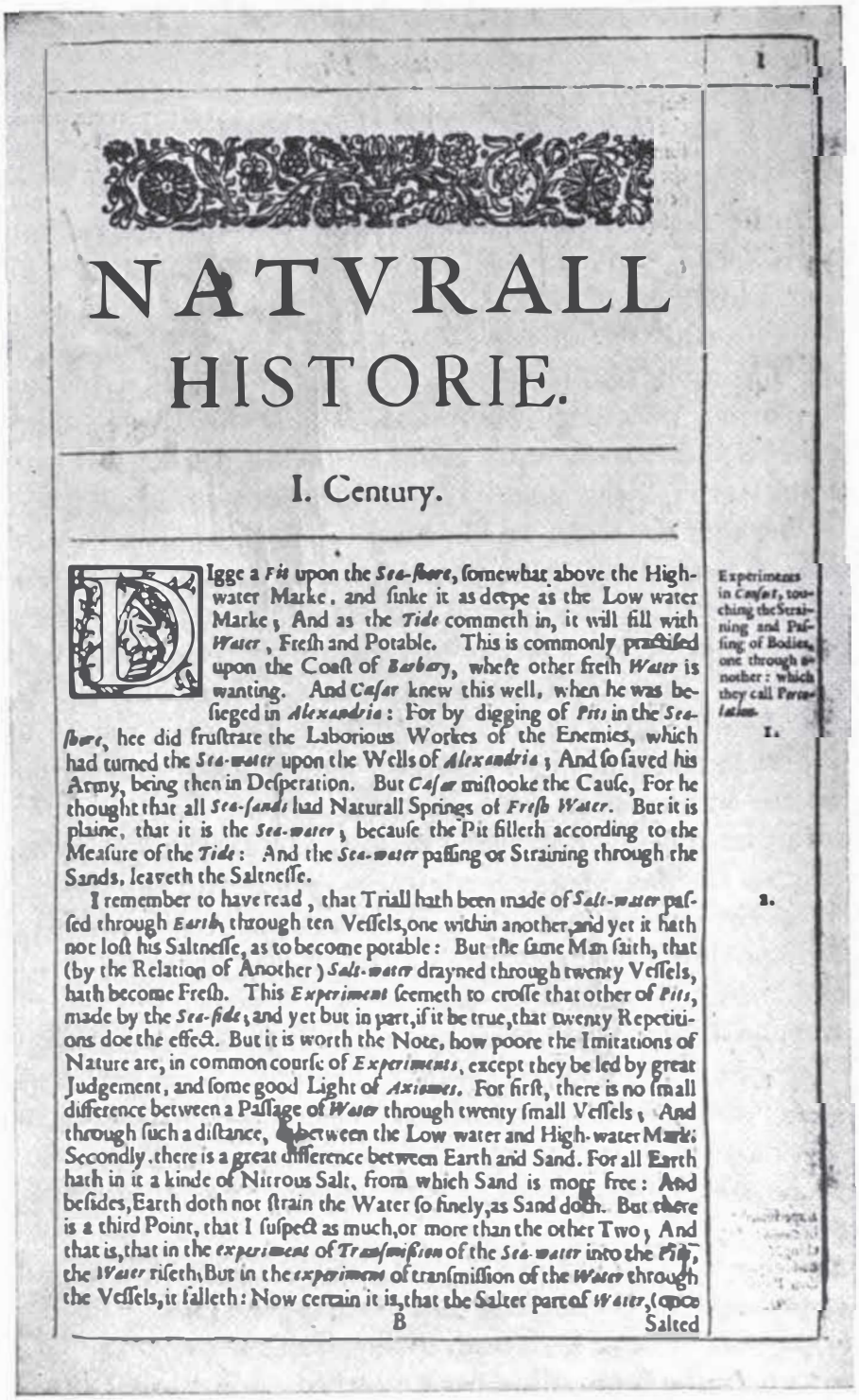
CHAPTER II

Seventeenth Century

Next to be noted in the quest for pure water is the philosopher Sir Francis Bacon. In his *Sylva Sylvarum, or a Natural History in Ten Centuries,* published in 1627, a year after his death, ten of the thousand "experiments" recorded dealt with water purification (1). Percolation or filtration, boiling, distillation, and clarification by coagulation were briefly reviewed. He repeated the notion that by digging a pit on the seashore, fresh water could be obtained from salt water by percolation through the sand. Caesar had been wrong, Bacon held, in believing that the water he obtained by digging pits at Alexandria (see Chap. I) came from springs fed from landward. Bacon had read that an experimenter who passed salt water through ten vessels had failed to freshen it, but that another person had succeeded by using twenty vessels. Ignoring the alleged success with twenty vessels, and accepting the old claims of success with the pit on the seashore, Bacon said that what man did not accomplish nature might and he pointed out that the water passed downward through the many vessels while it passed upward in the pits by the seaside. In another "experiment," he noted that clarifying water tends to improve health and increase the pleasure of the eye, and described clarification as "effected by casting and placing pebbles, at the head of a current; that the water may strain through."

Sir Kenelm Digby, naval commander, philosopher and author, said in his *Nature of Bodies* (1644) (2) that filtration was a form of motion familiar to "alchymists." He then described and explained the action of the wick siphon. In his better known *Powder of Sympathy* (3), in setting forth the various forms of "attraction," he again described the wick siphon.

Johann Rudolf Glauber, a German chemist and physician, who in 1658 produced the commercial salts bearing his name by treating sodium chloride with sulfuric acid, wrote (4) of the use of salt (presumably sodium sulfate) in ships "against thirst and also the Scurvy." Earlier (1651?) he had described methods of precipitating salt from sea water by passing it through a singular sand which not only drives



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NATVRALL HISTORIE.

I. Century.

DIgge a *Pit* upon the *Sea-shore*, somewhat above the High-water Marke, and sinke it as deepe as the Low water Marke; And as the *Tide* commeth in, it will fill with *Water*, Fresh and Potable. This is commonly practised upon the Coast of *Barbary*, where other fresh *Water* is wanting. And *Cæsar* knew this well, when he was besieged in *Alexandria*: For by digging of *Pits* in the *Sea-shore*, hee did frustrate the Laborious