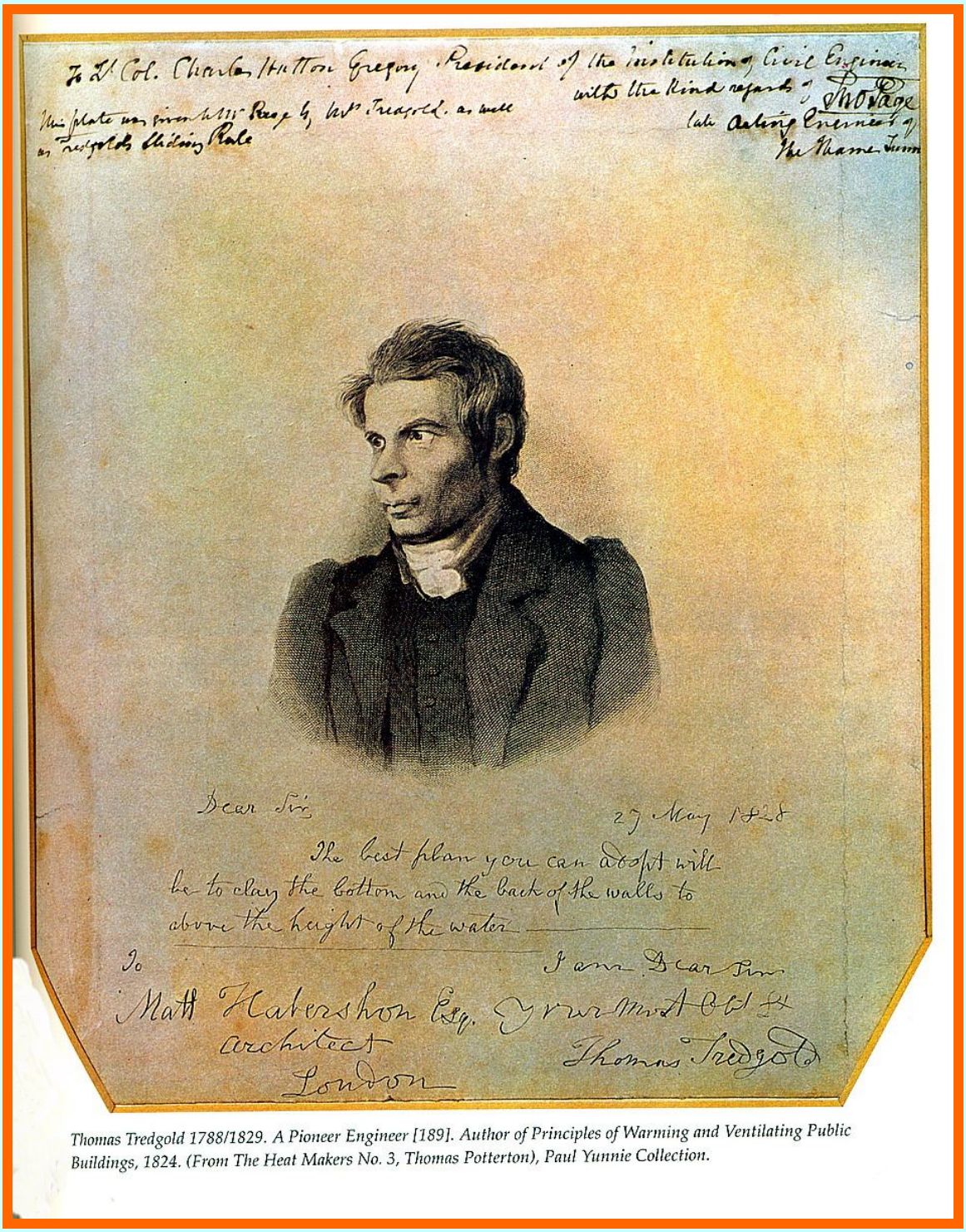
The COMFORT PIONEERS

Pages 63-80



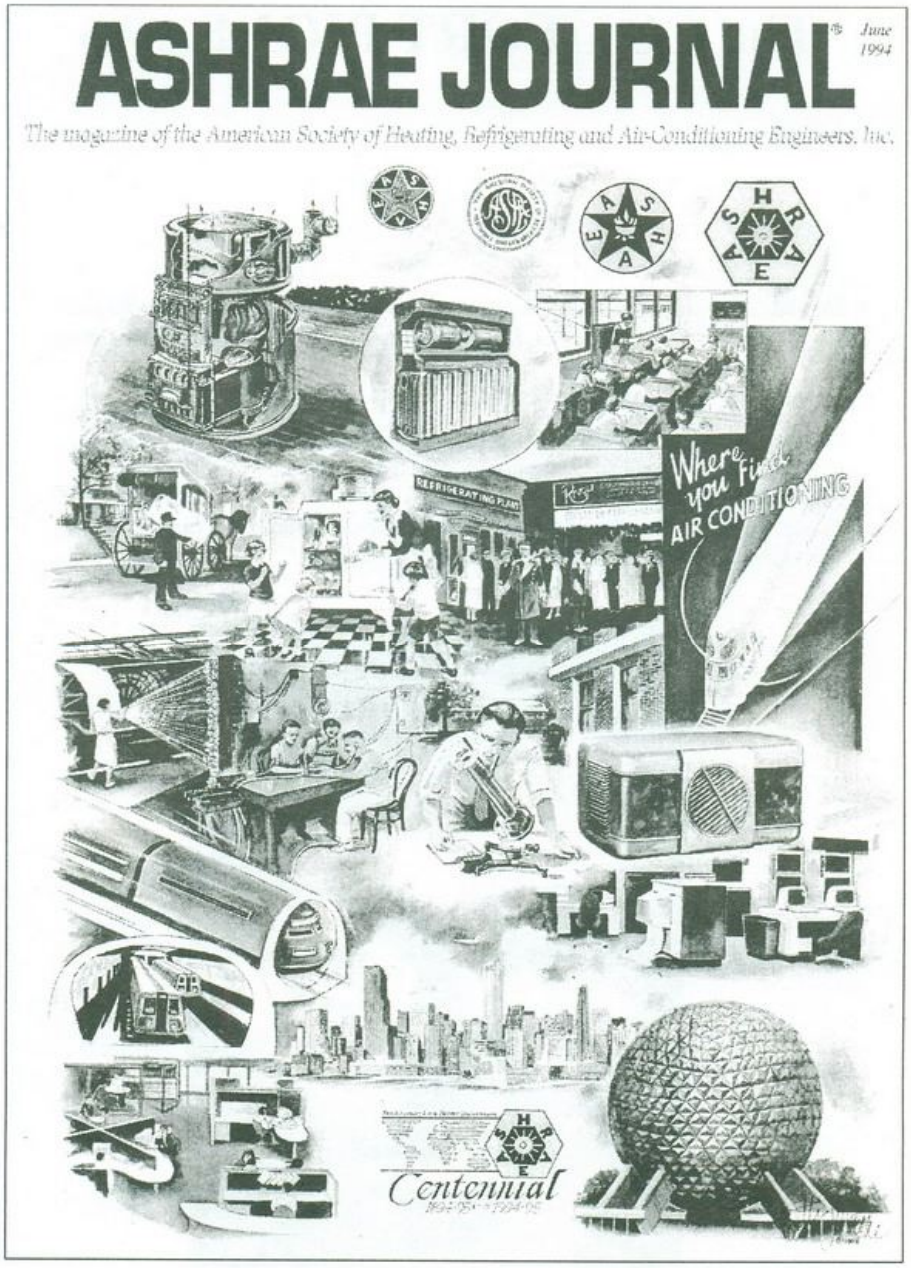
Thomas Tredgold 1788/1829. A Pioneer Engineer [189]. Author of Principles of Warming and Ventilating Public Buildings, 1824. (From The Heat Makers No. 