Building Services Engineering

A Review of Its Development

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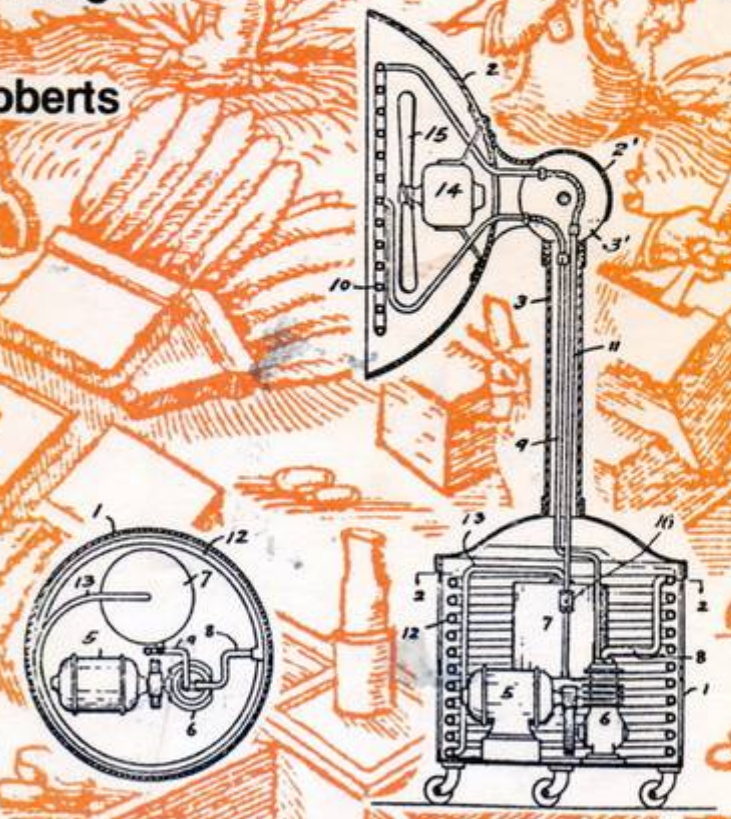

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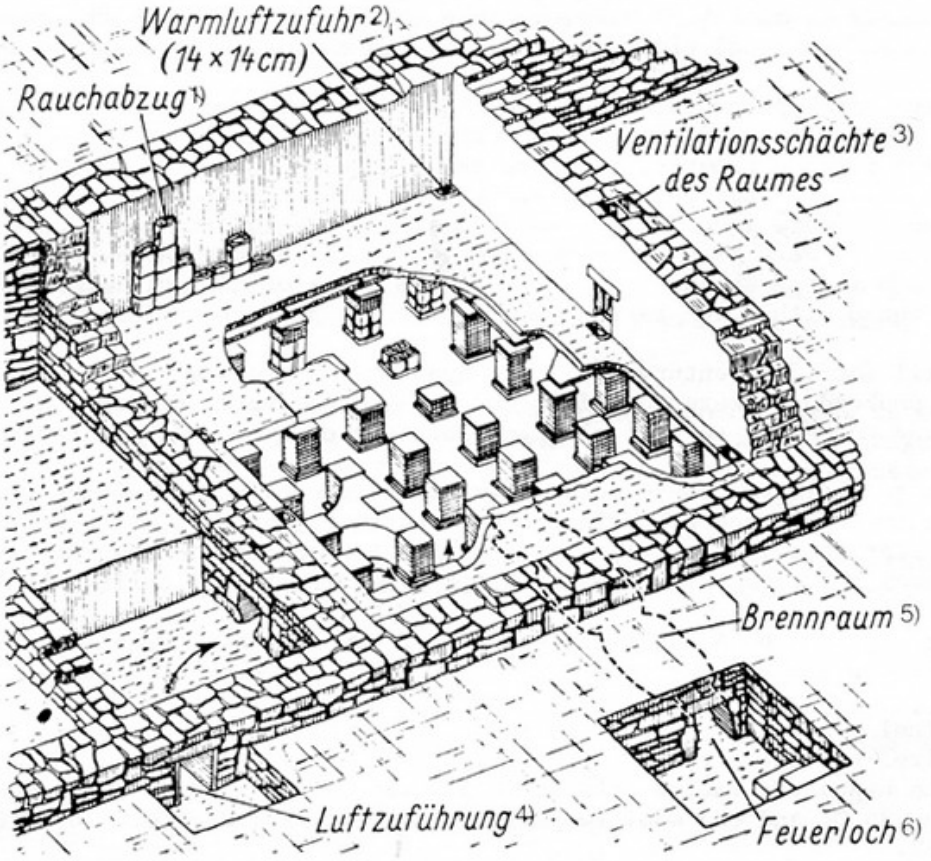
3.1.4 *The hypocaust*