Workes of the Enemies, which had turned the *Sea-water* upon the Wells of *Alexandria*; And so saved his Army, being then in Desperation. But *Cæsar* mistooke the Cause, For he thought that all *Sea-sands* had Naturall Springs of *Fresh Water*. But it is plaine, that it is the *Sea-water*, because the Pit filleth according to the Measure of the *Tide*: And the *Sea-water* passing or Straining through the Sands, leaveth the Saltnesse.

Experiments in *Consort*, touching the Straining and Passing of Bodies, one through another: which they call *Permutation*.

1.

I remember to have read, that Triall hath been made of *Salt-water* passed through *Earth*, through ten Vessels, one within another, and yet it hath not lost his Saltnesse, as to become potable: But the same Man saith, that (by the Relation of Another) *Salt-water* drayned through twenty Vessels, hath become Fresh. This *Experiment* seemeth to crosse that other of *Pits*, made by the *Sea-side*; and yet but in part, if it be true, that twenty Repetitions doe the effect. But it is worth the Note, how poore the Imitations of Nature are, in common course of *Experiments*, except they be led by great Judgement, and some good Light of *Axiomes*. For first, there is no small difference between a Passage of *Water* through twenty small Vessels, And through such a distance, as between the Low water and High-water Marke: Secondly, there is a great difference between Earth and Sand. For all Earth hath in it a kinde of Nitrous Salt, from which Sand is more free: And besides, Earth doth not strain the Water so finely, as Sand doth. But there is a third Point, that I suspect as much, or more than the other Two; And that is, that in the *experiment* of *Transmission* of the *Sea-water* into the *Pit*, the *Water* riseth, But in the *experiment* of transmission of the *Water* through the Vessels, it falleth: Now certain it is, that the Salter part of *Water*, (once

2.

FIG. 2. BACON'S EXPERIMENT ON FILTRATION

(Half-title and opening paragraph of *Bacon's Sylva Sylvarum, or a Natural History in Ten Centuries*, first published in 1627)

salt downward but also "all Phlegm, Sordes and Impurities" so that although the water should be "like to a Fen or Dunghill," in a few moments it would become clear and free from odor and taste. Glauber also indorsed the notion that passing sea water through sand would freshen it, because the sand would imbibe the salt, "for those two have a mutual communion and communication, seeing that both are generated of Water . . ." (4).

Catch channels to intercept the runoff from hillsides, with catch pits covered with grates to retain mud or filth carried by the water are described in Rapin's Latin poem *Hortorum* or *Of Gardens* (1665–66) (5).

