Water-Power in Portugal: The Town of Tomar and its Industrial Area

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The river Nabão which runs through the central Portuguese town of Tomar has provided an energy source for industry which can be documented for eight hundred years and presumed to go back to Islamic and Roman times. The water supply was canalised in the fifteenth century to create an artificial industrial island. In this area seven olive-oil factories and six flour-mills were constructed: four of the factories survive though used for different purposes. The site of another is occupied by a turbine-driven electricity station, while the southern end of the zone has a fine water-powered flour-mill built in 1882 and equally fine roller-mill opened in 1912. The central importance of water-power in this area over five hundred years was the subject of an intensive field and documentary study by a team of Australians in 1988 and is a stimulating contrast with the short-lived harnessing of water to colonial industry in Australia.

INTRODUCTION

Every industrial site in the Old World and the New has an energy source. Most energy sources, wind, water, steam, gas, electricity, leave archaeological traces, but none more regularly nor more revealingly than water. In Australia water has been significant in powering rural industry in the colonial period, particularly flour-mills, but it was quickly matched and soon superseded by steam. In Portugal water-power has remained of prime importance not only for rural industry but also for some urban industry into the present. This is despite problems of flood and drought which differ only in severity from the Australian experience. As a result of the continuity of very simple hydraulic devices, alongside much more sophisticated water innovations of the nineteenth and twentieth century, fieldwork in Portugal offers both the historian and the archaeologist uncommon opportunities to see in daily action technologies of work which were largely discarded in Australia a century ago. There are certain features of Portuguese water-exploitation, such as the use of horizontal wheels, which have no counterpart in Australian industrial archaeology, but there is a great deal that is shared experience, long since gone in Australia but alive and tolerably well in Portugal.

Fig. 1: The location of Tomar in central Portugal.

Fig. 2: The incipient town of Tomar and the river Nabão in the thirteenth century. The area reclaimed in the later middle ages lay between the ‘rua direita dos moinhos’ (mill street) and the main course of the river where Nabão is written on this map. (From da Costa Roas, 1981).
In 1988 the Australian team completed an archaeological survey of an industrial complex in the central Portuguese town of Tomar (Fig. 1). Tomar is a prosperous market-town north of Lisbon, situated strategically on the River Nabão, a medium-sized tributary of the Tagus.\(^1\) Throughout historic times Tomar and its area have produced grain and olives on a significant scale. Grain requires milling, olives crushing, and the Nabão provides a reasonably stable source of energy.

It is most unlikely that the Romans and the Moors, both in their own way masters of hydraulic engineering, with a farming settlement on the east bank of the river Nabão, did not exploit the power of the river. However, despite several archaeological excavations of the Roman town, no evidence has yet been produced to locate early water-diversions, wheel locations and industrialised or irrigated areas.\(^5\) This is partly because of changes in the course of the river, which was much wider in this period, spreading over marshy semi-islands well to the west of the present river-course, both upstream and downstream from the Roman bridge which occupied the site of the present Old Bridge (Fig. 2). The sole survivor of these islands is the park known as the Mouchão, to the north of the bridge. As late as the thirteenth century, similar semi-islands covered the entire area between the present Mill Street (rua dos Moinhos) and the present west bank of the Nabão. Any water-powered industry on the western side of the river must therefore have been located on what is now reclaimed land.

The decisive reversion of this region of Portugal to Christian hands came in the twelfth century when the military order of Knights Templars took over Tomar. The Templars probably inherited flour-mills and certainly built more. The first town charter of 1162 specifically refers to mills with vertical water-wheels.\(^6\) These mills are likely to have been situated at the south-eastern end of the present Mill Street.

By the fifteenth century there had been a great transformation. The Templars had been succeeded by the Order of Christ and the Christian population (still quite small) had expanded towards the river from the shelter of the great castle on the crag west of the river. The head of the Order of Christ at this time was Henry the Navigator, the Infante, and under his powerful direction the old town took its present form on the flats between the castle and the river, leaving the area of Roman, Visigothic and Islamic settlement on the opposite bank to become grazing paddocks and olive-groves under the control of the church (Fig. 3).\(^7\)

These urban developments prompted a rationalisation of water resources. The river Nabão was dammed and an artificial canal some 250 metres long was constructed running parallel to the river on the western side. The dams were a substantial capital investment by the Templars and their successors, the Brothers of Christ. Although in private ownership since the dissolution of the Order of Christ in the 1830s, the major weir just upstream from the Old Bridge is still known today as the Brothers’ Weir ( açude dos Frades) and is still the critical factor in controlling water-power in the town (Fig. 4).\(^8\)

The embankment to the west of the new canal in the fifteenth century formed the edge of the reclaimed swampy area extending eastwards from the old Mill Street. This area soon became tightly packed with urban housing.\(^9\) The long, narrow artificial island created between the canal and the river had from the outset an exclusively industrial nature. Although the actual industries operating there have changed over the centuries, the industrial character of the island is quite unchanged.

