PLUMBING & SANITATION
FROM EARLIEST TIMES

History Part-3

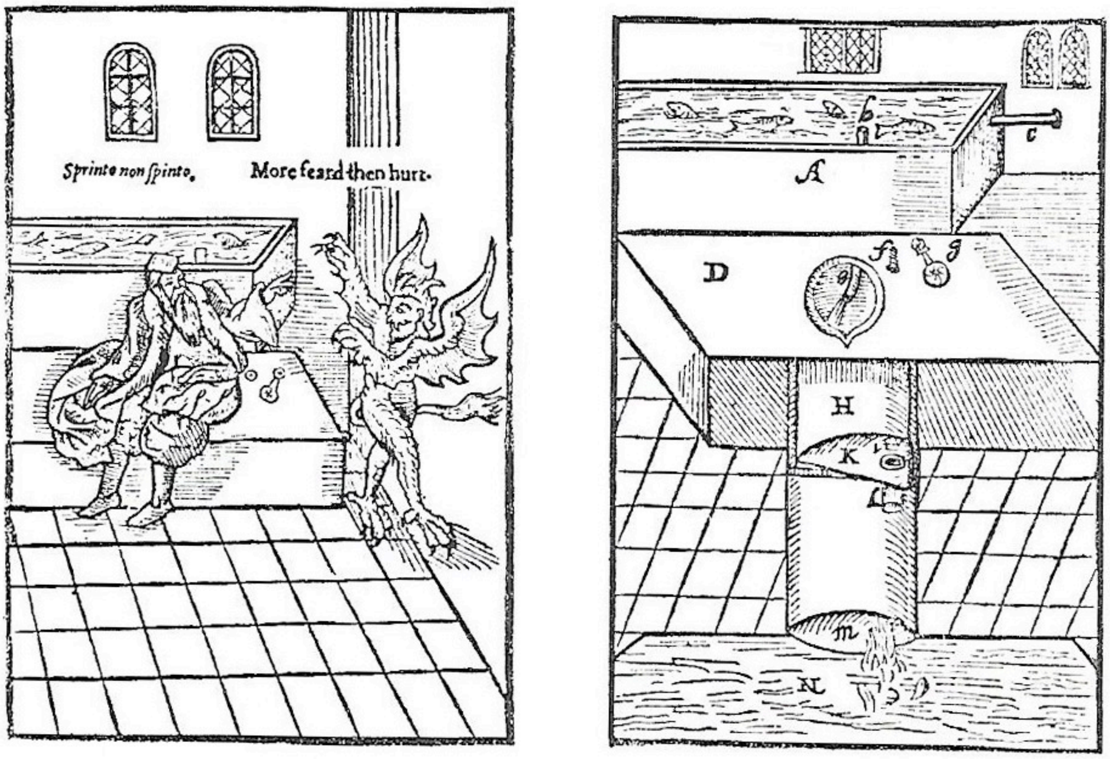

Fig. 7.15. Sir John's water closet.
(Courtesy, Science Museum, London)

From BUILDING SERVICES HERITAGE
A REVIEW OF ITS DEVELOPMENT
N S Billington & B M Roberts, 1982

Continued from PART-2

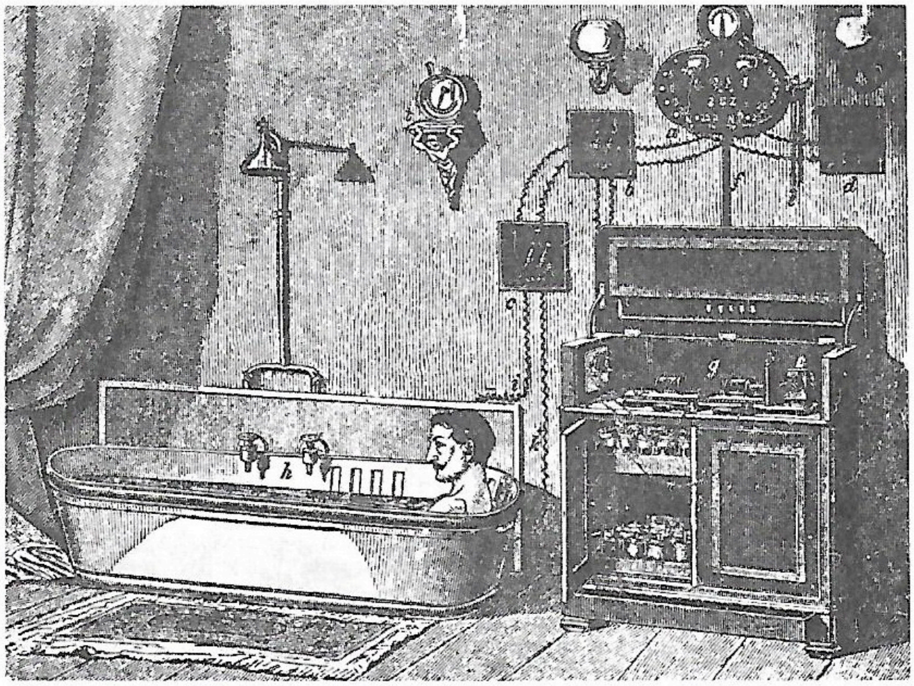

Fig. 7.13. Electric bath installation, with all necessary appliances for constant and Faradaire current application — from GEC catalogue of 1886.

On the continent of Europe, the bidet was introduced at about the same time; but showers were scarcely used in either Europe or the USA at the end of the 19th century.

7.4 CLOSETS

7.4.1 Greek and Roman times

Archaeological evidence indicates that water supply and drainage systems existed in many of the ancient civilisations. Toilet facilities existed in the palaces, and some private dwellings, in Assyria, Babylon, Egypt, Greece and Crete. The toilets comprised a stone or wood seat on pillars, built over a drainage channel or water course to carry the faeces away. At Knossos, it is possible that the toilet was flushed with water after use. Babylon had many public as well as private toilets. Four thousand-year old dwellings in the Indus valley provide evidence of latrines and water-borne sewage.