The advent of the patent era had now been reached. In 1675, William Walcott and, in 1683, Robert Fitzgerald were granted British patents on methods for making salt water fresh (see Chap. XV).

Porzio's Multiple Filter

The first known illustrated description of sand filters was published in 1685. Its author was Luc Antonio Porzio (Lucas Antonius Portius), an Italian physician who had gained distinction at Rome and Venice and gone to Vienna in 1684. The Austro-Turkish war of 1685 led him to write a book on conserving the health of soldiers in camps, probably the earliest published treatise on mass sanitation (6).

Multiple filtration through sand, preceded by straining and sedimentation, was proposed by Porzio. The filters could be placed in the hull of a boat or on land, depending on whether surface or ground water was to be purified. For a boat, he showed three pairs of filters, each pair consisting of a downward-flow filter and an upward-flow filter —the larger the boat and the more filters, the better the filtrate.

Water entered the first or settling compartment of the boat through a perforated plate acting as a strainer. The top or clearest water in the settling compartment flowed through two funnels in the top of the first partition, passed down through the first filter, out from it through oblong openings in the bottom of the second partition and up through the second filter of the first pair. The course of the water was the same in succeeding pairs of filters. Pebbles were placed "near the funnels of each partition." The funnels were diagonally across from each other in each pair of filters to increase total travel of the water between the raw-water and clear-water basins. "The smaller

