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MILL I. MILLS IN IRAN

i. Mills in Iran

Before World War II most of the corn ground to produce the flour for the staple in the Iranian diet, bread, was processed by traditionally powered mills, principally watermills (*āsīāb*). Except in remote areas they have been replaced by diesel or electrically-driven mills and old machinery has fallen derelict. Muscle power, provided by the women and animals of a household, was probably always the most widespread prime mover, but differing geographical conditions in various parts of the country encouraged the development of wind and waterpower. The large, fast-flowing rivers of Ḵūzestān, the mountain streams of Kurdistan and Azarbaijan, the fringes of the central deserts and the wide expanses of Khorasan favored milling technology in several guises. Medieval geographers, Arab and Persian, and more recent foreign travelers have commented briefly on these mills. Modern field-study can disclose what remained in operation until a few decades ago.

Simplicity. One constant strain in a thousand years of recorded milling history is simplicity. The inventive mind of Ebn al-Razzāz Jazarī restricted itself to curious automata worked by water for the entertainment of the court at Dīārbakr in the late 6th/12th century; it had no effect on the design of the practical devices used by the peasantry in the struggle for survival. The absence of gearing in windmills, the linking of only one pair of stones to a waterwheel, the lack of subsidiary machinery for cleaning the flour are examples of the refusal of this technology to develop into the efficient industry that European corn-milling became in the early 19th century. There are good

reasons for this almost deliberately unsophisticated approach: frequent disruption of the agricultural economy by invasion, harsh landlordship, and natural disasters, a non-specialized approach to the miller's role and skills and the implicit decision not to make the operation of corn-mills contribute significantly to the profit drawn by a landlord from his estate. Therefore mills were small and numerous, machinery was largely wooden, stones were dressed in a primitive fashion and nothing like the feudal European soke operated (the system whereby peasants were obliged to have their corn ground in the lord's mill). Most Iranian millers were always primarily small farmers; part-time milling brought in useful pin-money—one-twentieth of grain ground was the normal charge.

Vanished variety. Since wholemeal flour does not keep long, no household had large quantities of its grain ground at any one time. In most areas seasonal changes in weather conditions made it imperative that several milling options should be kept open: wind, water, and handmills. Sick womenfolk, draught animals desperately needed elsewhere, an exceptionally long period of dry, still weather, both flour jar and purse empty—these seldom all occurred at once. The hand quern (*āsīā dastī*) still used by some nomads, has a long ancestry. Its stones are about 50 cm in diameter and have no reliable device for preventing the runner stone from rubbing against the bedstone, an essential mechanism in true powered mills, where there must be no direct contact between the stones. A larger version, referred to by Wulff as the pot-quern, equipped with this latter device and with a differently mounted handle, was apparently once used in many Iranian households (Wulff, *Traditional Crafts*, p. 278).

Using animal power to operate mills, mentioned by the 4th/10th-century geographers Eṣṭaḵrī (p. 273) and Ebn Ḥawqal (tr. Kramers, p. 430) in reference to Saraḵs, still lingers on in the occasional bazaar for grinding small quantities of culinary substances in edge runner mills (*astarḵān*). The large, heavy stone is trundled round by a blinkered camel, gradually reducing sesame seeds for edible oil, pomegranate rinds for specialist tanning, henna leaves for dyeing, turmeric and saffron for flavoring food, etc. Most of these processes have been mechanized, not least because the same mill could not easily grind saffron one day and sesame the next.

Another formerly widespread use of donkeys and oxen was for raising water, using the so-called Persian wheel (*sāqīya*) with its endless chain of pots. Waterlifting for irrigation was in certain areas partly mechanized by the use

of windmills (*Tārīḵ-eSīstān*, p. 12), possibly in conjunction with an Archimedean screw, as in the Aden salt-pans until the 1950s, or with the simpler transmission required by the *sāqīya*. Norias (*mawāʿīr*), large waterwheels which raise water forced into their buckets by a fast-flowing river, were recorded in Ḵūzestān by Moqaddasī (late 4th/10th century) (p. 411) and still operate in Afghanistan and on the river Orontes in Syria.

Other long vanished waterworks which qualify more strictly under the heading *āsīā* were the floating mills at Baṣennā on a nearby stream (Moqaddasī, p. 408). According to Ebn Ḥawqal (p. 219; tr. Kramers, p. 213) mills (*maṭāḥen*, *ʿorūb*) at Mosul in the 4th/10th century "made of wood and iron, were suspended on iron chains in midstream. Each mill had two stones, each of which ground fifty muleloads per day." Those (*arḥāʾ wa nawāʿīr*) noted by Yāqūt (I, p. 411) at Ahvāz on the Kārūn in about 1225 were probably similar (Wiedemann, *Aufsätze*, p. 288). Their output thus far exceeded anything other mills were capable of, but they were very liable to flood damage. At Baṣra occurred also the only tidal mills mentioned along the Iranian coastline: "mills were erected at the mouths of the canals which were almost entirely fed by the tide, and these were driven at the ebb by the falling water" (Moqaddasī, p. 125). Unlike the floating mill with its large Vitruvian wheel, the tidal mill may equally well have used the horizontal wheel common in tidal mills on the Iberian peninsula and in watermills (*āsīāb*) throughout Iran.

