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Mine Pumping in Agricola's Time and Later

Robert P. Multhauf

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MINE PUMPING IN AGRICOLA'S TIME AND LATER

Coins are a source of information much used by historians. Elaborately detailed mining landscapes on 16th-century German coins in the National Museum, discovered by the curator of numismatics and brought to the author's attention, led to this study of early mine-pumping devices.

THE AUTHOR: *Robert P. Multhauf is curator of Science and Technology, Museum of History and Technology, in the Smithsonian Institution's United States National Museum.*

THE HABIT of heavy reliance on a single source for the substance of the history of Medieval and Renaissance mining techniques in Europe has led to a rather drastic over-simplification of that history, a condition which persists tenaciously in the recent accounts of Parsons, Wolf, and Bromehead.[1] Our preoccupation with Agricola, who has been well known to the English-language public since the Hoovers' translation of 1912, seems to have inhibited the investigation of the development of the machines he describes so elegantly. More seriously, the opinion that mining techniques remained essentially the same for a century or two beyond his time appears to have hardened into a conviction.[2]

The history of the technology of mining, as distinguished from metallurgy, is largely a history of mechanization, and that mechanization has until the last century consisted principally in the development of what Agricola calls *tractoriae*—hauling machines. That hauling machines of some complexity, Archimedian screws and a kind of noria, were used by the Romans for dewatering mines has been known for some time. Evidence of the survival of this technology beyond the fall of Rome remains to be found, and it is generally agreed that mining activity declined through the first millenium. The revival and extension of mining in the central European areas of German settlement is thought to have occurred from the 10th century, with an intensive development of the region known to Agricola (Erzgebirge) in the 13th century.[3]

This revival appears to have paralleled in general the political and cultural revival, but, as in any mining region, the exhaustion of easily workable surface deposits marked a critical point, when the necessity of deeper mining led to the construction of supported tunnels and the introduction of machinery for removing ores and water from deep mines. On the basis of revisions of capital structure and mining law which he regards as inspired by the financial necessities of deep mining, Bechtel dates this develop-

[1] W. B. Parsons, *Engineers and engineering in the Renaissance*, Baltimore, 1939. Abraham Wolf, *A history of science, technology, and philosophy in the 16th and 17th centuries*, New York, 1935; and *A history of science, technology and philosophy in the eighteenth century*, London, 1938. C. M. Bromehead, "Mining and quarrying to the seventeenth century," in Charles Singer and others, *A history of technology*, vol. 2, Oxford, 1956.

[2] According to Parsons (*op. cit.*, footnote 1, p. 629) the introduction of machinery worked by animals and falling water, "radical improvements" of the 15th century, fixed the development of the art "until the eighteenth, and, in some respects, even well into the nineteenth century." Wolf in his *History of science . . . in the eighteenth century* (p. 629, see footnote 1) agrees, saying that "apart from [the steam engine] mining methods remained [during the 18th century] essentially similar to those described in Agricola's *De re metallica*." Bromehead (*op. cit.*, footnote 1, p. 22), in referring to the date 1673 also sees "no appreciable change in methods of mining since Agricola."

[3] Parsons, *op. cit.* (footnote 1), p. 179. T. A. Rickard, *Man and metals*, New York, 1932, vol. 2, pp. 519–521

Mine-Pumping Machinery Illustrated By Brunswick Multiple Talers

These large silver coins weighing up to 15 ounces were first issued in 1574 in Brunswick by Duke Julius (1568–1589) of the Wolfenbuttel line. Their historical background is rather unusual and interesting.

In 1570 the Duke decided to increase the output of his silver mines in the Harz and arranged for the opening of three new mines. In order to insure the retention of a portion of this increased silver output under his control, the Duke decided to issue an entirely new kind of silver coin which he called "Loeser," meaning redeemer. These were larger than taler-size pieces, and were struck in denominations from $1\frac{1}{4}$ to 16 talers. The Duke ordered that each of his subjects was to purchase one of these large coins, the size of the coin to be acquired depending on the individual's wealth. The owners were not allowed to use these pieces in everyday trade, but could pawn them in case of dire need. They were expected to produce them at any time upon demand. Thus a means of hoarding, a "treasure piece," was created, and the risk of draining the country's wealth through replacement of good, full-weight silver coins with imported base currency was to some extent limited. At the same time, the Duke had a considerable sum of money at his disposal in case of emergency.