3, Thomas Potterton), Paul Yunnie Collection.

The COMFORT PIONEERS

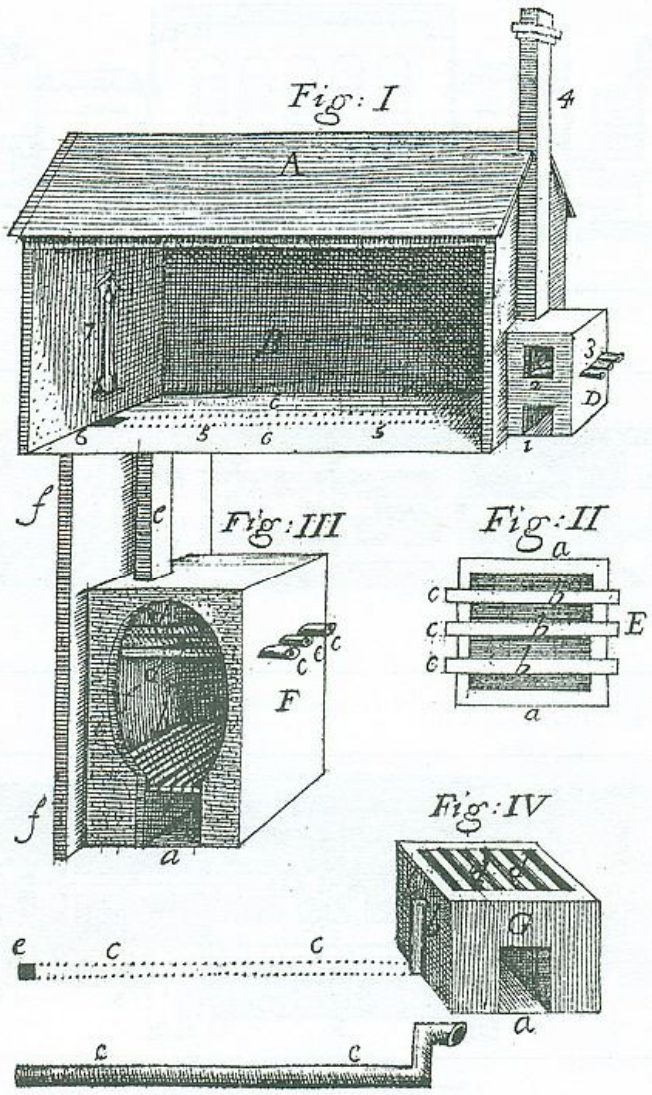
The roads you travel so briskly lead out of dim antiquity, and you study the past chiefly because of its bearing on the living present and its promise for the future.

