WATER SUPPLY ENGINEERING

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PREFACE TO THE FOURTH EDITION

In preparing the text for the fourth edition the conflicting demands to make the text brief, to retain everything of value already in the text, and to add recent valuable contributions to waterworks knowledge presented a problem difficult to solve with satisfaction. The authors' dilemma lay in choosing between an encyclopedia and a primer, neither of which would be satisfactory. A solution has been attempted in the emphasis of functional rather than structural procedure and practical applications rather than theoretical design. The discussion of theories available in more theoretical textbooks has, in general, been removed. These omissions include much of the theoretical development of formulas in the mathematics of finances, of the hydraulics of the flow of water, of steam and reciprocating pumping machinery, of electricity, and of the epidemiology of water-borne diseases. In their place appear applications of such theories to practice in finances, hydraulics, pumping machinery, electrical equipment, and water purification. The aim, in general, has been to apply theories and fundamentals to practice in the waterworks field. Revisions and additions have been made to emphasize the timeliness and utility of the information presented.

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URBANA, ILL.
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PREFACE TO THE FIRST EDITION

This book is intended primarily as a textbook for use in civil engineering courses as presented in many engineering college curricula. The authors have had the opportunity of presenting portions of the manuscript to their classes at the University of Illinois. In this presentation the need for a comprehensive and up-to-date text has been felt for years. The literature of waterworks is rich, and available textbooks covering such fundamentals as history, finances, hydraulics, etc., are unsurpassed. The use of such books for the teaching of fundamentals, supplemented by references to current literature, is laborious to the instructor, time consuming for the student, and unsatisfactory to all concerned. A textbook on waterworks, to be of continued value, must receive frequent revisions to keep pace with the rapid changes in practice. In preparing this book the authors have tried to combine both fundamentals and practical procedure in a single volume within the limitations of space and cost customary in engineering college texts in specialized professional courses.

Limitations of space have prevented the exhaustive treatment of all the subjects mentioned in the book. An exhaustive treatment of the subject of almost any chapter of the book would require a volume as large as or larger than this entire book. The design of dams is one subject worthy of greater space than is allotted to it. But few, if any, earlier textbooks on waterworks devote space to the subject of electrical equipment. Knowledge of the application of electricity to waterworks practice is not easily acquired by civil engineers. It is felt, therefore, that this subject should be presented for their benefit. The chapter on The Utilization of Electricity has been presented for students who have completed a study of the subject of electricity and magnetism in college physics and who have some acquaintance with the subject of electrical engineering. The space devoted to the subject is inadequate, but it has been filled with the idea that half a loaf is better than none. The textbook is not intended as a comprehensive treatise on waterworks or as a handbook. Such volumes are of little value as textbooks. In this book the student is introduced to the subject, fundamentals are stated, practice is explained, and, where desirable, references are made to articles of value on the subject. The problems presented in Appendix II should be found helpful to the teacher.

The value of a textbook in professional subjects is measured partly by its value to the engineer practicing in the same field. No book which treats the subject in an exclusively academic manner can be successful as a textbook. In this book an attempt has been made to illustrate fundamentals with practical applications thereof. Where recognized practice is based on empiricism, the procedure is explained and practical illustrations are presented.

An attempt has been made to give credit to all sources from which material has been taken. The authors apologize for any omissions of this character which may, unknowingly, have occurred. Thanks are due to the American Water Works Association, to the *Engineering News-Record*, and to others for their permission to quote from their publications.

The authors are greatly indebted to W. D. P. Warren and to Alex Van Praag, Jr., of the firm of Warren & Van Praag, consulting engineers of Decatur, Illinois, for their comprehensive and exhaustive review of the manuscript and for their valuable suggestions and contributions. Thanks are due to Prof. A. R. Knight, assistant professor of electrical engineering at the University of Illinois, for his review of the chapter on The Utilization of Electricity, and to W. N. Espy, associate in mechanical engineering at the University of Illinois, for his review of the chapters pertaining to mechanical engineering. The permission given by Dr. Elwood Mead, Commissioner of the United States Bureau of Reclamation, to reproduce the information taken from the standards of engineering practice in the Bureau is gratefully acknowledged.

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CHAPTER I

INTRODUCTION

1. Historical.[1] A knowledge of the history of the development of waterworks is desirable to emphasize changes in practice and the relatively recent development of present-day waterworks methods and equipment. The history of waterworks is as ancient as the history of man. Waterworks structures are found in the excavation of prehistoric ruins. The remains of Lake Moeris, in Egypt, indicate its construction about 2000 B.C. It was the largest of the reservoirs of the Nile Valley, which supported 20,000,000 people—four times the present-day population.