Similar Loesers were issued up to 1688 by different rulers of Brunswick. Some of the later issues are commemorative in character and might have served for presentation purposes. The workmanship of the majority is exquisite. They portray personages real and ideal and ornate coats of arms, in addition to the elaborate mining landscapes shown here. The U.S. National Museum is fortunate in having a number of examples through the generosity of Mr. Paul A. Straub.

For calling my attention to these coins, and for other invaluable assistance, I am indebted to the former curator of the numismatic collections of the U.S. National Museum, the late Stuart Mosher, and to the present curator, Dr. V. Clain-Stefanelli.

Figure 1 shows an overshot waterwheel driving through Stangenkunsten pumps in three separate shafts, each covered by the typical conical shaft house. It is possible that these shaft houses also cover horse whims used to operate bucket hoists such as that shown in the lower center. A house with three chimneys in the background may be the smelter. The horse over whose head the Deity holds a wreath is a symbol of Luneberg.

ment from the mid-14th century.[4] The mid-14th century situation is confused by the occurrence of the Black Death, which reduced mining activity drastically, and the events of which Bechtel speaks have been put as much as a century later.[5] In any case, the development of deep-mining methods had clearly made considerable progress in nonferrous mines when the *De re metallica* was written, in 1556.

Figure 1.—Brunswick Silver 3 Taler. Johann Friedrich, 1677. *U.S. National Museum, Proof. J. Straub coll.; Smithsonian photo* 43334 C.

For a detailed description of the mechanical equipment of this era we are largely indebted to Agricola. He classifies hauling machines into four types: the ordinary bucket windlass, the piston (suction) pump, the chain of dippers, and the rag and chain pump. Although the first three had been known in antiquity, and the last perhaps a century before his time,[1] their

[4] Heinrich Bechtel, *Wirtschaftstil des deutschen Spätmittelalters*, Munich, 1930, pp. 202–203. Bechtel calls this one of the most revolutionary industrial developments of the middle ages.

[5] Rickard (*op. cit.*, footnote 3, pp. 547–554, 561) also speaks of a decline through the exhaustion of surface deposits, but dates the revival 1480–1570. He supports this conclusion by statistics on the leading mine at Rammelsberg, which was unproductive from the Black Death (1347) to 1450, and only slightly active before 1518.

[1] According to F. M. Feldhaus (*Die Technik*, Leipzig and Berlin, 1914, p. 833), a manuscript illustration of this type of pump, which he calls Schopfkolbenkette, appears in the Mariano Codex latinus 197, B. 180, dated 1438, in the Munich Hofbibliothek.

Figure 2. Brunswick Silver 1½ Taler, Ernst August, 1688. (*U. S. National Museum, Paul A. Straub coll.; Smithsonian photo* 43334 *A.*)

use in mining would appear to date from the mid-14th century or later. His is not an historical account, and one who attempts to compare it with others of contemporary or later times encounters a difficulty in his use of descriptive Latin names rather than the common German names used by most others. English and German editors have interpreted them as follows: [7]

Latin	*English*	*German*
bulga	water bucket	Wasserkubel, Kehrrad
orbiculis	suction pump	Pumpe
situlis	chain of dippers	Kannen (werke), Bulgenkunst [8]
machina, quae pilis aquas hauriut	rag and chain pump	Heinzenkunst, Taschenkunst [9]

[7] Based on a comparison of the following editions of Agricola, *De re metallica:* Froben, Basel, 1556 (in Latin; the first edition); *The Mining Magazine*, London, 1912 (English translation by H. C. and L. H. Hoover); VDI, Berlin, 1928 (German translation by Carl Schiffner).

[8] The emergence of the term Kunst in German mining terminology is connected with the application of water power, especially to pumping (see Heinrich Veith, *Deutsches Bergwörterbuch*, Breslau, 1870, article "Kunst").

[9] According to Veith (*op. cit.*, footnote 8, p. 306), B. Rössler, in his *Speculum metallurgiae politissimum* (Dresden, 1700, p. 41) says that the Taschenkunst (pocket-work) was used with a pipe, like the rag and chain pump, and the translator of the German (1928) edition of *De re metallica* also uses Heinzen and Taschen interchangeably. Calvör and others, however, seem to use Taschenkunst for the ordinary chain of dippers, which seems better suited to its literal meaning.

