The Artificial Climate

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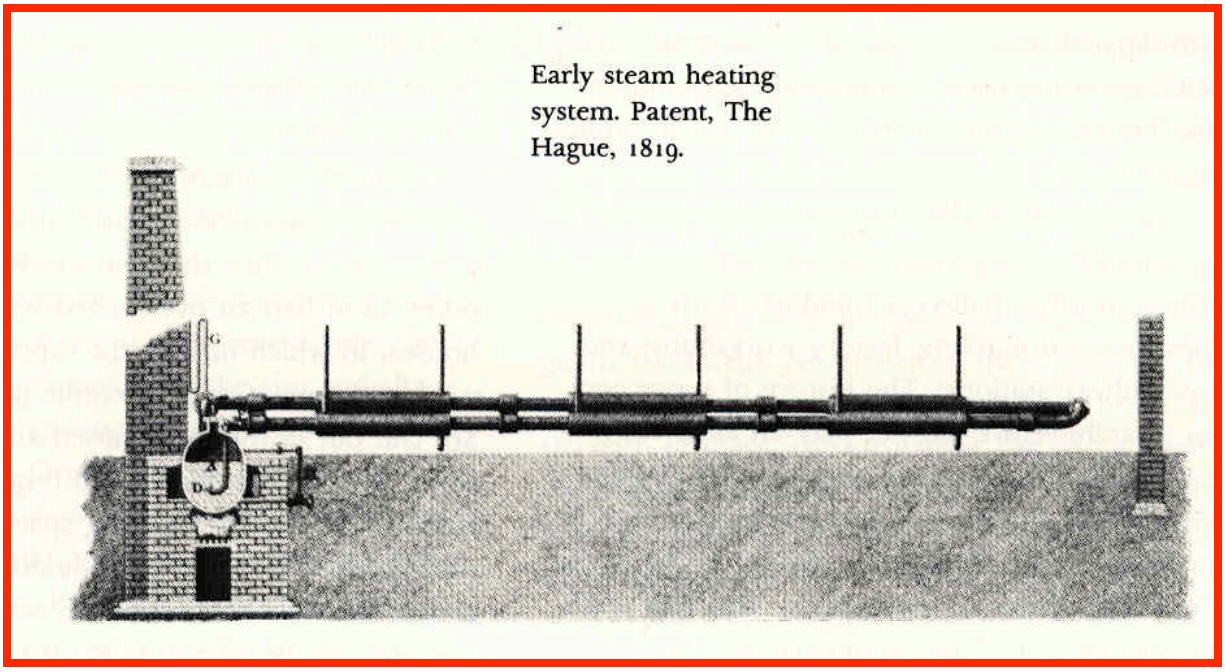

Early steam heating system. Patent, The Hague, 1819.

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As long as greenhouses had small dimensions and were (like the eighteenth-century orangeries) provided with a massive, heat-retaining north wall and a solid roof, primitive stoves or smoke flues sufficed to warm their interiors. After 1750, however, the increasing replacement of masonry walls by glass led to the building of extended glass fronts, although the north side and the roof were still solid with no windows. Any further development of greenhouses into free-standing glasshouses with transparent roofs depended at that time on a solution of the heating problem. The glazing created an enormous cooling surface (heat loss with single glazing was about ten times as great as that of a brick wall) and drastically reduced the heat-storage capacity.

The development of hot-water and steam heating at the start of the nineteenth century was the decisive step. These methods made possible free-standing hothouses and winter gardens glazed on all sides. The introduction of these heating methods coincided with the spread of steam power for driving machinery and the increasing use of coal and coke for fuel.

Stoves (particularly tile-covered stoves) were the usual method of heating in the early hothouses. Iron stoves were soon abandoned on account of the too-strong radiation of heat. The disadvantages of stove

heating included an uneven distribution of heat, greater fuel consumption in relation to the amount of air heated, and greater cost.[133]

Flue heating offered advantages over simple stove heating. It made possible the uniform and continuous heating of the space occupied by the plants. The flue installation consisted of clay or fire-clay ducts, of circular or square section, inserted into each other so that they were gas-tight and laid partly above and partly in the ground, covered with a grating. The flues had a gentle slope of 2.5–3 percent, which was sufficient to allow a draft up the chimney. Although flue heating was cheaper than stove heating, it also had great disadvantages. The slightest defect in the construction of the flues, or the wrong fuel, allowed smoke to escape among the plants, particularly in windy and rainy conditions. The plants were damaged badly by sulfur dioxide and soot; coke and the proper coal were the only satisfactory fuels.[134]

Hot-water heating, like steam heating, first came about in the early hothouses,[135] although the convective force of heated water was known 100 years earlier. The first use of water for heating a hothouse is attributed to Martin Triewald in Newcastle-upon-Tyne around 1716. Water was brought to the outside of the house for boiling and was fed through pipes below the plants. In 1777 the physicist Bonnemain informed the Academy of Sciences of the "principle of heating by water circulation." He had used this type of heating on a small scale in the breeding of chickens.[136] Water heating is based on the different densities of hot and cold water masses and the convective motion this causes, and is accomplished with a system of interconnected pipes in which water stands at equal levels in all branches.