### THE OLIVE OIL WORKS

From the fifteenth to the nineteenth century this industrial zone and the area on the river immediately to the south housed seven olive-oil works ( lagars) and five flour-mills, all built in stone and all water-powered. The main part of the artificial island was occupied for four hundred years by six lagars, cheek by jowl (Fig. 5). All these buildings are
Fig. 4: The principal late medieval weir in the river Nabão just north of the Old Bridge. The basic structure was the investment of the Brothers of Christ; thus its common name is still the Brothers' weir. The island in the middle background is Mouched, the only sand island in the river to survive today. The canal powering the industrial zone goes off to the bottom left while the river flows southwards off to the right.

Fig. 6: Lagars 1 and 2 immediately south of the Old Bridge, with the canal in the foreground.

Fig. 7: Lagar 7 with the royal arms of Portugal in an eighteenth century carving. JTP 1903 over the door commemorates the purchase of the lagars by Joao Torres Pacheco. The building is now a private restaurant for Mendes Godinho.
1837–38 when all the possessions of the Order of Christ were being secularised. There are two principal traditional methods of squeezing olives commercially: beam-presses and crushing-mills. Examples of both can still be seen in rural parts of Portugal today. The beam-press operates by the slow steady pressure of a vertical crusher attached to a heavy horizontal beam which is pivoted in a substantial stone footing usually within the outside wall of the building. The crushing-mills are normally of the sort which we in Australia describe as Chilean mills, in which a vertical grinding-stone is driven around a large bowl by a central axle connected through gearing to a source of power. In Tomar, as regularly in Portuguese zagars, this source of energy was water. The traditional beam-presses, however, required no power save the labour of man or occasionally an animal such as a horse or a donkey, turning a handle to screw the press down on the olives (Fig. 9). The olives were placed on circular mats woven for the purpose, piled high one on another.

The documentary evidence of the sale notices tells us that four of the five zagars described in detail had two Chilean mills apiece. All these zagars also had beam-presses, in three cases six each, in the fourth (lager 2 on Fig. 5) seven. The fifth lager described had six beam-presses and no Chilean mill: this implies that this lager uniquely had no need of water-power. This building, the former lager de Martim Telles, is still standing (number 3 on Fig. 5) and is now the casting-floor of the foundry. Inspection shows no trace of access to the canal, unlike the adjacent lager, now the machine-shop, which retains the sluice-gate needed to control the water-power for its two Chilean mills.

The written material gives no indication of the precise location of each lager, though it does demonstrate relative locations. Nor does it give information about water-power and it does not hint at the internal lay out of these zagars. Location can be made precise by external examination and, in the case of lager 2, formerly the Lagar do Secretario and now the machine-room of the foundry, the industrial plan can be recreated by an intelligent study of vestigial internal features (Fig. 10). Despite the century of reuse as a foundry, this lager retains on its eastern wall four stone footings for olive-oil beam-presses. Four pairs of stones are set vertically on a plinth 0.25 metres above ground level and at right angles to the eastern wall. On top of these vertical stones are stone blocks butted together to form a lintel, 2 metres above ground level. Each vertical stone is pierced by one rectangular hole and one circular hole. They are uniform in size and position and line up in horizontal rows. The round holes in the stones show that a circular wooden shaft extended the row of holes and that between each pair of stones a wooden press-beam projected horizontally.
westwards. Presumably a rectangular beam extended along the row of rectangular holes, either to brace the footings or to prevent the beam from being raised dangerously high (Fig. 11).

