the Nineteenth Century.

The work of the silk worm has been rivalled; and a *wool* as white and soft as that clipped from the cleanest lamb has been drawn by the hands of these magicians from the hot and furious slag that bursts from a blast furnace.

The silk referred to is made from a solution of that inflammable material of tremendous force known as gun-cotton, or pyroxylin. Dr. Chardonnet was the inventor of the leading form of the article, which he introduced and patented about 1888. The solution made is of a viscous character, allowed to escape from a vessel through small orifices in fine streams; and as the solvent part evaporates rapidly these fine streams become hard, flexible fibres, which glisten with a beautiful lustre and can be used as a substitute for some purposes for the fine threads spun by that mysterious master of his craft—the silk worm.

The gusts of wind that drove against the molten lava thrown from the crater of Kilauea, producing as it did, a fall of white, metallic, hairy-like material resembling wool, suggested to man an industrial application of the same method. And at the great works of Krupp at Essen, Prussia, for instance, may be witnessed a fine stream of molten slag flowing from an iron furnace, and as it falls is met by a strong blast of cold air which transforms it into a silky mass as white and fine as cotton.

[Pg 481]

INDEX.

A.

Abbe, Prof. Ernst, 412, 473.

Abbott Museum, N.Y., 242.

Abrading machines, 332.

Acetylene, 70, 456.

Accumulators, 177.

Achromatic lens, 410.

Acoustics, 406.

Addressing machines, 285.

Aeolipile, 74.

Affixers, 285.

African inventions, 340, 476.

Agriculture, Chap. 1, 2, 3, 4, 5.

Agricultural chemistry, 64.

Agricultural societies, 16.

Aeronautics. (See Air Ships and Balloons, 169, 445, 448.)

Air Atomizers, 467.

Air brakes, 89, 108, 193.

Air Brushes, 195, 418.

Air Compressors and propellers, 195.

Air Drills, 194.

Air Engines, 89, 193, 194.

Air propellers. (See Pneumatics.)

Air Pumps, 55, 113, 194, 195, 196, 197, 404.

Air Ships, 446, 449.

Airy, 410.

"Alabama," The, 261.

Alarm Locks. (See Locks.)

Alchemistry and alchemists. (See Chemistry.)

Alcohol, 65.

Alfred the Great, 386, 457.

Alembert, D., 167.

Alhambra, 373.

Allen, Horatio, 83.

Allen, Dr. John, 168.

Allotropic phosphorus. (See Matches.)

Allen and Yates. (See Puddling.)

Alloys, 237, 238.

Altiscope, 413.

Aluminium, 238.

Amalgamators, 380.

American Inventions, 341.

Ammonia, 191, 215.

Ammoniacal gas engines, 191.

Ampère, 122, 130.

Amontons air engines, 193.

Ancient smelting. (See Metallurgy.)

Anæsthetics, 2, 71.

Aniline dyes, 69.

Annealing and tempering, 248.

Antiseptics, 2, 72.

Antwerp, Siege of, 261. (See Ordnance.)

Aoisseau, Chas., 466.

Apollo, 400.

Applegath, 283, 284.

Aqueducts, 93, 166, 167.

Arabs, 253, 274.

Arabic notation, 2.

Arago, 122, 410, 411, 416.

Arc Lamps, 137.

Archimedes, 9, 165, 185, 442.

Aristotle, 58.

Argand burner, 456.

Arkwright, Richard, 42, 296, 298, 301.

Arlberg tunnel, 107.

Armor, plate, 262, 264, 265, 266.

Arnold, Asa, 301.

Arnold, watchmaker, 389.

Armstrong, Sir William G., 176, 263, 264.

Arquebus. (See Ordnance.)

Artesian Wells, 38.

Artificial Stone. (See Pottery.)

Artificial Silk. (See Glass.)

Arts, Fine, 197, 347, 353, 371, 400, 414, 418.

Art, Scientific, 228.

Artificial Teeth. (See Dentistry.)

Artillery. (See Ordnance.)

Asbestos, 421.

Assembling machines and system. (See Sewing machines, Watch, and Ordnance.)

Assyrians, 24.

Astronomical inventions, 390. (See Horology and Optics.)

Athens. (See Greece.)

Athanor, Alchemist's stone. (See Chemistry.)

Atmospheric and Gas pressure, 194.

Atoms—atomic theory, 59, 60, 453.

Atomizer, 197, 467.

Attraction of Gravitation, 2.

Augurs, 348, 349.

Auricular instruments, 406.

Australia, 40.

Austria, 24, 50, 358.

Autoharps, 405.

Automobiles, 89, 435.

Axes, 340.

B.

Babbitt, Isaac, metal, 237.

Babylonians, 384.

Bach. (See Pianos.)

Bacon, Roger, 214.

Bacteria, 213.

Bailey, 1822; 37.

Bain, Alex., 147.

Baling and Bale ties, 51, 52, 53.

Balloons, 169, 446.

Band Saw, 348.

Barber, John, 185.

Barker's Mill, 171.

Barlow looms, 305.

Barlow, Prof., 123.

Barrel making. (See Wood Working.)

Bartholdi, 105.

Bastie, 473.

Batcheller, 318.

Baths—closets, 178.

Bath system, Porcelain, 466.

Battam, Thomas, artificial marble, 466.

Baude, Peter, 224.

Beadlestone, metallurgist, 231.

Bean, B. W., 318.

Beaulieu, Col. (Ordnance), 264.

Beating engines. (See Paper.)

Becher, 58.

Bechler, 413.

Becquerel, 44.

Beds, 355.

Bed—printing, 282.

Beer. (See Chemistry.)

Bellaert, Jacob, 280.

Bell, Alex. Graham, 140, 141, 142, 407, 414.

Bell, C. A., 408.

Bell, Sir L., metallurgy, 223.

Bell's history of metallurgy, 223.

Bell, Rev. Patrick, 36, 38.

Bells and Bell making—Metallurgy.

Bending wood, 349, 357. (See Woodworking.)

Bennett, Richard, 46.

Bentham, Sir Sam'l, 242, 342, 349, 374.

Bergman, 61.

Berliner, Emile, 408.

Bernoulli, D., 167.

Berthollet, 64, 454.

Berzelius, 60.

Bessemer, Henry, and process, 176, 232, 233.

Besson, Prof. J., 75, 242.

Bicheroux, potter, 465.

Bicycles, 431.

Bigelow, E. B., 305.

Billings, Dr., 210.

Binding books. (See Printing.)

Binders, grain and twine, 39.

Bicycles, 431 to 435.

Bischof, Simon, 191.

Blacksmithing. (See Metallurgy.)

Blaew of Amsterdam, 281.

Black, chemist, 58.

Blair, iron and steel, 234.

Blakely Gun. (See Ordnance.)

Blake, Eli. W., Blake crusher, 376, 377.

Blanchard, Thos., 268, 343, 344, 350, 356, 369.

Blasting, 107.

Blast, steel. (See Bessemer.)

Blauofen furnace. (See Metallurgy.)

Bleaching and Dyeing, 69.

Blenkinsop, 82.

Blithe, Walter, 14.

Block Printing. (See Printing.)

Blodgett & Lerow, sewing machines, 318.

Bloomaries. (See Metallurgy.)

Blunderbuss, 257.

Bobbins—spinning, 302.

Boerhaave, 58.

Boetius, 365.

Bohemia, 357.

Boilers. (See Steam Engineering.)

"Boke of Husbandry," 1523, 14.

Bollman bridge, 103.

Bolting. (See Milling.)

Bolt making. (See Metal Working.)

Bombards, 254.

Bombs. (See Ordnance.)

Bomford, Col., 260.

Bonaparte, 89, 90, 256.

Bonnets and ladies' hats, 324.

Bonjeau, M., 325.

Bonelli, M., 305.

Book making and binding, 287, 288.

Boots and shoes, 366 to 371.

Boring machines, 345, 348.