Lt. Gen. James G. Harbord, 1866-1947.
U.S. Army and American Member of Council at London,
The Newcomen Society of England.
Quoted on the back cover of *Dr. Willis H. Carrier: Father of Air Conditioning*,
Newcomen Society, New York, 1949.

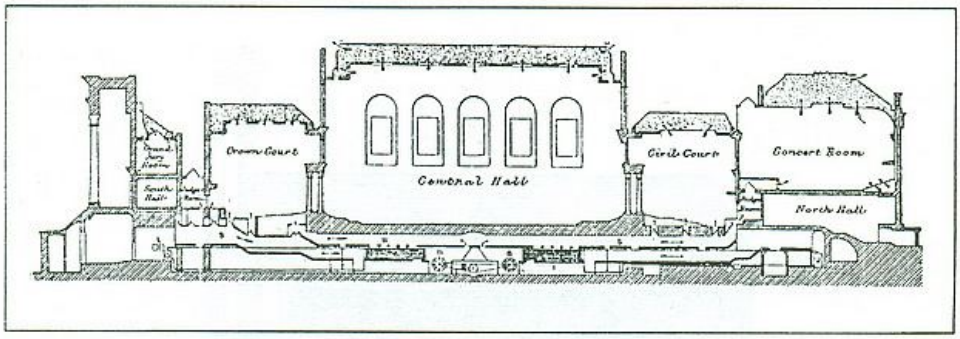
Nicolas Léonard Sadi CARNOT [159]



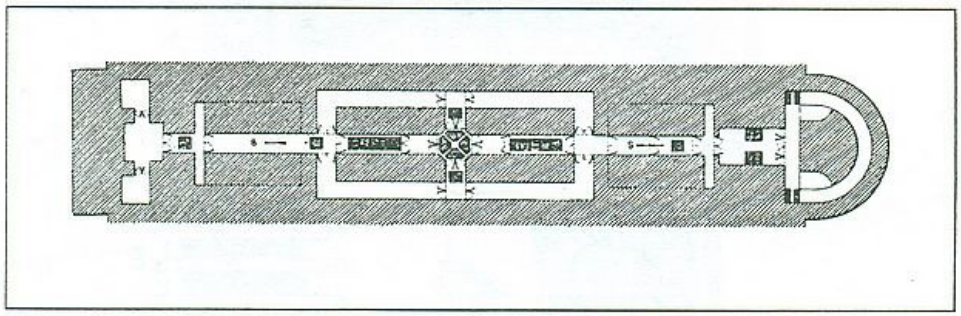
26. The Comfort Pioneers.
ASHRAE Journal, *June 1994, front cover.*



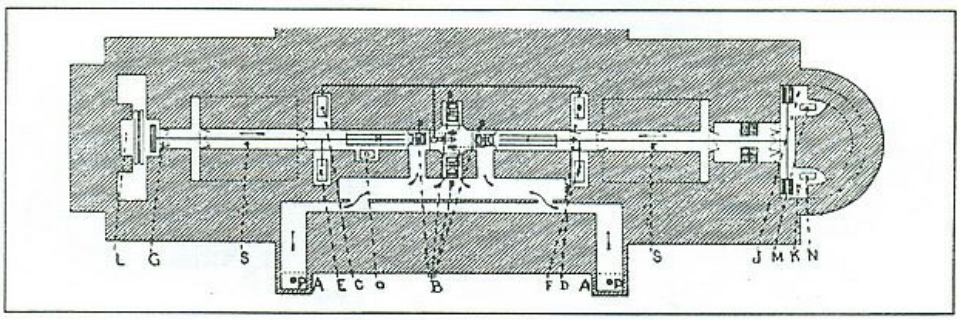
27. John Evelyn's Greenhouse Furnace, 1664.
Kalendarium Hortense, *1691.*



a. Longitudinal section of St. George's Hall.



b. Basement plan, St. George's Hall, at level of upper air channels.



c. Basement plan, St. George's Hall, at level of lower ducts.

28. *Section and Plans: St. George's Hall, Liverpool, 1854.*
The Mechanical Ventilation and Warming of St. George's Hall, Liverpool, The Heating and Ventilating Magazine, *October 1907.*

An appreciation of the work of some of the early pioneers is given by the late Gershon Meckler in his introductory essay **51.** *to the ASHRAE Centennial Book (1994),* **99.** *by Donaldson and Nagengast.*

[136] EMPEDOCLES c. 493-433 B.C.

