The VENTILATORS

Pages21-32

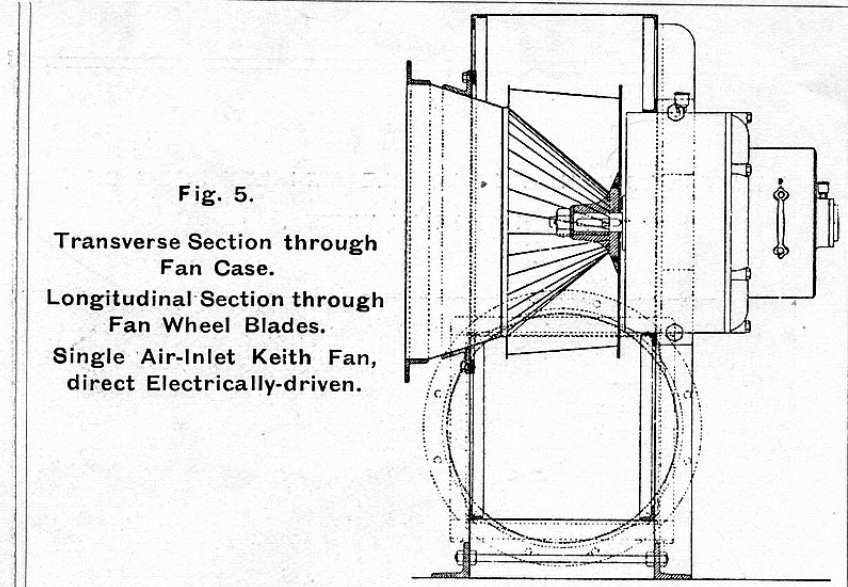


Fig. 5.

Transverse Section through Fan Case.
Longitudinal Section through Fan Wheel Blades.
Single Air-Inlet Keith Fan, direct Electrically-driven.

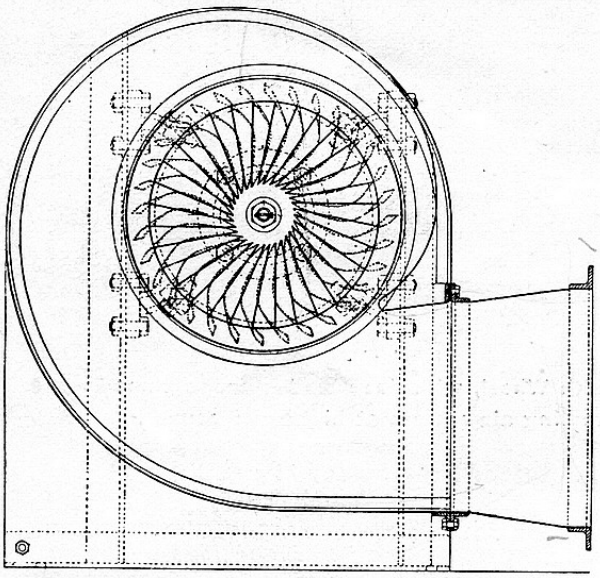


Fig. 6.

