Research Note

EARLY TIDE MILLS: SOME PROBLEMS

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The recent concern with energy problems has led to a reconsideration of the ways in which our forebears met their energy needs. Among the less important means available, which nonetheless was widely adopted along the western seaboard of Europe and the eastern seaboard of the Americas, was the tide mill. Despite the fact that stormy seas and seasonal variations in the tides lessened efficiency and sometimes made operation precarious, while the daily time lag of the tide demanded a constantly altering work regime, about 750 tide mills are known to have been in operation at one time or another along the shores of the Atlantic.[1] In its normal form, the tide mill was a water mill with an undershot waterwheel which was driven by tidal water ebbing from a pool in which it had been impounded as the tide flowed. But when, where, and for what purposes tide mills were first employed has as yet not been firmly established, and the current state of knowledge is confusing. In this note, therefore, I propose to set out some of the issues and to assess the evidence available. Where, then, were tide mills established in the Middle Ages? The various sites will be discussed in the following order: Basra, the Adriatic, Dover, France, England, the Low Countries, Portugal, Spain, and Italy.[2]

A. Basra.—Without giving his reference, the late R. J. Forbes wrote that "the coastal town of Basra on the Persian Gulf even had tide mills, mostly for grinding corn."[3] The source of his information could well have been an edition of the work of the great Muslim geographer, al-Maqdisī, Shams al-Dīn, who wrote: "The tide is a marvel and a

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[1]Of these 750 tide mills, approximately 300 were in North America, 200 in the British Isles, and 100 in France. Further investigation may well increase the number.

[2]Joseph Needham tells me he has no knowledge of tide mills in China or India, while Marion Johnson assures me there is no evidence of tide mills in Africa. I know of no pre-European evidence for North and South America and the Caribbean.

[3]In his chapter on "Power" in Charles Singer et al., *A History of Technology*, vol. 2, *The Mediterranean Civilisations and the Middle Ages* (Oxford, 1957), p. 610.

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blessing for the people of Basra. The water visits them twice every day, and it enters the rivers and irrigates the orchards and carries the ships to the villages. And when the tide ebbs it is also useful for the working of the mills because they are all situated at the mouth of the river and its tributaries. So when the water goes out to sea it turns them around."[4] As al-Maqdisī died in A.D. 1000, this statement suggests that tide mills were in operation at Basra, where the average tidal range is about 2 meters, by the 10th century.

B. The Adriatic.—In 1758 Girolamo Zanetti wrote of "*molendini . . . in palude*" which were located in the salt marsh around Venice in 1044 and 1078 and suggested that these mills were ship mills which were powered by the ebb and flow of the tidal current.[5] Then, in 1792, a dissertation on Venetian legislation on the conservation of the lagoon written by the abbot Christoforo Tentori noted that it was difficult, because of the enmity of their neighbors—particularly those of Padua—for the Venetians to establish water mills.[6] Instead, they set up mills on boats whose wheels were driven by the tide in the mouths of the rivers in the lagoons of Venice. When they compiled their volume, Bennett and Elton considered these mills as floating mills.[7] While these ship mills were driven by the tide, they are not what are conventionally described as tide mills, and to argue, as does Bradford Blaine, that since "tidal action was the essential fact of their operation: these, then are the earliest tidal mills of which we have evidence"[8] is conceptually unhelpful. Moreover, he failed to pursue the evidence of tide mills at Basra. In writing that in 1044 a tidal mill was operating in the lagoons at the head of the Adriatic and making comparison with Dover (see below), Lynn White, jr., appears, though this is not entirely clear, to consider this mill to be of a conventional type and not a ship mill.[9] It must be doubted whether a conventional tide mill could oper-

[4]Mark J. de Goeje, ed., *Ahsan al-Taqāsīm fi Ma'rifat al-Aqālīm* (Leiden, 1906), pp. 124–25. I am indebted to my colleague M. A. Shaban for this reference.

[5]Girolamo F. Zanetti, *Della origine di alcune arti principali apresso i Viniziani* (Venice, 1841), pp. 64–66.

[6]Christoforo Tentori, *Della legislazione Veneziana sulla preservazione della lagune: Dissertazione storico-filosofico-critica* (Venice, 1792), pp. 112–13. I am indebted to my colleagues M. V. Constable and L. Quartermaine for their translation of the relevant passages of this treatise.

[7]Richard Bennett and John Elton, *History of Corn Milling*, vol. 2, *Watermills and Windmills* (1899; Wakefield, Yorkshire, 1973), p. 63.