Boring square holes, 346.

Bormann, Genl., 259.

Bottle stoppers, 358.

Boulton and Watt, 84, 452.

Bouton, 415.

Bourseuil, Chas., 407.

Boyce, 1799, 35.

Boyle, Robert, 58, 184, 193, 194.

Box making. (See Woodworking Machinery.)

Braiding. (See Sewing Machines.)

Braithwaite, 83.

Brakes, bicycle, 433-436.

Brakes, steam, Railway and Electric, 87, 436.

Brakes and gins, 297.

Bramah, Jos., 82, 154, 170, 242, 244, 342, 349, 424.

Branch, 342.

Branco, 75.

Brahe, Tycho, 183, 388.

Brass, 219.

Brayton, G. H., 190.

Brazil, 281, 476, 477.

Breech-loaders, 257, 263, 264, 265, 269. (See Ordnance.)

Brewster, Sir David, 410.

Brickmaking machines, kilns and processes, 457, 464.

Bridges and Bridge Building, 93 to 104, 197.

Bright, John, 138.

Broadwood piano, 403.

Bronsen, 412.

Broom-making, 328, 329.

Brot, 411.

Brothers of the Bridge, 94.

Bronze, 218, 219.

Brooklyn bridge, 98, 99.

Brown, Sir Saml., 95, 187, 188.

"Brown Bess," 258.

Bruce, David, 284.

Brunel, I. K., 97.

Brunel, I. M., 351, 367.

Brunton, 82.

Brush—Brush light, 137.

Brushes and Brush making, 330.

Buchanan's Practical Essays, 244.

Buckingham, C. L., 148.

Buffing machines, 365.

Builders' hardware, 250.

Buildings, tall, 152, 153.

Buffers, 437. (See Railways, Elevator, etc., 160, 161.)

Bunsen, Robt. W., 119, 120, 230.

Bunsen light, 456.

Burden, Henry, 95.

Burdett, Wm., 188.

Burke, Edmund, 182.

Burns, Robert, 31.

Butter, 54, 55.

Button-hole machines, 323.

Bunsen. (See Chemistry.)

C.

Cable transportation, 109.

Cæsar, 457.

Cahill, Thaddeus, 287.

Caissons, 100.

Calcium-carbide, 70, 456.

Calico making and printing, 325, 326.

California, 382.

Cameo cutting, 475.

Camera obscura, 414.

Campbell printing press, 285.

Canada, 40, 430.

Canals, and boats for, 84, 106, 107, 109, 110, 440.

Canal locks, 110.

Cane woven goods, 308.

Cannons and firearms, 252-272.

Cantilever bridges, 103, 104.

Caoutchouc. (See Rubber, 476.)

Caps,—gun, 259.

Car heating, 211.

Cars, sleeping, 431. (See Railways.)

Car tracks, 108.

Car rails, 108.

Car wheels, 108.

Carbines, 266. (See Ordnance.)

Carbon—chemistry.

Carbonating, 68.

Carborundum, 70.

Cardan, 183.

Carding, 298, 300.

Cardova. (See Leather.)

Carlyle, 310.

Carnot. (See Ordnance.)

Carpentry, 339, 352.

Carpets and Looms, 305.

Carré Brothers, 214.

Carriages and carrying machines, 82, 428-437.

Carthagenians, 164.

Carts. (See Coaches and Waggons.)

Cartridges, 267.

Cartwright, Rev. Edwd., 297.

Carving machinery, 346.

Case-shot. (See Ordnance.)

Cash registers, 395.

Cast iron, 223.

Catalan furnace, 222. (See Metallurgy.)

Cauchy, 410.

Caus, Salomon de, 75.

Cavendish, 58.

Caxton, 280.

Centennial Exhibition. 1876; 38, 39, 40, 140, 246, 320, 352, 353, 393, 402, 430.

Centrifugal machines (pumps), 172, 173.

Charcoal. (See Metallurgy.)

Chairs. (See Furniture.)

Chaff separator. (See Milling.)

Chain wheels—hydraulics, 156.

Chairs, tables, desks, etc. (See Furniture, 351, 358.)

Challey, M., 97.

"Champion harvesters"—Harvesters.

Chance & Co., Glass makers, 470.

Channelling shoes. (See Leather.)

Chanute, Octave, 110.

Chappe, M., 125.

Charles I. (See Ordnance;
Charles II., 242;
Charles V., 387;
Charles VIII., 265.)

Chemistry, 58, 70.

Chemical Telegraph. (See Telegraphy.)

Chester-dial telegraph, 146.

Chili, 461.

Chill hardening, 250.

Chickering pianos, 403.

Chimes, 196.

China and Chinese inventions, 24, 52, 165, 222, 241, 253, 257, 273, 275, 280, 384, 386, 400, 423, 465.

Chlorates, 70.

Chlorine, 237.

Chlorination, 237.

Chromium, 70.

Chronometers, 390, 394.

Chubb-safes, 422, 425.

Cigar and cigarette machines, 56, 57.

Cincinnati Bridge. (See Engineering.)

Cincinnatus, 17, 31.

Circulation of blood, 2.

Civil Engineering, 93-110.

Clark, Alvan, 412.

Clavichord, 402.

Clayton, Dr., 1688, 451.

Clay, Treatment of. (See Brick and Pottery making.)

Cleaning grain, etc. (See Mills.)

Clement, metal worker, 244.

Clementi, pianist, 403.

Clepsydra, 384, 385, 386.

"Clermont." (See Steam Ships.)

Clippers, Ships, 439.

Clocks, 384. (See Horology.)

Clocks, Essential parts of, 386.

Closets. (See Baths.)

Cloth, Making, Finishing, 306;
Drying, 306;
Printing, 306;
Creasing and pressing, 306;
Cutting, 306-324;
Fancy woven, 205-306.

Clothes. (See Garments.)

Clover Header, 32.

Clutches, 161-162.

Clymer, of Philadelphia, press, 282.

Coaches, stages, mail, etc., 428-431.

Coach lace, 306.

Coal, 225, 378, 380;
Coal breakers and cleaners, 378-380.

Coal gas, 450;
Coal tar colors. (See Chemistry.)

Coal mining. (See Ores.)

Coaling Ships, 110.

Coehorn, shell, 255.

Coffin, journalist, 25.

Coke. (See Metallurgy.)

Cold metal punching, working and rolling, 246-247.

Colding of Denmark, 63.

Collards, pianos, 403.

Collen, Henry, 417.

Collins line. (See Steam Ships.)

Collinge, 430.

Coloring cloth, 325.

Colors and coloring, 464-467.

Color process. (See Photography, 417, Printing, 290.)

Colt, revolvers, 260, 267, 322.

Columbiad, 261.

Colossus of Rhodes, 34.

Comminges of France, 255.

Comminuting machines. (See Grinding.)

Compartment vessels, 442.

Compass, 2.

Compensating devices, 391.

Compound engines, 87-89.

Compressed air drills, 376.

Compressed air and steam, 193, 194, 378.

Compressed air ordnance, 265, 269.

Condensers, 87.

Condamine, 477.

Conservation of forces, 2.

Constitution, U.S., 8.

Convertibility of forces, 2.

Containers, 175.

Conveyors, transportation, 152, 153, 154, 158, 159, 160.

Cook, Telegraphy, 127, 146.

Cooke, Prof. J. P., 59.

Cooke, James, 25.

Cooking. (See Stoves.)

Cooper, Peter, 84.

Coopering. (See Wood Working.)

Copernicus, 183.

Copper, 218, 219, etc.

Corliss, 88.

Corn:
- Cultivators, 29-30;
- Mills, 46;
- Planters, 28.

Correlation of forces, 2.

Cort, Henry, 226-231.

Corundum, 70, 334.

Coster, 280.

Cotton, 42, 43;
- Gin, 42, 43, 297;
- Harvester, 40.

Cotton seed oil, 69.