In ancient times the valleys of the Euphrates and Tigris, now almost a desert, were densely populated. Four thousand years ago the rulers of Assyria had converted these sterile plains and valleys into gardens of extreme productiveness by the construction of immense artificial lakes for the conservation of the flood waters of the river, and great distributing canals for irrigation. One of these canals, the Nahrawan Canal, supplied by the Tigris, was over four hundred miles long and from two hundred to four hundred feet broad, with sufficient depth for the navigation of vessels of that time.

In India, tanks, reservoirs and irrigating canals were constructed many centuries before the Christian Era and a great part of that country was kept in the highest state of cultivation. Some of the tanks or artificial lakes covered many square miles and were often fifty feet or more in depth.

Evidences exist in New Mexico and Arizona that in prehistoric times a race, now extinct, had extensive irrigation works and cultivated large areas.

Biblical references to waterworks are frequent. For example, in II Kings 20:20:

And the rest of the acts of Hezekiah, and all his might, and how he made a pool, and a conduit, and brought water into the city, are they not written in the book of the chronicles of the kings of Judah?

And the reference to Elisha's purification of water with a coagulant which is stated in II Kings 2: 19–22.

The water supply for the city of Rome is one of the marvels of ancient times. The water was brought from surrounding hills in aqueducts totaling about 381 miles in length. The first aqueduct, the Appia, was

[1] See also BAKER, M. N., "The Quest for Water," American Water Works Association, 1948.

10 miles long and was built in 312 B.C. The Claudia Aqueduct is illustrated in Fig. 1. All these aqueducts were constructed along the hydraulic grade line in order to avoid the necessity for building pressure conduits. Iron pipe was unknown at the time. Lead was the only material available to carry water under pressure. As lead was not suitable for high pressures, it was necessary to convey water in aqueducts at atmospheric pressure.

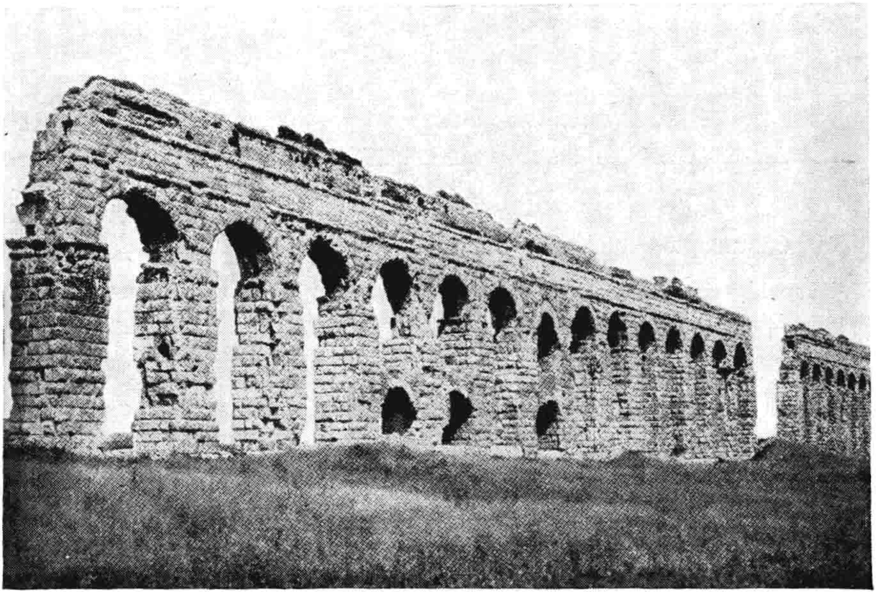

FIG. 1.—A Roman aqueduct. Claudia of dimension stone, and Novus of brick and concrete. *(From "Frontinus and the Water Supply of Rome," by Clemens Herschel.)*

Much detail concerning the history of the water supply of Rome is presented in "Frontinus and the Water Supply of Rome," translated by Clemens Herschel. Frontinus was water commissioner for the city of Rome about A.D. 100 under the Emperor Nerva. His records are a most human document, revealing the intimacies of the life of the people of Rome and relating his difficulties with human nature which was prone to err then as it is today. He had considerable difficulty with persons who stole water from the aqueducts:

> The cause for this is the fraud of the water-men whom we have detected diverting water from the public conduits for private use; but a large number of proprietors of land also, whose fields border on the aqueducts, tap the conduits; whence it comes that the public water courses are brought to a standstill by private citizens, yea, for the water of their gardens.

The baths constructed by the Romans are among the outstanding features of their era. The baths of Bath, England, illustrated in Fig. 2, are in an excellent state of preservation. Natural hot water still flows through the original pool. It is supposed that these baths were constructed during the first century A.D., possibly when Frontinus was governor of Britain, probably before his position as water commissioner of Rome.

