

Ancient Hydraulic Systems - Part II

by C. Mundigler

Turn on your tap at home and what do you get? Water - hot, cold or anywhere in between, and unless the water main in the front yard bursts, we don't really think about how it gets there. Even though we may not be using aqueducts and clay pipes anymore, the technology involved in these forms of water transportation systems is no less amazing than anything modern engineers can dream up!

Although justifiably praised for running aqueducts, conduits and pipelines across miles of deserts and over rugged terrain (and sometimes even through mountains), the Romans were not the first to devise clever ways of transporting water. Portions of copper drainage pipes have been found at the Fifth Dynasty pyramid complex of Abusir in Egypt dating from between 2750 B.C. and 2625 B.C. - well before anything comparable had even been thought of in the Graeco-Roman world. About a thousand years later, Aegean palaces, such as Knossos on Crete, followed suit with elaborate pipes and drainage systems which attended to many a royal need. In about 1240 B.C. on the Eastern mainland, subway-like tunnels, called qanats, brought water from neighbouring hills to Assyrian centers such as Nimrud. Miles of similar qanat tunnels have been found in Israel, Syria and Egypt, dating from 700 B.C. to 500 B.C. These were desert-dwelling people who recognized the need for a technology which would bring them an efficient and dependable water supply.

In the reign of the Assyrian King Sennacherib (705-681 B.C.), the earliest known aqueduct was constructed to supply water to the Empire's capital of Nineveh from mountain streams some thirty miles away. It proved to be a remarkable engineering feat of stone-masonry channels carried on bridges across rivers and valleys to supply both the population and agricultural needs of Nineveh. Excavated in 1933 by

the Oriental Institute of the University of Chicago, it was truly a fitting tribute to the technological ingenuity of a mighty empire.

In Italy, the Etruscans began hydraulic technology by directing streams in underground conduits - a method picked up by the Romans for their first aqueduct systems of around 312 B.C. Appius Claudius Caecus built an aqueduct, most of which was underground in the Etruscan manner, to carry fresh water to Rome from hills ten miles away. As Rome grew, her demands for water grew, and, by 150 B.C., engineers were called upon to devise more efficient channels, pipes and, of course, the famous Roman arch to support the aqueduct conduits across rivers and valleys alike. From the second century B.C. on, the Romans built incredible monuments to their engineering expertise in the form of elaborate aqueduct bridges to carry the conduits throughout the far-flung Empire. Not satisfied with single-level arches, the Romans pushed their art to the extreme with double-tier arches, such as those at Segovia in Spain, and even triple-level arches, such as those of the Pont du Gard near Nimes in France - both still standing as reminders of the genius that was Rome. (For an excellent engineering and structural analysis of the Pont du Gard aqueduct bridge, see the March 1989 issue of Scientific American magazine.)

There were a number of water transport systems available to the Romans, but the open conduit or channel system and the closed conduit or pipe system, working on the siphon principle, were the most frequently used. The latter, however, was much more difficult to plan, build and maintain than the open channel design. The first century B.C. Roman architect Vitruvius states that "there are three methods of conducting water, in channels through masonry conduits, or in lead pipes, or in pipes of baked clay" (Book VIII, Chapter VI.1 of his Ten Books on Architecture). He goes on to describe gradients and structural details and how to lay subterranean channels of either cut stone or vaulted masonry, and finishes up the section on "Aqueducts and Cisterns" with a description of standard sizes and pressures for lead and clay pipes. It is obvious that Vitruvius preferred clay pipes, for he says that "water ought by no means to be conducted in lead pipes, if we want to have it wholesome". Although both masonry conduits and lead pipes would have been coated internally with calcium carbonate from the water in a very short time, making the possibility of lead poisoning almost negligible, Vitruvius also preferred clay pipes to lead because "the taste is better", and who could argue with that?

In his book The Water Supply of Rome, the water commissioner of 97 A.D., Sextus Julius Frontinus, describes the construction, maintenance, and uses (both legal and illegal) of Rome's bountiful supply of fresh water, which he estimated to be 222,237,060 gallons of water a day (De Aquaeductibus, 65-73). The Greek historian and geographer Strabo also tells us of the abundance of water which "is brought into

the city through the aqueducts in such quantities that veritable rivers flow through the city and the sewers" (Geography, v.iii.8). It is both the private and public use to which the Romans put this great abundance of water which flowed into their cities that we will turn our attention to in the next article of this series.