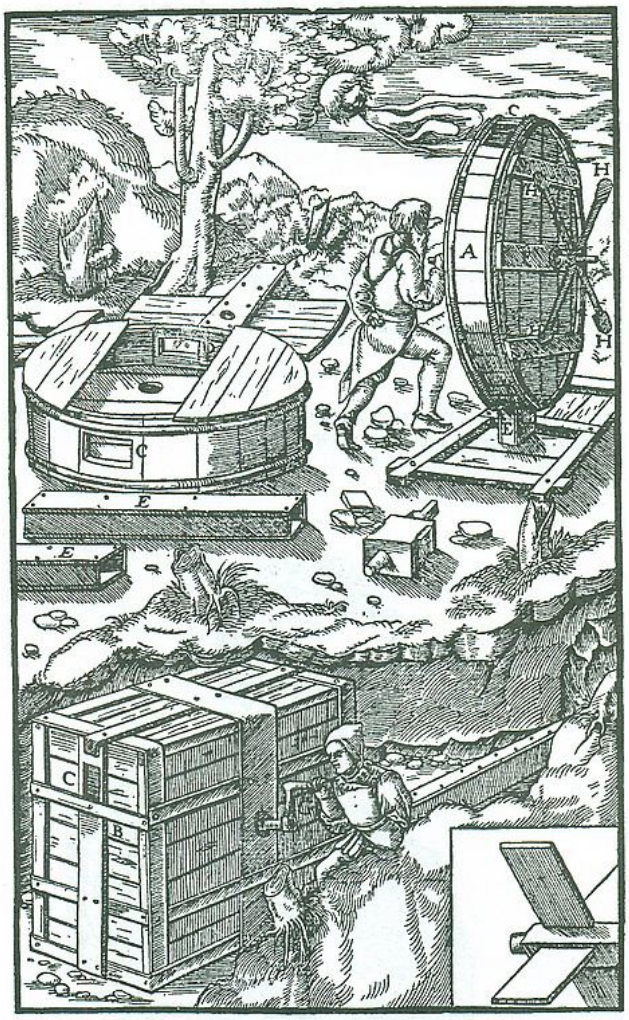
Longitudinal Section through Fan Case.
Transverse Section through Fan Wheel.
Single or Double Air-Inlet Keith Fan, direct Electrically-driven.

The VENTILATORS

I thought I heard Buddy Bolden say,
Open up that window, let the foul air get away!
Open up that window, let the foul air out!
That's what I heard him shout.

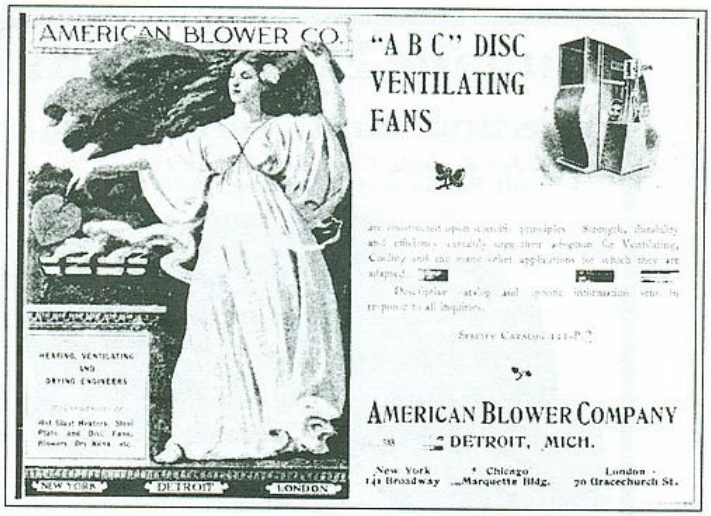
Traditional, quoted by **Reyner Banham** in the introduction to *The Architecture of the Well-Tempered Environment*, 1969.

Dr. David Boswell REID [58]

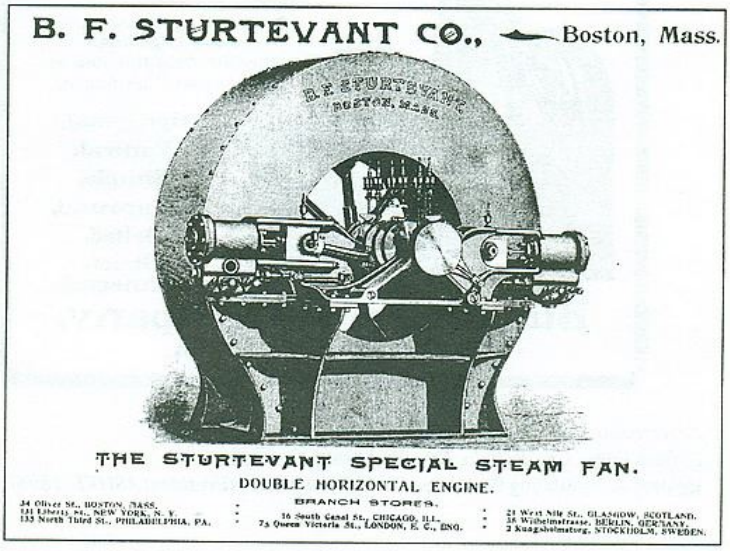


A—Drum. B—Box-shaped casing. C—Blow-hole. D—Second hole.
E—Conduit. F—Axle. G—Lever of axle. H—Rods.