Figure 2 shows two shaft-houses covering pumps driven by Stangenkunsten. The source of power, hidden by the curious "log cabin" at the right, was probably a waterwheel. I have not found evidence that the Stangenkunst was used to operate bucket hoists, as appears to be the case here. It will be noticed that the above and below ground portions of these illustrations do not correlate precisely. This coin, like the others, shows miners doing various things familiar from Agricola—divining, digging, carrying, and operating windlasses.

Figure 3 exhibits the principal advantage of the Stangenkunst, in its utilization to connect a waterwheel located in a valley stream to driven machinery on the mountain some distance above. The lute-playing girl

The resemblance of the German term for bag (Bulge) to the Latin term for bucket (bulga) instead of the Latin term for bag (canalis), and the presence of buckets (Kübeln), bags (Bulgen), pockets (Taschen), or cans (Kannen) as components of three of Agricola's four categories of hauling machines are reasons enough for the apparent superfluity of German names, if not for his decision to avoid the use of German names. But it should also be noted that the names sometimes refer to a pump and its prime mover considered as a single machine. Such

Figure 4. Medal, 1690, Showing St. Anna Mine, near Freiberg. (*Photo courtesy of Stadtisches Museum, Braunschweig.*)

(Lautenspielerin) refers to the Lautental mine. A Stangenkunst (fig. 7) existed here as recently as 1930.

The mines shown in figures 1–3 are in the Harz region.

Figures 4 and 5 show the St. Anna mine in the Erzgebirge, near Freiberg, as illustrated on a medal in the Brunswick museum. Prominent in figure 4 is an aqueduct, one function of which is to supply a waterwheel in the house below, which in turn delivers power through the Stangenkunst to two open shafts. The reverse (fig. 5), an unusually fine view of the inner workings of a mine, shows, above ground, a typical horse whim driving a bucket windlass. Below ground is shown a crank-driven piston pump typical of those driven by Stangenkunst. In this case, however, it is driven by an underground vertical treadmill.

is the case with the Kehrrad, a bucket windlass driven by a reversible waterwheel which Agricola describes as his largest hauling machine.[10]

[10] Agricola, *op. cit.* (footnote 7), ed. Hoover, p. 199. His contemporary and fellow-townsman Mathesius equates the Kehrrad to the Bulgenkunst (*Sarepta*, p. 145, Nurnberg, 1571). According to Veith (*op. cit.*, footnote 8, p. 286), Sebastian Münster in his *Cosmographei* . . . (p. 381, Basel, 1558), had previously mentioned its use in the mines of Meissen; and its introduction has been put as early as 1500 by Otto Vogel ("Christopher Pohlem und seine Beziehungen zum Harzer Bergbäu," *Beiträge zur Geschichte der Technik und Industrie*, 1913, vol. 5, p. 324.)

Figure 5. Reverse of Medal shown in figure 4. (*Photo courtesy of Stadtisches Museum, Braunschweig.*)

Figure 3.—Brunswick Silver 4 Taler, Ernst August, 1685. (*U. S. National Museum, Paul A. Straub coll.; Smithsonian photo* 43334-A.)

Agricola describes 23 hauling devices of these four types, the diversity resulting generally from the application of three types of prime movers, men, horses, and waterwheels, and in the endowment of each in turn with a mechanical advantage in the form of gearing.[11] Although he does not specify clearly the relative importance of the various pumps, the majority (13) use man as the prime mover. He speaks of the advantages of some, noting that the horse whim has a power two and a half times that of the man windlass, and emphasizing the even greater power available in flowing water "when a running stream can be diverted to a mine." The most powerful machine then in use for deep mines appears to have been the horse-powered rag and chain pump.

Such, then, were the important mining machines of this early period of deep mining, according to the leading authority. But did they continue, as has been claimed, to be the only important machines of the subsequent century? G. E. Lohneyss,[12] writing a little over a half century after the publication of *De re metallica*, declared:

> The old miners [alten Bergleute] had Heintzen, Kerratt, Bulgenkunst, Laschen-kunst, Pumpen, with which one lifted water with cans on pulleys or with a treadmill; and

[11] Agricola, *op. cit.* (footnote 7), ed. Hoover, pp. 160–199.

