INTRODUCTION

by Ángel Moreno Santiago

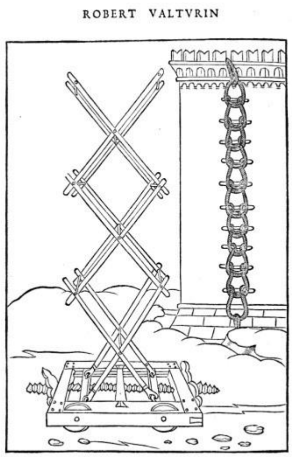
to the translation[1] of the chapter entitled ñJuanelo Turriano (1500-1585)ò in the book *Beitrage zur geschichte des maschinenbaus* (contributions to the history of mechanical engineering) by Theodor Beck, 1st edition, Berlin, Julus Springer, 1899, pp 365-390.

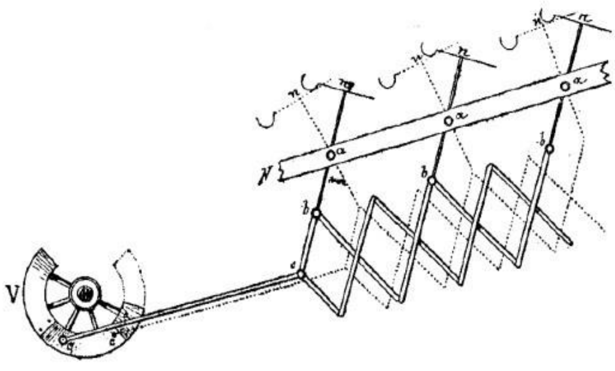
In 1861, Luis de la Escosura y Morrogh (1821-1904), forestry engineer and senator for the Spanish province of Albacete from 1882 to 1894, was commissioned by the Municipal Government of Toledo to study the cityôs water supply system. He was deeply impressed by the ruins of the Juanelo Turrianoôs device in the river, writing ***ñ**...(it) roused in me the desire to understand Juanelo**ô**s carefully designed and virtually splendid machine, and ever since I have spared no means within my reach to satisfy that curiosity.**ò***

Luis de la Escosuraôs findings on the subject were published in 1888 in the *Memorias de la Real Academia de Ciencias Exactas, Físicas y Naturales de Madrid* (proceedings of the Royal Academy of Mathematics, Physics and Natural Science of Madrid), volume XIII, part 2, under the title "El Artificio de Juanelo y el Puente de Julio Cesarò (Juaneloôs device and Julius Caesarôs bridge).
One of the issues that troubled Luis de la Escosura when drawing the conclusions to his study was to determine how the Valturio scissor ladder cited by Morales in his *Antigüedades de las Ciudades de España* (ancient infrastructure in the cities of Spain) fit into the design.

The Valturio scissor ladder is a simple mechanism that the Italian engineer included in his *De re militari*, a treatise on machinery published in 1472. The horizontal plane at the top could be raised or lowered without tilting by turning the threaded axle on the bottom.

Escosura came up with two solutions for adapting the ladder to Juaneloôs device.





In one, the ladder would have been used to transfer the back and forth motion. As shown in the figure, two similar mechanisms would have been positioned in parallel: the second is drawn in dotted lines in the background. The semi-wheels labelled ñVò would moved the two ladders which would in turn cause the buckets hinged to the anchorage points (ñaò in the figure) in timber plank to rock back and forth. Behind N is a similar plank that holds a second set of

1 We are grateful to Birgitt Klein van der Felden for her assistance with the translation.

buckets, also shown in dotted lines.