Cotton and wool machinery, 298. (See Textiles.)

"Counterblast to Tobacco," 155.

Couplers, 437.

Cowper, 31.

Cowper, printer, 283.

Cowley, 77.

Cradle, grain, 33.

Cranes and derricks, 110, 152, 153, 171.

Crecy, (1346). (See Ordnance.)

Cristofori, pianist, 402.

Crompton, Saml., 42, 297, 298, 301.

Crompton, George, 305.

Crookes, Prof. Wm., 149.

Crooke tubes, 149.

Cros, Charles, 407.

Crushers, stone and ore, 376.

Crystal Palace, 470.

Ctesibius, 74, 165, 168, 385.

Cultivators, 29, 30.

Curtet, 121.

Cugnot, 1769, 81.

Culverin. (See Cannon.)

Cunard line, 86.

Cuneus, 115.

Curtains Shades and Screens, 356.

Cyanide. Cyanide process, 236.

Cyclometers, 396.

D.

Daguerre, 415-416.

Daguerreotype, 415.

Dahlgren, Cannon, 264.

Danks, Rotary puddler, 231.

Dalton, John, 59-60, 186, 194, 453.

Damascus Steel, 221. (See Metallurgy.)

Dana, Prof., 126.

Daniell's battery, 119, 126.

Darby, Abraham, 1777, 95, 225.

Darwin, Dr., 18th cent., 73.

Davy, Humphry, Sir, 16, 63, 64, 70, 118, 122, 125, 188, 209, 236, 415.

David's harp, 6.

Decker, piano, 403.

Delinter, 43.

Dentistry, 72.

Dental Chairs, 72, 358;
Drills, 72;
Engines, 72;
Hammers, 72;
Pluggers, 72.

Deoville, St. Clair, 238.

Derricks, 110.

"Deutschland," The, 445.

Desks, 355.

De Susine, 192.

Dewar, Prof., 216.

Dial Telegraphs. (See Telegraphy.)

Diamonds. (See Milling; Polishing; Artificial, 70.)

Diamond Drill, 375.

Diana, Temple of, 34.

Diastase, 54.

Didot, Francois, 1800, 276.

Dickenson, 277.

Digesters. (See Chemistry.)

Differential motion, 301.

Dioptric Lens, 410.

Diorama, 415.

Direct Acting Engines, 88.

Direct Feed Engines, 88.

Discoveries, distinct from inventions, 1, 2.

Disk Plows, 21, 30.

Distaff and Spindle. (See Textiles, 292.)

Dodge, James M., 159.

Doffers, 301.

Dog Carts. (See Carriages.)

Dollond, John, 410.

Donkin, 277.

Donovan, 454.

Don Quixote, 222.

Douglass, Nicholas, 105.

Draining, 105, 106, 107.

Drags and Drays. (See Waggons, 430-431.)

Drais, Baron Von, 432.

Drake, E. S., Col., 382.

Draper, J. W., Prof., 412, 416, 450.

Drawing Machines, Spinning, 296, 298, 301.

Dredging, 105, 106, 107.

Dressing;
of thread and cloths, 299, 302;
of skins. (See Leather.)

Drills, seeders, 20, 27.

Drills, stone ore and iron, 375, 378.

Drying apparatus. (See Kilns.)

Dreyse, 266.

Dualine, 270.

Duboscq, 137.

Dudley, Dud, 224.

Duncan, John, 311.

Dundas, Charlotte, 84.

Dundonald, Lord, 451.

Dundas, Lord, 83, 440.

Dunlop, J. B., Bicycles, 433.

Duplex Engines, 88.

Dulcimer. (See Music.)

Dust Explosions and Collectors, 50.

Dutch Paper, 277;
Printing, 280.

Dutch Canals, 107.

Dutch Clocks, 388, 391.

Dutch Furnaces and Stoves, 203.

Dutch Locks, 424.

Dutch Ships, 439.

Dutch Ware, 459.

Dutton, Maj. C. E., 261.

Dynamometer, 187, 398.

Dynamite, 270.

Dynamo Electric Machines, 130, 134, 251.

E.

Eads, James B., 102.

Eames of U. S., 234.

East River Bridge, 98, 99.

Eddystone Lighthouse, 105.

Edison, 137, 144, 145, 148, 407, 408.

Egyptian agriculture, arts and inventions, 5, 13, 42, 45, 58, 164, 184, 220, 241, 273, 292, 340, 354, 400, 402, 423, 457, 460, 470.

Eiffel, M., 105.

Electricity, 5, 111-151.

Electric Alarms. (See Locks.)

Electric Batteries, 117-132.

Electric Cable, 138.

Electric Heating, 213.

Electric Lighting, 108, 119, 121 to 137, 360, 456.

Electro-Chemistry, 70.

Electro-magnets, 120-133.

Electro Metallurgy, 70, 238, 249.

Electrodes, 113, 135.

Electrolysis, 129, 131.

Electrometer, 113, 122.

Electrical Music, 148.

Electro Plating, 249.

Electric Railway, 143, 144.

Electric Signals and Stops, 160, 162.

Electric Telegraphy, 2, 114, 122, 123, 145, 146, 147.

Electrotyping, 283, 290.

Electric Type Printing, 147, 148.

Electric Type Writer, 287.

Electric Voters, 396.

Elevators, 6, 148, 152, 153, 154, 155, 156, 157.

Eliot, Prof., 410.

Elizabeth, Queen, 402.

Elton, John, 46.

Elvean, Louis T. van, 155.

Embossing, 346, 347.

Embossing, weaving, 306.

Embroidery, 310, 313.

Emery, abrading, 70, 334.

Emery, testing machines, 398.

England, 8, 17, 25, 50, 188.

Engraving Machines, 290.

Enamelling. (See Pottery.)

Enamelled Ware, 459, 468.

Engineering. (See Civil.)
Electric, 143;
Hydraulic, 168;
Marine, 442;
Mining, 373;
Steam, 2.

Eolipile. (See Hero.)

Erard, pianist, 403.

Erasmus, 183.

Ericsson, John, 83, 86, 441, 443, 444.

Euclid, 9.

Euler, 167, 173.

Evans, Oliver, 1755-1819; 46, 47, 48, 81, 83, 87, 154, 374.

Evaporating, 52.

Evelyn, John, 1699; 25.

Evolution of modern inventions, 153.

Excavating, 105, 106.

Explosives, 270.

Eylewein, 167.

F.

Fabroni, 66, 118.

Faience, 459, 466.

Fairbairn, Sir Wm., 100, 176, 226, 440.

Fairbanks, scales and testing, 397.

Fahrenheit, 183.

Fanning Mills, 45.

Faraday, Michael, 63, 118, 129, 130, 131, 133, 134, 138, 188, 209, 411, 472.

Fan mills, 41.

Fare registers, 395.

Farmer, Moses G., 133, 135, 145.

Factory life, 298.

Faure, M. Camille, 120.

Faur, Faber du, 230.

Faust, 280.

Felt making, 325.

Fermentation, 65, 66, 67.

Fertilizers—machines and compositions. (See Agriculture.)

Field, Cyrus W., 138.

Filament-carbon, 360. (See Electric Lighting.)

Filters, filtering, 167, 180, 181.

Filter Press, 465.

Fink bridge, 103.

Fire-arms, 252-272.

Fire crackers, 252.

Fire engines, 76.

Fire place, 205.

Fiske, range finder, 266.

Fiske, 148, 413.

Fitch, John, 1784, 81.

Fitzherbert, Sir A., 1523, 14.

Fireproof safes. (See Locks.)

Flax machines, 42.

Flax brakes, 42.

Flaxman, 464.

Flax-threshers, 41, 42.

Fleming, 247.

Fleshing machines, 364.

Fletcher, 244.

Flexible shafts, 350.

Florence, 459.

Flour. (See Mills.)

Fly Shuttle. (See Spinning and Weaving.)

Foods, preparation of, 53, 54.