In ancient Rome, sanitation reached a peak of development. In the earlier days of both Greece and Rome, rooms were set aside as toilets, and portable vessels were used. The baths of Lepcis Magna had large marble latrines in which the occupants sat on marble seats on three sides, while regarded by a statue in a niche on the fourth. Later, in Rome, the richer people had closets with water cleansing, sometimes from a flushing tank, operated by a tap. Many public toilets and urinals were provided, for the use of which a charge was made. Arrangements for public lavatories, which were a normal social feature of Roman towns, can be seen in well-preserved ruins as at Ostia and at Timgad in North Africa, founded as a "colonia" by Trojan in A.D. 100. At the centre of the town of Timgad lay the Forum, and off one side the public lavatory containing rows of stone seats sometimes separated by arms carved as dolphins, but otherwise public in the truest sense of the word (Fig. 7.14). And in Britain:

> "At Housteads on the Roman wall in Northumberland as many as twenty men could sit and enjoy the sight and company of their companions, sending their offerings to Stercutius and Crepitus, the gods of ordure and conveniences, and Cloacina, the goddess of the common sewer."(37)

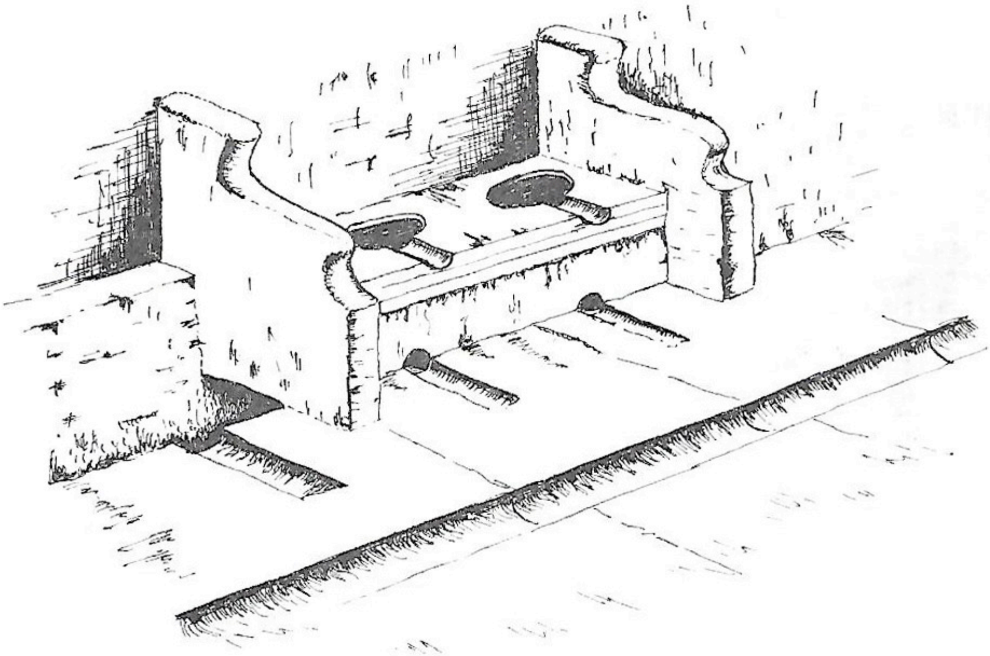

Fig. 7.14. Public toilet at Timgad (Algeria).

An obsessive preoccupation with sanitation may have even contributed to the downfall of the Roman Empire according to the writings of Rolleston (1751):

> "- we may date the commencement of (their) ruin from the introduction of gold and silver chamber pots and close stool pans".

In Islamic and Jewish countries, cleanliness was highly regarded, and there were definite requirements as to toilet and bathing facilities. In Islam, there were many public toilets, especially close to mosques and bath-houses. The English traveller, Ogilby, reported that in 1670:(2)

> "In Fez there are, near the mosque, about 150 common conveniences, each with a tap and marble cistern, and all trim and clean, as if these places had been intended for more pleasant purposes."

7.4.2 Medieval castles and palaces

In those parts of northern Europe which remained free from Roman influence, or from which the Romans withdrew early, sanitary arrangements were primitive. Only in the monasteries and castles was good sanitation to be found.

In mediaeval castles, this often comprised a small turret projecting from the facade, and provided with a toilet seat. Excrement was allowed to fall directly into the moat, or into a receptacle which had to be periodically cleared. In the Northumbrian castle of Langley, in the 13th and 14th centuries, closets on three floors were arranged so that the separate waste shafts from each led into a common cess-chamber. At the Castel del Monte (built *ca.* 1240), rain water collected from the roof was used for washing down the toilets.

> "Henry III, in a typical order, instructed his sheriff at Southampton 'to make in our castle at Winchester, behind the chapel of St. Thomas the Martyr, a certain chamber for the use of the bishops, and a chimney (fireplace) and a certain privy chamber for the same! Where practicable, the privy was placed as far away as possible, on account of the smell, at the end of a passage in the thickness of the wall, with access to the chamber by means of a right-hand turn. Sometimes, as at Woodstock, Henry III ordered double doors to reduce the smell further."(35)

Henry III (1716-72) subsequently ordered privies to be built into all his residences. At Winchester Castle he ordered a garderobe tower constructed "in the fashion of a turret", and complete with a ventilation shaft.

At the archbishop's palace at Southwell (*ca.* 1360) the privies were housed in a separate circular building away from the palace. Bodiam Castle in Sussex (*ca.* 1386) was furnished with twenty-four privies built into the walls, all with drainage. Water flushing devices were provided in the Eagle Tower (1317) of Caernarvon Castle and at Denbigh Castle, but in spite of all these improvements the problems of smell and cleaning generally proved insuperable.(35)(57)(58)

At St Cross Hospital, Winchester, which dates from the late 15th century, the brethren's dwellings are on two floors, and each includes a closet, built in a gabled projection on the external wall. "A swiftly flowing water course, diverging from the River Itchen, to which it returns at some distance from the building, immediately gets rid of all impurities, and is a most simple and effective sanitary arrangement." (Since the water course flowed beneath the bedroom and scullery windows, the hygiene is rather doubtful — NSB/BMR.)

In the towns, arrangements were primitive, and the discharge went straight into the streets. Only in the richer towns were privies erected, but these were seldom emptied. In the 14th and 15th centuries, London had only a dozen or so public latrines, some built over the Thames (on London Bridge), over the Fleet and the Walbrook — all rivers from which the city obtained much of its water.

In the 17th century, private toilets were introduced to Germany from France, but then only for the richer people. Up to then, the better class had only portable commodes. In 1588, the Elector of Saxony had made a commode on wheels, which he took with him whenever he left his residence. It also had a table with drawers, a medicine cupboard and a small stove to warm water. When opened up, the contrivance could be used as a bed.

As a consequence of the unhygienic conditions in which the mass of the population lived, illness was rife. Attempts were made to ameliorate them. The architect Filarete built the Ospidale Maggiore in Milan (*ca.* 1456). In this hospital, the toilets were emptied into a shaft,* while ventilating ducts at ceiling level were provided to remove the foul air. Leonardo de Vinci sketched an odourless toilet,

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*In Filarete's original plans, access to the lavatories was to be by trapdoors between the beds (Pevsner).

in which the whole toilet was mechanically closed off from the dung-pit when not in use.