The evidence of these press-beam footings confirms that there were seven in all. The intervals between the pairs of stones, from north to south, are 0.70, 0.92 and 0.73 metres. One stone of each of the southernmost pairs has been removed and fill inserted: the depression at the base of a removed stone confirms its former position. If all stones were in position the gaps between the pairs would be regular at approximately 0.7 metres. At the northern end, three more pairs of stones have been taken away to allow the insertion of a concrete wall and a sliding door; brick infill indicates the area where the original stone plinth has been removed. If all seven pairs of stones, and therefore footings for seven beam-presses, were in place, they would leave a space of 3.72 metres between the footing and the southern wall and a space of 4.65 metres between the footing and the northern wall (Fig. 12).

The archaeological evidence therefore shows that seven beam-presses, as advertised in 1837–38, projected from the eastern wall into the centre of the rectangular lagar, leaving a substantially larger space to the north than to the south. The metal sluice-gate inside the foundry is in the extreme north-western corner. When the canal outside is drained the water-courses into the old lagars can be seen low down on the eastern wall of the canal. The entry of water to lagar 2 is only at the place where the sluice-gate is located internally (and there is no provision of water at all for lagar 3 which had no Chilean mill). The power-source therefore for lagar 2 was in the corner where there was maximum free space left by the great beam-presses, and it is highly likely that the two Chilean mills were erected in this north-western sector of the floor-space.

A very similar lay-out was observed in an intact, though disused, lagar, the Lagar de San Guilherme, out in the country near Dornes. Here the single Chilean mill was in a corner directly adjacent to the water-source (in this case a breast-shot vertical wheel), while the beam-presses were bedded in the opposing wall.\textsuperscript{13}

\section*{THE FLOUR MILLS}

Unlike most of the lagars, the flour-mills at Tomar in the 1830s and before have almost completely vanished. Our knowledge of these mills is quite good because an inventory compiled for the Order of Christ in 1809 is unusually specific about their capacity and technology.\textsuperscript{14} Three of the six mills are described as azenh\~as, three as moinhos. The distinction between azenha and moinho in this case is that the azenh\~as had vertical undershot water-wheels, whereas the moinhos were powered by horizontal wheels called \textit{rodizi\~os} (Fig. 13). The milling capacity of the complex was considerable and only flour suitable for bread was produced. Each of the three azenh\~as had two vertical wheels, each wheel driving only one pair of grindstones. The moinhos had a larger number of grinding stones, eleven pairs in all, apportioned 4, 3 and 4 among the three mills. Each pair of stones was driven by its own \textit{rodizio}.

Seventeen pairs of stones and eleven water-wheels constitute a substantial milling enterprise and the flour produced was of vital importance to the well-being of Tomar. Without mills on this commercial scale in the eighteenth and nineteenth century the growing town could not have been adequately supplied with flour and bread. Although the number of azenh\~as was reduced to two by 1836, the milling capacity was unaltered, since the two remaining azenh\~as had six pairs of stones just as the three had had thirty years before.\textsuperscript{15}
One of these mills was on the site of the present Nabantina mill, but the others just downstream have entirely disappeared. The final vestiges of their foundations and water-systems were swept away by the building of the New Bridge across the Nabão in 1967 and the attendant road-works on the western approaches.

The creation of the present-day mill complex was begun by a prominent Tomarensian, Francisco Alves Cristovão Pinheiro. Over the years 1879 to 1882 this prosperous pharmacist and local politician acquired the various shares of the old mill-buildings which had been divided among the heirs of the original purchasers of the Order of Christ’s property.

The buildings bought by Pinheiro included the two-storeyed mill on the site of the Nabantina, just to the east of Lagar. Pinheiro had capital and by the end of 1882 was transforming the old mill with its horizontal wheel into ‘an important milling factory’ powered by a large vertical wheel. Pinheiro retained the two old vertical-wheel driven azenhas to the south. The distinction drawn between the azenhas and the factory (fabrica) seems to have been one of scale rather than of technology, since the single vertical wheel of the factory was geared to drive at least six pairs of millstones, whereas the azenhas had a vertical wheel for each pair of stones. The principle was the same, but the interior of the new factory was more sophisticated.

A French millwright called Le Moine was employed to plan and erect the new mill in 1882–83. The new, iron water-wheel is known only from a photograph, and was some five metres in circumference. It was under-shot and the water supply came from a new mill-race leading south from the basin on the canal. The water-wheel was placed against the eastern wall of the mill, where the turbine house is now. The south-eastern wing of the mill area, which is still there today, was built at an angle of 60 degrees to the main

mill, so the effective length of the eastern wall as a wheel-housing was reduced by 1.5 to 2 metres. This left a wall-surface some 7 metres long for the wheel. A doorway into the mill occupied the northern end of the eastern wall, exactly where the present internal doorway from the turbine house into Level 1 of the mill is located today. The axle of the wheel appears on the photograph to be a little above the floor level of the mill and the edge of the wheel comfortably clear of the doorway.