[12] G. E. Lohneyss, *Bericht von Bergwerken*, 1617?, n. p., p. 3.

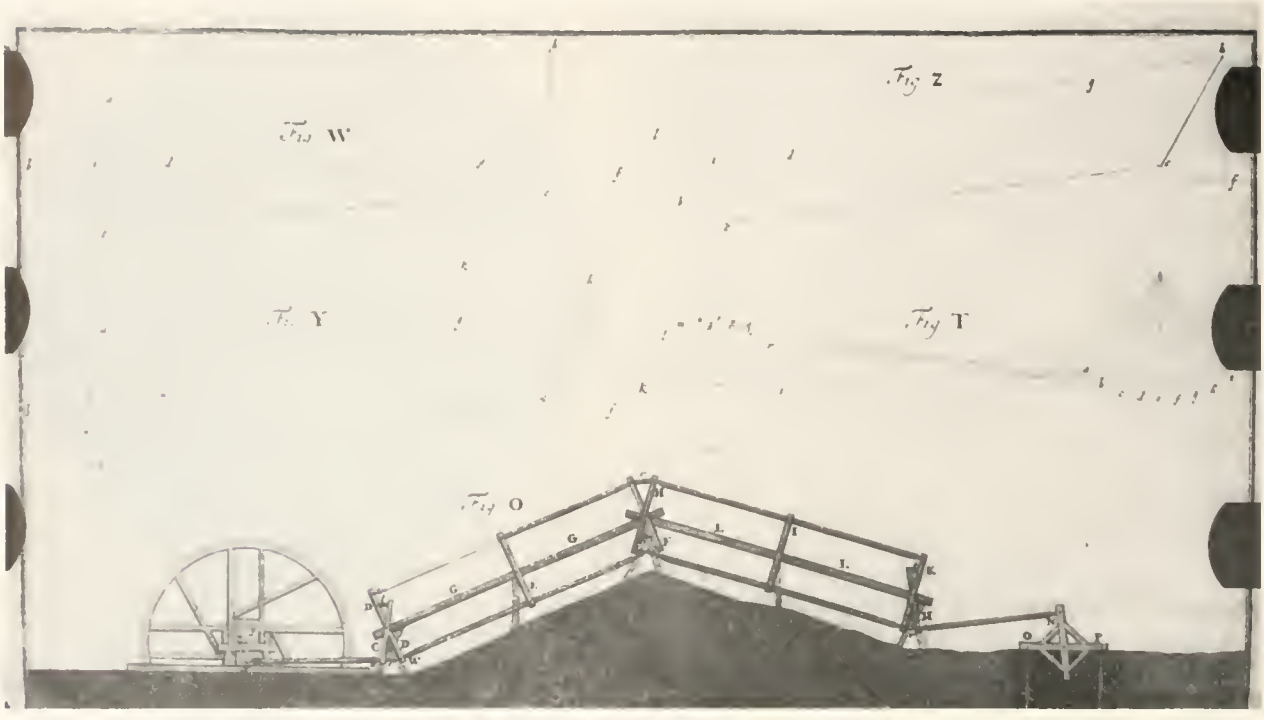

Figure 6. Stangenkunst, Showing Driving Wheel, Feldkunst, and Kunstkreuz. From H. Calvör (see footnote 15).

they devised and constructed these in which the poor people moved like cattle and wore themselves out. At that time they had powerful machines (Kunst) using swift water, although it cost much to erect and maintain them, and was very dangerous since an iron chain of a Bulgenkunst alone often weighed 200 centner [over 10 tons] and more.

But today's artisan [jetzigen Künstler] far surpasses the old . . . since we have in the present time invented many other mining machines; such as the *Stangenkunst mit dem krummen Zapffen*, which raises water at small cost over 100 Lachter [562 feet].

The Stangenkunst, which can be roughly translated as "rod work with crank," was a piston pump driven through a crank and rods by a prime mover located at a distant point. Agricola describes a crank-driven piston pump, calling it a new machine invented ten years earlier.[13] But it is not driven by a distant prime mover. Like his other water-powered hauling machines it can only be used "when a running stream can be diverted to a mine." So far as we can determine from internal evidence, Agricola did not know the Stangenkunst.

