

In the previous article of this series on ancient hydraulics, we investigated some of the water-lifting devices developed in Egypt and how these systems met the needs of the ancient Egyptians and Romans alike. Whether used in irrigation, mine drainage, private, public, military water supply systems or harbour construction, the low lift shaduf and water-screws described previously ushered in a new technology which would change forever the way people used water.

Despite the invention of the shaduf around 3000 BC, it would be many centuries before a system was developed which would improve upon the water-lifting capabilities of this simple device. One such notable change, for example, was the introduction of draught animals as a power source to

side." (VL200). Vitruvius further explains that "although it does not lift the water high, it raises a great quantity very quickly." (X.IV.1). He goes on to explain, in detail, the construction of the tympanum and the fact that "the thing is turned by the tread of men" by which "a large quantity of water is furnished for irrigation in gardens, or for supplying the needs of saltworks." (X.IV.2). One major concern, and an obvious drawback with the tympanum, was that it was easily clogged and probably required considerable maintenance. The tympanum was in use throughout the ancient world with archaeological evidence for its existence being found in Spain, Romania, Italy and Britain, although literary and papyrological references maintain that it was used in the Eastern Mediterranean as well.

Finally, the last mechanical water-lifting device we will look at in this article is the bucket-chain, once again clearly described by Vitruvius. It is simply a horizontal axle with a treadmill attached, and passing around the axle is a closed "double iron chain, which will reach the surface (of the water) when let down..." (Vitruvius, X.IV.4). Attached to the chain are a number of bronze buckets which carry the water from the stream below to the conduit above as they tip over at the top of their cycle (see Figure 1(b)). One of the advantages of this device is that the height to which the water can be raised is virtually unlimited, unlike the other three devices described above which are limited by the size of the main wheels or drums. Given enough power, the bucket-chain could raise water to almost any height. Once again, it is likely that a water-wheel turned by the current of a river operated the bucket-chain in some cases, providing an alternative power source to the use of human or animal labour. This meant that the bucket-chain, or any other water-lifting device connected to a water-wheel, could be operated for twenty-four hours a day if necessary with no reliance on manual labour of any kind except for occasional maintenance.

Literary evidence for the bucket-chain can be found in the fifth century Dialogues of Sulpicius Severus in which he describes a trip to the Nile where he met a hermit who "possessed one ox whose only task was to raise water by driving a machine fitted with wheels..." (1.13). Despite the parched desert climate, ample water was obviously supplied by this device for irrigation purposes "for the copious watering gave such fertility to the sandy soil that we saw the vegetables of that garden flourishing and bearing fruit marvellously." (1.13).

For archaeological evidence of the bucket-chain, we can look at a bath building complex at Cosa in Italy, northwest of Rome. A bucket-chain supplied the bath installation at Cosa with water as early as about 150 BC, and there is evidence for similar uses in Egypt and Palestine dating from the third century BC to the end of the Roman Empire. While it seems to have been used during this long period mainly for irrigation in Egypt, the

rest of the western Empire used it mostly to supply bath installations such as those at Cosa and not for something as utilitarian and basic as agricultural irrigation.

In the next article of this series, we will conclude our overview of the ancient hydraulic systems and mechanical water-lifting devices with a look at the various types of water-wheels, including their construction and use in easing everyday labours.