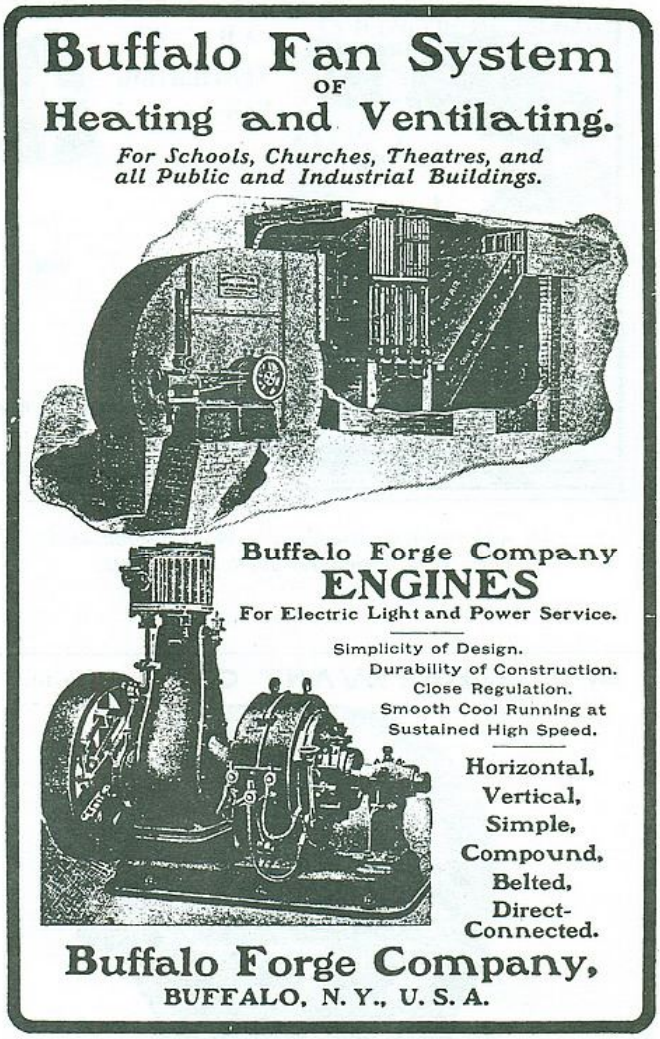
14. Woodcut: Manufacture of Fans for Mine Ventilation, Germany, 1556.
De Re Metallica. *Georgius Agricola, 1556. From* **13.** *p. 204.*



15. Advertisement: American Blower Co., Detroit, Mich.
Engineering Review, *Vol. 12, November 1902.*



16. Advertisement: B.F. Sturtevant Co., Boston, Mass.
Heating and Ventilation, *June 1895, p. xvii.*



17. *Advertisement: Buffalo Fan Systems and Engines.*
Buffalo Forge Co., Buffalo, New York State.
Heating & Ventilating Buildings, *Rolla C. Carpenter (President ASHVE, 1896), 1910, p. 3.*

[51] Georgius AGRICOLA (Georg Bauer) 1494-1555

German scholar and physician. Worked in Saxon mining towns. His great work *De Re Metallica* (published in 1556 after his death) is regarded as the foundation of mineralogy. The book is notable for its excellent descriptions and woodcut illustrations of the mining machinery then in use, particularly fans, ventilation devices, and pumps.