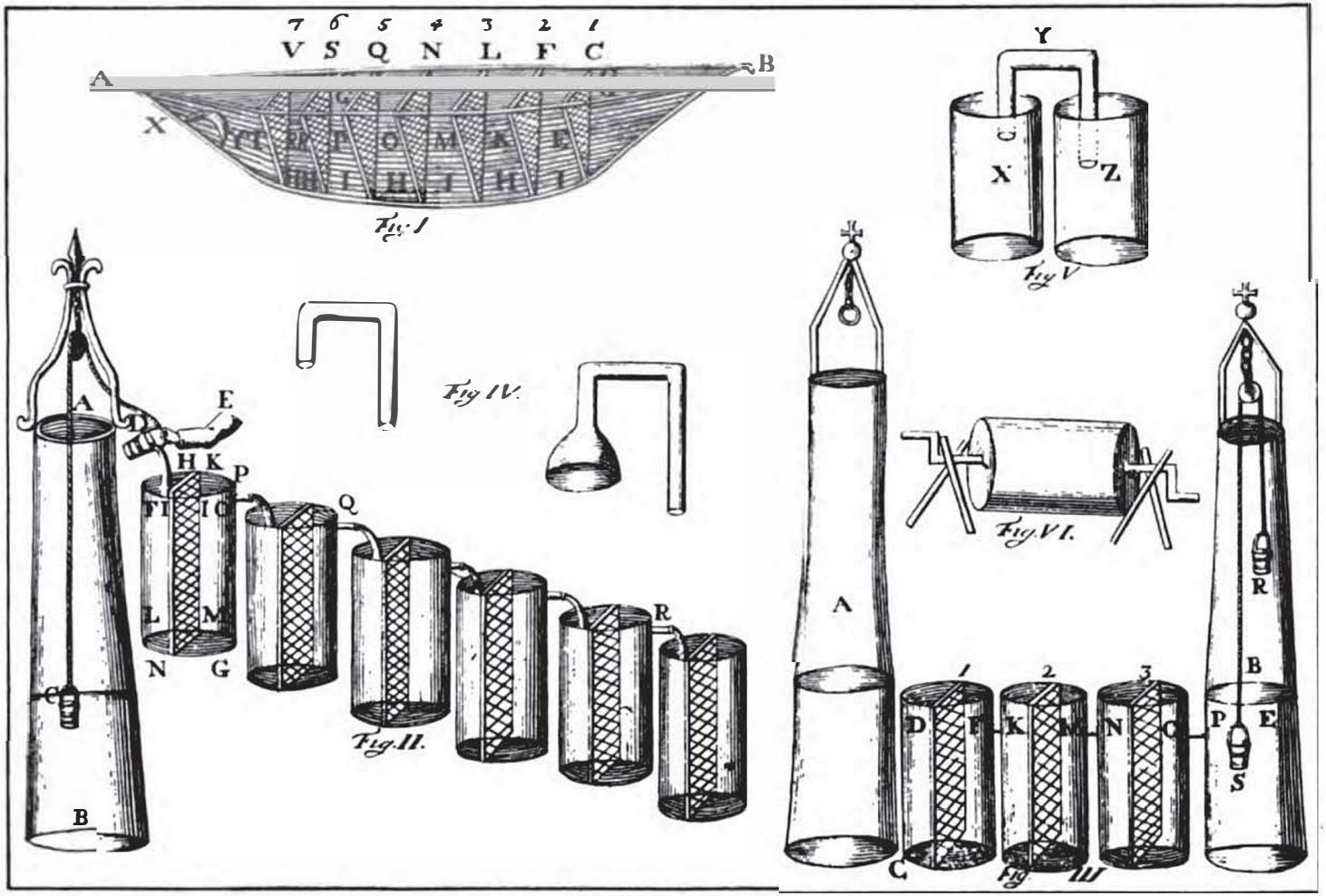

FIG. 3. PORZIO'S MULTIPLE FILTER

Three types of filters are shown: one floating; two on land, for well water

(From *Militis in Castro Sanitate Tuenda*, 1685. Translated into English as *The Soldier's Vade Mecum*, 1747)

the pebbles and the larger the sand," Porzio said, "the better they are; but there is no necessity for being over-nice in this respect, since 'tis sufficient that they be both clean."

Porzio said his plan was an imitation of Nature's method of passing water through the "Bowels of the Earth," producing at last "Fountains whose Waters are good and salutary." One statement by Porzio (6) seems to indicate that he had built multiple filters and certainly indicates that he had constructed a simpler type of sand filter. He said, "We have also made use of the same Means employ'd by those who built the Wells in the Palace of the Doges in Venice and in the Palace of Cardinal Sachetti at Rome."

Filter-Cisterns at Venice

Venice, Queen of the Adriatic, occupies a unique position in the quest for pure water. Built on a hundred islands, she depended for 1,300 years primarily on catching and storing rain water in cisterns. Her only means of supplementing this was to bring water in boats from the mainland. Other cities largely dependent on rain from the skies above them could build large storage reservoirs, as was done at ancient Carthage. This could not be done on the sea-encircled isles of Venice, and therefore hundreds of cisterns were built. Many if not all of these were surrounded with sand filters. The cisterns must have dated from the founding of Venice in the fifth century A.D. but how soon and how generally filters were provided cannot be stated. Probably it was soon enough to put Venice first among cities to be largely supplied with filtered water.

Most famous of the Venetian filter-cisterns were two in the great courtyard of the Ducal Palace, which was founded early in the ninth century. After being several times destroyed, rebuilt and extended, it attained its "perfected" state in 1550 (7). There remained to be brought into harmony with the palace, however, the curbs protecting the cisterns. To that end "well-heads" of richly sculptured bronze were provided—one, in 1556, by Nicolo de Conti, Director of the Foundries of the Republic, the other in 1559, by the sculptor Alfonso Alborchetti. Although the dates and the designers of the well-heads are known those of the filter-cisterns are not.

A half century after these well-heads were completed, they were seen by Thomas Coryat and described in *Coryat's Crudities,* his book of travels published in 1611 (8). No filters were mentioned by Coryat.

