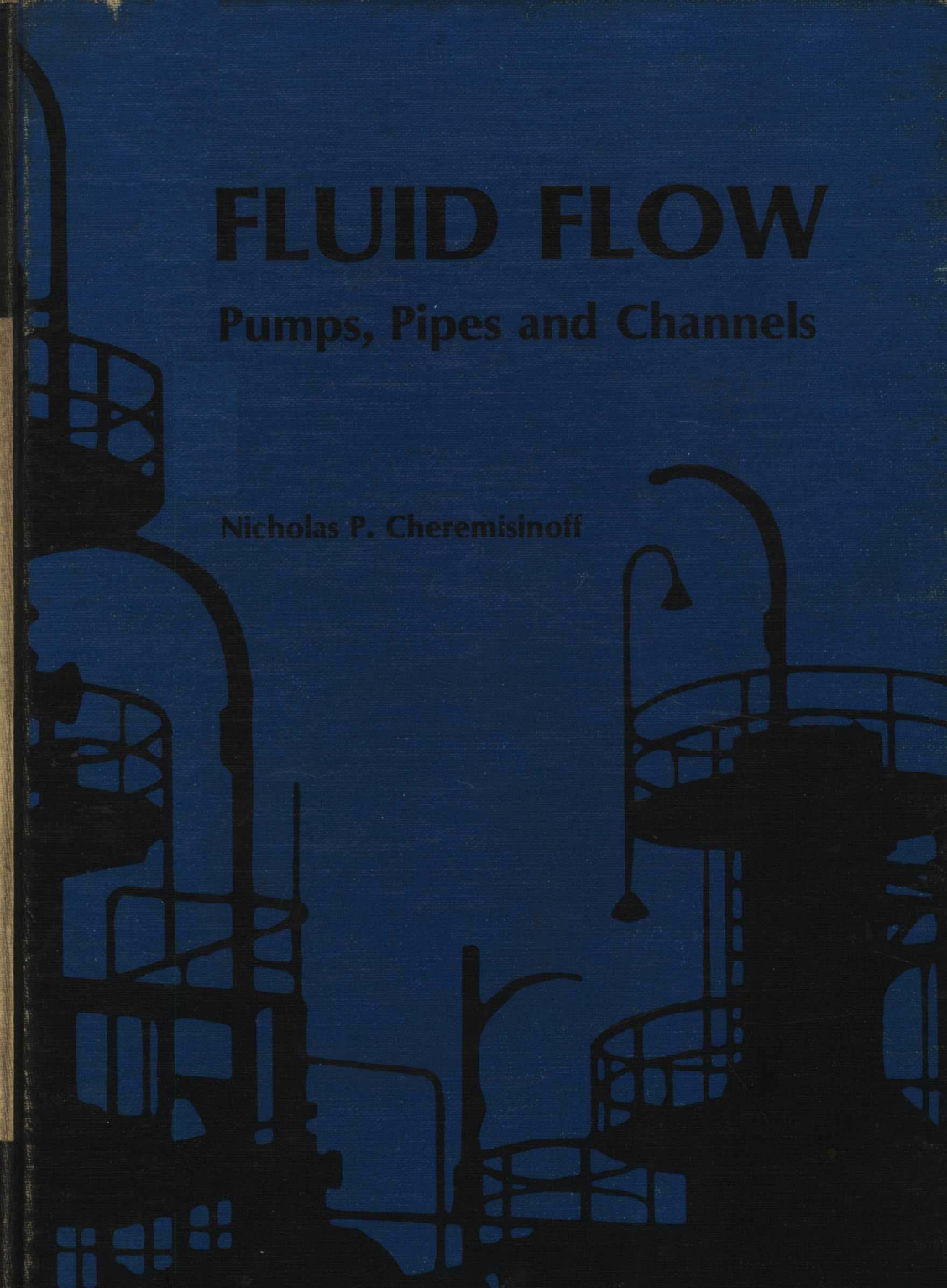
FLUID FLOW

Pumps, Pipes and Channels

Nicholas P. Cheremisinoff



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PREFACE

Fluid flow is a fundamental area in all manufacturing, process design, and, particularly, chemical, petroleum and allied industries. Design of fluid flow systems is the basic building block of chemical manufacturing. If a pump is the heart of such systems, the pipes, channels and conduits that carry fluids are the arteries. The methods described in this book are important to 10,000 chemical manufacturing and processing firms, employing more than 1.1 million people, with sales of more than $100 billion. The chemical industry alone represents 7.5% of the U.S. gross national product (GNP), and enjoys an annual growth rate nearly twice that of the overall GNP.

The Romans employed lead pipes to collect their water, and the ancient Chinese conveyed natural gas through bamboo tubes. However, centuries passed before the science of fluid mechanics was born. Gradually, fundamental laws governing the mechanics of flow phenomena began to be understood and applied to engineering problems. Sanitary conditions created a demand for the water distribution systems that have become ubiquitous throughout the developed nations. Discoveries of uses for oil and natural gas gave impetus to the design and construction of millions of kilometers of additional pipelines. In addition, millions of kilometers of additional piping networks and channels are employed in scores of manufacturing plants and refineries throughout the world, and in pollution control, utilities, etc.