Partly obscured by subsequent changes, there is an arched opening one metre broad in the original eastern wall of the mill: this opening now allows the passage of an horizontal auger from the silo into the mill but is largely blocked by modern bricks. The northern edge of the original aperture is 3.3 metres from the inside northern wall of the mill. It is therefore possible that this aperture is the original housing for the axle of the water-wheel of 1882.

The drive-axle of the wheel which generated 26kW to 30kW (35 to 40 horsepower) was certainly much more central in Level 1 of the mill than the present drive, which leads directly to the conversion gears along the northern side. It is unlikely that the gearings and the stones were centrally placed in the 1883 mill, so it is plausible to assume that the drive was taken from the central axle to the present location of the gearings either by cogwheel or by belt.

The mill building was fully utilised from the start, although the number of grinding-stones varied over the years. In 1895 there were five pairs, by 1902 seven pairs, a mixture of imported French stones (the majority) and native Portuguese stones; today only stones from the French Pyrenees are employed.

The needs of this new, much more highly capitalised mill provoked a series of petty squabbles on the use of water from the river Nabão. The owners of the five lagars immediately upstream from the Pinheiro mill reached an agreement in May 1882 to protect the interests of the users of the mill basin adjacent; José Pereira Mendes and other owners of upstream weirs gave similar undertakings the following month; and in July 1883 further assurances were sought from the owners of the various big irrigation wheels on the river to ensure that their weirs did not impede the functioning of the mill-wheel. Pinheiro also owned the critically important Brosiers’ Weir upstream from the mills and lagars (Fig. 4). He was the object of criticism for his use of the weir, just as he had complained about other weir-holders on the river. In 1885 he was required to reconstruct...
the face of the weir to create the present overflow channel: the purpose of this was to abate the nuisance of the increasing build-up of sand in the river below the weir.24 Two years later, Pinheiro incurred 'the hatred of the local people' by attempting to build a stone and cement barrier at the bridge end, which would prevent the local women from washing laundry on top of the weir: the protests won the day and photographs of the 1890s show the washerwomen still at work.25

Ownership of A Nabantina had passed in 1889 to a nephew of the founder, Joao Torres Pinheiro, who was president of the local council from 1890 to 1904.26 The major industrial innovation instigated by Torres Pinheiro was the conversion of the mill's undershot wheel to a compact and efficient turbine. Turbines were not new to Tomar. Its largest employer, the Royal Textile Factory, had introduced turbines as early as 1874 and two others were in operation by 1895. In the early 1890s the paper factories at Porto do Cavaleiros and Prado had also harnessed the river Nabão to drive turbines.27 Pinheiro cautiously followed in 1902. He bought a French turbine and installed it at an olive-oil works he owned on the east bank of the Nabão. After a successful trial of the turbine there, Torres Pinheiro dismantled his uncle's wheel at A Nabantina and on 16 August 1902 installed the turbine in its present place.28 It is striking that the use of steam-power was not even considered: and why should it when water-power still drives the entire mill with great reliability and efficiency today?

The turbine made certain physical changes necessary. The turbine drive had to enter the mill building much closer to the northern wall than previously so a new entry had to be cut in the eastern wall, the entry which is still in use today. This allowed a direct line drive from the conversion gear above the turbine to the gearing for the sets of millstones above (Figs 14-19). It was also necessary to protect the turbine's conversion machinery from the weather: the old wheel had survived happily in the open air. So in 1902 a lean-to shed was erected against the eastern wall of the mill, constructed of wood on a stone footing, with a corrugated iron roof (Fig. 20). This was later superseded by the present
three-storeyed stone wing which completely masks the old eastern wall of the mill (Fig. 21).