Force feed-seeders, 26.

Forneyron, 171, 172.

Forsythe, Rev. Mr., 259, 260.

Foucault, 137.

Fourcroy, 64.

Fourdrinier, 277. (See Paper making.)

Frackelton, Susan, portable kiln, 465.

France, 63, 203, 253, 274, 275, 313.

Francis, S. W., 286.

Frank, pottery, 463.

Franklin, Benj., 5, 111, 112, 115, 116, 117, 121, 125, 168, 203, 281, 446.

Franklin Institute, 455.

Fraunhofer, von, Jos., 61, 412.

Frederick, Henry, 255.

Freiberg Mining Academy, Metallurgy, 223.

Fresnel, 410.

Frictional Electricity, 111.

Frieburg Bridge. (See Bridges.)

Frogs, R. R., 108.

Flintlock, firearms, 258.

Froment, 146.

Frontinus, on Roman aqueducts, 166.

Fruits, Preparation of, 51, 53.

Fruit jars, 359.

Fry, Laura, 467.

Fulton, Robt., 84-85.

Furnaces, hot air; hot water, 206, 207.

Furniture, 351, 354, 359.

Furniture machinery, 351, 352.

Fuses, 259.

G.

Gaffield, Thos., glass, 472.

Gale, Prof., 126.

Galileo, 1, 166, 183, 388, 409.

Gally, self-playing pianos, 406.

Galton, Capt. Douglas, 205.

Galvani, 5, 117, 118, 125.

Galvanism, 112,121.

Galvanic batteries, 121, 122.

Galvanic music, 148, 406.

Galvanometer, 122, 139.

Gamble, 277.

Garay, Blasco de, 75.

Garments, 310-327.

Gas, 450;

illuminating, 69, 185, 450-456.

Gases, motors, 188, 190.

Gas checks, 266.

Gas engines, 76, 18, 184-194.

Gasoline and stoves, 213.

Gas pumps, 190.

Gatling, Dr., gun, 269.

Gaul, 32, 33.

Gauss, 126.

Gay-Lussac, 60, 185, 194, 209.

Ged, Wm., 281.

Geissler tubes, 135, 149.

Generator, Electric, 113.

Gentleman Farmer, 1768, 20.

George III., 389.

German inventions, 50, 203, 255, 313, 387, 391, 430, 473.

Germ theory, 67.

German clock and watch making, 387.

Gibraltar, 253.

Giffard-injector, 173.

Gilbert, Dr., 1600, 5, 113.

Gill, J. G., 268.

Giers, 234, 250.

Gin-cotton, 297.

Gladstone, inventor, 1806, 35.

Glass, 469, 474.

Glass, wool, and silk, 474, 480.

Glazes, 475. (See Porcelain.)

Glauber, 58.

Glycerine, 69.

Gold. (See Metallurgy.)

Goodyear, Chas., 434, 476, 478, 479, 480.

Googe, Barnaby, 14.

Gompertz, 432.

Gordon, 82.

Gothic architecture, 373.

Governors, 87.

Graham (chemist), 391.

Graham. (See Horology.)

Grain Binder. (See Harvesters.)

Grain cradles, drills, and seeders. (See Agriculture.)

Grain elevator, 110.

Grain Separators, 49.

Gramme, Z., 134, 136, 137.

Gramophone, 406, 408.

Graphophone, 406, 408.

Grass burning stoves, 211.

Gray, Elisha. (See Electricity.)

Gray, S., 1729, 114, 125.

"Great Britain," The, 440.

"Great Republic," The, 439.

Great Urgroez, 357.

Greece and Greek antiquities and inventions, 9, 13, 18, 45, 74, 113, 164, 182, 218, 257, 340, 386, 457, 459.

Grenades, 255.

Green, N. W., driven well, 383.

Greenough, J. J., 318.

Gribeauval, 256.

Griffith, Julius, 82.

Griffiths of U. S., 234.

Grinding by stones, 45 to 49.

Grinding glass, 475.

Grindstones, 375.

Grossat, 477.

Grover and Baker sewing mach., 320.

Grooving, 245.

Grove, Sir Wm. Robert, 119.

Gruner, 234.

Gun carriages. (See Ordnance.)

Gun cotton, 270.

Gun making, 345.

Gunpowder, 253, 262, 263, 270.

Gunpowder eng., 192.

Gun-stock, 345.

Guericke, Otto von, 113, 183, 193.

Guillaume, Puy, 253.

Gurney, 82.

Guttenberg, John, 280.

H.

Hales, Dr., 451.

Hall, John H., 267.

Hall safes, 422.

Hamberg, 58.

Hamblet, 146.

Hamilton (stove inventor), 212.

Hammers, steam and air, 88, 244.

Hanckwitz, Godfrey, 1680, 199.

Hancock, Walter, 82.

Handel, 402.

Hanging Gardens, 34.

Hardening metals, 249.

Hardware. (See Metal Working.)

Hargreaves, Jas., 42, 294, 297.

Harnesses, 431.

Harp, The, and the Harpsichord, 6, 402.

Harvesters, 32, 33, 35, 39, 40, 41, 322.

Hartshorn, spring roller shades, 356.

Harveyized steel, 234, 249.

Harrows, 22, 28.

Hautefeuille, 77.

Hauteville, Abbé, 185, 389.

Hat making, 325.

Haydn, 402.

Hay, rakes and tedders, 15, 40.

Headers, 32.

Heat as power, 186, 187.

Heating, 86, 199, 210.

Hebrews, 45, 362, 423.

Hele, P., 388.

Helmont, J. van, 58, 184.

Hell Gate, 107.

Helmholtz, 66, 131, 141, 403, 406, 407, 411, 417.

Hendley, Wm., 82.

Henry, Joseph, 63, 123, 124, 126, 131, 146, 210.

Henry, rifle, 267.

Henry, Wm., 78.

Herissent, M., 477.

Hermetical sealing, 359.

Herodotus, 362.

Hero of Alexander, 5, 9, 74, 76, 87, 89, 165, 171, 404.

Herring, safes, 421.

Herschel, 228, 412.

Hides, treatment of. (See Leather.)

Hide mills, 364.

High and low pressure engines, 87, 88.

Hindoos, 220, 241, 254, 273, 292, 340, 384.

Hodges, James, of Montreal, 101.

Hoe, Robert, and son, R. M., 284.

Hoe drill-seeders, 27.

Hoes, 29, 30.

Hoffman, Dr., 464.

Hoisting, conveying, and storing, 152-163.

Holland, 18, 255, 257, 275.

Holley, A. L., 232.

Holtzapffel, J., 241.

Homer, 459.

Hooke, Dr., 388, 389.

Hoopes and Townsend, 247.

Hoppers. (See Mills.)

Hopper boy. (See Mills.)

Hoosac tunnel, 107.

Hornblower, 1781, 87.

Horrocks, 305.

Horse power, 187.

Horseshoes, 248.

Horology, 384-395.

Hot air engines, 185.

Hot air blast, 231.

Hot furnaces. (See Heating.)

Hot water circulation. (See Heating.)

Hotchkiss gun, 270.

Houdin regulator, 137.

Houses, their construction, 351, 352.

Houston. (See Telegraphy.)

Howe, Elias, 314-318.

Howe bridge, 103.

Howitzer. (See Ordnance.)

Hunt, Walter, 314, 315.

Hungary, 357.

Huggins, Dr., 63, 412.

Hughes, D. E., 147.

Hugon, 189.

Hulls, Jonathan, 78.

Huntsman, Benj., 225.

"Husbandry, The whole art of." (See Agriculture.)

Huskisson, 83.

Hussey, 1833, 37, 38.

Huxley, 65.

Huygens, 61, 77, 183, 184, 192, 388, 391.

Hydraulicising, 174.

Hydraulic elevators, 156, 157, 164, 165, 166.

Hydraulic jacks, 174.