The practical use of the convective force of hot water is associated with the discovery of human blood circulation. When the Marquis de Charbannes obtained a British patent for a highly developed hot-water heating system, in 1810, he knew of Bonnemain's work. At the same time, William Atkinson and Anthony Bacon were engaged in the improvement of hot-water heating, particularly the boiler. Whereas at first (for example, in Atkinson's system) only horizontal circulation was possible, the discovery of the siphon by Thomas Fowler led to the use of vertical circulation too. In 1825 the translation of Thomas Tredgold's *Principles of the Science of Heating and Ventilating Buildings*[137] appeared in Paris. Among the many hot-water heating systems that appeared in the 1830s, A. M. Perkins's high-pressure system was the most remarkable. Previously, water was not heated above the boiling point, but in Perkins's system it was. The boiler and the pipes had to be her-

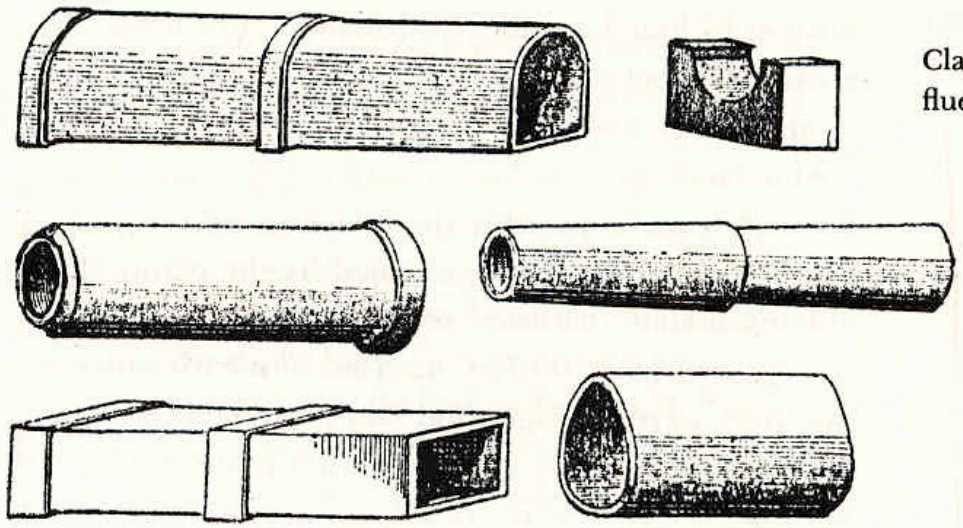
metically sealed and strong enough so they would not burst. Aside from the higher temperature, this system allowed faster circulation. Around the same time, Hood and Richardson published their treatise on the heating of buildings. In France, the technology of hot-water heating received greater attention about the middle of the century through the work of Grison, the head gardener at Versailles. In collaboration with the stove manufacturers Léon and René Duvoir he built heating systems which were also suited to domestic buildings.[138]

Neumann stated that "hot-water heating systems have undeniable advantages for the heating of greenhouses, and particularly all those places where it is a matter of maintaining a mild and very steady temperature. In addition, eight to ten hours after the heating has been turned off the temperature in the glasshouse does not fall to a dangerously low level.

This type of heating is also suitable for those places where considerable quantities of warm air have to be produced." Neumann quoted as an example the Council of State building and the Treasury at the Quai d'Orsay. "The boiler of this heating system," he wrote, "is located in a cellar, but it sends through the pipes the water required for heating all the rooms on the first and second floors (45 feet high). These pipes run for a distance of more than 900 feet and heat all the rooms to 20°C within one hour. Therefore, every difficulty is overcome, and no one can say that the thermosiphon is not applicable to larger premises."[139]

The first initiatives toward steam heating came from Sir Hugh Platt in the times of Queen Elizabeth I, but not until 1788 was the idea reintroduced by Wakefield in Liverpool for hothouse heating. In the early method, a single pipe led from a boiler through the hothouse, and this pipe was always

threatening to burst. In the most comprehensive account of the early use of steam, in 1792, Butler, the Earl of Derby's gardener, told of heating melon and pineapple houses with it. He used perforated pipes laid in a steam-permeable bed in which potted plants were placed. In 1807 the garden architect John Hay of Edinburgh carried out similar tests with pipes perforated along their whole length and laid in a bed of stone of 3 by 4 feet in cross-section. The stones were warmed up to steam temperature, and the heat stored in them was sufficient to heat a plant house for a full day in cold weather and for two to three days in mild weather. By about 1816, steam heating was far enough developed to be used to heat a spacious hothouse. It was already in use at this time in Loddiges Nursery at Hackney in London. Loudon, who built his first curvilinear hothouse here,



Clay pipes for smoke flue heating.