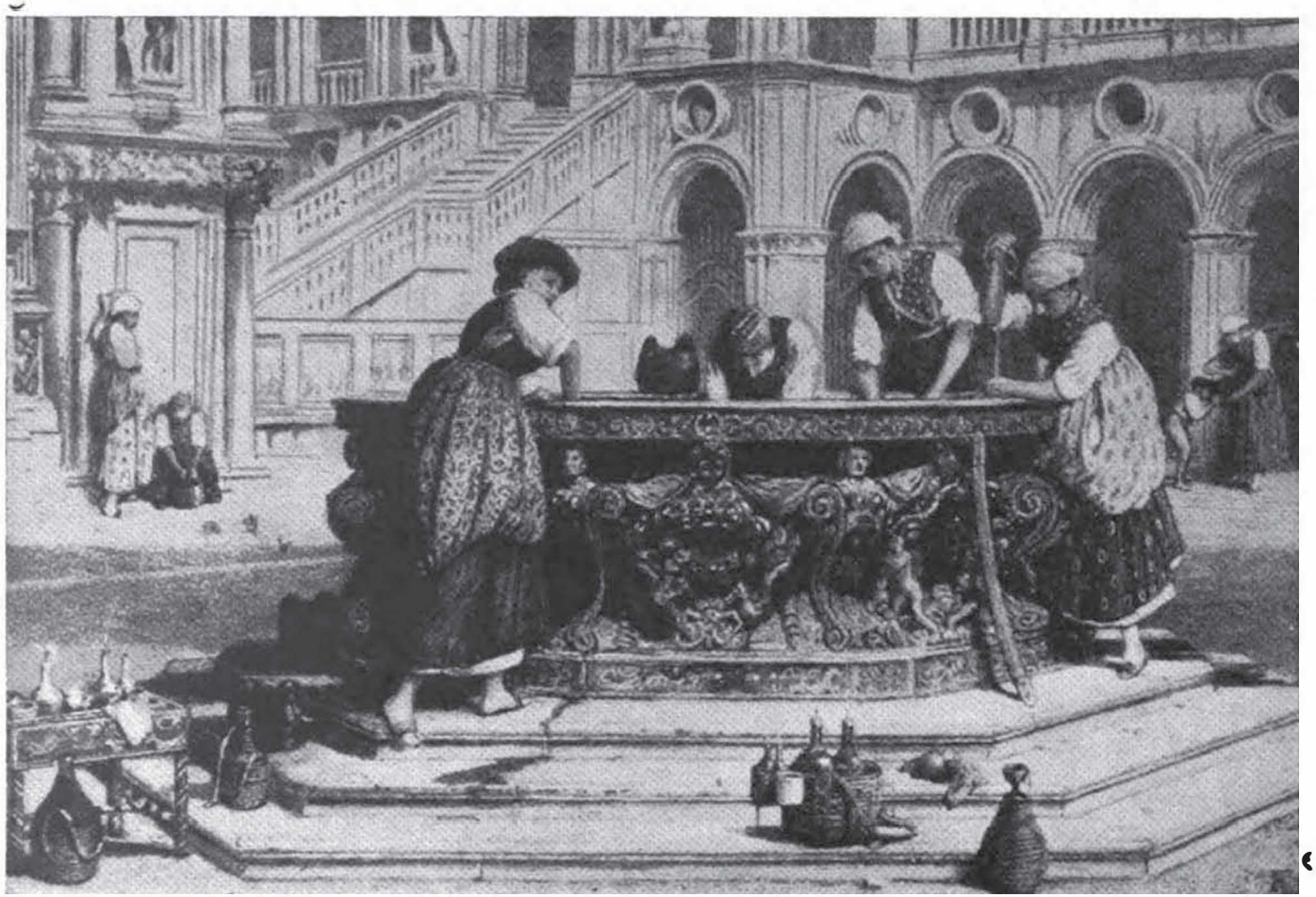

FIG. 4. SCULPTURED BRONZE CURB TO VENETIAN FILTER-CISTERN
In courtyard of the Ducal Palace, Venice. Curb placed in the 1560's
(From a water color by Birket Foster made about 1868. Reproduced from Cundall's *Life of Birket Foster*, 1906)

In the part of his book relating to the Ducal Palace at Venice he wrote:

———in the middest of the court there are two very goodly wels which are some fifteen paces distant, the upper part whereof is adorned by a very faire work of bronse that incloseth the whole Well, whereon many pretty images, clusters of grapes, and of Ivy berries are very artificially carved. There is a fair ascent to each of these wels by three marble greeses [steps?]. They yield very pleasant water. For I tasted it. For which cause it is so much frequented in the Sommer time, that a man can hardly come thither at any time in the afternoone, if the sunne shineth very hote, but he shall finde some company drawing of water to drinke for the cooling of themselves. (8)

More detailed were the observations of Porzio, made at Venice in 1683 and related in his treatise on military sanitation (6). In the very dry summer of 1683, said Porzio, when vast numbers of Venetians

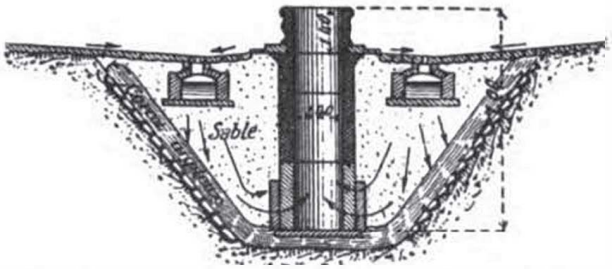

FIG. 5. CROSS SECTION OF VENETIAN FILTER-CISTERN
Accompanying text also described filter-cisterns in the Orient
(From Edouard Imbeaux's *L'Alimentation en Eaux*, 1902)

flocked to the wells at the Ducal Palace and they soon became dry, the water was "salutary and pure" because there was no mud or nastiness at the bottom.