7.4.3 Sir John Harington

Queen Elizabeth I was considered by her court to be extremely fastidious in matters of hygiene, taking a bath once a month "whether she need it or no". By comparison, her godson, the poet Sir John Harington, was considered eccentric in the extreme, because he had a bath every day. But Harington is not remembered for his bathing habits, but because in 1596 he designed the first valve water closet.[44][48] He described an odourless toilet in the book *The Metamorphosis of Ajax* (1596). It incorporated all the main features of a water-closet — a cistern with operating lever and overflow, a bowl, flushing pipe, plug outlet valve and a seat. It was flushed from "a barrel of water placed in the room above, whence the water may, by a small pipe of lead of an inch, be conveyed under the seat... to which pipe you must have a cock or washer to yield water with a pretty strength when you would let it in." The bowl was closed by a plate at its base, and contained a few cm of water. After use, the plate was removed, and the contents of the bowl deposited in a drain beneath. Sir John installed one of the closets in the Queen's Palace at Richmond, and one in his house near Bath (Fig. 7.15).

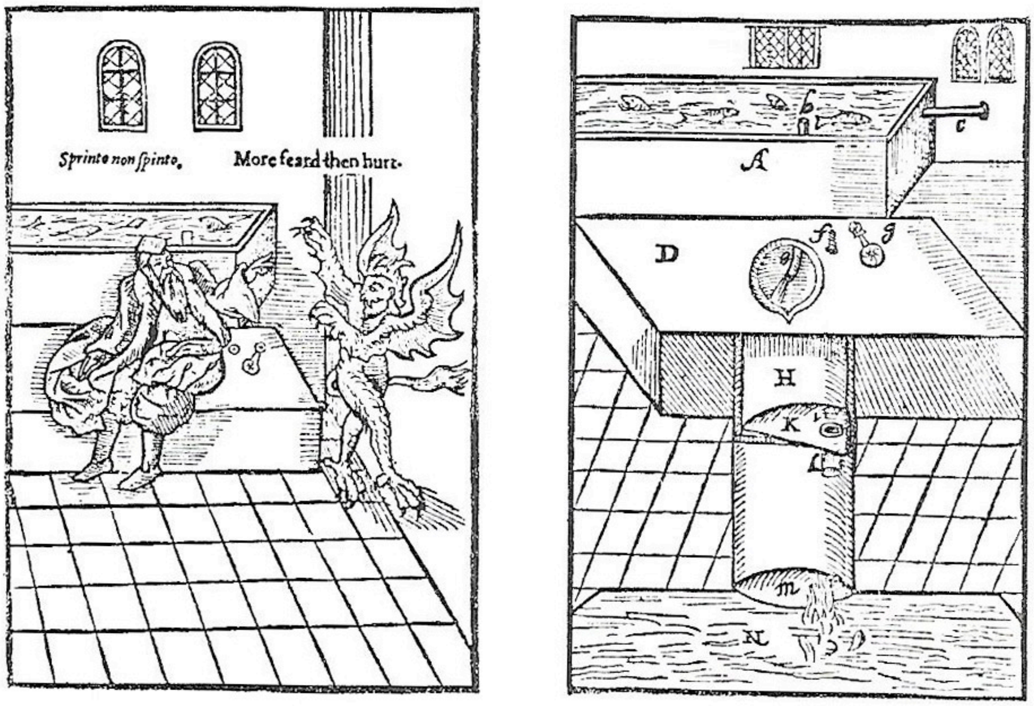

Fig. 7.15. Sir John's water closet.
(Courtesy, Science Museum, London)

However, there were two major practical difficulties to be overcome before the re-invention and wide adaption of the valve water-closet nearly two hundred years later. There were few drains or sewers in Elizabethan England, so the effluent would have to be discharged into a pit, unless the water-closet happened to be installed next to a river or stream. Moreover, water supplies were extremely limited.

7.4.4 The 17th and 18th centuries

It appears that during the 17th and early 18th centuries only a few rich and enterprising persons had water-closets built for them, including Sir Francis Carew, who had an automatically flushing lavatory in his house at Beddington, Surrey, described in 1678 as:(48)

> "... a pretty machine to cleanse an House of Office, viz. by a small stream of water no bigger than one's finger, which ran into an engine made like a bit of a fire-shovel, which hung upon its centre of gravity, so that when it was full a considerable quantity of water fell down with some force".

At Windsor Castle, Queen Anne (1702-14) is said to have had "a closet that leads to a little place with a seat of easement of marble and sluices of water to wash all down"; other stately homes followed suit:

> "The water closet was at last in working existence. This was a primitive apparatus made of marble, with a long handle attached to a plug which you simply pulled up to release the contents of the vessel into the D-trap – a D-shaped container filled with water – which had another pipe leading out from the top of it, which of course was never emptied properly."(54)

In France, J. F. Blondel (1738) designed a water-closet consisting of a marble bowl, with a seat which could be covered with a lid. The bowl was rounded, and its base had a slight slope towards the discharge opening, which could be closed by a plug. Two water taps were provided – one for flushing the bowl, and the other for personal cleanliness.

Some years later, in 1775, Alexander Cummings, a London watchmaker, patented a closet which incorporated an important advance – the use of a water seal to isolate the bowl from the drain (Fig. 7.16). In addition to the seal, he also used a sliding plate at the base of the bowl to effect mechanical closure: this had the advantage of retaining a quantity of water in the bowl after use. A single operating lever worked both the mechanical valve and the flush. In Cummings' patent, an inlet pipe in the bowl cleansed the lower portion with a swirling jet of water.

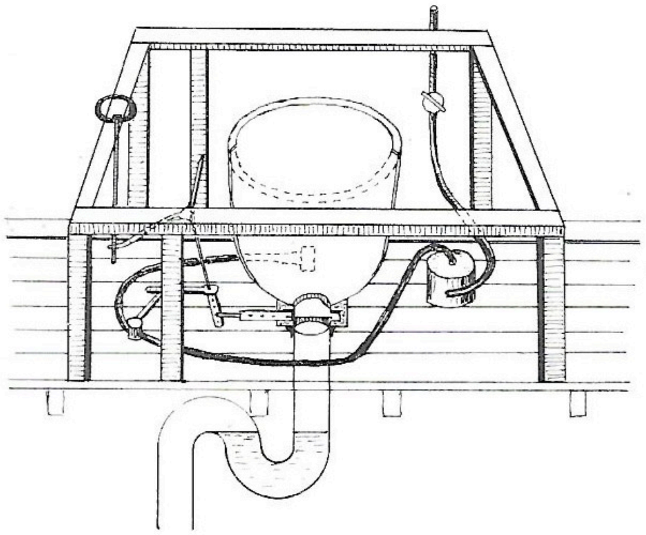

Fig. 7.16. Cumming's water-seal closet (1775).