Born in Silicy. Greek philosopher. Put forward a theory of four indestructible elements, fire, air, water, and earth, of which, variously blended, all material substances are composed. This idea was taken up and improved on by Aristotle, who identified the four qualities dry, wet, cold, and hot.

[137] Gauis Sergius ORATA active c. 80 B.C.

Roman businessman. Lived near Naples. He described the heating of fish ponds and oyster ponds and the development of the heating of baths by means of warm air ducts under the floor. It is recorded: "Builders learned to apply the Oratan systems, called a 'hypocaustum' (from the Greek words for 'under' and 'burning') to whole buildings. Romans who went to live in the northern provinces of the Empire built 'hypocaust' houses."

99. *Donaldson and Nagengast, p. 5.*

[138] Leonardo DA VINCI 1452-1519

Florentine artist. Military engineer and scientific observer. Drew all sorts of mechanical devices and war engines. He proposed an odorless toilet, a cooking spit driven by a chimney fan (powered by the hot rising gases), and an anemometer. Said to have constructed the first elevator, including one for the Milan Cathedral. Produced amazing drawings relating to hydraulics and water flow, including a jet issuing from an orifice. The works of da Vinci had a profound effect on later scientists and researchers.

Leonardo (in three volumes: The Inventor, The Scientist, The Artist*), Hutchinson, 1981.*

[139] Francis BACON 1561-1626

English philosopher. Also, member of Parliament, lawyer, scientist, and essayist. Prominent at the Court of Elizabeth I; later a favorite of James I, becoming Lord Chancellor, then Baron Verulam. Shortly after becoming Viscount St. Albans (1821), he fell from grace. Summarized much of his scientific and philosophical ideas in *Novum Organum* (1620). He concluded, "Heat is an expansive motion restraining and striving to exert itself in the smallest particles." Bacon advocated rational experimentation to uncover the fundamental laws of nature. He was said to have been unprincipled and the Pope described him as "the wisest, brightest, meanest of mankind." We are told Bacon jumped out of his coach in a snowstorm on Highgate Hill (North London) to stuff a dead hen with snow to prove his theory that cold could delay putrefaction. For this exploit, from which it is said he caught a fatal chill, Bacon has been called the "Father of Refrigeration" (though a number of ancient civilizations, including the Chinese, the Egyptians, and the Romans, used ice and snow to cool drinks, the Romans also cooling fish and fruit in the time of Nero).

20. *David, p. 66.* 98. *Billington and Roberts, p. 239. Portrait is a detail from the frontispiece of the first history of The Royal Society of London for Improving Natural Knowledge, Thomas Sprat (later Bishop of Rochester), 1667 (The Royal Society).*

[140] Otto von GUERICKE 1602-1686

German physicist and engineer. Appointed Mayor of Magdeburg (1646), serving for 35 years. Became interested in philosophic arguments regarding the existence of a vacuum and decided to settle this by practical methods. Constructed the first air pump and experimented with evacuated vessels. In his famous demonstration (1654), he used two metal "Magdeburg" hemispheres that fit together along a greased flange. After evacuation of the air inside, teams of eight horses pulling in opposite directions failed to separate the two halves. This led to the historic work on the physical properties of gases by Boyle [142].

Portrait from 124. *p. 17.*

[141] Evangelista TORRICELLI 1608-1647

Italian physicist. Succeeded Galileo [117] as court mathematician to the Grand Duke of Tuscany. Urged by Galileo to find out why ordinary lift pumps could not raise water more than 32 feet, he suspected atmospheric pressure played a role. Torricelli then devised a mercury barometer (1643) and demonstrated both atmospheric pressure and the existence of a vacuum prior to the classic demonstration of Guericke [140].

[142] Robert BOYLE 1627-1691

Physicist and scientist. Born in Ireland. Influenced by Bacon [139]. Came to believe in the value of experimentation. After hearing of the experiments of Guericke [140], he set about building his own air pump. Ably assisted by Hooke [119], his investigations were reported in his *New Experiments Physico-Mechanical Touching the Spring of the Air and its Effects* (1660). This led to his important conclusion, now known as Boyle's Law (1662), on the behavior of gases. Boyle was a principal player in the early days of the Royal Society. He experimented with freezing mixtures, publishing the results in *Experimental History of Cold*, and has been called "the man who opened the door to the science of refrigeration."

Portrait by permission of the President and Council of Royal Society.

[143] Sir Isaac NEWTON 1642-1727

English scientist and mathematician. Universally acknowledged as one of the greatest thinkers of all time for his work on gravitation, the laws of motion, calculus, astronomy, and optics. Carried out thermometric experiments and stated what is now termed *Newton's Law of Cooling* (1701). He and Hooke [119] were in continual conflict. Newton was elected President of the Royal Society (1703) but only after Hooke's death. Pope wrote, "Nature and Nature's laws lay hid in night:/ God said, Let Newton be! and all was light."