When Torres Pinheiro sold the mill in January 1908 to his friend, the local contractor and entrepreneur Manuel Mendes Godinho, he passed on an up-to-date and flourishing business. Almost at once Mendes Godinho laid plans for building a second mill beside A Nabantina. This involved demolishing the last of the working lagars and buying some adjacent land from the municipality, but these plans had to be postponed. A major flood wreaked havoc in the whole industrial area of Tomar in December 1909, doing major damage to A Nabantina and immobilising the water-powered electricity generating plant on the industrial island erected in 1903. Seven months after the flood, Mendes Godinho acquired the electricity plant and the contract to supply the town of Tomar with power and light. In the following year the old lagar beside A Nabantina was pulled down and in May 1912 a new five-storey mill was opened, fully equipped with the latest roller machinery from Switzerland (Fig. 22). The Swiss supplier, Daverio, still operates in Zurich and maintains a model industrial archive. We have the complete order-book entries for 1911-12 and the detailed working drawings of each floor which were done during alterations to the upper floors in 1937. Comparison with the present equipment in the mill shows how little has changed since May 1912 and nothing at all since 1937.

The new mill was named A Portuguesa, perhaps to emphasise that its economic horizons were wider than those of the old mill named after Tomar and the river. The new mill was powered by electricity, supplied by Mendes Godinho's own Central Eléctrica 100 metres to the north (Fig. 8). The electricity cables were run, as they still are today, across the canal to the eastern wall of the mill. Since the electricity was itself generated by water-power, A Portuguesa is still as dependent on the canal for its power as its predecessor, the Lagar de El-Rei, had been, yet it is not reliant on any energy-source outside the control of the Fabricas Mendes Godinho.

From 1912 until the present day the two flour-mills, A Nabantina, grinding by stones, and A Portuguesa, grinding by rollers, have worked in conjunction. No substantial change has taken place in either over the past three-quarters of a century: some Daverio equipment (the governor on Level 1, the separator and winnower, ‘tararu’, on Level 3) was installed in A Nabantina and a roller selector for wheat made by the Austrian firm of Heid was brought in from elsewhere in 1973, but João Torres Pinheiro would have no difficulty in recognising his mill of 1902 and Manuel Mendes Godinho could nod with pleasure at all the well-known features of his A Portuguesa as it was in 1912.

The two flour-mills remain complementary, just as they were three quarters of a century ago. The artificial industrial island immediately to the north remains the congested, busy, diverse complex which it has been for half a millennium. The informed planning of the Brothers’ Weir and canal south from the Old Bridge remains as impressive in the twentieth century as in the middle ages. The virtually intact Portuguesa roller-mill, still fully operational, is an exemplar of a species best represented in Australia by the roller-mill at Young: but Young lacks the documentation of the mill machinery available from Mendes Godinho’s engineers. The no less intact Nabantina mill adjacent, grinding still by traditional stones, offers a most instructive example of the potential of a small nineteenth century turbine drive, rarely employed in Australian industry except in Tasmania. It is also an example of the interdependence of archaeological, photographic and documentary evidence for the clarification of a complex series of physical changes.

The industrial archaeology of a 400-metre stretch of waterway in the middle of an old Portuguese country town is relevant to the study of water-power and entrepreneurship in colonial Australia. The reasons for success and continuity in harnessing the energy of the river Nabão have much to suggest to anyone exploring the virtual abandonment of water-power on the Australian mainland a century ago.
NOTES

1. The team, headed by Aedeen Cremin and Ian Jack, comprised Kirsty Altenburg, Anne Cannon, John Cannon, Wayne Johnson, Roger Parris and Eve Stemning.


8. Amorim Rosa 1964 Os Lagares e Moinhos da Ribeira da Vila pp.7-30. Amorim Rosa is too enthusiastic in dating the canal as early as the twelfth century.


10. Sobreiro de Figueiredo and Silva 1943-50 'Os Lagares e Moinhos da Ordem de Cristo' pp.149-55.


13. The existence of such an analogy in the hinterland of Tomar supports the conclusions drawn by Kirsty Altenburg and the author at the lagar do Secretario.


20. Printed in Custodio and Santos 1985 O Nabao e Tomar nas Origens da Industrializacao Portuguesa p.68. Custodio and Santos calculate the diameter of the wheel to be 8 meters (ibid. p.74) but this is a misreading of the evidence.


27. Vieira da S. Guimaraes 1985 Catagolo da Exposicio Conclusio Industrial - Agricola de Thomar pp.11-12, 14; Custodio and Santos 1985 O Nabao e Tomar nas Origens de Industrializacao Portuguesa pp.76-77.

28. Sousa 1903 Noticia Descriptiva e Historica da Cidade de Thomar p.38; the date 16 August 1902 is inscribed on the floor of the turbine-house of A Nabantina.


32. My thanks to Eve Stemning for obtaining this information.


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