Hydraulic motors, 164-181;
pumps, rams, 166, 168;
press, 52, 53, 154, 155, 168, 171, 175;
testing, 398, 399.

Hydrogen gas, 454.

Hydrostatic engines and presses, 166, 190, 194.

I.

Ida, mountains of, iron, 218.

Illuminating gas. (See Gas.)

Impulse pump. (See Ram.)

Incandescent light, 135, 456.

Incubators, 207.

India, 373, 400.

Industrial mechanics, 328-338.

Injectors, 173.

Intensifiers, 174.

International Exposition, London, 246, 352.

Invention, what it is, how induced, distinctions, growth, protection of, 1-8.

Iron, 218.

Iron Ships. (See Ships.)

Iridescent glass, 474.

Ironing machines, 338.

Italy, 255, 280.

Ives. F. E. (three-color process), 417.

J.

Jablochoff, M. Paul, 136.

Jacks, 245.

Jacobi, of Russia, 249.

Jackson, C. T., Dr., 71.

Jacquard Loom, The, 304, 323, 326.

Jacquard, Joseph Marie, 304, 305.

Jenk's ring frame, 302.

Jenkins, Prof. F., 192.

Jefferson, Thos., 16,18.

Jenkin, Prof. Fleeming, 144.

Jewelry, 333.

"Jimcrow," 245.

Johnson, Denis. (See Bicycle.)

Jones, iron and steel, 234.

Jonval, 172.

Joule, 2.

Jupiter, statue of, 34.

K.

Kaleidoscope, 410.

Karnes, Lord, 1768, 20.

Kaolin. (See Lighting.)

Kay, John, 293, 295.

"Kearsarge," The, 261.

Kepler, 183.

Kennedy, Diss and Cannan, 331.

Kilns, 463, 464, 465.

Kinetic energy, Age of, 86.

Kinetograph, 417.

Kirchoff, G. R., 62, 412.

Kitchen and table utensils, 356.

Knabe piano, 403.

Knight, Edward, 36, 51, 170, 202, 232, 276, 321, 429.

Knitting, 307, 308.

König and Bauer, 283.

König, acoustics, 407.

Koops, 277.

Koster, 1620, rifle, 258.

Krag-Jorgensen rifle, 268.

Kramer, 146.

Krupp, steel, 234.

Krupp, Fredk., guns, 264.

Krupp, glass, 480.

Kutler, Augustin, 258.

L.

La Condamine, 477.

Labor organizations, 11.

Labor, how affected by inventions; reducing, and increasing, 152, 153, 162, 163, 293, 308, 380, 381, 460.

Lace making, 306.

Laconium, 202.

Ladd electric machine, 133.

La Hire, 167, 170.

Laird, John, 440, 443.

Lallement, P. (See Bicycle.)

Lamps and lamp lighting, 359, 450.

Lancaster, cannon, 263.

Land reclamation, 107.

Lane, 1828, 37.

Lane-Fox light, 137.

Langen and Otto. (See Gas Engine.)

Langley, Prof., 4.

L'Hommedieu, 348.

Lapping-cotton, 299, 300.

Lasts, making of, 344, 345.

Lathes, 241-243, 340, 345, 349;
for turning irregular forms of wood, 344.

Lattice work bridges, 103.

Laundry, 335.

Lavoisier, 58, 60, 63.

Lawn mowers, 40.

Lazy tongs mechanism, 160.

Le Bon, 1801, 185, 452.

Leaching, 236.

Lead, 219. (See Metallurgy.)

Leather, 361-372.

Leeuwenhoek of Holland, 65.

Leeu, 280.

Leckie, 41.

Le Conte, 63.

Lefaucheux, M., 267.

Leibnitz, 183.

Lenoir, 189.

Lesage, 121.

Lescatello, 1662, 24.

Leyden jar, 114.

Libavius, 58.

Liebig, 64.

Lieberkulm, Dr., 409.

Light, 2.

Lighting. (See Lamps and Gas.)

Light Houses, illumination, 105, 410.

Linotype, 288, 289, 290.

Linville bridge, 103.

Lippersheim, 409.

Liquid air, 216, 217.

Livingstone, Dr., 221.

Livingston, Robt., 84, 85.

Lixiviation, 236.

Locks, 420-427.

Locomotives, 82, 83, 84, 88.

Looms, 293, 297, 302. (See Textiles.)

Loomis, Mahlen, 150.

"London Engineering," 288.

London exhibition, 1851, 470.

London Times, 283, 285.

Lontin regulator, 137.

Lost arts, 219.

Louis XI., XIV., 254, 255.

Lowell, Francis C., 298.

Lowe, T. S. C., gas, 454, 455.

Lubricants, 237.

Lyall, James, 306.

Lyttleton, 442.

M.

MacArthur-Forrest, cyanide process, 236.

Macaulay, Lord, 10.

Mackintosh, of Glasgow, 477.

Machine guns, 269.

Madersperger, Jos., 312.

Magdeburg, 193.

Magic lantern. (See Optics.)

Magnets and Magnetic Electricity, 112, 122, 123, 124, 130, 133.

Mail bags and locks, 427.

Mail service, 427.

Mail marking, 285.

Majolica. (See Pottery.)

Malt, 65, 66.

Man a tool-using animal, 310.

Manning, 1831, 37.

Marble, artificial, 468, 469.

Marine propulsion, 442.

Marconi, 151.

Mariotte's law of gases, 184, 194.

Markers and cutters, 324.

Markham, 30.

Marsland, looms, 301.

Marr, Wm., 421.

Martin, Prof., 63.

Marvin's safes, 421.

McClure's Magazine, 445, 447.

McCormick reaper, 37, 38.

McCallum bridge, 103.

McKay, ships, 439.

McKay, shoe machines, 369.

McMillan bicycle, 433.

Mary, Queen, 402.

Mason, Prof. O. T., 458.

Massachusetts, mills, 298, 369.

Massachusetts, shoe making, 370.

Master locks, 423, 426.

Matches, 199, 200, 201.

Matting, 309, 312.

Maudsley, Henry, 243, 349.

Maurice of Nassau, 255.

Maurice, Peter, 167.

Mauser rifle, 269.

Mausoleum, 34.

Maxim electric light, 137.

Maxwell, 417.

Mayer, Prof., 404.

Meares, 1800, 35.

Meat, Preparation of, 55.

Mechanical powers, 4.

Medicine and surgery, 70, 71, 72.

Meigs, General M. C., 102.

Meikle, 1786, 41.

Megaphone, 407.

Melville, David, 452.

Menai Straits bridges, 96.

Mendeljeff, 2.

Menzies of Scotland, 41.

Mergenthaler, 288.

Merrimac and Monitor, 268, 441.

Metals and Metallurgy, 218-239.

Metal founding, 249.

Metal working and turning, 240;
boring, planing, 251;

hammering, shaping, 240;
modern metal working plant, 250.

Metal, personal ware, buckles, clasps, hooks, buttons, etc., 250.

Meters, gas and water, 178.

Mexico, 281, 292.

Microphone, 148.

Microscope, 409.

Middlings purifier, 49, 50.

Milk, milkers, 54, 55.

Millet, 30.

Mills, 45 to 51.

Milling, high, low, 49.

Miller, wood working, 342.

Miller and Taylor, 81.

Millwright, The Young, 47.

Milton, 105, 218.

Mineral wool, minerals and mining, 373-383.

Minneapolis mills, 50.

Mitrailleuses, 269.

Modern machinery, its commencement, 364.

Mohl, von, Hugo, 67.

Moigno, Abbé, 411.

Mold, aging. (See Chemistry.)

Moulding. (See Wood-working and Glass making.)

Monks, 387.

"Monitor," The, 268, 441.

Montgolfier, 169.

Moody, Paul, 298.

Moors, 253.

Morin, Genl., 209, 238.

Morland, Sir Sam'l, 77.

Morrison, Chas., 115.