The water came into the wells "perfectly purify'd" because all around the wells was "a large quantity of Sand, which the Venetians call the Spunge of the Wells." Surrounding the sand was "a kind of Fence" of "fat earth . . . which hinders the salt Water from penetrating into the Well." Rain water, or water brought "from adjacent Rivers in Boats," was conveyed in pipes or canals to the sand, flowed through it and the sides of the well, falling into it "clear and pure." Many of the bad qualities of the water were corrected by passing through the sand, especially "their Taste and Smell of Pitch and Tar" resulting from four or five hours of contact in the "small pitch'd Boats" used as carriers. This correction, Porzio said, led him

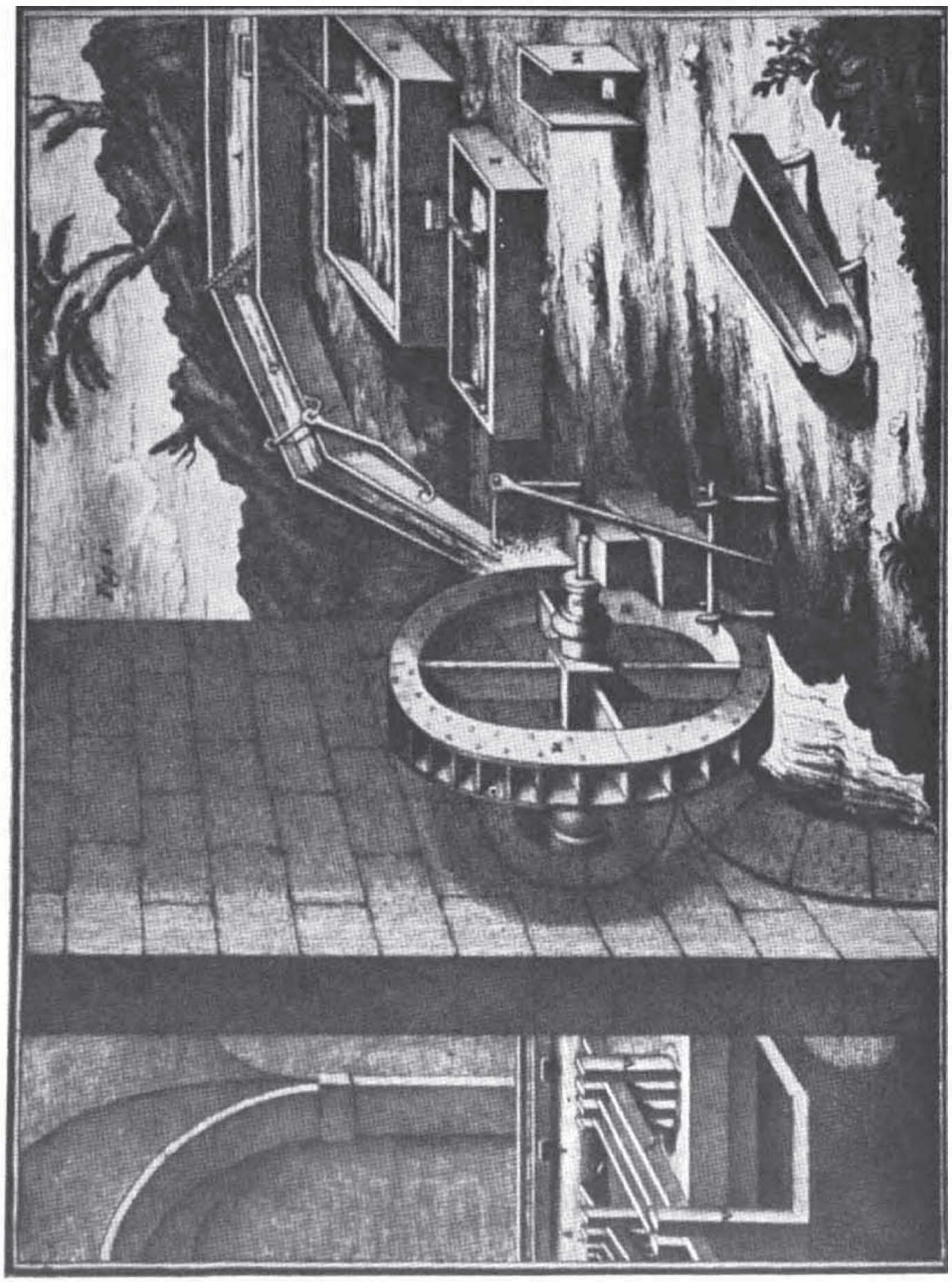

FIG. 6. WATER POWER AND CLARIFICATION PLANT FOR SEVENTEENTH CENTURY PAPER MILL AT AUVERGNE, FRANCE
Water for use in mill is drawn from power flume through two settling tanks working in series, passing through screens en route; *M* is detail of stilling box, shown in reverse
(From de la Landes' *Art de Faire de Papier*)

to believe that filtration was "a very efficacious Method of correcting the bad Qualities of Water" (6).

In 1835, Matthews' *Hydraulia* (9) gave the depth of the excavation for the filter-cistern at the Ducal Palace as 24 ft. and said the bottom was shaped like a parabola 6 or 7 ft. in "diameter."

In 1855, the Imperial Gazetteer (10), in its article on Venice, said that in the inner court of the larger houses of the city a rain-water cistern was never wanting. In addition there were then 160 public cisterns.

A comprehensive article on the water supply of Venice as it existed shortly before a modern water works system was built appeared in *The Practical Mechanics' Journal* in 1863 (11). The land area of Venice was 5,200,000 sq.m., or nearly 12.85 acres. The rainfall in an average year was 32.3 in. Nearly all of the rainfall was collected in 177 public and 1,900 private cisterns. Their joint storage capacity was 7,160,600 cu.ft. or 1,002,484 gal. (U.S.), affording a daily average supply of about 4.2 gal. per capita. This low average was due in part to the absence of sewers and to the practice of washing clothes in the Lagoon.