[8]"The Application of Water-Power in Industry during the Middle Ages" (Ph.D. diss., University of California, Los Angeles, 1966), p. 34.

[9]*Medieval Technology and Social Change* (Oxford, 1962), p. 85. In a letter to me of November 30, 1976, Lynn White, jr., stated in support of his view set out in *Medieval Technology*, p. 85, n. 1, that "Mediterranean tides are certainly not so powerful as those in oceans, but they have been—at least moderately!—flushing the garbage and sewage

ate in the Adriatic because of the limited tidal range of about 1 meter.

C. Dover, 1086.—In the Domesday Book there is the statement that "in the entrance of the port of Dover, there is one mill which shatters almost every ship, by the great swell of the sea, and does very great damage to the king and his men; and it was not there in the time of King Edward. Concerning this, the nephew of Herbert says that the bishop of Bayeux granted leave for its erection to his uncle, Herbert, son of Ivo."[10] The mill, therefore, was built between 1067 and 1082 when Bishop Odo of Bayeux was earl of Kent. While Bennett and Elton[11] (whose view is adopted by Rex Wailes)[12] enter a note of caution by writing that this mill is presumed to have been a tide mill, other historians have followed the suggestions first made, as far as I have been able to discover, by Abraham Farley in 1783 that the Dover mill was a tide mill.[13] Leopold Delisle, Roger Grand, and Lynn White, jr., are all of the opinion that a tide mill was built at Dover in the reign of William the Conqueror.[14] But there are also some deviant views. Misinterpreting the passage which clearly suggests that the mill was built after the Conquest, R. J. Forbes has written that Dover harbor had an early tide mill "dating from before the Conquest (1066)."[15] And Bertrand Gille appears to suggest that there was more than one mill, for he writes that "a special type of mill was the tidemill, of which the oldest examples, those at Dover, were built in the time of William the Conqueror," a view adopted by Claude Rivals.[16]

A strongly dissenting opinion has been put forward by George M. Meyer, who argued that "it has been stated by many authors that this

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out of the canals of Venice for over a millennium so, I had assumed, they would be capable of operating rather inefficient mills."

[10]Lambert B. Larking, ed., *Domesday Book of Kent* (London, 1869), p. 93.

[11]Bennett and Elton, 2:218.

[12]Rex Wailes, "Tide Mills in England and Wales," *Transactions of the Newcomen Society* 19 (1938–39): 1–33, reprinted as *Tide Mills in England and Wales*, 2 vols. (London, 1956), and as "Tide Mills in England and Wales," *Edgar Allen News* 36, no. 421 (July 1957): 160–62; no. 422 (August 1957): 184–88; and no. 423 (September 1957): 207–8.

[13]*Domesday Book seu libri consualis Wilhelmi Primi* (London, 1783), 1:1. In his edition of the *Domesday Book* (London, 1833), 1:124, Sir Henry Ellis, the editor, writes referring to the Dover mill: "This must have been a Tide-Mill, probably worked by a reservoir at high water."

[14]Leopold Delisle, "The Origin of Windmills in Normandy and England," *Journal of the British Archaeological Association* 6 (1850–51): 403–6; Roger Grand, *L'Agriculture au moyen âge: De la fin de l'Empire Romain au XVIe siècle* (Paris, 1950), p. 626; White, p. 85.

[15]In two places: Forbes (n. 3 above), p. 610, and *Studies in Ancient Technology*, 10 vols. (Leiden, 1955–72), 2:107.

[16]In English, Bertrand Gille, "Machines," in Singer et al. (n. 2 above), 2:648, and in French, in "Le Moulin à eau: Une revolution technique médiévale," *Techniques et civilisations* 3 (1954): 5; Claude Rivals, "Tidemills in France," in *Third Transactions of the International Molinological Society*, ed. M. van Hoogswaker (1973), p. 159.

mill was a tidal mill; but no evidence for the statement has been discovered. It appears rather more probable that the Dour [the river on which Dover stands] was tapped near its mouth and the mill race was carried on a jetty as far seaward as possible in order to make use of the greatest possible drop at low tides,"[17] thus causing the disturbance of the sea reported in Domesday Book. This view has not, however, won support. On the second matter, Bradford Blaine has also found "such great turbulence of the water mystifying,"[18] but experience of English tide mills suggests that a tide mill could give rise to considerable turbulence.[19] Evidence from the Netherlands also appears to support this view. There the harbor was normally used as a basin for the mill race so that the current of the ebb tide which turned the mill wheel also washed through the harbor.[20]