Portrait from 4, January 1982, p. 10.

[144] Daniel BERNOUILLI 1700-1782

Swiss mathematician (born in the Netherlands). Professor of Physics at Basle. Made significant contributions to the study of fluid flow in *Hydrodynamica* (1738), containing the outline of the now famous *Bernouilli Equation*. Also pioneered the kinetic theory of heat.

[145] Edward Gerald NAIRNE 1726-1806

Scottish researcher. Continued some of the research started by Cullen [76]. Observed the strong absorption of water in concentrated sulfuric acid in an evacuated bell jar (1777), the fundamental principle of the absorption refrigerating machine, using water as refrigerant. This idea was later developed by Leslie [150].

[146] Joseph BLACK 1728-1799

Scottish chemist (born in France). Student of Cullen [76]. Considered the founder of scientific calorimetry. Clarified the concepts of quantity of heat, intensity of heat (temperature), and specific heat (1757-1764). Experimented with melting ice and boiling liquids. Introduced the idea of *calicorum latens* (1761). This "latent heat" concept was employed by Watt [13] in developing the steam engine.

Portrait from 46. *p. 38 (drawn by Michael Ayrton).*

[147] Joseph PRIESTLEY 1733-1804

English Unitarian church minister. Said to have embarked on a scientific career after meeting Benjamin Franklin [8]. Wrote histories of electrical research and optics before turning to chemistry. Discovered (1750s) "fixed air" (carbon dioxide). Later (1774) isolated "dephlogisticated air" afterwards recognized (1777) as oxygen by Lavoisier [148]. Priestley demonstrated that fixed air would not support combustion and that mice soon died when placed in it. He found that in dephlogisticated air "a candle burnt...with a remarkably vigorous flame" and he studied the respiratory response of a mouse placed in it. Spent his last years in the United States (from 1794), where he gained the friendship of Thomas Jefferson [188] and returned to religion.

Portrait from 119. *p. 501 (Engraving by W. Holl after a painting by Gilbert Stuart).*

[148] Antoine Laurent LAVOISIER 1743-1794

French chemist. Often called the "Father of Modern Chemistry." Constructed the first table of elements and helped establish the metric system. His many interests included street lighting, the manufacture of gunpowder, and the process of combustion. He met Priestley [147] and, repeating his experiments with air, discovered and named oxygen. He also studied the behavior of animals in air, oxygen, and nitrogen and measured the amount of metabolic heat they produced. There were two actions he would later regret. He became a farmer-general (tax-collector), and he made an enemy of Jean-Paul Marat. Worked with the young Laplace (1782-1784) on heat, perfecting the "ice calorimeter" of Black [146]. Later, he published his *Elementary Treatise on Chemistry* (1789), the year of the French Revolution. In due course, as a tax-collector, he was arrested; the officer remarked, "The Republic has no need of scientists." His trial was a farce, with Marat, who became a revolutionary leader, eager to settle old scores. Marat was assassinated (1793), but Lavoisier still went to the guillotine.

[149] Jacques Alexandre César CHARLES 1746-1823

Professor of Physics, Paris. Friend of Franklin [8]. Studied the properties of gases and established the relationship between pressure, volume, and temperature. Sometimes called *Charles' Law* but he did not publish his findings, which were later repeated by Gay-Lussac [154]. He also constructed the first hydrogen balloon (1783).

[150] Sir John LESLIE 1766-1832

Scottish Professor of Mathematics at Edinburgh. Improved on the earlier laboratory cooling researches of Nairne [145] and was able to make 2.7 kg of ice in less than an hour (1810). (Later 1824, John Vallance of Brighton improved on this apparatus.) Experimented with absorption refrigeration and provided the scientific basis for its later commercial development. Suggested that artificial cooling be introduced into hospitals and aboard ships (1813).

Portrait from Smithsonian Institution, Division of Engineering and Industry.

[151] John DALTON 1766-1844

English chemist. Professor at Manchester. Famed for his meteorological observations. Studied the composition of air and created what is now known as *Dalton's Law of Partial Pressures* (1801). He developed atomic theory and published *New System of Chemical Philosophy* (1808). His work contributed to the later development of air-cycle refrigeration and, in time, to the development of psychrometric charts and tables, an indispensable tool of the air conditioning engineer.

Portrait from 46, *p. 50* *(Drawn by Michael Ayrton).*

[152] Jean Baptiste Joseph FOURIER 1768-1830

French mathematician. Professor at military school. Accompanied Napoleon to Egypt (1798) where he served as a governor. Later, turned heat studies into a theoretical science. Made a Baron (1808) then joint secretary of the Academy of Sciences (1822). In his paper *The Analytic Theory of Heat* (1822), he presented mathematical theories of heat conduction and radiation. Fourier believed "heat to be essential to health so he always kept his dwelling place overheated."