Although the full development of the Stangenkunst came later, it was apparently introduced in Agricola's time. Its introduction to the Erzgebirge has been put as early as 1550.[14] According to another authority it was introduced to the Harz in 1565 by one Heinrich Eschenbach of Meissen.[15] Its significance is only made clear to us by later authorities. As shown in figure 3 it was adapted to the utilization of a distant stream, through the Feldstangen, an extended horizontal series of reciprocating rods, and the Kunstkreuz (fig. 6), a lever in the shape of a cross for changing at right angles the direction of power transmission. These improvements may have been almost contemporaneous with Agricola, as Calvör

[13] Agricola, *op. cit.* (footnote 7), ed. Hoover, pp. 184–185. The crank was centuries old at this time, and had been applied to pumping earlier than the time mentioned by Agricola, although perhaps not in mining. A drawing dated 1405 shows an Archimedian screw turned by a crank (Feldhaus, *Technik*, footnote 6, p. 834). The *Mittelalterliche Hausbuch* (ed. H. T. Bossert and W. F. Storck, Leipzig, 1912, Tafel 32), a German description of technology that appeared in 1480, shows an arrangement very like that described by Agricola, although not in mining service.

[14] O. Fritsche and A. Wagenbreth, "Die Wasserhaltungsmaschinen bei Agricola und sein Einfluss auf ihre weitere Entwicklung," in *Deutsche Akademie der Wissenschaft zu Berlin, Georgius Agricola*, (East) Berlin: Akademie Verlag, 1953, p. 112.

[15] Hennig Calvör, *Acta historico-chronologico-mechanica circa Metallurgiam* . . . , Braunschweig, 1763, pp. 36–37.

mentions the use of the Feldkunst, which term signified the extended rods, as having been known in 1565.

The disadvantage of moving the weight of a long extension of rods was obviated, during the 17th century, through the use of a double set of balanced rods, resembling a pantograph. At some later date the horse whim was fitted with a crank and adapted to the Stangenkunst,[16] thus permitting the establishment of a veritable power network, as suggested in figure 1.

The Freiberg mine director Martin Planer reported in 1570 the installation since 1557 of thirty-eight "Kunsten und Zeugen" in mines under his charge. That these were water-powered machines is clear from his remark that their cost was only 10 to 20 percent that of "Pferden und Knechten."[17] It is likely that many if not most were Stangenkunsten, for mining treatises of the 17th and 18th centuries testify to the continuous extension of this mechanism.[18]

Perhaps the most striking evidence of its importance is its representation on the illustrated coinage of the 17th century. These multiple talers (figs. 1, 2, 3), happy products of the ingenious fiscal policies of the Dukes of Brunswick, picture mining activity in the 17th century no less elegantly than do the woodcuts of *De re metallica* a century earlier. The Stangenkunst received its most spectacular application in France, in its application to the driving of the second- and third-stage pumps in the famous waterworks at Marly (1681–88), but