If, in fact, it can be accepted that the Dover mill was a tide mill, further questions arise. First, why was the mill built at Dover, which does not immediately appear to be the most propitious place for siting a tide mill because of its exposed position? Although the topography of the harbor was certainly different in the 11th century than today, the tidal range of about 6 meters would have been the same. An inlet off a river which would have provided a more sheltered location might have been expected to be the first English location to have been chosen. And why had the mill been recently set up by a Norman? Does this suggest that there were already tide mills in Normandy or Brittany and that the Dover tide mill is an example of imported technology? Certainly the general evidence is that France in the 11th century was technologically ahead of England.

D. France.—The history of French tide mills has not been explored in detail, but it has been stated that in the 12th century there were tide mills in the neighborhood of Nantes,[21] at Bayonne (1120–25) and in the Labourd area, in the *barthes* of the Adour or the Nive, where the mill of the Mufale is said to date from 1125–33, and at Esbouc before 1251 and St. Bernard in the 13th century,[22] while in Brittany, in the

[17]"Early Water-Mills in Relation to Changes in the Rainfall of East Kent," *Quarterly Journal of the Royal Meteorological Society* 53, no. 224 (1927): 407–19, quotation from p. 410.

[18] Blaine, p. 54.

[19] I am grateful to David Jones for this information.

[20]A. Tutein Nolthenius, "Getijmolens in Nederland," *Tijdschrift van het Koninklijk Nederlands Aardrijkskundig Genootschap* 71 (1954): 186–99.

[21]George Beauchesne, "Les Possessions en Bretagne aux XIe et XIIe siècles des abbayes benedictines de Touraine, d'Anjou et de Normandie," summarized in *Positions des theses presentées a l'Ecole Nationale de Chartes pour l'annee 1935* (Paris, 1935), p. 10, cited by Grand, p. 626.

[22]Eugene Goyhenèche, "Bayonne et la region Bayonnaise du XIIe au XVe siècle,"

Quimiac channel, the Templars owned two seawater mills between Marrel (Merquel) and Mesquer in 1182.[23] In the 13th century there were tide mills belonging to the abbey of Fécamp at Veules (1235) and at Ponte d'Ouve near Carentan (1277) which operated, it is stated, until 1619, while the archbishop of Rouen had two mills *de marée* at Dieppe in the 14th century[24] and the Templars one at La Rochelle before 1325.[25] After this period information about the dating of tide mills in France is scarce.

E. England again.—After Dover a number of tide mills were established in England. For Wootton (Isle of Wight), the date of 1132 has been suggested; for Bromley-by-Bow, 1135; for Woodbridge (Suffolk), 1170; and for Bayards Castle (London), 1180. Six other tide mills are said to have been built in the 12th century, making eleven by 1200. In the 13th century, twenty-seven were built; in the 14th, eight; in the 15th, six; while there were seven to which no more precise date can be given than "medieval." In the 16th century a further thirty were built. Thus a total of eighty-nine tide mills were set up in England by 1600.[26]

F. The Low Countries.—Although the Netherlands is commonly thought of as the land of the windmill, there is evidence for the existence of tide mills there from 1220.[27] And by the 14th century there was at least one tide mill in Flanders at Rupelmonde.[28] Here the method adopted was not to create a tidal pool but to make a cut off the Meuse.

G. Portugal.—Like other seaboard countries of Western Europe, Portugal had a long coastline, tides of some amplitude, and suitable sites for tide mills. So far we have only an outline account of Portuguese tide mills, but there is some evidence that there was a tide mill

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summarized in *Ecole Nationale de Chartes: Positions des theses soutenues par les eleves de la promotion de 1949* (Paris, 1949), p. 75. I owe this reference to Bradford Blaine.

[23]Rivals, p. 160.

[24]For Veulles, see Cartulaire de Fecamp, fol. xxxvii, 2 (viam que ducit ad molendinum maris); for Ponte D'Ouve see Archives Nationale, Paris: Trésor des Chartes, Carentan no. 1, Carton J. 222; and for Dieppe, see Mss des Archives du Département de la Seine Inférieure: Cartulaire de Philippe d'Alencon, fol. cccxlvi, all cited in Delisle, p. 406. For La Rochelle, see Henri Goblot, "Les Moulins à mer de La Rochelle," *L'Onde: Bulletin d'information no. 2 de l'Association les Moulins d'Eau* (Winter 1977–78), p. 10.