Describing what had probably been standard practice for some time, the article went on, in substance: The cisterns were seldom deeper than 10 to 12 ft. In building them the earth was excavated to the shape of a truncated inverted pyramid. A timber form was then built against the sides of the pit. On this an inclined wall of well-puddled clay was built. A flat stone was placed in the bottom of the pit. On this as a base a cylindrical wall was built from brick molded to curves. The bricks were laid with open joints. Those in the three or four lower courses were perforated with radial holes. The space between the wall and the inclined puddle lining was filled with sand. If the cisterns were to receive water from roofs and interior courtyards of a palace, the pavement was sloped gently toward the cistern. At each corner above the sand forming the filter, the pavement was dished and connected with perforated stone blocks. The stone blocks were connected with perforated square drain tiles, discharging the water into the filter sand. Pitchers were let down by cords to draw filtered water from the cistern. The water was always fresh and cool, with a temperature of about 52°F. Venice, the article stated, "is a city with nearly no soot and scarcely any dust." Whether because of

this or of circumstances not explained, the filter-cisterns were used for years, "without renewal or washing of sand."

In or about the sixteenth century the Senate of Venice ordered a canal built to carry water from the River Brenta to lagoons at the edge of the mainland from which it was taken to the city in barges and from them discharged by buckets into conduits leading to the filter-cisterns. In 1884, the Compagnie Générale des Eaux de Paris completed works to supply Venice with filtered water from the River Brenta (12). In 1924, a company supplied water to Venice from tubular wells on the mainland, eighteen miles distant (13).

Water Purification for Industrial Use

The first known designs for an industrial water purification plant are found in an engraving dated 1698 and repeated later in a French treatise on papermaking (14). The engraving shows the interior of a paper mill at Auvergne, France, with a flume leading to a water wheel and with a branch flume conveying water through grate screens and two small settling basins into the mill. Whether or not this was the beginning of water treatment for paper mills is a question that Dard Hunter, historian of papermaking and curator of the paper museum at Massachusetts Institute of Technology, cannot answer. He reproduced the engraving without giving its date and origin in his *Paper Making Through Eighteen Centuries* (15).

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CHAPTER II

Seventeenth Century

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