Evidences of ancient waterworks that were constructed in the Western Hemisphere are to be found in Arizona, New Mexico, Central America, and the northern parts of South America. The Cenote, or Great Pool of

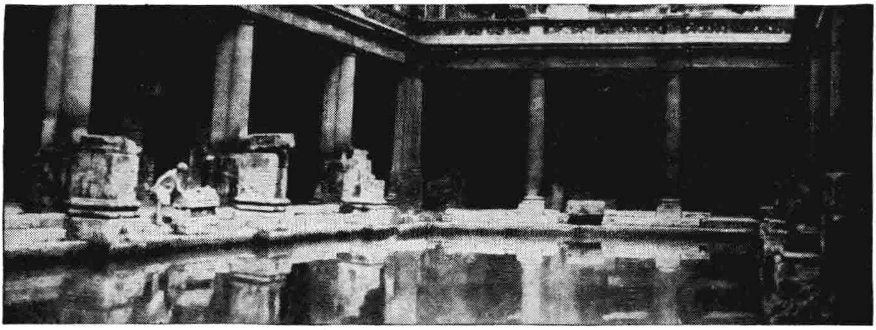

FIG. 2.—Roman baths at Bath, England.

Sacrifice, was constructed at Chichen Itzá, Yucatán, Mexico. No legible record has been left by the people who constructed this pool. It is possible that much of the work of the prehistoric races in Central America was done during the Christian Era, but proof to that effect is not certain. The aqueduct of Zempola, in Mexico, was constructed about A.D. 1560. It was about 28 miles long and supplied the city of Otumba.

During the Middle Ages in Europe there was more destruction than construction. It is probable that the use of polluted water was the cause of many of the epidemics that swept the continent. All was not destruction, however, as some aqueducts were constructed in Spain by the Moors during the ninth century, and the Roman aqueduct at Seville was repaired in 1172. London and Paris increased the capacity of the public water supplies. A small aqueduct was constructed in Paris in 1183, and water was brought to London from the outlying districts by means of lead pipes and masonry conduits in 1235. Cast-iron pipe was laid in France during the reign of Louis XIV to supply water to the fountain at Versailles.

The modern renaissance in waterworks construction is marked at the start of the nineteenth century by the appearance of steam-driven pumping machinery and of cast iron. Previous to the appearance of these features, a general public water supply with a service connection to each house was unknown. Wood and lead were the only materials available for pipes, and, as then constructed, the pipes would withstand but little internal pressure. The first steam-driven pumping engine is said to have been installed in London in 1787.[1] Previous to this, pumps driven by the river current had been used. The first steam pumping engine in the United States was installed in Philadelphia in 1800. Cast-iron pipe was laid in Philadelphia in 1804 and in London, England, in 1807. "Public water supplies in the United States date from 1652 at Boston, about 1732 at Schaefferstown, Pa., and 1761 at Bethlehem, Pa."[2]

2. Development of Water Purification. The first steps in water purification were probably taken in China and India thousands of years ago. For centuries it has been the practice of the Chinese to put alum in tubs of water to clarify it. The same thing was done in Egypt:[3]

In the "Ousruta Sanghita"—a collection of medical lore in Sanskrit, probable date 2000 B.C., Chap. XIV, verse 15—appears this instruction: "It is good to keep water in copper vessels, to expose it to sunlight, and filter through charcoal." In the "Neghrund Bhusan"—a collection of medical maxims from the "Ayura Veda," the earliest Sanskrit work on medicine extant, of about the same date—in the chapter on water, in the last sloka but two, it is directed to treat foul water by boiling and exposing to sunlight and by dipping seven times into it a piece of hot copper, then to filter and cool in an earthen vessel.

An early reference to water purification occurs in the Bible, as follows:[4]

19. And the men of the city said unto Elisha, Behold, I pray thee, the situation of this city is pleasant, as my lord seeth; but the water is naught, and the ground barren.

20. And he said, Bring me a new cruse, and put salt therein. And they brought it to him.

21. And he went forth unto the spring of the waters, and cast the salt in there, and said, Thus saith the Lord, I have healed these waters; there shall not be from thence any more death or barren land.

22. So the waters were healed unto this day, according to the saying of Elisha which he spake.

There are but few records of advance in water purification up to the introduction of the slow sand filter or the "English system," which dates back to A.D. 1829. The first filter was constructed during this year by

[1] KIRBY, R. S., and P. G. LAURSON, "Modern Civil Engineering," p. 191, Yale University Press, New Haven, 1932.

[2] "Water Works Practice," p. 3, American Water Works Association, 1925.

[3] *Water*, Aug. 15, 1905.

[4] II Kings 2: 19–22.