[25]Goblot, p. 12.

[26]This paragraph is based on my "Tidemills of England and Wales," *Fourth Transactions of the International Molinological Society* (in press). See also Wailes (n. 12 above), and, for the history of a particular mill, see Emily M. Gardner, *Tide Mills. Part 3: The Three Mills, Bromley by Bow* (London, 1957).

[27]Nolthenius, p. 186.

[28]A. Tutein Nolthenius, "Getij- en watermolens in Vlaanderen," *Tijdschrift van het Koninklijk Nederlands Aardrijkskundig Genootschap* 73 (1956): 162–67.

in the Algarve in 1290, in the Tagus estuary by 1313, and at Aveiro near the mouth of the Vouga by 1449.[29] While the English and at least some of the French tide mills had vertical wheels, the Portuguese mills appear to have had horizontal wheels.

H. Spain.—Tide mills are known to have existed in Spain, in the north and around Cadiz, in the 19th and 20th centuries,[30] but were there tide mills in Spain in the Middle Ages, and where were they? Certainly the existence of tide mills both in Portugal and in south-western France suggests that there is an a priori case for believing that there were tide mills in the Middle Ages in Spain as well, but the evidence has yet to be presented.

I. Italy again.—In the *Book of Machines* written about 1430 by a Sienese, Mariano Taccola, there is a description of a tide mill with an illustration (see fig. 1) which runs as follows:

> For the device on the seashore constructed as shown on the other side of this sheet, let there be a natural pool or body of water which can have flux and reflux, near the ocean or along rivers but

35. Tide mill (III, 34v–35r).

FIG. 1.—Drawing of a tide mill from Mariano Taccola, *De ingeneis* (ca. 1430) (reproduced in Frank D. Prager and Gustina Scaglia, eds., *Mariano Taccola and His Book De Ingeneis* [Cambridge, Mass., 1972], p. 86).

[29]Fernando Castel-Branco, "A Plea for the Study of Tide Mills in Portugal," *First Transactions of the International Molinological Society* (Lyngby, Denmark, 1978), pp. 80–84.

[30]Reported by Alan Stoyel at a meeting of the Wind and Water-Mill Section of the Society for the Protection of Ancient Buildings, November 11, 1977.

> desirably near the ocean. If there is no natural pool, let one be made artificially, with two connections, one of them which allows water to enter into the pond when the sea rises. Thereafter, when water of the sea is low, let the inlet be closed by a sluice gate, and then let the other way be opened as an outlet, water may then go to the wheels of the mill as seen in the above-named mill design. [These operations may be repeated] from time to time.[31]

The editor comments that the tides were "forces that were much marvelled at, partly 'measured' in their dependence on phases of the moon, and in no way understood. They were reliable enough to be used and also were large enough," he goes on, "at least in the Adriatic although not in the Ligurian Sea near Siena, to make their use economically worthwhile." Taccola may have derived the information for this chapter from the Adriatic region; as so often happens, the channels of information are unknown. He also knew that tides extend into rivers and thereby into regions where mills can be relatively accessible—a fact only partly recorded before (for instance, by Grosseteste in the early 13th century).[32]

Nearly two centuries later, Faustus Verantius, in his *Novae machinae*, posed the question, "Has it ever been possible until this hour to put a yoke upon the sea, so that it may turn millstones, and serve for other operations in need of motion?" He replied to his rhetorical question: "We judge that it can be done, although not everywhere, but only in narrow and confined places."[33] Keller argues that Verantius's idea of placing a mill on some narrow coastal strait presumably was suggested by tide mills. Verantius suggests that a reservoir be formed which would be filled by the tide then emptied as the tide ebbs, turning the mill wheels as it did so. However, he goes on, "it could more suitably be applied on the Ocean [meaning the Atlantic, Keller suggests], since its ebb and flow is much greater than in the inner seas."[34] This proposal is put forward as an afterthought to his project of a mill "in some cleft of a cliff where the water forces itself with great violence [*in freto maris appositae*]. And the mill itself is to

[31]Frank D. Prager and Gustina Scaglia, eds., *Mariano Taccola and His Book De Ingeneis* (Cambridge, Mass., 1972), p. 87. See also Arturo Uccelli, *Storia della tecnica del medio evo ai nostri giorni* (Milan, 1945), p. 8, fig. 4; Franz M. Feldhaus, *Die Technik der Antike und des Mittelalter* (Leipzig, 1931), p. 351, fig. 373; manuscript in Bayerische Staatsbibliothek, Munich, Cod lat. 197, fol. 99v; Forbes, "Power" (n. 3 above), p. 610.