[153] Sir Humphry DAVY 1778-1829

English chemist. Influenced by the writings of Lavoisier [148] but disagreed with his caloric theory, believing instead that heat was a form of motion. Discovered nitrous oxide (1800). Appointed by Rumford [15] lecturer at the Royal Institution, London (1801). Famous for his electrical experiments, demonstrated his arc lamp (1808) and invented the miners' safety lamp, or Davy Lamp (1815). Took responsibility for improving the ventilation of the House of Lords (1811), providing numerous holes in the floor for air distribution, combined with ceiling screens and heated metal tubes to accelerate the upward air movement. As recounted, "For boring twenty-thousand holes/ The Lords gave nothing. Damn their souls." Some consider Davy's most far-sighted decision was the appointment of the young Faraday [158] as his assistant (1813).

[154] Joseph Louis GAY-LUSSAC 1778-1850

French Professor of Chemistry, Paris. Established rules relating to the expansion of gases (1802), the *Gay-Lussac Law* (earlier discovered by Charles [149], who did not publish his findings). This work led to Avogadro's hypothesis that equal volumes of different gases at equal temperatures contain equal numbers of particles. Gay-Lussac made important improvements in a number of industrial processes, including the manufacture of sulfuric acid.

[155] William PROUT 1785-1850

English chemist and physiologist. Pioneered research into organic chemistry and the digestive system. Investigated the concentration in air of carbon dioxide resulting from respiration and perspiration, a subject later researched by Pettenkofer [165].

[156] Pierre Louis DULONG 1785-1838

French Professor of Physics. His most important work was on specific heats, in collaboration with Petit [157]. Together they studied the heat loss from surfaces by radiation and convection. Dulong also studied respiration in humans.

[157] Alexis Thérèse PETIT 1791-1820

French Professor of Physics. Best known for his collaborative heat transfer research with Dulong [156].

[158] Michael FARADAY 1791-1867

Outstanding English physicist and chemist. Initially assistant to Davy [153]. Renowned for his electrical discoveries, particularly magnetic induction (1831), which led to the generation of electricity and the electric motor. He studied the liquefaction of gases and was able to liquefy (from 1823) chlorine, ammonia, and carbon dioxide—important for the later development of refrigerating machines. He is commemorated by the name *farad*, given to the SI unit of electric capacitance.

Portrait from 115. *p. 43.*

[159] Nicolas Léonard Sadi CARNOT 1796-1832

Military engineer and French physicist. Studied heat engines (from 1819). Published *Reflections on the Motive Power of Heat and on Machines Appropriate for Developing this Power* (1824), which "secured a place for Carnot among the immortals of science." This work led to the later formulation of the Second Law of Thermodynamics by Clausius [167] and Kelvin [168]. Carnot conceived an ideal, reversible engine cycle, the "Carnot Cycle," which came to form the basis of the study of mechanical refrigeration. Though he used the caloric theory of heat in his analysis, most historians now agree his notes show he had serious doubts about it. Through his brilliant work, Carnot is generally regarded as the founder of thermodynamics. He died of cholera at an early age.

51. *Meckler, pp. xvi-xvii. Portrait from* 4. *April, 1982, p. 257.*

[160] James APJOHN 1796-1886

Irish chemist. University of Dublin. Put forward the theory of adiabatic absorption of moisture by air (1835-1836) but was unable to prove it. This was that the wet-bulb temperature was related to the total heat (enthalpy) of moist air, a fundamental of psychrometrics.

[161] James GLAISHER c. 1808-1903

English meteorologist. Made what was probably the first attempt to tabulate psychrometric data (1847). He computed reliable tables of the stationary wet-bulb and dry-bulb temperatures. These were used in the *Cotton Cloth Factories Act* (1889).

[162] Julius Robert von MAYER 1814-1878

German physicist. Trained as a physician and while serving as a ship's doctor became interested in animal heat. His resulting paper (1842) presented a value for the mechanical equivalent of heat. Along with Joule [163] he recognized the principle of the conservation (indestructibility) of energy. His work was virtually ignored, and after attempting suicide, he was committed to a mental institution (1851). Later released, it was only near the end of his life that his work was recognized.

[163] James Prescott JOULE 1818-1889

English physicist. Son of a wealthy brewer. Suffered poor health, so his father provided a home laboratory. He was tutored by Dalton [151] and influenced by Faraday [158]. Showed exceptional aptitude for experimental work, his efforts culminated in a paper (1845) on the free expansion of compressed gases and when (1850) he derived a value of 772.5 footpounds of work per British thermal unit as the mechanical equivalent of heat. His initial work gained little attention until cited by Helmholtz and Kelvin [168]. Joule subsequently presented his paper to the Royal Society when Faraday was his sponsor. He was elected Fellow (1850) and was awarded their medal (1856). He is commemorated by the name *joule*, given to the SI unit of energy, work, quantity of heat.

[164] William John Macqourn RANKINE 1820-1872

Scottish engineer. Trained in physics. Took up civil engineering. Professor of Engineering at the University of Glasgow (1855). Designed a fan with a spiral, or scroll-shaped, housing (1857). Wrote *Manual of the Steam Engine* (1859) and "introduced working engineers to the realm of thermodynamics."