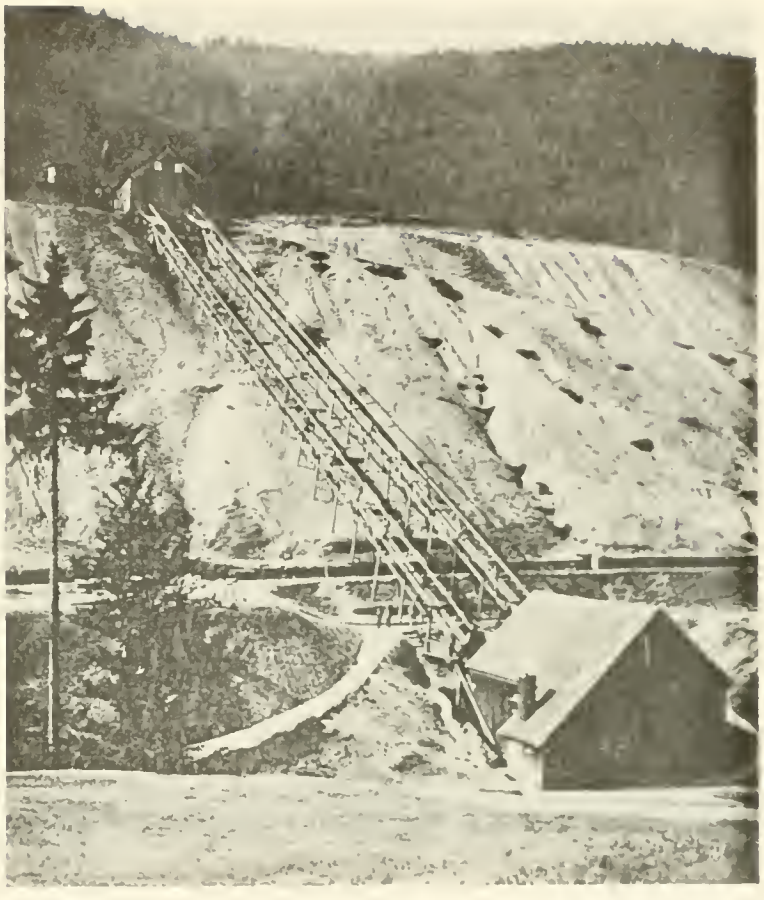

Figure 7. Feldgestängi (Stangenkunst) Near Lautental. From C. Matschoss, *Technische Kulturdenkmal*, Munich, 1932.

its real importance is better illustrated in central Europe, by the many descriptions and drawings showing its use in the mines, driving machinery as distant as a mile[19] from the source of power.

It seems, therefore, that Lohneyss' "old miners" were those described by Agricola, and that the mine-hauling machinery used in central European mines changed in the century after him far more than has been recognized.[20] This thesis may further cast some light on other technological questions. The

[16] I have been unable to find an early reference to this innovation, which appears in a sketch of 1784–85 illustrating Conrad Matschoss', "Die Maschinen des deutschen Berg- und Hüttenwesens vor 100 Jahren," *Beiträge zur Geschichte der Technik und Industrie* (1909), Band 1, p. 7. Its introduction may be connected with the appearance of the term Rosskunst for the horse windlass, known earlier as the Göpel.

[17] "Bericht des Bergverwalters Martin Planer über den Stand des Freiberger Bergbaues im Jahre 1570," ed. R. Wengler, *Mittheilungen Freiberger Altertumsverein*, 1898, vol. 35, pp. 75–83.

[18] The description of the Stangenkunst in its various modifications is one of the chief topics of the previously cited work of Calvör (footnote 15), and from his and other references it is clear that the subject was also treated extensively by such earlier writers as Lohneyss (1617) and Rössler (1700).

[19] Fritsche and Wagenbreth, *op. cit.* (footnote 14), p. 112.

[20] The hauling of ores, as opposed to water, seems to have remained as shown by Agricola until the end of the 17th century. In 1694, however, the famous Swedish engineer Christopher Polhem built at Falun a water-powered conveyer system which brought the ore from the point of origin in the mine to the smelter in a single operation, terminating with the automatic unloading of the buckets (Vogel, *op. cit.*, footnote 10, p. 306).