Watermills. a. Horizontal. Horizontal mills are to be found in association with mountain streams from the Shetlands to the Himalayas. In Iran they are fed by a leat diverted from a stream or a *qanāt*. The head of water to drive the wheel is generally penned up in a stone tower or well (*tanūr*) or hollowed-out tree trunk (*nāv*) or allowed to run down a wooden channel set at a fairly steep gradient. The head varies from one to eight meters, depending on the water supply and the output required. If a farmer wants to set his mill running untended for several hours, a small head and a slowly rotating wheel and stones grinding a mere trickle from the grain hopper suit his purpose better than the great volume of water that gushes from the Bāḡ-e Fīn into the watermills outside Kāšān for example. There the water issues under great pressure from a nozzle fixed at the bottom of each wide, deep penstock and is directed against the paddles (*par*) of the horizontally placed waterwheel (*čarḵ*). Inclined wooden penstocks (*āsīāb-e nowdāna*) are more common in Azarbaijan (Figure 51).

The paddles may be shaped like rough spoons or spatulas, wedged at an

oblique angle into the base of the shaft just above its foot bearing. Their outer ends are sometimes linked by a wooden or metal hoop. As they are spun by the jet of water from the penstock the shaft revolves and drives the single runner stone above. The steel or stone foot bearing which supports this main shaft

is well lubricated by the water; it is placed on the footbeam by means of which the gap between the millstones can be adjusted, as the miller alters its height fractionally by repositioning the wedges holding the lightening rod steady against the floor of the millhouse. Otherwise, apart from the wicker, wooden or built-in mudbrick grain hopper from which a feeder channel leads to the eye of the stones, the millhouse is empty of machinery. The flour is collected on a large stone slab or polished area of rammed earth beside the stones. Such mills can seldom grind more than one hundred kilos per hour, and in fact may only grind that amount in a day. The mill at Bāḡ-e Fīn, still operating, has an abundant head of water and unusually large stones (155 cm diameter), which grind considerably in excess of that figure. These stones, used throughout the Kāšān and Isfahan areas, are quarried from the nearby Kūh-e Ḵarkas and should last about eight years, grinding wheat, barley, and millet. They are dressed whenever the inner surfaces become too smooth to break open and reduce the grain.

Watermills fed by *qanāt*s were most often built near the lower end of a system, since a sudden drop of several meters (providing the head of water) part way along its length would pose great problems for the surveying and digging of a *qanāt*. Caravanserai mills were often built on the same pattern (Beazley, *Iran* 15, p. 97). Litigation over water rights for irrigation, which so often bedevilled the Iranian rural scene, seldom extended to watermills, which benefited from, but did not obstruct the flow of water from a *qanāt* or stream on its way to the fields.

Watermills also occurred beside ancient dams in well-watered areas. G. N. Curzon photographed those at Šūštar and Dezfūl (*Persia and the Persian Question*, repr., London, 1966, pp. 303-04, 373) and a dozen were still working at Band-e Amīr near Shiraz in 1963 (Beazley, op. cit., pp. 95-96). The dam lends itself to the incorporation of stone penstocks, grouped round short leats channeling water from the lake behind the dam. Mill construction on this scale and on such a site was the affair and ultimately the profit of a major landowner. The proceeds of Band-e Amīr, built by ʿAżod-al-dawla in about 350/960, like many other pious and practical works were endowed as *waqf*, i.e.,

in trust for the community.

b. Vitruvian. Vitruvian mills (*āsīāb-e čarḵī*) are far less common, occurring on major rivers, like the Zāyanda-rūd, which had a sufficient flow of water to turn the waterwheels through most of the year. Those near Isfahan are breast-shot from a mill race about 2 m above the tail race. The waterwheels, generally one on each side of the millhouse and sometimes constructed in pairs on the same shaft since they are so narrow, consist of twenty spokes, to which wooden blades are attached by wedges, and are held rigid by sticks pegged to the perimeter. The wheels on either side of a millhouse drive separate pairs of stones. Pit wheels and lantern pinions are also made of wood. Due to the gearing ratios Vitruvian mills grind at roughly the same speed as horizontal mills and employ the same size stones; however, they suffer more from damage from floodwater, from reduced flow in the summer and there are in any case more working parts requiring maintenance than in the simple, ungeared horizontal mills.