[165] Max Joseph von PETTENKOFER 1818-1901

German chemist. Obtained medical degree at Munich (1843). Studied under the famous German chemist Liebig. He specialized in hygiene, being appointed professor in this subject at Munich (1865). Like Reid [58] earlier, Pettenkofer made a particular study of the effects of ventilation on health. Through the generosity of an enlightened Elector of Bavaria, he built a human respiration chamber, where his researches included measurement of the exhalation of carbon dioxide at varying rates of activity.

Portrait from the program of CIBSE Heritage Group Christmas Lecture 1997 on Pettenkofer (by Harald Loewer, Technical University of Hamburg).

[166] Florence NIGHTINGALE 1820-1910

English nurse. Ran the military hospital at Scutari (from 1854) during the Crimean War and later at Balaclava. Became immortalized as "the Lady of the Lamp." Battled incessantly against incompetence and medical jealousy to successfully introduce cleanliness and sanitation. Finally a Royal Commission on the Sanitary Condition (health) of the Army was appointed (1857). Her privately printed *Notes* stressed the importance of general hygiene and her phrase, "Our soldiers enlist to die in the barracks," caught the public ear. The battle against officialdom continued for many years. She acquired Galton [171] as a useful ally. After visiting hospitals across Europe, she reached the conclusion that lack of drainage and ventilation was a prime cause of patient deaths and in *Notes on Hospitals* (1859) championed the "Pavilion" layout. She became involved in hospital design and construction, including the new St. Thomas's, London (1871), where she insisted on the importance of natural ventilation and free circulation of air. Though a virtual invalid in later life, Nightingale devoted herself to reform of the living conditions of soldiers in India. She was the first woman to be awarded the Order of Merit (1907).

Florence Nightingale, *Elspeth Huxley, Weidenfeld and Nicolson, 1975.*

[167] Rudolf Julius Emanuel CLAUSIUS 1822-1888

German theoretical physicist. Contributed to the kinetic theory of gases. In a classic paper (1850) at the Berlin Academy, *On the Motive Power of Heat and the Laws Which Can Be Deduced from It for the Theory of Heat,* he brought together the ideas of Carnot [159], Mayer [162], Joule [163], and Kelvin [168]. He derived the concept of *entropy* and is generally considered the discoverer of the Second Law of Thermodynamics.

Portrait from 4. *April, 1982, p. 258.*

[168] Lord KELVIN (William THOMSON) 1824-1907

Scottish physicist. Born in Belfast. Studied physics and mathematics at Glasgow University (from the age of ten), then Cambridge University. Worked in Paris on steam thermodynamics with Regnault [234]. Enabled Joule [163] to obtain recognition for his work (1847). He proposed the absolute temperature scale, later called the *Kelvin* scale (1848). Wrote the classic paper, *On the Dynamical Theory of Heat, with Numerical Results Deduced from Mr. Joule's Equivalent of a Thermal Unit, and M. Regnault's Observations on Steam* (1850). Kelvin's outstanding contribution to HVAC&R technology was his *On the Economy of the Heating or Cooling of Buildings by Means of Currents of Air* (1852). This accorded him recognition as the inventor of the heat pump.

51. *Meckler, pp. xviii-xix.*

[169] Francois-Marie RAOULT 1830-1901

French physical chemist. His study of solutions and partial pressures led him to formulate *Raoult's Law* (1886), which is of significance in the fundamental theories of absorption refrigeration.

[170] Dr. William Henry DUNCAN 1805-1863

Medical Officer of Health for Liverpool (1847-1863) and the first in the U.K. When the original design for St. George's Hall (completed 1855) was drawn up by the architect Elmes [194], it did not include any system of heating and ventilating. It was at the instigation of Duncan that Reid [58] was engaged to undertake this task. Duncan was concerned at the way infectious diseases seemed to spread where there was a lack of adequate ventilation, for Liverpool had recently experienced severe outbreaks of cholera (1847 and 1849).

Duncan of Liverpool, *W.M. Frazier, Carnegie, 1997, with portrait from frontispiece. Early Heating, Ventilating and Air Conditioning in the United Kingdom, Paul Yunnie,* ASHRAE Trans., *1995.*

[171] Sir Douglas Strutt GALTON 1822-1899

English "man of science." His mother was related to William Strutt of Derby [22]. Captain Royal Engineers (1855). Secretary to Railway Commission. Referee for plans for main drainage of London (1857). Member Royal Commission on the improvement of the sanitary conditions of military barracks and hospitals (1858), member army Sanitary Committee (from 1862). Also involved with Atlantic telegraph cable and formation of a national physical laboratory. Galton was particularly associated with sanitary science. Designed Herbert Hospital, Woolwich (1860-1862). Invented Galton's ventilating fire grate (early 1860s) adopted for barracks and hospitals. Wrote numerous papers relating to heating, ventilating, and sanitary engineering and to hospital construction. Member many learned societies, including Chairman Council Sanitary Institute (he urged their motto should be *Prevention is better than cure*). He died of blood poisoning.