Soon after, in 1777, Thomas Prosser patented inventions relating to controlling the water flow.[44] These first patents were for so-called valve closets, similar to Harington's much earlier invention, the essential feature of which was the pan with an opening at the bottom sealed by a leather-faced valve; when flushing took place a complicated arrangement of handle, lever and counterweights admitted water to the bowl whilst temporarily removing the valve.

Bramah's closet of 1778, which was similar to Blondel's, had a hinged outlet valve, and when flushed it discharged its contents directly into a cesspool in the basement or under the garden. A trap with water seal was patented in 1782, and before Cummings' siphon-trap became general, other types of seal were tried. In one English example of the late 18th century, the bottom of the wc bowl was closed by a pan containing water. After use, the contents were discharged by tilting the pan; this action also started the flush, which continued after the pan was returned to its original closed position, to reform the seal. The "valve-closet" used a water-tight plate, operated by a lever, to close the bowl and retain water after flushing.[27] In the "pump-closet", devised by Downton in 1825, a pump opened the closure plate upwards, and at the same time, flushing took place. It was claimed that this design gave more secure closure than vertical or downward-opening valves.

7.4.5 19th century closets

In the 100 years after Cummings' invention, some 300 patents were taken out, but there were few real advances in design. Nor was the wc yet in common use. The chamber-pot remained the favourite convenience. Soldiers fared no better — perhaps worse — than the ordinary person, *vide* the 1857 Commissioners' report:

> "What adds greatly to the discomfort of the men in barracks, and what tends to increase the nuisance and vitiate the atmosphere of the barrack room is the abominable practice of having an open wooden vessel or tub standing in each room as a urinal. Why cannot that nuisance be removed, and what difficulty can possibly exist in forming in the corner of each room, a basin and flow pipes, concealed and well ventilated, to carry off these pestilential odours? It may be partitioned off by a small air-tight door, from the room, and a small stream of water with proper attention would always keep it sweet and clean."

The two closets most used in the 1800's were Bramah's valve-closet* and the pan closet introduced in 1796 by William Law (Fig. 7.17). The latter, says Hellyer:

> "remains the most unsanitary closet in use. It is now condemned by all sanitarians and it is inhibited by the Local Government Board and the LCC"[33]

but it was still exported to Russia. In use, waste matter is deposited in the moveable pan below the bowl; operation of the lever starts the flush and empties the pan into the receiver and thence into the trap and soil-pipe. The hopper closet comprised a conical hopper only, liable to fouling, and regarded as old-fashioned and insanitary, though it seems to have been fairly widely used at the time.

The earth closet, invented in 1860 by Rev Henry Moule, and the pail closet, were developed because of the lack of water supply and drainage networks.[59] But as these facilities became more generally available, the wc was further developed and its use expanded. Variants of Cummings' design began to be made, in the second half of the 19th century, in the USA, France and Germany.

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*By 1797, Bramah claimed to have made 6000 closets (Girouard).

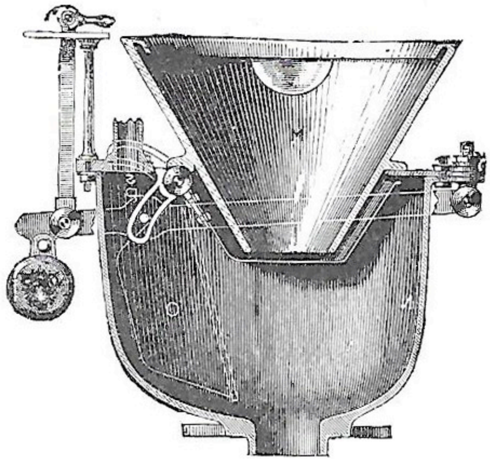

Fig. 7.17. Section of a pan-closet.(1796)

For outside use, the Berlin "Hofcloset" was used in Germany. The spoil entered a vertical pipe with the water seal $1\frac{1}{2}$ m below ground level to prevent freezing. The flushing valve was located at the same depth, and any water remaining in the flushing pipe discharged into the seal.

The wash-out and the wash-down closets were designed in the later years of the 19th century. In the former, a pool of water is retained in the bottom of the basin to cover the stool; the whole contents are washed out by the flush. The wash-down closet has sloping sides so that any waste falls immediately into the trap. The solid matter receives the full force of the flush and is readily washed down and out of the trap with 9 litres of water.[33] In the wash-out type, the force of the flush is broken by the contents of the bowl. By 1900, the wash-out pattern was on the wane.[47]

The Vortex closet, designed by Hellyer in about 1890, had a larger water surface than most other wash-down closets, and a water jet was used for flushing. It was admitted to be difficult to ensure satisfactory operation. One pattern of the time had "seat action". On sitting, a little water was trickled over the basin surface to wet it to prevent adhesion of solid matter; flushing was initiated on rising from the seat.

Mann had designed a siphonic closet in about 1870. A different version — the Dececo — had a double trap. This was followed by Jennings and Morley's siphonic closet of 1892 (Fig. 7.18) which was claimed to overcome the occasional failure of earlier models to reform the water seal. The water from the cistern not only flushed the bowl, but also initiated a siphon action which withdrew the contents of the bowl into the soil-pipe. This closet was capable of working satisfactorily with only 9 litres of water.

