HYDRAULICS

Published @ 2017 Trieste Publishing Pty Ltd

ISBN 9780649609642

Hydraulics by R. L. Daugherty

Edited by Trieste Publishing Pty Ltd.
Cover @ 2017

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BY

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FIRST EDITION
SECOND IMPRESSION

McGRAW-HILL BOOK COMPANY, INC.
239 WEST 39TH STREET. NEW YORK

LONDON: HILL PUBLISHING CO., LTD.
6 & 8 BOUVERIE ST., E. C.
1916

THE·MAPLE·PRESS·YORK·PA

PREFACE

This book has been prepared as a text for students who are required to cover a wide field in hydraulics in a limited amount of time. Therefore the treatment has been made as brief and concise as is consistent with clearness. Attention has been given mostly to matters which are of fundamental importance and but little space has been devoted to those things which are of small practical value, except where necessary to illustrate basic principles. As a step in saving the student's time a liberal use has been made of diagrams, curves, and half-tones. These not only save words but often give a clearer idea at a glance than can be obtained in any other way.

The treatment throughout has been made as consistent as is possible. The solution of all problems involving the flow of water is made to depend upon applications of Bernoulli's theorem, which is the key to a rational treatment of the subject. The student is not told in the very beginning that $V = \sqrt{2gh}$ and then compelled to unlearn it later. Experience in the class room has shown that many students will persistently apply that formula whether it fits the case or not. By deriving it at a later time by an application of Bernoulli's theorem, they will more readily see that it is a very special case and thus realize more fully its limitations.

An effort has been made to avoid special cases so far as is possible. The treatment in the text and the equations are for the most part perfectly general. Special cases are given only when necessary to illustrate the application of some general principle, or where a special case makes some proposition clearer, and when the general treatment is too complex. But the attention of the reader is called to the fact that the equations there given are not universally applicable.

Class-room experience has shown that very few students obtain a true physical conception of the subject of hydraulics. To most of them, even some of the best, it is very largely an abstract subject. This is partly due to the fact that, with their limited experience and observation, they have actually seen but few of

the things with which the book deals and hence they can form no adequate mental picture of the physical facts. In order to overcome this, so far as possible, a large number of illustrations from photographs have been employed. As a further step in implanting a true physical idea in the mind of the student, a great deal of care has been exercised in the arrangement and presentation of the subject and a constant attempt has been made to connect one part with another. In many cases the problems have been taken from actual practice and have also been arranged so as to be instructive in themselves.

In considering turbines and centrifugal pumps the first essential is to convey a fair idea as to the general appearance, construction, and arrangement of such machines and possibly some simple features of their operation, since it is useless to plunge directly into a mass of equations which are no more than mathematical gymnastics to most students. The second step should be the presentation of the principles of operation together with a general idea as to actual characteristics. These facts could then be explained by as much theory as one had time to go into. In this text but very little theory has been given and that of the simplest kind, though it is believed that what is given is both general and rational. By the aid of this theory the nature of the characteristics of these machines can be accounted for. After that one is ready to take up certain very useful and practical commercial factors by the aid of which one can classify turbines or pumps, can compare one type with another, and can make an intelligent selection of the best type for certain conditions.

The simple theory of hydraulic machinery that has been given here covers about all that is really useful in a text of this scope. The design of turbines and pumps is too empirical, and requires too much judgment and experience backed up by a good supply of test data, to be expressed by a few equations. Any brief treatment of this phase of the subject would be false and misleading, hence it has been omitted. For any more extended treatment of these subjects the reader is referred to other publications of the author.

The main idea underlying the entire text has been to present fundamental principles. After this ground has once been covered, those who desire to specialize in hydraulics are prepared to

study certain topics more intensively. The devotion of considerable space to an account of experiments and test data is unwarranted here, though the student should not lose sight of the fact that the study of such is desirable when important work is undertaken. However, a sufficient amount of information on experimental coefficients and empirical factors has been given so that a correct idea may be formed both as to the range of values and the considerations that enter into the choice of a suitable value for a given case.

Very naturally some very important topics in practical hydraulics have been omitted altogether or treated very briefly and superficially because they did not involve fundamental principles and hence were not within the scope of this text, or else were of such a nature as to belong to advanced treatises. The final apology which the author makes for this work is that it has been prepared primarily to meet the needs of his own classes.

The author wishes to acknowledge his indebtedness to the various parties whose names are attached to certain of the illustrations for their kindness in furnishing the same. He is also indebted to E. H. Wood, Professor of Mechanics of Engineering in Sibley College, and to D. R. Francis, Instructor in Sibley College, for valuable assistance in the criticism of the manuscript and the reading of the proof. R. L. D.

ITHACA, N. Y.
April, 1916.

NOTATION

A = angle between V and u (Fig. 142)
a = angle between v and u (Fig. 142)
c = coefficient of discharge or coefficient of flow
c_c = coefficient of contraction
c_v = coefficient of velocity
D = diameter of turbine runner or pump impeller in inches
d = diameter of pipe in feet
d'' = diameter of pipe in inches
e = efficiency
e_h = hydraulic efficiency
e_m = mechanical efficiency
e_v = volumetric efficiency
F = area in square feet; in turbines and pumps it is the total area of the streams measured normal to the absolute velocity of the water
f = friction factor in pipes
= area in square feet in turbines or pumps measured normal to the relative velocity of the water
G = any weight in pounds
g = acceleration of gravity in feet per second per second
H = total effective head in feet, $= p + z + V^2/2g$
H' = any loss of head in feet
h = head in feet
I = moment of inertia
k = any coefficient of loss
l = any length in feet
m = hydraulic mean depth (or hydraulic radius) in feet
N = revolutions per minute
N_s = specific speed, $= N \times \sqrt{\text{B.hp.}}/h^{5/4}$
n = factor in Kutter's formula
= any abstract number
P = total pressure or force in pounds
p = intensity of pressure in feet of water
p' = intensity of pressure in pounds per square foot
p'' = intensity of pressure in pounds per square inch
q = rate of discharge in cubic feet per second
r = radius to any point in feet
s = slope of hydraulic gradient, $= H'/l$
= tangential component of absolute velocity, $= V \cos A$
T = torque or moment of a force in foot pounds
u = linear velocity of a point in feet per second
V = absolute velocity of water (or relative to earth) in feet per second