107. *Billington. Portrait from* **59.** *p. 66 (Illustrated London News).*

[172] Professor E.P. BONNESEN active 1892

Worked at the Technical College in Denmark. Credited with being among the first to carry out calculations for systems for distributing heat and air.

From **106.** *Usemann.*

[173] Josiah Willard GIBBS 1839-1903

American physicist. Ph.D. Yale (1863) then Professor of Mathematics (1871). Wrote some 400 papers including *Graphical Methods in the Thermodynamics of Fluids*. He originated temperature entropy and volume entropy diagrams and later the *Gibbs-Dalton Law* relating to the properties of mixtures. Gibbs' contributions were significant in thermodynamic analyses of heating and cooling, combustion processes, refrigerants and refrigerating machines, and he assisted technological development. Later (from 1900), his work was important to psychrometry and the understanding of air-conditioning processes. His contributions went largely unrecognized in Europe until the turn of the century.

51. *Meckler, p. xx-xxiii. Portrait from* 119. *p. 237 (Courtesy Burndy Library).*

[174] Professor Osborne REYNOLDS 1842-1912

English researcher into hydraulics. Best known for his analyses of fluid motion and for the *Reynold's number* (Re). Responsible for important improvements to the design of centrifugal pumps. Later (1875) patented the multi-stage centrifugal pump and subsequently introduced guide vanes to enable the fluid kinetic energy to be converted to pressure head within the pump, thus increasing efficiency.

98. *Billington and Roberts, p. 378.*

[175] Sir James DEWAR 1842-1923

Scottish chemist and physicist. Educated at University of Edinburgh. Professor at Cambridge (1875), then worked at the Royal Institution (1877). His most important work was in the field of low temperatures and the liquefaction of gases, stimulated by the researches of Pictet [91] and others. He invented the double-wall *Dewar flask*, or vacuum flask (1892). He was the first to prepare liquid and solid hydrogen (1898-1899).

Portrait from 46. *p. 130 (Drawing by Thomas Freeth).*

[176] Dr. Heinrich Rudolf HERTZ 1857-1894

German physicist. Studied under Helmholtz and Kirchoff. Renowned for his electromagnetic studies and the name *hertz* (Hz) describing frequency in SI units. He also devised a graphical method of defining changing conditions in moist air (1884).

From 106. *Usemann.*

[177] Dr. Mary E. PENNINGTON **active 1908**

First female member of ASRE. Chief of the Food Research Laboratory in the U.S. Department of Agriculture. Consultant on development of ice usage and cold storage. Regarded as the foremost American authority on home refrigeration. Presented paper on the influence of low temperatures upon perishable produce at the First International Congress of Refrigerating Industries, Paris (1908). Pioneered cold storage of eggs and poultry. Experimented with transportation of meat and poultry by rail using ice-wagons (from 1912). Later directed the Household Refrigeration School.

17. *Thévenot.* 94. *p. 83. Portrait from ASHRAE: 100 Years of Progress, ASHRAE Journal, June 1994, p. 36.*

[178] Dr. E. Vernon HILL **1876-1950**

American comfort researcher. ASHVE President (1920). Developed the *Synthetic Air Chart* (1922), which "offers a means of determining the percentage of perfect ventilation by considering all the known factors that make up the air conditions in a room." He also developed (1925) a set of rules, *Don'ts for Theatre Ventilation*.

94. *with portrait from p. 178.*

[179] F. Paul ANDERSON **1867-1934**

ASHVE Laboratory Director (1921-1925). During his tenure, some 62 scientific papers were published. Most notable the *Comfort Zone Chart* (1924), "superimposed upon the Effective Air Chart and can be used to determine the relative comfort of ordinary indoor conditions from the dry- and wet-bulb temperatures of the air." ASHVE President (1927). Later, Dean of Engineering at Kentucky State University until his death. The F. Paul Anderson Award (established 1930) is awarded annually by ASHRAE for notable scientific achievement relating to HVAC&R. Anderson was one of the first members inducted into the ASHRAE Hall of Fame.

ASHRAE Journal, *September 1994, p. 10.* 94. *pp. 32 and 35. Portrait from* ASHRAE Hall of Fame, *ASHRAE Headquarters.*

[180] Francis HUTCHINSON **active 1930**

American pioneer in the air-conditioning and refrigeration industry. Professor of Mechanical Engineering at the universities of Berkeley and then Purdue. Saw the potential of solar energy as a heat source with a research program for Purdue Housing Research Association. Hutchinson was a specialist in thermodynamics and heat transfer in heating and cooling panels and co-author (with B.F. Raber) of *Panel Heating and Cooling Analysis* (1947). He was one of the first members inducted into the ASHRAE Hall of Fame.

ASHRAE Journal, *September 1994, p. 10, with portrait.*