Our knowledge of fluid mechanics has become exceedingly great, with principles that not only affect fluid transport, but also numerous process designs. It is not possible to design rationally for heat and/or mass transfer operations without understanding the fluid mechanics of the process. To this end, there have been scores of investigations, papers and textbooks devoted to various aspects of flow phenomena. Unfortunately, few books have been devoted entirely to industrial applications, and even fewer provide design procedures and recommendations for even the most common flow situations that engineers often encounter.

This volume originated as a guide for process engineers. Basic calculation methods, design practices and recommendations, in addition to definitions

and theorems, are included. This book is not intended to be a definitive work. Indeed, many important flow situations, such as slurry flows and two-phase flows, are not treated in this volume. Instead, the book is meant to be an introductory and practical reference text to standard process flow problems. There are three types of readers who may find this volume useful: (1) engineering students in fluid mechanics; (2) engineers who desire a refresher course in principles and standard calculations; and (3) process engineers in first job positions.

The book is divided into two sections. The first is devoted entirely to reviewing basic fluid mechanics principles. Although illustrative examples are included in the discussions, no problems are given at the end of this section. If used as a textbook, the instructor must provide his or her own problems to supplement Section 1. The second part of the book applies these principles to problem solving, and a collection of problems and selected solutions by subject are presented in Chapter 2.12. There are a number of chapters in the second section that are specific in nature and provide valuable information most relevant to the process engineer.

Finally, there are several contributed chapters and appendixes prepared by experts. I wish to acknowledge each of these contributors. Without the efforts of these individuals and organizations, this volume simply would not have been possible.

Nicholas P. Cheremisinoff

Nicholas P. Cheremisinoff is employed by Exxon Research and Engineering Company in Florham Park, New Jersey. He received his BS, MS and PhD degrees in chemical engineering from Clarkson College of Technology and was an instructor there in 1976–1977.

Dr. Cheremisinoff has contributed to the industrial press and is the author of several engineering reference books. Among his research interests are the study of flow phenomena of multiphase systems and the development of biomass based energy resources. He is a member of a number of professional societies including Tau Beta Pi, Sigma Xi and AIChE.

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CONTENTS

Section 1
Principles of Fluid Flow

Section 2
Calculations and Design Basics for Incompressible Flows

SECTION 1

PRINCIPLES OF FLUID FLOW

SCOPE AND SECTION OVERVIEW

To the chemical engineer, fluid mechanics is the backbone of his education. However, process engineering draws from the ranks of many engineering disciplines, which often do not stress the importance of this subject in a single course or series of courses. This book attempts to summarize major fluid mechanics principles and apply them to basic process flow situations encountered in plant operations. More specifically, the overall thrust of this volume is to provide guidelines useful in selecting and sizing pumps and pipelines, and in handling channel flow problems. This includes criteria for selecting and using proper flow instrumentation and troubleshooting pumping operations. Emphasis, then, is placed on incompressible flows, although as noted in the Foreword, not all types of incompressible flow situations are addressed. Admittedly, the book is limited as a general text and, if used so, is recommended only as an introduction for undergraduate chemical engineers, or for non-chemical engineers taking a course in fluid mechanics. The second section does, however, provide some challenging problems that may stimulate graduate student thinking.

The material presented was compiled from three sources: (1) the author's lectures given to undergraduate and graduate classes at Clarkson College of Technology and New Jersey Institute of Technology; (2) a collection of design notes compiled over the last six years working in industry; and (3) contributed chapters and notes provided by several organizations and companies.

This first section presents an overview of important principles in fluid mechanics. There are seven chapters covering Systems of Units, Fluid Statics and Pressure Measurement, Properties of Fluids, the Equations of Motion and Energy, Laminar Flows, Turbulent FLows and an introduction to Dimensional Analysis. The importance and coverage in each of these chapters is noted in some brief introductory remarks to each chapter.

One point that should be noted up front is the use of consistent units in calculations. Among practising engineers there is a serious problem in adjusting to the SI system of units. The transition to a universial standard of units is inevitable; however, it may be some time before "the old school" (of

which I include myself) of English unit users completely surrenders. Consequently, engineers must be familiar with a dual system. The first chapter explains the SI system of units in detail and Appendix B provides conversions from English to SI units. This Appendix was prepared by the American Petroleum Institute, which should be commended for its efforts to achieve industry acceptance of SI. In an attempt to please all readers, a dual system is used throughout the book and solutions to selected problems are given in both English and SI.

A final note is that the two sections are independent. That is, the more experienced reader can go directly to Section II. Chapter 2.1 essentially summarizes major points brought out in the first section and relates them to basic design procedures. It is recommended that Chapter 1.1 ("Notes on Systems of Units") be read first before proceeding to Chapter 2.1. Each section is provided with its own table of contents and lists of figures and tables to enable users to gain quick access to data/information needed for specific problem solving.

CONTENTS FOR SECTION 1

LIST OF FIGURES FOR SECTION 1

Chapter 1.4

Chapter 1.5

Chapter 1.6