Morse, S. B. F., 126, 127, 128, 129.

Mortars, 253.

Mortise making, 345.

Morton, Dr. W. T. G., 71.

Motor vehicles, 435.

Mont Cenis Tunnel, 107.

Mowers, 32, 33, 35, 36, 37, 38, 39.

Moxon, Jos., 242.

Mozart, 402.

Murdock, Wm., 185, 452.

Music, 400-406.

Musical instruments, 6, 400.

Musical electrical apparatus, 406.

Muschenbroeck, Prof., 1745, 114, 115.

Mushet, iron and steel, 234.

Muskets. (See Ordnance.)

Muzzle loaders, 263, 264.

N.

National Assembly, France, 9.

Napoleon. (See Bonaparte.)

Naphtha, 454.

Nasmyth, 243, 245.

Needle, 310, 313.

Needle gun, 266.

Niedringhaus, 468.

Netting. (See Spinning.)

Newcomen, 5, 77, 78, 79, 167, 187.

Newbold, Chas., 19.

Newbury, Wm., 348.

Newton, Sir Isaac, 9, 11, 61, 114, 167, 183, 414.

Niagara bridges, 97, 98, 104.

Niagara power, 171, 172.

Nicholson and Carlisle, 118.

Nicholson, Wm., of England, 282.

Nickel. (See Metallurgy.)

Niepce, Jas. N., 415.

Nitro-glycerine, 270.

Noah's Ark, 438.

Nobel, A., 192.

Nollet, Prof., 132.

Noria, The, 165.

Norway, 266, 430, 439.

Nozzles, flexible, 174;
water, 179.

O.

Oersted, 121, 130.

Ogle, 1822, 36.

Ohm, G. S., 125.

Oils and fats, 69.

Oil cloth, 306.

Oil lamps, 359.

Oil stoves and furnaces, 190, 212.

Oiling waves, 446.

Oil wells, 190, 382.

Omnibus. (See Stages and Carriers.)

Opening and blowing machines, cotton, 299.

Opthalmoscope, 411.

Optical instruments, 409-412.

Ordnance, arms, explosives, 252 to 272.

Ores, treatment of, 229, 250, 251, 373 to 380.

Ore separators, 379. (See Metallurgy.)

Organs, 404.

Ornamental iron work. (See Metal Working.)

Ornamental wood work. (See Wood Working.)

Oscillating engines. (See Steam.)

Osmund furnaces. (See Metallurgy.)

Otis elevators, 155.

Otto, Nicolaus A., Otto engine, 190, 191.

Oxygen, 58, 453. (See Priestley.)

P.

Paddle wheels and vessels, 443.

Paints, 466.

Painting, 418, 419, 459.

Painting machines, 193, 418, 467.

Paixhans, Genl., 261, 264.

Page, Prof. C. G., 132, 141.

Page, Ralph, 224.

Palissy, Bernard, 458.

Palmer, stage-coaches, 429.

Palladius, 32.

Panoramas, 415.

Paper and printing, 273-291.

Paper bag machinery, 279.

Papin, 5, 77, 184, 192, 193.

Papyrus, 273, 274.

Paraffine. (See Oils.)

Parchment, 274.

Parkinson, Thos., 194.

Parliament, House of, 209.

Parquetry. (See Wood-working.)

Parrott, gun, 264.

Parthenon, 373.

Partridge, Reuben, matches, 200.

Pascal, 166, 168, 170, 183.

Pasteur, 68.

Patents, their origin and purpose, 8, 21.

Pattern making. (See Wood, Metal, and Textiles.)

Pauley, Col., 266.

Pegs, 367, 368.

Pencils, 418.

Pendulum. (See Horology.)

Pendulum machines, 365.

Penelope, 306.

Pennsylvania fireplace, 203.

Percussion caps, 259, 260.

Percy. (See Metallurgy.)

Permutation locks, 425.

Pernot, 234.

Perin & Co., saws, 348.

Persians, 362.

Petroleum, 359, 382.

Petzold, 403.

Pfaff, 121.

Pharos of Alexandria, 34.

Phelps, G. M., 147.

Phœnicians, 439, 459.

"Phœnix," The. (See Ships.)

Phonautograph, 141, 407.

Phonograph, 2, 406.

Phonophone, 414.

Phonoscope, 414.

Photophone, 414.

Phosphorus matches, 200.

Photochromoscope, 417.

Photography, 410, 414, 416, 418.

Photo-processes, 417.

Piano, 6, 401-404.

Picking machine, 298, 299.

Picker-motion, looms, 297.

Piezometer, 262.

Pigments, 70.

Pitt, inventor, 1786, 33.

Pixii, 131.

Planes, 340, 350. (See Wood-working.)

Planing machines, 245, 349, 350. (See Wood-working.)

Planté, G., 120.

Planters. (See Chap. III.)

Plaster, 469.

Plato, 385.

Platt, Sir Hugh, 14.

Platt, Senator, 35.

Pliny, 32, 164, 223, 227, 273, 340.

Ploughs, 5, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 24, 27, 28, 29, 30.

Plucknett, 1808, 35.

Pneumatics, 165, 182 to 198.

Pneumatic machines, 195, 197, 198.

Pneumatic propellers, 444.

Pneumatic tires, 433.

Pneumatic tubes and transmission, 159, 196.

Polemoscope, 413.

Polishing glass, 475.

Pope, Alexander, 394.

Porcelain, 465, 466.

Poririer (match machine), 201.

Porta Baptista, 414.

Porta G. della, 75.

Portable engines, 88.

Potato planters, 28.

Potassium, 236.

Potter, Humphrey, 78.

Pottery, 457-469.

Pousard, 465.

Powder, 253.

Power, measure of, 187.

Prehistoric inventions. (See beginning of each Chapter.)

Pressing machines, 51, 52, 53.

Priestley, 58, 453, 477.

"Princeton," The, 443.

Printing press, 2, 6, 273-291.

Prince of Orange, 255.

Projectiles, 253-270.

Prometheus, 199, 200.

Protoplasm, 67.

Prussia, 266.

Providence, R. I., Tool Co., 322.

Psalteries, 401.

Ptah, 241.

Puckle's patent breech loader, 258, 259.

Puddling, 226, 227, 231.

Pug mills, 461.

Pullman car, 107.

Pulp, 275-279.

Pumps, 187.

Ptolemy, 428.

Puillet, 411.

Puy Guillaume, battle of, 1338, 253.

Pyramids, 34, 93.

Q.

Quadruplex telegraphy. (See Telegraphy.)

"Queen Ann's Pocket Piece," 256.

Queen of Sheba, 326.

Quern, 45.

Quilting machine, 324.

R.

Radcliffe, 305.

Radiation and radiators, 205, 206.

Railways, rails and tracks, 106, 108;
cars, 108, 109;
frogs, 108.

Railway cars, 436, 437.

Rakes. (See Agriculture.)

Ramage Press, 281.

Ramseye, David, 1630, 76.

Ramelli, Cardan, 75.

Ramsey, David, 1738, 168, 389.

Ram, water. (See Pumps.)

Randolph, David M., 367.

Randolph, Elder and Co., 440.

Ranges. (See Stoves.)

Range finder, 413.

Raphael, 418.

Rawhides. (See Leather.)

Read, Nathan, 1791, 87.

Reapers. (See Harvesters, 32, 33, 36, 37, 38.)

Reichenbach, 382.

Reis, Prof., 141, 407.

Refining metals, 227.

Refrigeration, 213, 214, 216.

Regenerators, 465.

Regenerative furnace. (See Metallurgy, also, 464.)

Registers, 395.

Regulators, Electric, 137;
time, 137.

Rennie, 244.

Repeating watches, 389.

Reservoirs, 166, 180.

Resonators, 404.

Revault, 1605, 75.

Revolvers. (See Fire Arms.)

Rhode Island, 298.

Ribbon making, 306.

Rickel, Dr., 451.

Rider bridge, 103.