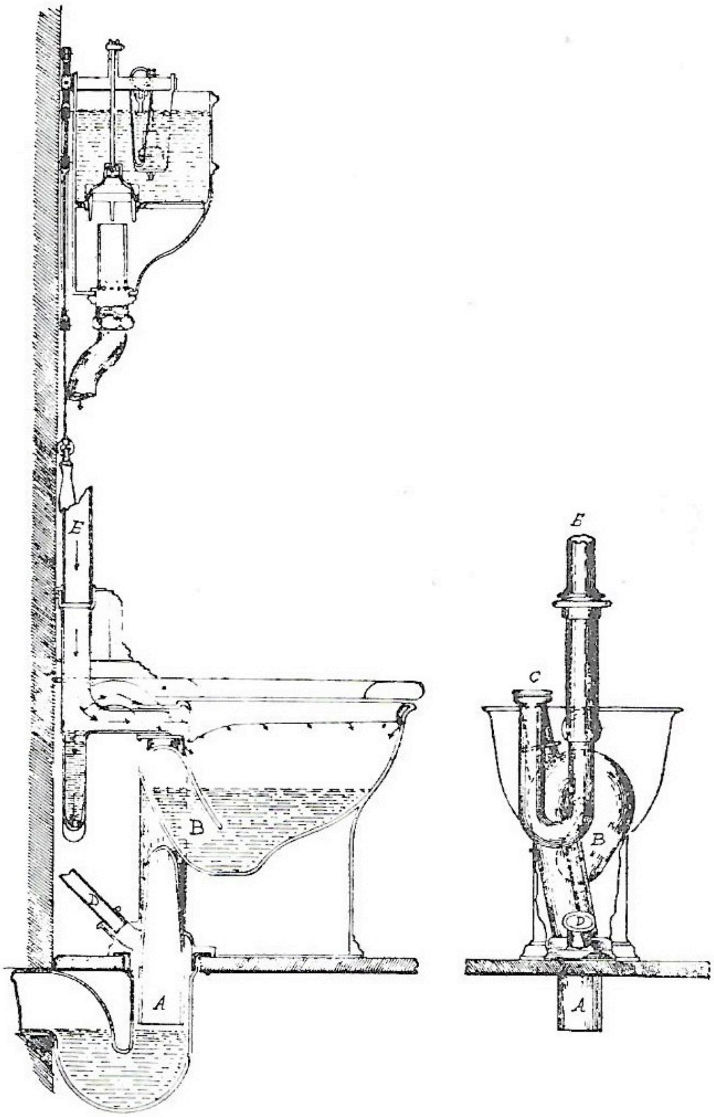

Fig. 7.18. Jennings' 'closet of the century'(1892).

Hellyer considered it a great step forward when the self-cleansing trap was first used (about 1860). In 1890, he introduced the Anti-D and S traps, to replace the older Bell and D traps which could not be cleaned and were largely ineffective. The new Hellyer traps were self-cleansing, and the small water content ($1\frac{1}{2}$ litre) and rounded waterways of the Anti-D trap ensured that the water was completely changed at every flush. Experiments by Carmichael (GB) and Wernick (Germany) in 1880-1 showed the value of traps in excluding noxious smells from the dwelling. Ventilation of traps was introduced by Hellyer in 1869-70; the need to do so was confirmed by Waring (US Board of Health) in 1881 and by Bowditch and Philbrick (US) in 1882. Hellyer himself had, a year or two before, experimented with various traps to investigate loss of seal. He also carried out a series of tests to determine the performance of traps, and in particular the quantity of water required to clear solid waste. One gallon was sufficient to remove the material (paper and rubber-tubing) from his Anti-D trap; double this quantity was needed if the waste was placed in the bowl of a valve-closet.

A Boulton design of the late 19th century had a mechanical seal as well as the water seal (just as Cummings' original design); an American wc (Henry Huber of New York) of the same period had a double hydraulic seal. Both these had flushing rims on the bowl. The unreliability of mechanical seals was such, however, that the water trap rapidly gained supremacy.

When wc's were first introduced, flushing was done by allowing water to flow from a cistern, the duration of the flush being determined by the time the handle was pulled. This led, perhaps, to over use of water. To overcome this, the water-waste preventer or flushing cistern was developed, giving a pre-determined volume of water at each operation. It was first introduced by Cropper in 1872. The Frenchman, Bean, and in Germany, Growe Co. made the first useable flushing cisterns with the modern bell, in 1885.

Some London water companies had been trying to restrict the quantity of water used in wc's to 9 l* — up to 40 l had been used — and the "Builder" thought this was a highly retrograde step. Professor H. Robinson recalled tests by the Sanitary Institute in 1893. With a 9-litre flush, 5% of the solid matter was left in the trap, and 21% in a drain 50 ft long; with a 13½-l flush, the corresponding figures were 1% and 3%. Robinson himself proposed 13½ l but recognised that sometimes 9 l were sufficient. The LCC decided to use a 13½ l flush, but in 1895, the Local Government Board (now Ministry of Health) refused to sanction the change from 9 to 13½ l. Nine litres eventually became the usual in Great Britain, though nowadays dual flush cisterns, releasing only 6½ l for flushing liquid waste, are being introduced.

Early models of wc's were in cast iron, brass, lead or copper. In about 1800, Twyford's began to make glazed earthenware bowls with flushing rims, and in 1885, T. W. Twyford made the first one-piece wash-out wc (the "Unitas"). The same firm later introduced vitreous china.

7.4.6 Some early 20th century systems

A curious and clearly insanitary arrangement was in use in some American schools in the early years of the 20th century. It was the "dry-closet" system, not to be confused with the earth-closet, which was "unobjectionable on sanitary grounds". The dry-closet system was used where no water supply was available.(1)

The closet seats were located on the roof of a tunnel leading to an aspirating chimney, and each seat was provided with a cover intended to be kept closed when not in use. Urine was sometimes drained off, but the solid matter remained on the floor of the tunnel, and gradually dried by the current of air that passed over it to the chimney. At the end of the school term, the deposits were saturated with kerosene and then destroyed by fire. The chimney was warmed either by the school heating apparatus or by a separate small fire. The system had several serious objections. If, as was sometimes done, the chimney also served to exhaust air from the school rooms, there was a risk of blow-back, and of foul air being driven into the school. The draught was not always sufficient to ensure the entry of air into the tunnel when all the seats were in use, or left uncovered, and some of them allowed foul air from the tunnel to enter the lavatory block. Further, the fecal matter is reduced, in drying, to dust which is carried up the chimney and dispersed into the atmosphere.

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*The Metropolis Water Act of 1871 legalised this action.

"The dry closet system of heating and ventilating school houses is one of the worst disease breeders that can be devised in schoolhouse construction."(1)

Up to 50 years ago the pipework arrangement in most common use was the two-pipe system. This system required separate discharge pipework for wc plans and for waste fittings, together with separate anti-siphon pipes for each. The materials used were cast iron stacks with lead branches, or often lead pipework for the whole system with the entire arrangement hung from the outside of the building. Although a great deal of skill was required to install such systems then very quickly deteriorated into spaghetti-like trays of sagging pipes.

The American one-pipe system for drawing in both soil and waste was introduced into this country during the 1930's and soon became the norm for large commercial and residential buildings. It combined soil and waste into one net of pipework reducing the material quantity used. It had no great visual or technical advantages over previous systems and the materials used were still cast iron or lead and, with few exceptions, plumbing was still fixed externally.

7.4.7 Soil pipes

Of equal importance to the waterseal trap on sanitary fittings is the 'disconnection' of the house drain from the sewer or cesspool, and the substitution of self-cleansing traps for valve-flaps (which gave imperfect sealing against sewer gases). Anti-siphon ventilation of the soil-pipe trap seems to have been first practised by Hellyer in about 1872.

Hellyer thought that soil-pipes should be only just large enough to carry the discharge, for otherwise they are not adequately cleansed by use. He preferred lead to lead-caulked cast-iron pipes; stoneware pipes were rare and unsatisfactory. The top of the pipe was first vented to atmosphere in about 1830; the bottom should also be open to the air, for example by a vented trap.