13. *Hoover. See also* 105. *Roberts, fig. 2.*

[52] John Théopile DESAGULIERS 1683-1744

French/English physicist and engineer. Experimenter in many fields, including electricity, where he is said to have been the first to use the word *conductor.* Translated the work of Gauger [54] in the book *The Mechanism of Fire Made in Chimneys* (1716). Introduced a *Fanning Wheel*, similar to those described in Saxon mines by Agricola [51] for ventilation at the Royal Society, London (1734), having previously (1727) made a fan for the Earl of Westmoreland "to clean foul air out of mines." Went on to apply his fan engine to ventilate the House of Commons (1734-1736): "a Committee was appointed to order me to make such a machine, which accordingly I effected, calling the Wheel a centrifugal, or blowing Wheel, and the Man that turn'd it a Ventilator." This apparatus was a wooden paddle wheel 7 ft in diameter with radial blades 1 ft wide in a wood casing with rectangular ducts and remained in use for many years (until 1791).

99. *Donaldson and Nagengast, pp. 21-23. See also* 105. *Roberts, fig. 46.*

[53] Rev. Stephen HALES c. 1700-1761

Perpetual curate of Teddington in Middlesex. Scientist, botanist, inventor, and ventilation engineer. Elected Fellow Royal Society (1717). His most famous work, *Vegetable Staticks* (1727), deals with his experiments on plants. He became interested in ventilation by fans and bellows. Wrote his *Treatise on Ventilators* (1758). Proposed to ventilate a ship "using 10-foot-long inject and exhaust pumps similar to a blacksmith's bellows." He estimated that his "machine would expel a ton of air at each stroke, or six tons a minute by two men working at the lever..."His methods are similar to those of Triewald [9]. Hales also worked on the design of bellows ventilation of the county hospital and county jail in Winchester, the Savoy Prison, and Newgate Prison. In his ventilated prisons, "the diminuition in the annual mortality...seems to have been very great."

99. *Donaldson and Nagengast, p. 23 and figs. 3-7.Portrait drawing by Robert Austin RA,* 46. *p.30.*

[54] Nicolas GAUGER (Cardinal Polignac) active 1713

French cardinal and poet. Early improvements to the fireplace were attempted by Prince Rupert (c. 1678) and by Dalesme (1680) with his *Heating Machine.* Building on these and the work of Savot [3], Gauger wrote *Mechanique du Feu* (1713), in which he described some seven different types of fireplaces. He also studied various symptoms, such as eye and heart disturbances, fainting, indigestion, and difficult breathing, all of which we now know to be consequences of lack of ventilation and exposure to carbon monoxide. His work influenced Desaguliers [52], who produced an English translation (1716).

98. *Billington and Roberts, p. 82.*

[55] Mikhail Vasilievich LOMONOSOV 1711-1765

Accomplished Russian scientist, relatively unknown to Western nations. Educated at the University of Marburg in Germany. Later (1745) appointed professor of Chemistry at St. Petersburg. Anticipated the work of Lavoisier [148] and the theory of heat of Rumford [15]. Was the first to record the freezing of mercury. Repeated the kite experiment of Franklin [8], in which his friend was killed. It is said his dissertation (1736-1741) in Friedberg, Saxony, laid the foundation of scientific mine ventilation.

From **106.** *Usemann.* **47.** *Asimov, entry 237.*

[56] Prof. Dr. Paul Traugott MEISSNER 1778-1864

German/Austrian engineer. Devised an air-circulating system of ventilation. In his book, *Die Heizung mit erwärmter Luft, durch eine Erfindung* (Vienna, 1821), he spelled out the essential requirements for air heating. He noted that the failure of some earlier air-heating systems was due to the lack of understanding that it is difficult to ensure the entry of warm air into a room full of colder, denser air. He proposed floor level inlets with exhaust ducts terminating above the roof. Meissner also gave a drawing and description of a mixing damper. (Warm air heating received considerable impetus in Germany from 1824 due to the efforts of Burnitz of Frankfurt/Main, who used it in several large buildings.)