Riehle, testing mach., 398.

Rifles, 258, 259, 260.

Rifled cannon, 262, 263.

Ring frame-spinning, 302.

Ritter, 118, 121.

Riveting, 176.

Road carriage, steam, 83.

Roads, 106, 107.

Road making, 106.

Robia, Luca della, 459.

Robert, Louis, 276.

Roberts, 244.

Rock drilling, 107.

Rockers, ore, 235.

Rockets, 253.

Rodman, General, gun, 264.

Roebling, John A., engineer, 98, 99.

Roebling, Washington, 98, 100.

Roentgen, X rays, 149.

Rohes, M. Beau de, 189.

Rogers, Saml. B., metallurgist, 229, 230.

Rogers, type maker, 289.

Roller press, 283, 284.

Roman arts, inventions, etc., 10, 13, 14, 45, 93, 164, 166, 178, 202, 274, 457, 459.

Rookwood pottery, 467.

Romagnosi, G. D., 121.

Roscoe, Prof. (See Chemistry.)

Rose, H., 238.

Rotary engines. (See Steam.)

Rotary printing press, 284. (See Printing.)

Rotary pumps. (See Water and Steam Eng.)

Roving, spinning, 298, 299.

Rubber, 69, 434.

Ruhmkorff coil, 132.

Rumford, Count, 63.

Rumsey, James, 81, 168.

Russia, 40, 254, 430.

Russian leather, 362.

Rust, Saml., 282.

Ruth, 16.

S.

Sabot, projectiles, 262, 263.

Safes and locks, 420-427.

Safety valves, 87.

Saint, Thomas, sewing machine, 311.

Salman, scales maker, 396.

Salonen, 1807, mower, 36.

Samians and Samos, 459.

Sand blast, 332, 334, 475.

Sand filters. (See Filters.)

Sandwich, Earl, 1699, 25.

Saracens, 274.

Sarnstrom, Prof., 234.

Savery, Thos., 5, 77.

Saws, 340, 341, 342, 348, 351.

Saw mills, 341, 342.

Saxton, Jos., 131.

Scales, 395.

Scaliger, 183.

Scandinavians, 363.

Scarborough, 85.

Schilling, Baron, 126.

Schönbein, 270.

Schapper, Hartman, 241.

Schoeffer, Peter, 270.

Schreiber, 403.

Schrotter (matches), 200.

Schweigger, S. C., 126.

Scoops, 178.

Scotland, 19, 20, 33.

Scott, phonautograph, 141, 407.

Scott, Sir Walter, 45, 80.

Scott, Gen. W., 260.

Scott, Rich'd, 420.

Scouring machines. (See Leather and Cloth, and Grain.)

Screw, Archimedean. (See Ships and Propeller.)

Screw, press, 52.

Screw propeller, 85, 443.

Screw making, 245, 246.

Scythians, 362, 428.

Scythes, 32, 33, 35.

Seed drills, 24, 25, 26, 27.

Seely, F. A., 3.

Self-playing Instruments, 406.

Seguin, 83.

Sellers, Wm., 234, 247.

Separators, Grain, 48, 49;
milk, 54;
ore, 379. (See Mills.)

Seppings, Sir Robert, 440.

Serrin, 137.

Serviere, 166.

Seward, Wm. H., 3.

Seven Wonders, The, 34, 35.

Sewing machines, 311-323.

Sewer construction, 107.

Shades and screens, 356.

Shaping machines, 245.

Sharp's carbine, 267.

Shaw, Joshua, 260.

Sheele, 415.

Sheet metal ware, 250.

Shells, 264.

Shingle making, 350.

Shinar, Brick making in, 457.

Ships, war, and others, 261, 343, 438-449.

Shoes and machinery, 365-371.

Sholes, inventor, type writing, 286.

Shrapnel, 259.

Shuttles, 293. (See Textiles.)

Sickle, 32, 33.

Side wheel steamboats, 85.

Siemens, Dr. Werner, 133.

Siemens, Wm., Sir., 144, 171.

Siemens and Halske, 144, 146.

Siemens, C. L., 147, 234, 465.

Silk making. (See Spinning.)

Silk, artificial. (See Glass.)

Silver, 219.

Singer, sewing machine, 319, 320.

Sinking shafts, Mode of, 106, 107.

Skiving. (See Leather.)

Slade, J. T., 155.

Slater, Thomas, 298.

Slaughtering, 55.

Sleighs, 430, 431.

Slide, rest, 243, 349.

Slotting machines, 245.

Small arms, 266. (See Ordnance.)

Small, Jas., 1784, 18.

Smeaton, 87, 105.

Smelting, 220. (See Metallurgy.)

Smiles, Self Help, 95.

Smith & Wesson, revolvers, 269.

Snellus, 234.

Snow ploughs, 109.

Soda, pulp, 278.

Solarmeter, 413.

Solomon's temple, 242.

Somerset, Marquis of Worcester. (See Steam.)

Sound, 406. (See Acoustics.)

Sowing, 23.

Spanish inventions, 25, 75, 253, 274, 280, 292.

Spectacles. (See Optics.)

Spectrum, analysis, 60, 61, 62, 63, 412.

Spectroscope, 2, 412.

Speed Indicators, 396.

Spencer, gun, 267.

Spencer, metal coating, 249.

Spinet, 402.

Spinning, 6, 292, 296, 300. (See Textiles.)

"Spinning Jenny," 297.

Spinning Mule, 297, 300.

"Spiritalia," 404.

Splitting, leather, 366.

Spooling, 302.

Springfield musket, 268.

Spun glass. (See Spinning and 474.)

Stamp mills and metal working, 236, 250.

Standard time, 394.

Stanhope, Earl, 282.

St. Gothard tunnel, 107.

St. Louis bridge, 102.

Steam engines, 2, 5, 73 to 95;
boilers, 86;
heating, 207;
pumps, 79, 81, 88.

Steam ships, 2, 84, 85, 440.

Stearns, 145.

Steel, manufacture of. (See Metallurgy.)

Steinheil, 126, 412.

Steinway, pianos, 403.

Stenographing, 290.

Stereoscope, 410, 411.

Stereotyping, 281.

Sterilisation, 54, 213.

Stephenson, Geo., 82, 83, 84, 85, 98.

Stephenson, Robert, 98, 100, 101, 155.

Stevens, John C., 84, 85, 86, 443.

Stevinus, 166.

Stitching machines. (See Sewing.)

Stocking making, 307.

Stone cutting, carving and dressing, 374, 375.

Stone crushing, 376.

Stone, artificial, 468.

Storage battery, 120.

Storm, W. M. (Gunpowder Engine,) 192.

Store service, 152, 153, 158, 159.

Stoves, 200-206.

Street, Robert, 185.

Street sweeping, 331.

Stow, 350.

Stückofen, metallurgy, 224.

Sturgeon, inventor, 122, 123, 124.

Sturtevant, B. F. (shoes), 368.

Submarine blasting, etc., 107.

Suez canal, 107.

Sugar, 69.

Sun-dial, 384.

Subdivision of labor, 392. (See Ordnance and Sewing Machines.)

Surgery and instruments, 70.

Suspension bridges, 95, 96-100.

Swan, light, 137.

Sweden, 266.

Sweeping machines, 331.

Swiss manufactures, (See Watches, etc.)

Switzerland, 16, 46, 391.

Symington, 81, 83, 85.

Syphon recorder, 139.

T.

T-rail, 108.

Tables, 354. (See Furniture.)

Tachenius, 58.

Tack making, 344.

Tainter, C. S., 408, 414.

Takamine, 68.

Talus, or Perdix, saw inventor, 340.

Tanning. (See Leather.)

Tapestry, 275.

Teasling, 306.

Tedders, 40.

Telegraph, 124-128, 139, 140.

Telegraphic pictures, 419.

Telephone, 2, 140, 141, 142, 406.

Telescope, 2, 409.