Practice in Paris was "a disgrace to any civilised country", though it was improving. The 8-in (200-mm) soil-pipe emptied into a "tinette" to screen the solids and allow only the liquid waste to enter the sewer. The tinette was changed every three days. Bath- and rain-water were discharged into a separate trapped drain to the sewer.(33)

Except for the introduction of thin-wall copper tube as an alternative to lead, plumbing systems were not significantly changed until 1950, when the B. R. S. published bulletin No. 48/49 "Principles of single stack plumbing". This was the first research into methods for reducing the complexity of plumbing anti-syphonage arrangements. It started a line of continuous development which has resulted in the simplified pipework arrangements in use today. The tall buildings which have become common since the early sixties gave added impetus to plumbing development, leading to more compact and economical arrangements, with quicker installation methods and lead pipe has been finally supplanted by copper tube. The 1962 Building Regulations for the first time prohibited the use of external plumbing pipework except for rainwater pipes. This meant that plumbing now had to be housed inside the building and therefore had to be designed and integrated in the same fashion as the other building services.

PVC came into use in 1958 and although originally used for low cost housing, it was quickly adopted by the industry and by local authorities for all classes of work. Now it is probably the most widely used plumbing material because it is cheaper to produce and quicker to install than its metal counterparts.

7.5 DOMESTIC HOT WATER SUPPLY

There is little in the literature to suggest any significant technical advance in methods of providing hot water for washing until the 19th century (Fig. 7.19). Most people then, as many still do today, obtained their hot water from pans and kettles on the fire. The original kitchen range had, at the side of the fire, a boiler which had to be filled by hand, and was provided with a tap to draw off the hot water.

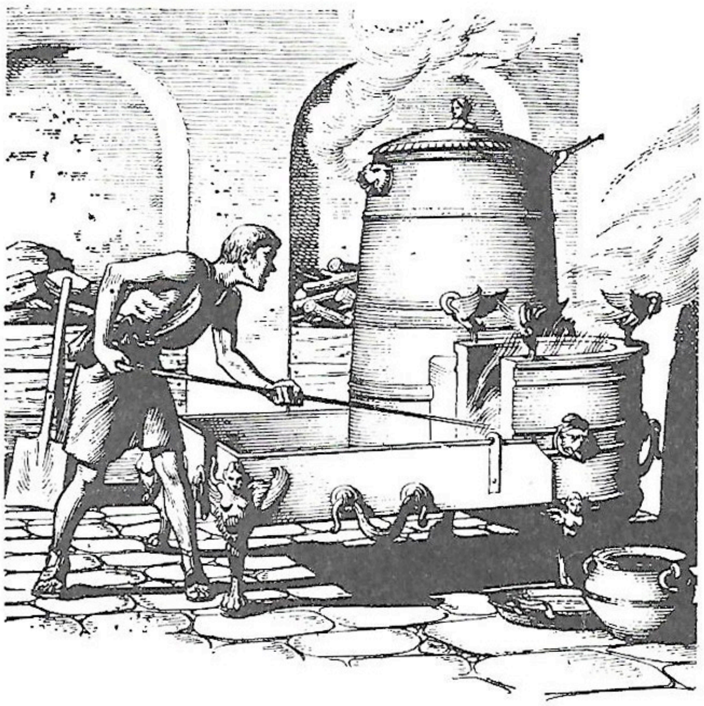

Fig. 7.19. 1st century A.D. water heater.

Picard illustrates a solid-fuel water heater which stood in the bathroom, to heat the bath water directly by gravity circulation through flow and return pipes plumbed directly into the bath. The heater itself consisted of a cylindrical water jacket surrounding the combustion space (Fig. 7.20). Joly devised a method using the flue gases from a cooking range. The gases passed round a large water vessel before entering the chimney. When hot, the water was withdrawn through a tap over the bath.

A combination water heater and cooking oven, again using solid fuel, was said by Picard[46] to be widely used in France. He condemned it as unhygienic, even dangerous, because of the possibility of the escape of fumes into the kitchen (Fig. 7.21).

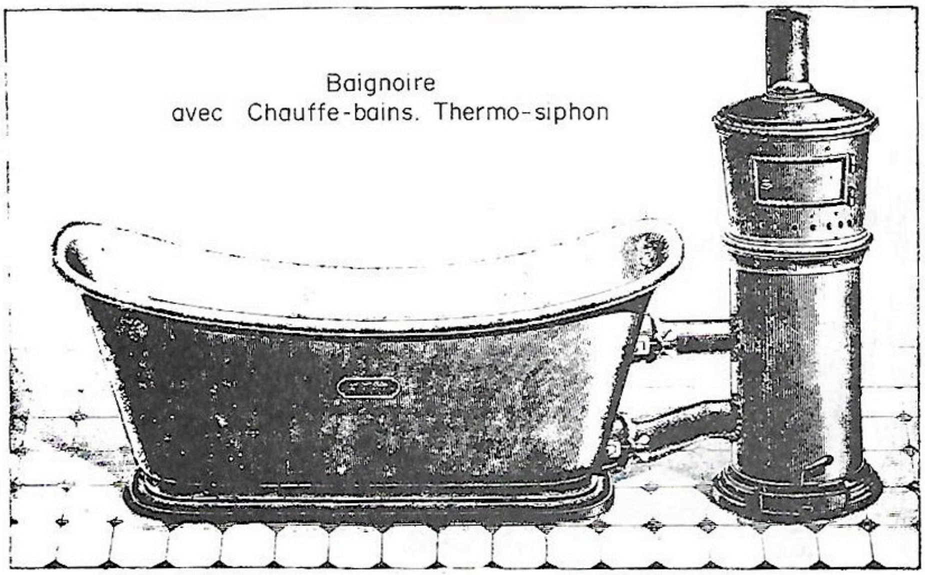

Fig. 7.20. Solid-fuel water heater and bath(1897).

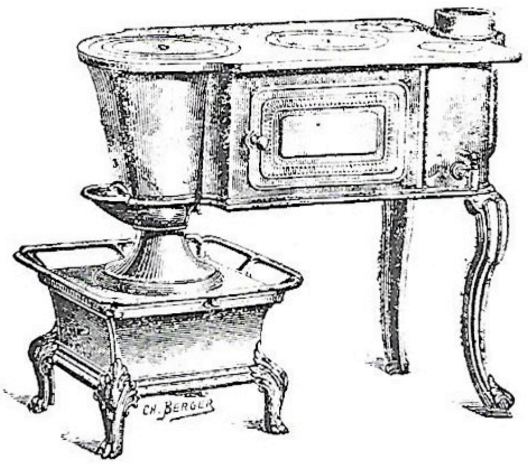

Fig. 7.21. Combination water heater and cooking range(1897).