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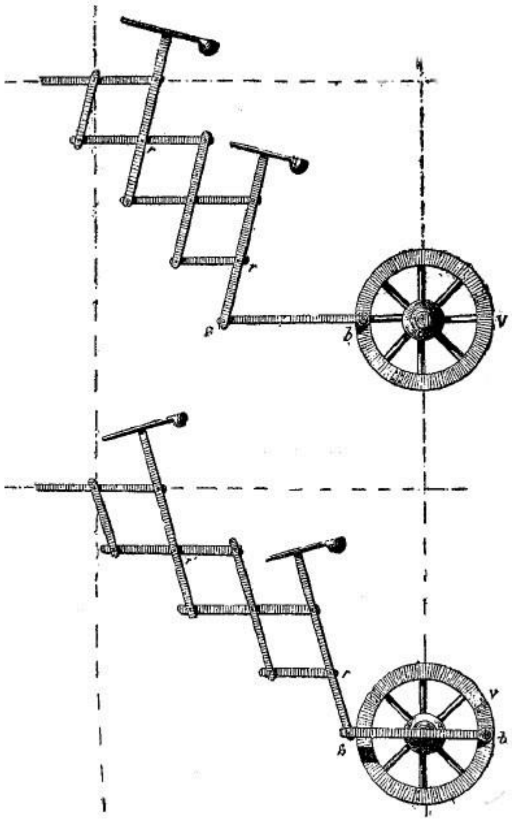
For this mechanism to work, the hinges could only be positioned at the points shown as tiny circles, for the rhombi were not supposed to change shape when the device was in operation. In that case, however, while it would look like a Valturio ladder, it would fail to fulfil its primary purpose. As the result of this solution would be a static ladder, engineer Escosura devised a second solution that would take account as well of its dynamic potential.



The second figure shows the two extreme positions of a mechanism that works with two points of fixity: the centre of the wheel and the upper hinge on the ladder. Ignoring the extra degree of freedom that would entail and the fact that the left end of the lower connecting rod would need to travel in a horizontal guide track, this mechanism would make the buckets rock back and forth and thereby lift the water if, as in the first case, two parallel systems were in place and made to operate synchronically. The problem would be to synchronise the horizontal components so the water would have time to spill *preferably* into the receiving buckets

Comparing the two alternatives, Escosura reasoned as follows.

ñIn the first figure, the channels alternately receiving and spilling the water would revolve on pins in a fixed position, whereas in the second, these pins would change position: i.e., they would move forward or backward depending on whether the system of pivoted levers was opening or closing. Consequently, the distance between two adjacent pipes would grow during backward motion (lower drawing), because the rhombi formed by the narrow boards would stretch in the general direction of the drawing arm, while during forward motion (upper drawing) the distance would shorten because the rhombi would stretch perpendicular to its axis. If the ladder had worked like a drawing arm with pivoted levers, which is hardly believable, the N boards would not have formed part of the machine; rather, the drawing arm would have been attached directly to the sturdy wall that rises from the river to the fortress.

Given the aforementioned difficulties and the scant data with which Morales described the device, I believe that the sole solution for adapting the Valturio ladder to Juaneloôs machine is as depicted in the first figure.

The scissor ladder on the device, comprising narrow timber boards, is a perfect body, far and away better than Ramelliôs iron bars and rings, which in the frequent changes of direction would necessarily collide, inducing jerking that would shorten the life of the system.

I must admit that I see no need for two buckets on each pipe... one would suffice, for the pipe could empty directly from the opposite end into the closest bucket on the other row, as in Ramelliôs apparatus.ò

Proof of the interest that Escosuraôs essay aroused in Beck is that the German engineer devoted a full chapter in *Beitrage zur geschichte des maschinenbaus* to Juanelo Turriano The translation of Escosuraôs text into German took up most of its 26 pages, which nonetheless also contained a number of interesting remarks and Beckôs suggestions for solutions to the dilemma posed by his Spanish colleague. Although we do not know whether Escosura learned about Beckôs reflections before his death in 1904, it is safe to say that they would have been to his liking.

The following translation of the chapter entitled ñJuanelo Turriano (1500-1585)ò in *Beitrage zur geschichte des maschinenbaus* was based on the copy of the first German edition of the book on deposit in the Fundación Juanelo Turriano Library stacks, which also hold a copy of Luis de la Escosuraôs original essay, dated in 1888.