From **106.** *Usemann. See also* **98.** *Billington and Roberts, p. 192.*

[57] John ERICSSON 1803-1889

Swedish/American inventor. In England, his locomotive *Novelty* competed unsuccessfully with Stephenson's *Rocket*. He went on to devise the marine screw propeller (patented 1836). Later, in the USA, he built the famous ironclad warship *Monitor* (1861) used by the Union against the Confederate *Merrimac* in the Civil War. His warship was equipped with a system of forced ventilation. Ericsson was also a pioneer investigator in the use of solar energy and constructed a *Sun-Motor*.

How We Found the Monitor, John G. Newton, National Geographic, *147, 1 Jan. 1975, pp. 48-61. Portrait: engraving by Samuel Hollyer,* **119.** *p. 195.*

[58] Dr. David Boswell REID 1805-1863

Scottish doctor, chemist, and ventilating engineer. Admitted to the Royal College of Physicians, Edinburgh (1831). A particular interest was physiology. He devised an experimental chamber to investigate respiration and fresh air needs. Advocated the addition of various chemicals to ventilating air, some to aid recovery in hospital wards, others to counteract the deleterious effects of vitiated air. Reid demonstrated his theories at a dinner in Edinburgh, claiming that, as a result of his methods of ventilation, the diners consumed two or three times as much alcohol as usual, without ill effect. Next, the ventilation of public buildings engaged his attention. He devised the heating and ventilating of St. George's Hall in Liverpool (1842-1851) in conjunction with Elmes [194], the architect, being appointed on the recommendation of the city surveyor, Dr. Duncan [170]. Reid worked on the ventilation of the House of Commons (rebuilt after the Great Fire of 1834). He proposed to introduce filtered and humidified air through holes in the floor and to extract the vitiated air by means of a chimney at its base. The scheme included provision for summer cooling "by nocturnal ventilation, by evaporation of water, by passing cold water through a heater battery, and in rare cases by the use of ice (a rudimentary form of air conditioning)." His recommendations for acoustic treatment were well in advance of their time. He was in continual conflict with the architect, Barry [191] and eventually dismissed (1852). His scheme was altered by Sir Goldsworthy Gurney and others and never was successful. Reid wrote *Illustrations of the Theory & Practice of Ventilation* (1844), which was a major influence on ventilating engineers for many years thereafter.

98. *Billington and Roberts.* **99.** *Donaldson and Nagengast, pp. 66-73.* **105.** *Roberts, pp. 102 and 113, figs. 43, 48, 59 and portrait fig. 190.*

[59] Isambard Kingdom BRUNEL 1806-1859

English engineer and perhaps the most renowned of all Victorian engineers. His wide ranging talents involved him in many engineering projects, including Clifton Suspension Bridge (started 1831) and the Great Western Railway (Chief Engineer 1833-1846). Designed the largest transatlantic steamships of their time: *Great Western* (1837), *Great Britain* (1843), and *Great Eastern* (1858). Not so well known is his involvement in the design of a prefabricated hospital with all its services during the Crimean War. The existing Turkish hospital at Scutari was a charnel house in spite of the valiant efforts of Florence Nightingale [166]. In February 1855, Brunel was asked if he could design a hospital for rapid site assembly and by March 5, he was explaining his detailed proposals, which included the ventilation arrangements. "Each patient was allowed 1000 cubic feet of air space and one large ventilator fan was provided for each unit (2 wards each of 24 patients). This fan, he was careful to point out, was designed to force air *into* the wards and not extract it as that might draw smells from the closets into the wards." Erection at the site (Renkoi) started May 21. By July 12, the hospital was ready to admit 300 patients. By December 4 it was equipped with its full quota of 1000 beds and was a complete success.

14. *Rolt, pp. 291-298. Portrait* **125.** *p. 92.*

[60] Bryan DONKIN **1835-1902**

British engineer. Conducted many experiments on centrifugal fans (1880s). Developed the earlier work of Heenan and Gilbert. Conducted a series of tests on 11 types of fan and concluded that "few English and Continental makers make experiments to ascertain the quantity of air delivered, the pressure, and the power absorbed. Sufficient attention is not given to the admission of air to the centre of the fan to reduce friction."