One of the strangest watermills recorded in Iran was at Marand in Šams-al-dīn Demašqī's day (d. 727/1327). It contained two pairs of millstones operated by water piped from a reservoir within the millhouse. The same water that dropped onto the blades of one wheel was in due course sucked up and funneled across to turn the wheel on the other side. How efficiently it ground corn Demašqī does not say, but the mill seemed to him one of the wonders of the world, the age, and civilization (*Manuel de la cosmographie du Moyen Age*, tr. A. F. Mehren, Copenhagen, 1874, p. 254).

In the Caspian provinces where rice is the main crop, water-powered rice-husking mills (*ābdang*) were driven either by a large undershot wheel in low-lying areas or, further up the Alborz valleys, by a mountain stream diverted down a hollowed-out tree trunk. The water strikes spoon-shaped blades typical of a horizontal mill, but set vertically on a horizontal shaft, which works the rice-husking pestle by means of a cam (Wulff, op. cit., pp. 290-91). Such an application of waterpower may have been introduced in the Mongol period from China where it had been used for many centuries (J. Needham, *Science and Civilization in China* IV/2, Cambridge, 1965, pp. 390-92).

Windmills. Whilst watermills of various kinds are to be found all over Iran, windmills are restricted to eastern Khorasan and Sīstān, an area subject to the 120-day-wind (*bād-e sad-o-bīst rūz*) in the late summer and early autumn. Windmills which only operate in response to this wind still function in certain

villages. When they were first described in detail by Demašqī (op. cit., p. 246) they differed in two important respects from their few surviving descendants: The stones were placed above the horizontally revolving wind-wheel and shrouding walls were so constructed as to admit wind from all four points of the compass (illustration in Needham, op. cit., p. 557). It is generally reckoned that the first point may be Demašqī's mistaken assumption that this windmill closely resembled the horizontal watermill (from which it undoubtedly derives). All later descriptions place the stones below the wind-wheel, where one would expect to find them. The discarding of the four-sided, slitted superstructure was doubtless pragmatic: The strong, reliable wind came from the north at a season when there was little water to power watermills; also, for reasons of convenience and greater security, windmills were built in rows—as many as about sixty-three strung together at Neh—sharing their east and west walls.

In 336/947 Masʿūdī (d. 345/956) made the first known reference to windmills anywhere in the world when he recorded Abū Loʾloʾa's (q.v.) boast to the caliph ʿOmar in 23/644 that he could indeed build a mill driven by the wind (*Morūǰ* IV, pp. 226-27; ed. Pellat, III, pp. 64-65). He murdered ʿOmar the following day and stabbed himself, and we hear no more of windmills except that they were used for corn-grinding and water-raising in Sīstān in Masʿūdī's own day (*Morūǰ* II, p. 80; ed. Pellat, I, p. 246). There is no evidence that the invention predates the Arab conquest, but these horizontal windmills have certainly two, possibly five centuries' start on the independently developed, vertical post-mill of western Europe.

There has been very little conscious imitation of the Iranian horizontal windmill, either further west in Iran itself or further west at all. The Chinese became acquainted with the device at Samarkand in A.D. 1219 and again in A.D. 1414 and adapted it to suit their coastal salt-pans. The mills have remained restricted to the region bounded by Mašhad, Herat, Zāhedān, and Bīrǰand, which experiences the 120-day-wind. They only work in those few months after the harvest, standing idle for the rest of the year.

Within the millhouse are the stones, grain hopper and detachable lower end of the windshaft (*peyvand*). Beneath the stones the lightening cone (*mošt*), made of ashwood and about 40 cm high, stands on a heavy footbeam. This cone supports both the runner stone and the entire weight of the wind-wheel (*čarḵ o par*) and windshaft (*tīr*). The windwheel occupies the open upper storey above the stones, rising about 5 m to the thick crossbeam resting on the

sidewalls, which contains its top bearing. Spokes radiating from the windshaft in up to fourteen layers hold eight (at Neh nine) sails (*par*) made of pinewood slats or reed mats. There is little apparent striving for precise workmanship, for a skilled carpenter is seldom available. Any handy wood is pressed into service and the odd gaps in the sail area serve to spill the excess wind much of the time. The ramshackle structure clearly suits local needs and requires little maintenance. Trenails and old wire wedge and strap the contraption together. Its total diameter is rather over 3 m, but only one sail's width (about 85 cm) is exposed to the wind at any one time, as it rotates into the path of the draught through the wind slit (*dargāh-e bālā*).