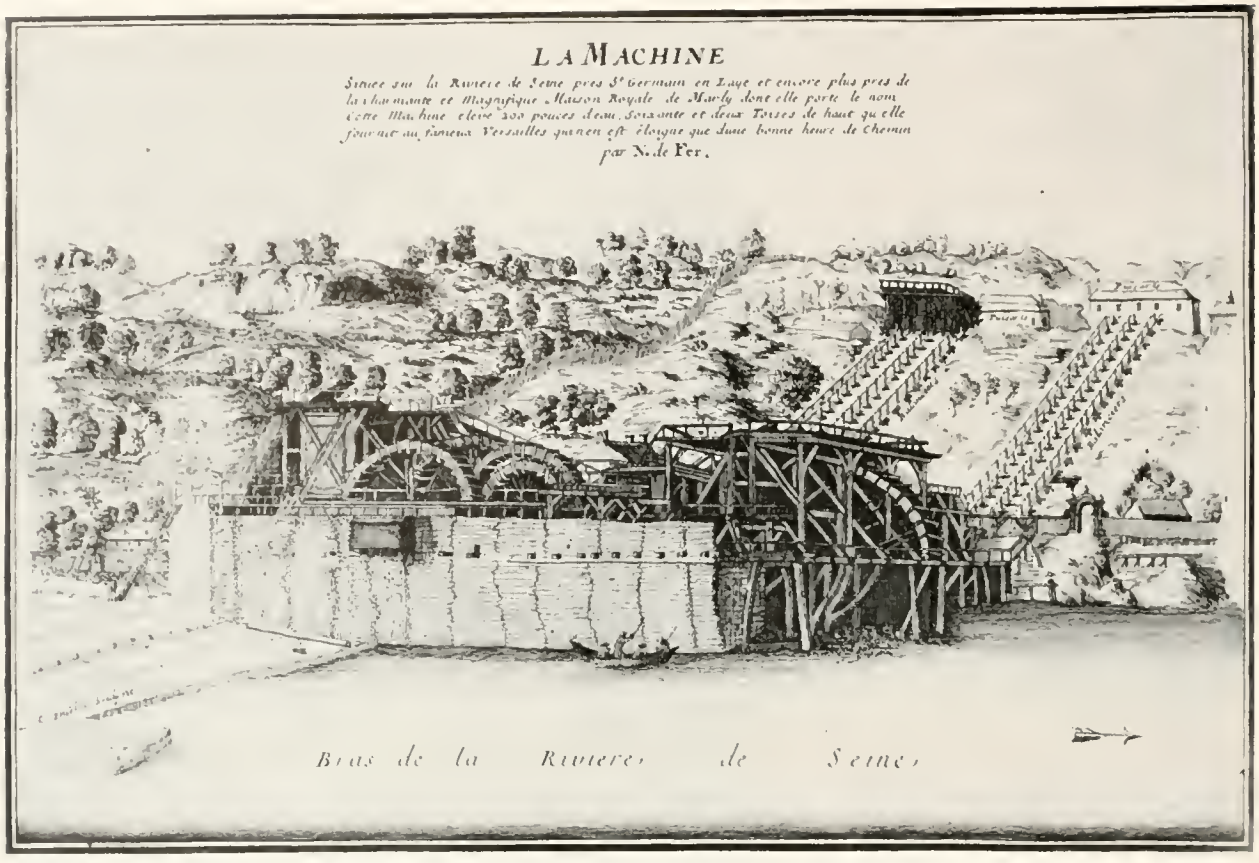

Figure 8.—The Waterworks at Marly-le-Roi, on the Seine River, Built in 1684 to Supply the Fountains at the Royal Palace at Versailles. From a print by de Fer, 1705. (*Smithsonian photo* 45593.)

connection between the urgency of the problem of mine drainage in England, and the invention of the steam engine, has often been suggested.[21] Perhaps the "backwardness" of Germany in steam-engine experimentation, and later in the introduction of the Newcomen engine, was to some extent due to the adequacy of existing machinery to meet the problem of mine flooding, for it is not clear that this problem existed on the continent.[22]

A comparison of the techniques described by Agricola with those of a century later suggests that this was a century of significant progress in that earlier industrial revolution described by Mumford as his "Eotechnic phase," characterized by "the diminished use of human beings as prime movers, and the separation of the production of energy from its application and immediate control."[23]

[21] Dickinson, H. W., *A short history of the steam engine*, New York, n. d., p. 3.

[22] In 1673 Edward Browne visited Hungary and the Erzgebirge. His report on the trip, *A brief account of some travels in diverse parts of Europe* (2nd ed., London, 1685, p. 170), says little about machinery, but does not mention flooding as a serious problem. Of an 84-fathom mine called Auff der Halsbrucker, near Freiberg, he says "they are not so much troubled with water, and have very good engines to draw water out." Yet the chain of dippers and rag and chain pump were evidently fallen into disuse, as they do not appear among the mining machines reported by Fritsche and Wagenbreth as having been described by Lohneyss (1617) or Rössler (1700); and Fritsche and Wagenbreth declare that German hydraulic machinery was able to compete with the steam engine in mine dewatering for some time into the 19th century (*op. cit.*, footnote 14, pp. 111, 112).

[23] Lewis Mumford, *Technics and civilization*, New York, 1934, p. 112.