Telpherage, 144.

Telford, 95, 96.

Tennyson, 67.

Tesla, 145.

Testing machines, 398.

Textiles, 292-309.

Thermo-electricity, 112, 120.

Theodore of Samos, 340.

Thimonnier, 313.

Thomson, Sir Wm., 63, 139.

Thompson, Robt. Wm., 433, 435.

Thompson & Houston, 137.

"Three color process," 417.

Thread making. (See Spinning.)

Threshing machines, 40, 41.

Throstle, 296.

Thurston, Prof. R. H., 86.

Tiles, 350.

Tilghman, B. F., sand blast, 332, 475.

Time locks, 425.

Time measuring of the ancients, 384.

Tissier, 238.

Tobacco and machinery, 55, 56, 57.

Tools, primitive, 310, 328, 339.

Torpedo vessels, 271, 445.

Torpedoes, 271.

Torricelli, 166, 183.

Tour, Cagniard de la, 65.

Towne's lattice bridge, 103.

Traction railways and engines, 436.

Transplanters, 29.

Transportation, 107, 109.

Treadwell, Daniel, 284.

Tresca, M., 247.

Trevithick, Richard, 81, 82.

Tripler, C. E., liquid air, 216.

Trolley lines. (See Electric, etc.)

Trough batteries. (See Electricity.)

Truss bridges, 102, 103.

Tubal Cain, 218, 239.

Tubes and tubing, making, 248.

Tubular bridges, 100, 102.

Tull, Jethro, 1680-1740, 14, 25.

Tungsten. (See Metals.)

Tunnels, 106, 107.

Turbines, 89, 168, 171, 172.

Turning, Art of, 242, 339, 344.

Tusser, Thomas, 14.

Tweddle, 176.

Twine binders. (See Harvesters.)

Twinings (inventor, refrigerator), 215.

Tympanum, 164.

Tyndall, John, 411, 412.

Type, 280, 281.

Type Distributor, 279.

Type setter, 278, 279.

Type writers, 6, 286.

V.

Vail, Alfred, 126.

Valerius, 388.

Valves, valve gear, 87, 89.

Vapor engines, 190-192.

Vapor stoves, 200-206, 212.

Varley, Alfred, 133.

Varro, 32.

Vegetable cutters, 51.

Velocipedes, 431.

Venetians, 280.

Ventilation, 209.

Veneering, 351.

Vestibule cars, 437.

Vick, Henry de, clockmaker, 387.

Victoria bridge. (See Bridges.)

Vienna, 38.

Vienna exposition, 348.

Vince, Leonardo de, 75.

Virgil, 32.

Virginal, 6, 402.

Vitruvius, 227.

Volta, voltaic electricity, 112, 117, 118, 112 to 120, 125, 133, 134, 249.

Von Alteneck, H., 138.

Von Drais, 432.

Vortex theory, 2;
  Vortex wheel, 171.

Voting machines, 395.

Vulcan, 246.

Vulcanisation. (See Rubber.)

W.

Waggons, 431.

Walker, John (matches), 200.

Walker, Joseph, 367.

Wales, Thos. C., 477.

Wallace and Maxim, 137.

Wall paper, 275, 279.

Walter, John, 285.

Watches, 391. (See Clocks.)

Waltham watches, 393.

War, effect on by inventions, 271, 272.

Washington, 15, 16.

Washing and ironing machines, 335-338.

Wasp, first paper maker, 273.

Watches. (See Horology.)

Water. (See Hydraulics.)

Water clocks, 385, 386.

Water closets, 178.

Water distribution, 167, 178;
gas, 454.

Water wheels, 165;
mills, 167;
engines, 178.

Water frame. (See Spinning.)

Water metres, 178;
scoops, 178.

Watts' Dictionary of Chemistry, 59.

Watt, James, 5, 8, 78, 79, 80, 81, 86, 154, 167, 170, 176, 182, 203, 206, 296, 341, 460.

Watson, Bishop, 451.

Weaving, 6, 292, 304. (See Textiles.)

Weaver's shuttle, 307.

Weber piano, 403.

Webster, Daniel, 91.

Wedgwood, 459, 460, 464.

Weeks, Jos., 364.

Weighing, scales, etc., 396, 397, 398.

Weisenthal, C. F., 310, 312.

Welding, 248.

Wellington, Duke of, 83.

Wells, making and boring of, 373, 379-383;
driven, 382;
Artesian, 381.

Welsbach lamp, 456.

Westinghouse, electric light, 137, 138.

Weston, Sir Richard, 14.

Weston, electrician, 137.

West (destroyer of bacteria), 213.

Whaleback ships, 438.

Wheat, its cultivation, 25, 26.

Wheatstone, Chas., 127, 133, 146, 147, 410.

Wheeler and Wilson, 319.

Wheelbarrow, seeder, 24.

Whewell, 166.

Whitehurst, Geo., 168.

Whitney, Eli, cotton gin, 42, 43, 297.

Whitworth, Sir J., 244, 246, 263.

Wilde, electric magnet, 133.

Wilder, safes, 421.

Wilkes, 277.

William of Malmesbury, 75.

Wilson, A. B., sewing machinery, 319.

Wilson, Genl. John M., 180.

Winchester rifle, 267.

Wind mills, wheels, etc., 404. (See Mills.)

Window glass, window screens, 359.

Wine making. (See Chemistry.)

Winter, Sir John, 225.

Wire working, 250.

Wire wound gun, 263.

Wireless telegraphy, 150, 151.

Wolf, aeronaut, 447.

Wöhler, chemist, 238.

Wollaston, 60, 249, 412.

Woodbridge, Dr. W. E., 262, 263.

Woodbury, Oscar D. and E. C., 330.

Woodworth, Wm., planing machinery, 349.

Wood, lathe turning, 344.

Wood, bending and trenting of, 347, 352, 356.

Wood working machinery, 242, 339, 352, 369.

Woods, variety and beauty, 352.

Wood carving, 346.

Wool. (See Spinning, Weaving, Textiles.)

Wool, mineral, 474, 480.

Wooden shoes, making of, 367.

Worcester, Marquis of, 5, 75, 77, 81.

Work shop, a modern, 251.

World's fair, 1851, 36, 38.

Woven goods, variety of, 308, 309.

Wright (gas engine), 188.

Wren, architect, 209.

Wyatt of Lichfield, 294, 295.

X.

X rays, 149, 150.

Xyloplasty, 347.

Y.

Yale, Linus, Jr., locks, 425.

Yankee clippers, 438.

Yarn. (See Weaving, etc.)

Yeast, 65.

York, Duke of, 124, 125.

Young of America, 63, 417.

Young, Arthur, 1741-1800, 14, 15.

Youmans, Prof., 450.

Z.

Zanon, 1764, 24.

Zech, Jacob, 388.

Zeppelin, Count, 446.

Zimmermann, self-playing pianos, 406.

Zinc, 236.

Zinc batteries. (See Electricity.)

Economic and Industrial Progress of the Century.	By H. de Beltgens Gibbins, D. Lit., M. A., F. R. G. S.
Inventions of the Century.	By William H. Doolittle.
Wars of the Century, and the Development of Military Science.	By Professor Oscar Browning, M. A.
Naval Battles of the Century.	By Rear-Admiral Francis John Higginson.
Naval Development of the Century.	By Sir Nathaniel Barnaby, K. C. B.
Presidents of the United States in the Century (from Jefferson to Fillmore).	By Francis Bellamy.
Presidents of the United States in the Century (from Pierce to McKinley).	Francis Knowles.
The Fine Arts in the Century.	By William Sharp.
Progress of Education in the Century.	By James Laughlin Hughes and Louis R. Klemm, Ph. D.
Temperance and Social Progress of the Century.	By the Hon. John G. Woolley, M. A.
Progress of Science in the Century.	By Professor J. Arthur Thomson, M. A.

Edinburgh: Printed by W. & R. Chambers, Limited.