Piped hot water supplies were introduced in about 1855. Both independent boilers and ranges were used. Dye was a keen supporter of the independent boiler, for in 1897 he referred to the controversy between the protagonists of the two methods:

> "Many people suppose that the kitchen range fire heats the boiler behind it by means of heat which would otherwise be wasted; and consequently an independent boiler with its separate fire must of course burn an additional quantity of fuel... . This idea is however totally wrong... it can be said with the utmost truth no extra fuel is consumed."

The earliest form of piped installation was the "tank" system, in which the boiler flow and return pipes are connected to a storage tank. The draw-off pipes are all connected to the main flow pipe, on the assumption that hot flow water would emerge. Dye showed that this was a fallacy, and that the water from the taps was a mixture of flow water and water from the tank. By 1897, the tank system had been almost entirely superseded by the cylinder system, which is still in use.

Dye was well aware of the large heat losses which can occur with long circulating and draw-off pipes, and he advocated placing the cylinder as close as possible to the boiler.

The Corporation of Birmingham adopted by-laws in May 1887 governing the installation of "bath apparatus". The requirements included:(36)

"1. For the supply of baths a cold-water cistern, containing at least 270 l must be provided.

2. The same 270-l cistern may be used to supply a hot-water apparatus, but the cold water supply to the bath must in that case be connected to the cistern at a point not below one half the depth of the cistern.

3. The feed cistern to the hot water circulating cistern or apparatus must be fixed at a lower level than the bottom of the said cold water cistern. Or when the hot water apparatus is carried out upon the cylinder system, the bottom of the aforesaid 270-l cold water cistern may be connected directly to the hot water cylinder, but all the hot water draw-off pipes must be connected at or above the top of the hot water cylinder."

(Few towns required the provision of separate feed and cold-water cisterns.)

Jones illustrates an adaptation of the Perkins' system for hot water supply, which he used in 1884 (Fig. 7.22). Indirect cylinders were also used in hard water areas, and Jones designed a storage boiler incorporating primary and secondary cylinders for the same purpose (Fig. 7.23). Raynes would not use indirect cylinders except in hard water areas, because they were more expensive, and less responsive, than the simple direct cylinder. He mentions also a mixed cylinder-tank system which was claimed to give a better service at the high draw-offpoints. A 135-l cylinder was proposed, to allow one bath to be taken.

During the years 1902-4, A. Sayers, a lecturer in plumbing at the Municipal Technical Institute in Belfast, carried out a careful series of experiments on hot water systems.(51) These were designed partly as a means of instruction, but they yielded a number of valuable results. He used the cylinder system, with a 100 l cylinder and a gas-fired boiler (gas rate, 2.5 m^3/h). He measured water temperatures over time at various points in the system; he investigated the position of the flow connection to the cylinder, the arrangements of the draw-off pipes and of cold feed, and the effect of dips in return and flow pipes. He found that the primary flow connection should be at the extreme top of the cylinder, and the latter should be vertical to encourage stratification. The cold feed should be at the bottom and directed downwards to discourage mixing. In the secondary circulation, the return can be of small diameter to minimise water movement.

The back boiler and the independent boiler remained the principal means of obtaining hot water in British households until the spread of central heating in the 1960's. The back boiler was commoner in the North, owing partly to the lower cost of coal, and partly to the concessionary coal given to miners. The independent coke boiler was almost entirely confined to Southern England, where its use was encouraged by the gas companies to provide a market for their surplus coke.

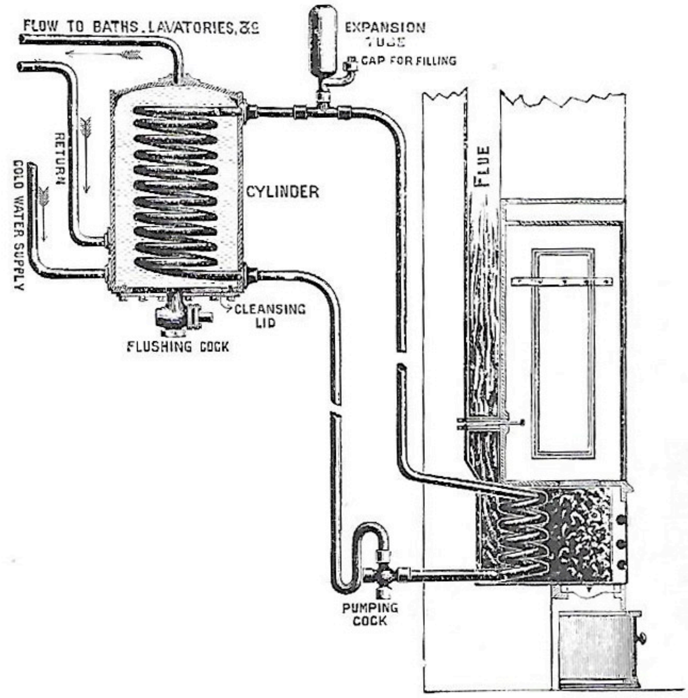

Fig. 7.22. Indirect hot water supply from high pressure coil in kitchen range(1884).

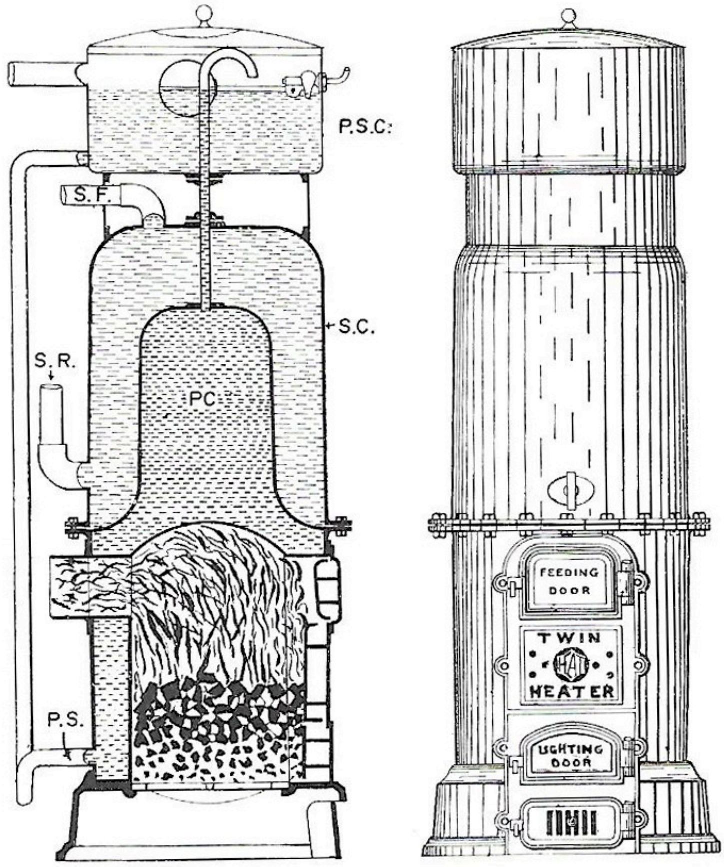

Fig. 7.23. Twin heater (patent) for indirect hot water supply(1904).