The hypocaust was devised by the Romans, and used for some centuries from about 80 B.C. to the end of the Roman Empire in 450 A.D. in the villas throughout Europe and Britain. In the Roman motherland, it was used almost exclusively for heating baths, and in a few large houses. Only after the destruction of Pompeii in 79 A.D. did the hypocaust begin to oust the brazier as a means of room heating. Some excellent examples are to be seen in Britain at Chester, Bath and Chedworth (Glos.), the last of these being perhaps the finest. Here the boiler was believed to have been made from thick sheet lead, supported on massive iron bars. In Europe, the castle at Saalburg and the baths at Trier are well preserved (Fig. 3.1). The hypocaust is said by Kretzschmer to have been devised by G. Sergius Orata in about 80 B.C.; it was described by Vitruvius in his book *De architectura* in 16 B.C.(56)



1) Fume extraction
2) Warm air supply
3) Room ventilating
4) Air intake
5) Fire chamber
6) Fire hole

Fig. 3.1. Hypocaust at Saalburg.

According to Vetter, the Roman word "laconicum" (the hottest of their sweat rooms) was derived from Lasodemon, and suggests that the hypocaust had been used earlier in Greece. It could be that Orata merely made use of an example he had seen there. It seems certain however that the wall flue was of Roman origin, so that the Romans may be given the credit for the invention of hypocaust heating.(92)

There were three kinds of hypocaust — floor heating only, heating via floor and walls, and a warm-air system in which the air was admitted to the room through holes in the floor. The latter could be controlled to some extent by covering or stopping the holes as required. The hypocaust structure and floor was warmed by the furnace, which was then allowed to die out, the smoke flues were closed and the ventilation holes opened, so that air warmed by passage through the underfloor space was discharged to the room. The hypocaust at Carrière du Roi seems to have been more refined.(2) Tubes were found running through the primary smoke passages. One end of these tubes communicated with the open air, and the other with secondary horizontal and vertical pipes which discharged the warm air into the room.

In the earliest hypocausts, the floor of the room was supported on pillars 0.7 — 1m high and spaced about 1.3m apart. Part of the space beneath the floor served as a furnace chamber, the fire being stoked through a stoke-hole in the external wall. The hot gases circulating beneath the floor warmed it. Later, tile flues (tubuli) were incorporated in the walls. The furnace gases ascended through these tubes and were discharged to outside just below the eaves. These can be very clearly seen in the Chedworth villa. In the baths of this villa, these wall flues were continued within the barrel-vaulted roof to prevent condensation.

Later still (*ca.* 2nd century A.D.) the hypocaust pillars were abandoned, and instead, smoke-ducts were formed in the sub-floor, radiating from the furnace chamber and connected to wall flues. (This system, too, was adapted for ventilation.)

According to Seelmeyer these methods sufficed for the mild Mediterranean climates. If more warmth was needed, as in the more northerly parts of the Empire, it was a simple matter to admit the flue gases direct to the room through valves in the wall flues. From the room they were exhausted via holes in the ceiling.(80)

New researches at the Aula Palatine in Trier gave the following facts about the combined floor and wall heating:

> The fuel consumption was about 130 kg/h of wood. The low useful output required a lengthy preheating time, of the order of two days. The temperature in the hypocaust varied between 90 and 184°C; the floor temperature was between 25 and 35°C; and the wall temperature between 19 and 32°C. The efficiency was 90-96%.

Kretschmer's tests on the reconstructed hypocaust at Saalburg gave very similar figures.(56)

The ducted hypocaust was used very occasionally after the fall of the Roman Empire — in 820 at Klosters St Gallen*, at the Kaiserhaus at Goslar in the 11th century and at Klosters Loccum in the 13th century. It appears to have been revived in later times — Heigelin described its spread in 1827.(35)

The Chinese kao-kang was very similar to the original hypocaust. The tong-kang had vertical flues in the walls of the house, and was thus similar to the hypocaust used

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*Vetter considers this not to have been a true hypocaust, but a stove heating system with a large furnace chamber.

in Rome. A tong-kang was built to heat the Orangery at Kew in 1761, and in 1792, an orangery in South Wales was constructed with an extensive hypocaust.(15)

In addition to the kang, the Chinese also used braziers of burning charcoal, and open fires upon a hearth.

In spite of the use of the kang, the Chinese kitchen usually had no chimney — only a hole in the roof. In the better houses, the kangs had chimneys carried above the roof. Water-vessels in the rooms (goldfish- or flower-bowls) were used to humidify the warm air from the kang.

The economy and health advantages of the kang, with day and night ventilation, greatly impressed the (English) Royal Society. It saw, further, in the kang, the technical possibility of improving the heating of English hospitals, by using a tong-kang for wall heating. The Society in about 1771 recommended research into the application of the kang in different trades, to test its suitability for use in Britain.(35)