The Fan, *Charles Innes, 1916, pp. 83-103.*

[61] William WALKER **active 1850**

English engineer. Wrote *Useful Hints on Ventilation* (1850). To improve the condition of the working classes, suggested an underground warm air supply to a row of factory cottages, the air being heated by waste steam from the factory and moved by a steam-driven fan. He also put forward various schemes of natural ventilation but was a firm believer in the necessity of heating air before admitting it to the room. He considered filtration important and recommended the use of gauze filters in plenum ventilation. Walker favored the screw fan "as an instrument for imparting a forward motion to air...this good opinion having resulted from experience of its effects on a considerable scale in several cases...." He tested a screw fan strap-driven from a steam engine. "The quantity of air delivered in one minute by a screw 4 feet diameter, performing 500 revolutions per minute, was tested by the writer, by a delicate anemometer, and found to exceed 5000 cubic feet." A William Walker, Jr. (thought to be the same person) devised a means of Warming & Ventilating Apartments and Buildings (BP 10,183: 1844).

Useful Hints on Ventilation, *W. Walker, 1850. See also* **105.** *Roberts, fig. 45.*

[62] Benjamin Franklin STURTEVANT **born c. 1824**

American fan engineer, possibly the most important name in ventilation during the second half of the 19th century. "Started out as a shoemaker and cobbler. Being a very large man, he was greatly bothered with the heat....so he rigged up, (in) about 1850, a stand with a disc (4 blade) fan run by a belt on an eccentric pulley to a pedal which he worked with his foot." Invented a pressure blower (1861), patented a hot-air furnace blower (1869), and patented a compound air heater and steam condenser (1870). Started commercial fan manufacturing (1855) and formed the Sturtevant Blower Co. in Boston. Later known as B.F. Sturtevant Co., the firm produced steam fan drives and then electric fan drives, a wide variety of types and sizes of fans, including the *Cone-Wheel Fan* (c. 1896, a type of plug fan) and dual-duct fan apparatus. Also, devised a combination fan and heat exchanger for heating or cooling (USP 92460: 1869). Company publications, such as *Ventilation & Heating* (c. 1886) were widely used in both the USA and Europe.

99. *Donaldson and Nagengast, pp. 109-112 and 269. See also* **105.** *Roberts, figs. 49, 53, 61, and 62.*

[63] Lewis LEEDS active 1860-1870

American ventilating engineer. Devoted his attention to the ventilation of government buildings, especially hospitals, during the Civil War. Influenced by the work of Reid [58]. Gave a popular exposition of the principles of warming and ventilation through a series of cartoon illustrations projected by magic lantern onto a screen in a series of lectures at the Franklin Institute, Philadelphia (1866-1867). These were called *Man's Breath is His Greatest Enemy.* "In little domestic scenes on the screen, the audience could observe how the people sat in clouds of purple air that had been vitiated, while robust, pink, fresh warm air clung to the ceiling because of the faulty design of the heating system." Later wrote *Treatise on Ventilation* (New York, 1871). He demonstrated his abilities in a hospital design for the U.S. Surgeon General and Quartermaster General, for which he was awarded a grand prize at the Paris Exhibition. His catchphrase was, "If you would be healthy, always keep your feet warmer than your head, and your back warmer than your face."

3. *Ferguson, p. 172-174.* 99. *Donaldson and Nagengast, p. 102.*

[64] General Arthur MORIN active 1864

French military hygienist and ventilator. Made studies of ventilation and appeared to prefer to introduce warm air near the ceiling and to extract near the floor. Developed a system for warming hospitals and infirmaries "effective but expensive." This was a development of the scheme (1840) employed at Pentonville Prison by Jebb [204] and comprised "a hot water system with cased coils (calorifères) in the wards and other rooms, each case having a fresh air inlet." Morin proposed ventilation "for the renewal of air in buildings...only rendered necessary by the vitiation resulting from the respiration and exhalations of the occupants, and by the accumulation of the products of combustion from artificial lighting." His recommended ventilation rates were generally greater than those previously used. He gave the figures required for barracks as 1059 ft^3 per hour by day and twice that amount at night for each man (1860).