A gas geyser was invented by B. W. Maugham in 1865, and appliances of this kind, giving instant hot water, found use in dwellings where there was a piped supply of cold water only, or in cases where an intermittent supply was satisfactory, as when the occupants are away from home all day. An early alternative was the gas circulator, to supplement or replace the boiler of a storage system: these were available at the beginning of the century. All these appliances, and gas-fired storage sets, were still in use in the 1950's.

The electric immersion heater made its appearance at the turn of the century, but its general use depended on the availability of mains supplies. It was widely used prior to World War II as an adjunct to solid fuel systems, to be used in summer instead of the boiler. Although "once-through" instantaneous electric water-heaters have been constructed, the immersion heater in a storage vessel holds its position, not least because it can make use of cheap "off-peak" energy.

REFERENCES

1. Anon (1905) ICS Reference Library, International Textbook Co., Scranton.
2. Anon (1955) History of baths, w.cs, heating, *Sanitäre, Heiztech.*, 20, (1), 1.
3. Anon (1978) Water Supply, *Encyl. Britt.* (15th Ed.).
4. Anon (1962) *The Epic of Man*, Time-Life Books.
5. Anon (1973) *The First Cities*, Time-Life Books, Emergence of Man Series.
6. Anon (1966) *Ancient Egypt*, Time-Life Books, Great Ages of Man Series.
7. Anon (1968) *Treasures of Britain*, Drive Publications.
8. Anon (1975) *Heritage of Britain*, Readers' Digest Assoc.
9. Anon (1963) *Mexico, Sunday Times* World Library.
10. Anon (1977) *Guinness Book of Records.*
11. Anon (1975) The Maya, *National Geographic*, 148, (6), 729.
12. Abel, -. (1927) Die Entwicklung des Gesundheitstechnik während der letzten 50 Jahre, *Gesundh-Ing*, 50, (53), 962.
13. Adams, H. C. (1923) *Domestic Sanitation and House Drainage*, Hodder & Stoughton, London.
14. Barker, F. and Jackson, P. (1974) *London: 2000 Years of a City and its People*, Cassell.
15. Boudet, J. *et al.* (1962) *Great Works of Mankind*, Bodley Head.
16. Braudel, F. (1973) *Capitalism and Material Life, 1400-1800*, Weidenfeld.
17. Briggs, A. (1968) *Victorian Cities*, Penguin.
18. Buchanan and Redcliffe (1870) Privy Council Medical Officer, Report 12, Appendix 4, HMSO, London.
19. Burton, E. (1972) *The Early Victorians at Home*, Longman.
20. Busby, P. R. A. (1974) The evolution and development of London's main drainage, Paper to IEE London, April 30.
21. Chadwick, E. (1965) *Report on the Sanitary Condition of the Labouring Population of Great Britain 1842*, Reprinted, with introduction by Flint, Edinburgh UP. 1965.
22. Charles-Picard, G. (Ed.) (1972) *Larouse Encycl. of Archaeology*, Hamlyn.
23. Coe, M. D. (1971) *The Maya*, Pelican.
24. Darwin, J. (1980) Yesterday in Parliament, *BSE*, 2, (1), 21.
25. Davey, N. (1964) *Building in Britain*, Evans.
26. De la Heba, L. (1973) Mexico — The city that founded a nation, *National Geographic*, 143, (5), 638.
27. Derry, T. K. and Williams, T. I. (1960) *A Short History of Techology*, O.U.P.
28. Forbes, R. J. (1958) *Man the Maker*, Constable.
29. George, M. D. (1925) *London Life in the 18th Century*, Kegan Paul.
30. Gibson, W.L. (1951/3) The water supply of Cambridge, *Trans. Neuris. Soc.* 28.
31. Gimpel, J. (1977) *The Medieval Machine*, Gollancz.
32. Girouard, M. (1978) *Life in the English Country House*, Yale Univesity Press.
33. Hellyer, S. S. (1900) *The Plumber and Sanitary Houses*, (6th Ed.), Batsford.

34. Inoue, U. (1979) Private communication.
35. Johnson, P. (1978) *The National Trust Book of British Castles*, Book Club Associates.
36. Jones, W. (1904) *Heating by Hot Water, Ventilation and Hot Water Supply*, (3rd Ed.), Crosby Lockwood.
37. Lambton, L. (1978) *Temples of Convenience*, Gordon Fraser.
38. MacLeish, K. (1968) Reunited Jerusalem faces its problems, *National Geographic* 134, (6), 857.
39. McIntyre, L. (1973) The lost empire of the Incas, *National Geographic*, 144, (6), 729.
40. Manchester, H. (1967) *The Incas' Last Stronghold*, Book of World Travel, Readers' Digest Assoc.
41. Michell, G. (Ed.) (1978) *Architecture of the Islamic World*, Thames & Hudson.
42. Moseley, M. G. and Mackey, C. J. (1973) Chan Chan, Peru's ancient city of kings, *National Geographic*, 143, (3), 318.
43. Nicolais, J. (1979) Stepped tanks of India, *Arch. Record* (Oct.), 166, (952), 240.
44. Palmer, R. (1973) *The Water-closet – A New History*, David & Charles.
45. Péclet, E. (1861) *Traité de la Chaleur* (3rd Ed.), Massone, Paris.
46. Picard, Ph. (1897) *Chauffage et Ventilation*, Baudry, Paris.
47. Raynes, F. W. (1909) *Sanitary Engineering and Plumbing*, Longman.
48. Robertson, P. (1974) *'Shell' Book of Firsts*, Ebury Press, Michael Joseph.
49. Robins, F. W. (1946) The Story of Water Supply, O.U.P.
50. Rowntree, N. (1976) Water engineering – 100 years of evolution, *Proc. I Mech E*, 190, 65-76.
51. Sayers, A. (1906) *Experiments on Hot Water Systems*, Sanitary Publishing Co., London.
52. Strandh, S. (1979) *Machines*, Mitchell Beazley.
53. Wheeler, M. (1964) *Roman ARt and Architecture*, Thames & Hudson.
54. Wright, L. (1960) *Clean and Decent*, Routledge.
55. Burchell, S. C. (1972) *Upstart Empire*, Macdonald.
56. Curl, J. S. (1973) *Victorian Architecture*, David and Charles.
57. Warner, P. (1971) *The Medieval Castle*, Barker.
58. Gilyard-Beer, R. (1958) *Abbeys*, HMSO, London.
59. de Haan, D. (1977) *Antique Household Gadgets*, Blandford Press.