Roman wooden force pumps: a case-study in innovation

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In 1868 M. Schultz, the village schoolmaster of Kertzfeld in Alsace, found a Roman pump in his garden. He wrote a report on it, which was read to the Archaeology section of the annual meeting of the learned societies of France at the Sorbonne on 2 April, 1869. The minutes[1] record that 'Unfortunately, archaeologists are rarely versed in the mathematical sciences; hence there was no discussion on this novel subject submitted for the consideration of those attending the Sorbonne. Nevertheless, [even] if there was no discussion of the work of M. Schultz, everyone was in agreement in praising the wisdom, zeal, and selflessness which this zealous teacher has shown in this matter'. It is hoped that the present study may help to increase interest in this 'novel subject'.

The wooden pump is an instance of a Greek invention the original design of which was cleverly re-engineered in Roman times to be easier to manufacture, to use cheaper materials, and to provide several advantages over its predecessor. This was done by adopting a radically different approach to the problem of creating spaces to contain pressure. The force (or pressure) pump is attributed to Ctesibius of Alexandria (*fl.* *c.*270 B.C.). A cylinder is filled with water; a piston then pressurises the water and displaces it to a higher level. Initially, force pumps were made by fabricating the individual elements in bronze and fixing them together. The Roman design enabled a pump to be manufactured in a radically different way, by cutting apertures into a single large block of wood, and making internal spaces pressure proof by plugging their extremities.

This paper describes the history, use, design, operation and performance of the Roman wooden force pump. Section 1 sets out the background, discussing sources of water and the means used to raise it, then the concept of the force pump, first in bronze, later in wood; the 19 known wooden examples are then described. Section 2 explains the generic design of the wooden force pump, the individual features of each part, and then the method of driving the pump, and its operating cycle. Calculations are set out of the possible performance of the pump, and the manpower required to drive it.

1. BACKGROUND

Sources of water and methods of supplying it[2]

Water is essential for domestic use, for irrigation, and for some industrial processes, but its supply poses numerous problems. As a fluid, water will always gravitate to the lowest point it can reach; it is very heavy (heavier than most wood, a cubic metre of water being one tonne or 1,000 kg); and it is somewhat viscous — it does not flow completely freely. The issue is not only how to find enough water, but how to provide it where it is needed. Raising water requires substantial power: energy must be supplied in some form to move the mass of water from a low level to a high level. In addition, as water moves, there is friction between it and the surface of the channel or pipe in which it is carried. Unless pumped, water will only flow if this friction is countered by allowing the water to run downhill — i.e., by sloping the carrier. The friction increases as the carrier decreases in size, so the smaller the carrier, the greater the slope must be before water will flow; and even then the speed with which it does so (and thus the rate at which water is delivered) depends on the slope of the carrier.

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1 Chabouillet 1869.

2 Oleson 1984 (hereafter simply "Oleson") is a monumental study of the whole field of Greek and Roman water-lifting devices. Hodge 1992 surveys Roman water-supply generally and discusses aqueducts in detail.