99. *Donaldson and Nagengast, p. 100.*

[65] Charles BARLOW active 1878

British fan engineer. Possibly the first patent for a multiblade or multivane centrifugal fan was that awarded to Bennet Hotchkiss of New Haven, Conn. (USP 40,482: 1863). A similar fan was developed by Barlow (BP 3253: 1878) to be followed by the similar designs of Ser [67] and by Fournier and Cornu of Paris (FP 254,064: 1896). Subsequently, Davidson [68] and Keith [70] developed their own versions and a series of bitter court cases over patent rights developed. Barlow's patent is practically identical to the later *Sirocco* patent claim of Davidson.

The Origin and Progress of Multiblade Fans, *1911.*

[66] Joseph CONSTANTINE active 1880

Heating and ventilating engineer. Devised the *Convoluted Stove* "constructed of ribbed sections bolted together and enclosed in a brick setting through which air could pass." His stove incorporated an arch of fireclay slabs over the combustion chamber to ensure efficient and complete combustion. Used to warm the Free Trade Hall, Manchester. He rated his stoves by the weight of metal employed, "The difference in weight gives the difference in heating power. Every pound of metal has a certain capacity for radiating heat and no more, and the heating power of an apparatus may be readily ascertained in this manner." Wrote *Practical Ventilation & Warming* (1881). He bemoaned the lack of attention to warm-air heating.

98. *Billington and Roberts, pp. 95 and 193.*

[67] Marie Antoine SER active 1884

French engineer. Developed a forward-curved multiblade centrifugal fan (BP 13,871: 1884). "It comprised a circular plate with up to 32 blades on each side, and air entered the wheel from both sides. It had a scroll casing and a *Guibal* chimney. Ser fans were made in sizes up to 2.5 m diameter and 0.5 m wide. A fan of this size, running at 186 rev/min, could deliver 40 m^3/s." Later, another centrifugal fan design was patented by Levet (1890).

98. *Billington and Roberts, p. 225. Also see* **105.** *Roberts, fig. 47.*

[68] Samuel Cleland DAVIDSON 1846-died after 1909

Belfast fan manufacturer. Patented his *Sirocco* multiblade centrifugal (BP 4609: 1898), but its "large open eye" seems to have been anticipated in the earlier patents of Henry Aland of Wandsworth (1883) and George Greig of Scotland (BP 12,611: 1884). Davidson tried to block the later fan designs of Keith [70] but eventually failed. However, there is no doubt that the Davidson fan was extremely successful: "It has enjoyed a success unrivalled by any other design and has been manufactured in greater numbers than any other form of flow machine. Apart from its compactness, it is remarkably silent in operation. There is no other fan which operates as silently at comparable pressures" (from a 1973 assessment of the Sirocco fan by the German fan engineer, Bruno Eck). The Davidson fan was later marketed in the USA by the American Blower Co. (from 1908) after the Sirocco Eng. Co. of New York went out of business. Davidson was also involved in the designing, installation, and maintenance of the Royal Victoria Hospital, Belfast (1903), where the environmental engineering design was carried out by Lea [208], who was believed to have been influenced by Key [98].

98. *Billington and Roberts, pp. 232-233.*

[69] Robert BOYLE, Jr. active 1898

Ventilating engineer. Not to be confused with his illustrious namesake [142]. Carried on the engineering work of his father Robert Boyle, Sr. (1821-1878). Boyle Jr. was a passionate advocate of natural ventilation and strongly opposed to mechanical methods. Robert Boyle & Son published *Natural & Artificial Methods of Ventilation* (1899), which refers to the work of many pioneer ventilators and hygienists, including Billings [73] and Galton [171]. Boyle refers to "the evils of forced down-draught ventilation and of hot-air heating (he believed heating and ventilation should be separate) and the dangers of open-window ventilation in cold weather." The company also published *Ventilation of Public Buildings* (1923) with many detailed examples.