Well before the wind reaches gale force, not infrequent during these months, its force must be moderated by stretching a curtain or reads across the wind slit. Like the pinewood (*nājŭ*) near Ḵāf and the popular (*safīdār*) in the Neh area, the reeds (*ney*) are grown locally. The essential metal parts—the thrust pin (*mīḵ*), embedded in the bottom end of the shaft, and the rind (*tobra*), slotted in the runner stone, which it engages—are easily made by the village blacksmith. The stones in both Ḵāf and Neh areas are quarried from nearby mountains and, like all Iranian runner stones, are always in one piece. They rotate at the speed of the windwheel, seldom more than 30 revolutions per minute. As a result the corn is ground much more slowly than in most watermills. The few remaining active windmillers in 1977 agreed that 300 kilos represented an average day's work. The dressing of these large stones (about 150 cm diameter) once a season now that business is hardly brisk, the replacement of a worn lightening cone periodically and the replastering of the mud roof in the autumn are almost the only tasks involved in the upkeep of an Iranian windmill.

The initial construction of a windmill demanded time more than money. Several peasant farmers would pool their resources during slack periods and gradually construct one for themselves. A millhouse has two or three domed mudbrick bays, typical of domestic vernacular architecture, and the walls which shroud the windwheel on all sides except the south rise 5.5 m above the roof (they are usually stepped downwards on the leeward side of the crossbeam). One ingenious detail of the construction, which almost deserves the name subsidiary machinery, is the winnowing passage (*dār-e bād*). This tunnel runs from an opening low on the north wall of the millhouse to a convenient point near the door and enables the miller to winnow the grain in comfort, close to his stones. The most expensive items would have been a pair

of stones, which cost 3,500 rials in 1335 Š./1956, and the tree-trunk for the windshaft.

Once their mill was completed the shareholders would determine the allotment of milling time for their own requirements, the extent to which they could engage in milling for profit (levying one-twentieth of grain ground, as in watermills) and the duty rota. Being relatively unspecialized, the task of supervising the mill at work could fall to any of the shareholders; but in course of time it often became the prime responsibility of one man, older than the rest or infirm so that he was less well fitted to the work in the fields than his companions.

Gradually long rows of windmills grew up on the northern side of villages in Khorasan. In Sīstān more massive, isolated structures remain from the prosperous days of Malek Ḥamza (1030/1619-1055/1645), notably the so-called "Chigini" windmill, dominating an empty landscape in Tate's photograph taken nearly eighty years ago (*Memoir on the Ruins of Sistan*, Calcutta, 1910, p. 160). But in Sīstān such derelict remains are the only echo of the time, over a thousand years ago, when Masʿūdī marveled at the industry and skill with which the local people used the wind to turn their mills and to pump up water to irrigate their gardens. In Il-khanid times Abū Yaḥyā Qazvīnī confirmed the continuing tradition: "There the wind never rests, so that in view of this they build their mills. They grind corn only with these mills. It is a hot country and it has mills using the wind" (quoted by R. J. Forbes, *Studies in Ancient Technology*, Leiden, 1955, II, p. 113). The wind and heat remain, but the windmills of Sīstān have fallen victim to oil-powered progress.

BIBLIOGRAPHY

A brief historical summary and a detailed description of the machinery and operation of the Neh windmills occurs in H. E. Wulff, *The Traditional Crafts of Persia*, Cambridge, Mass., 1966, pp. 277-91.

However, many of the characteristics of Afghan windmills carefully recorded in 1960 by K. Ferdinand, "The Horizontal Windmills of Western Afghanistan,"

Folk 5, 1963, pp. 71-89; 8-9, 1966, pp. 83-88, apply more closely to the windmills of Khorasan investigated by the author in 1977 and referred to in *Living with the Desert* (see below), pp. 88-102.

The medieval descriptions of mills are most accessible in Le Strange, *Lands*, A. Mez, *The Renaissance of Islam*, Patna, 1937, pp. 451-67, and E. Wiedemann, *Aufsätze zur arabischen Wissenschaftsgeschichte*, Hildescheim, 1970, pp. 216-21, 276-303.

A recent first-hand record of watermills also forms part of E. Beazley and M. Harverson, *Living with the Desert*, *Working Buildings of the Iranian Plateau*, Warminster, 1982 (with a comprehensive bibliography).

Figure 52. Structure and lay-out of a Persian windmill based on mills recorded at Nīštafūn in 1977. (From *Living with the Desert*, p. 89.)

PLATE XXIX. Windwheel on working at Nīštafūn, 1977, viewed from leeward side.

PLATE XXX. Reed mat sails on a village near Neh, 1977, noticeable for its unusual windshaft, crooked spokes, and ramshackle rigging.

PLATE XXXI. Wickerwork hopper in an Afghan watermill, 1977.

PLATE XXXII. Vitruvian millwheel outside Isfahan, 1962.