[32]Prager and Scaglia, p. 57. For Grosseteste, see Richard C. Dales, "The Text of Robert Grosseteste's 'Questio de fluxu et refluxu maris' with an English Translation," *Isis* 57 (Winter 1966): 455–74, esp. p. 467.

[33]Alex G. Keller, A Theatre of Machines (London, 1964), p. 107.

[34]Ibid. He continues: " . . . such as for some centuries had been in use on the Venetian lagoons." But for the mills on the Venetian lagoons, see above.

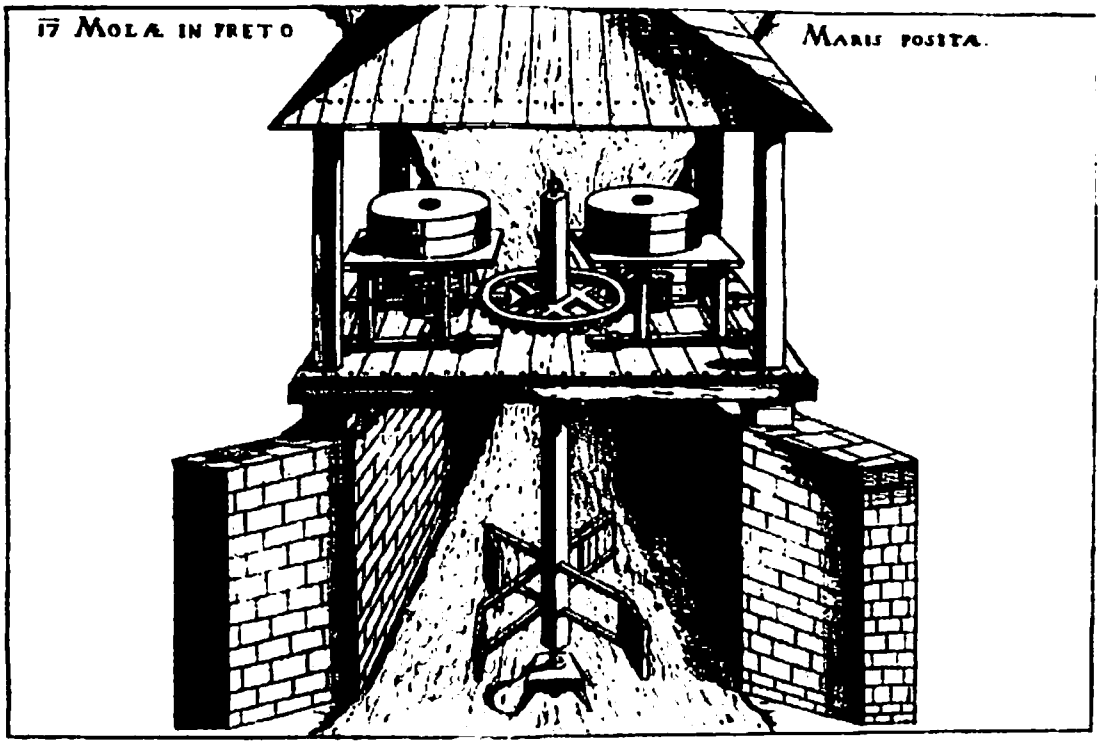

FIG. 2.—Drawing of a tide mill from Faustus Verantius, *Novae machinae* (1615), plate 17 (reproduced in Alex G. Keller, *A Theatre of Machines* [London, 1964], p. 8).

have a horizontal waterwheel with hinged vanes" (see fig. 2).[35] While Keller states that he has never come across a description of the operation of an actual tide mill, the discussion in Italy of the theoretical possibility of harnessing the tides in this way raises at least two questions. First, could tide mills operate in the Mediterranean or in the upper Adriatic and the Venetian lagoons? If so, Italian writings about tide mills would be understandable. Or, if this is not the case and Italians were relying on accounts of tide mills from the Atlantic coast of Europe, from whence came their information? And what accounts for their interest in a method of power which for their own country was not a possibility?[36]

Such, then, is a summary of the available information about the early history of tide mills, the invention of which, although a modest step, as Lynn White, jr., has pointed out, beyond the mill run by a flowing stream, nevertheless is a sign that men who lived on marshy estuaries or on small harbors where the streams were inadequate were no longer content to accept their fate and so sought this way of obtain-

[35]Keller notes: "Only one side will catch the force of the water, while the other is pushed back against its frame. This is an artful idea, but one which greatly reduces the effective area on which wind or water could be brought to bear" (ibid., p. 107).