15. *Boyle. See also* 105. *Roberts, figs. 42, 44, and 50. See the biography* Robert Boyle, Inventor & Philanthropist, *Lawrence Saunders. Portrait from preface.*

[70] James KEITH active 1907

British heating and fan engineer. Devised the *Challenge* sectional boiler (1875). He also patented an early sectional radiator (1882). His firm, James Keith Co. (founded in Arbroath, 1823) amalgamated (1900) with the Blackman Air Propeller Ventilating Co. to become Keith Blackman. Later, Keith developed two new forms of multiblade fans (BP 10,048: 1906; BP 3246: 1907). An improved version was said "to have so far outstripped every other type or form of fan for volume-pressure work, that it took the whole world by storm" (BP 11591: 1908). Keith eventually won a protracted patent battle with Davidson [68]. He secured further patents for an electric table fan and the Keith *Open* fan (1909-1910). He wrote the booklet *Fan Tests, Theories and Facts* (1908).

The Origin & Progress of Multiblade Fans *"by a Technical Expert" (probably James Keith), 1911.*

[71] J.D. SUTCLIFFE active 1905

Ventilation engineer and fan manufacturer. Founded Sutcliffe Ventilating & Drying Co., Manchester. Presented the IHVE classic paper *The Practice of Ventilation* (1905), in which "The Advantages and Limits of Natural and Mechanical Systems [were] Compared." His paper looked at air purity and referred to the work of Dalton [151] and Pettenkofer [165].

105. *Roberts, fig. 51.*

[72] Sir William Napier SHAW 1831-1912

Expert on ventilation. Chaired the Royal Sanitary Institute Committee on *Chimney Cowls* (c. 1900). Also gave evidence to a Select Committee of the House of Commons on *Ventilation.* He looked into the effect of winds around buildings and air infiltration. A significant advance in this field was his classic *Air Currents and the Law of Ventilation* (1908). Shaw made use of the idea of the resistance to air flow of an opening, formulated the aerodynamic equivalent of Ohm's Law, and showed how to compute the resistance for simple openings. He then developed a simple network theory based on electrical analogy, but his work was largely neglected for more than half-a-century.

98. *Billington and Roberts, p. 496.*

[73] Dr. John Shaw BILLINGS **1838-1913**

Eminent American surgeon and librarian. Designed and supervised the construction of the New York Public Library (from 1895), which consolidated a number of important collections. Served as its Director until his death. Considered the leading American authority on ventilation, he wrote *The Principles of Heating & Ventilation* (1884). Recommended 60 ft^3/min of ventilating air per person to minimize the spread of disease and 30 ft^3/min as adequate for comfort. As a physician, he was considered ineligible for membership of the ASHVE but was elected the first Honorary Member (1896).

94. *ASHRAE, p.110-111 and* **103.** *p.109. See also* **105.** *Roberts, fig. 60. Portrait* **94.** *p. 110.*

[74] Walter YATES **died 1953**

Fan engineer and manufacturer. Director of Matthews & Yates. 11th IHVE President (1909). Presidential address, *Review of Membership, Design of Economy in the Boiler Plant.* Papers to IHVE include *Mechanical Ventilation* (1902) and *Ventilation of the House of Commons* (1907). Twice awarded IHVE Bronze Medal (1902, 1907).

93. Proc. of IHVE, *1909. His portrait is included in the composite of the IHVE Council, 1910, in the section "The Comfort Organizations," p. 113.*

[75] Oswald STOTT **1880-1965**

Fan engineer and manufacturer. Worked for a number of well known fan/ventilation firms: Blackman Ventilating, Sutcliffe Ventilating [71], Allday & Onions. Then formed Oswald Stott Ltd. Director Matthews & Yates (from 1926). 26th IHVE President (1926). Presidential address, *Institution as a Scientific Body.* Served on IHVE Committees: Research, Ventilation Bye-Laws, Technical Education, and Fan Standardisation. Papers to IHVE include *A Few Thoughts About Fans* (1909), *Characteristics of Propeller Fans* (1911), and *Water Gauge* (1924). Awarded the IHVE Silver Medal (1911).

93. Proc.of IHVE, *1926.*