[36]This paragraph is based both on *Theatre of Machines* and on correspondence with Keller, to whom I am greatly indebted.

ing an additional source of power by harnessing the tides.[37] A number of points may be made in conclusion:

1. The earliest tide mills of which we now have knowledge appear to have been those at Basra. But how was it that this was the earliest location? And when and how and by whom, if indeed such was the case, was the knowledge carried to Europe?

2. Though further evidence and discussion may resolve the situation, doubts must be cast on the existence of conventional tide mills in the upper Adriatic in the 11th century—or at any other time—because of the limited tidal range.

3. If the Dover mill was a tide mill, was it the first in Europe? And how did this apparently unpropitious site come to be chosen? Were there, in fact, earlier tide mills in western France, and was the Dover tide mill an example of imported technology?

4. Our knowledge of the chronology of the establishment of tide mills is still very sketchy. Only for England and Wales do we have a reasonable foundation of knowledge. For all other countries—Spain, Portugal, France, Belgium, Holland—much more investigation is needed so that we can tell more fully the history of tide mills in Europe.

5. The Italian case in the later Middle Ages invites more investigation also. Were the Italian writers merely discussing the theoretical possibility, or did they have practical examples in mind when they wrote?

6. The precise location of the tide mills deserves study, since this may well cast light on the technology involved. The area of the pool, the construction of the dam, the position of the mill, the nature of the sluices, the type of wheel (vertical or horizontal), and other aspects all require further analysis. Before 1600, for example, did tide mills operate on the flux and reflux of the tide?

7. Detailed information about chronology, location, and methods will also enable some study of the diffusion of the technology to be made. Who, for example, were the agents of diffusion? And the speed of diffusion is also worth consideration.

8. How, further, is the development of tide mill technology related to the development of the water mill (and perhaps the windmill)?

9. Such research will enable some assessment to be made of the reasons for the establishment of tide mills in terms of need—the absence or shortfall of alternative sources of power in relation to population pressure. Is the use of tide mills evidence of a power-intensive and power-hungry society anxious to mobilize all the resources avail-

[37] White (n. 9 above), pp. 84–85.

able to solve an energy crisis, or were tide mills cheaper and therefore more economic in particular locations? The first case would indicate that the marginal cost of power had risen as the cheaper sources were exploited, and so higher-cost alternatives needed to be resorted to for additional power; in the second case, the marginal cost of provision of power by tide mills would be lower than that of alternatives.[38]

10. Then there is the question of entrepreneurial initiative—Who were the men who made the decisions to build tide mills? and investment—How much capital was required, and how was it obtained? In the choice of a site, how much depended on local energy needs, how much on the enterprise, initiative, competitive emulation, or gambling instinct of the local landowner or municipality?

11. And then there is the purpose for which the mills were built. Most of the European tide mills appear to have been corn mills, but was this true in all cases, or were tide mills used for other purposes?

12. Finally, study of the early history of tide mills would enable us to obtain a better idea of the chronology of the contribution made by such mills. R. J. Forbes has written that most tidal mills date from the 18th century,[39] a statement unsupported by either the English or the Dutch evidence.[40] In the English case, 105 of the 169 known tide mills were established before 1700, while, in the western and southern Netherlands, twenty-one tidal mills had once been in use, for the most part as corn mills, the oldest dating from about 1220, the last from 1697.

By bringing together the existing information about tide mills, this note has attempted to indicate in outline the contribution made by a neglected source of power. But it also has a further purpose: to stimulate interest in this aspect of the history of technology. The study of a subject like this is handicapped by the absence of an easily identifiable tide mill archive, and the information is likely to be come across in the process of other researches. I would therefore welcome any items of information, however small or scattered, which will enable me to fill out the picture given here.

[38] I am indebted to a referee for this formulation of this point. It should be noted that a tide mill would provide a more regular, if limited, source of power than a windmill, which depended on there being sufficient wind, or a water mill, whose supply might dry up in summer or freeze in winter.

[39] Forbes, "Power," p. 610, and *Studies in Ancient Technology* (n. 15 above), 2:107.

[40] See Minchinton (n. 26 above), discussion above, and Nolthenius, "Getijmolens in Nederland" (n. 20 above), p. 186.