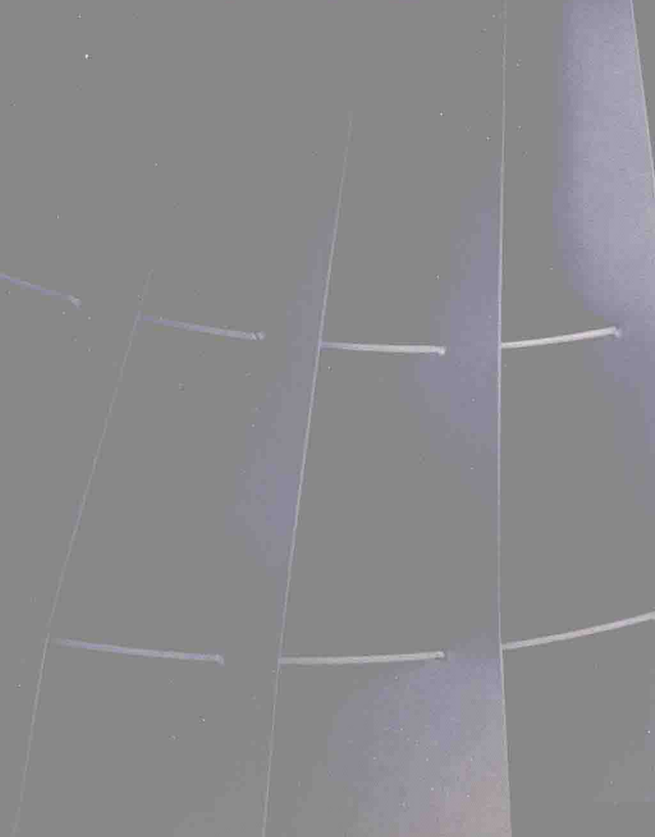
STUART SABOL

Case Studies in MECHANICAL ENGINEERING



Decision Making, Thermodynamics, Fluid Mechanics and Heat Transfer

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CASE STUDIES IN MECHANICAL ENGINEERING

This book is dedicated to my wife. She is my companion,
my support, greatest believer, and my best friend.

Foreword

Professors teaching engineering and corporate managers teaching entry level engineers will find this book an invaluable resource not found in any university curriculum. The author, Mr. Stuart Sabol, has drawn from his many years in engineering in industry and has enthusiastically written this book in an attempt to complement the engineering knowledge gained from a university curriculum with real complex system engineering problems that were actually encountered in the real world and that impacted both his career and the bottom line of the companies involved.

Stuart Sabol is an engineering expert who was not only intimately involved in but was pivotal to the solutions of some of the most critical and complex problems in large-scale system engineering. In most university engineering courses students are given the problems to solve with only the data required to solve them. This unrealistically hints at the correct solution. In the real world, however, an abundance of information is available or can be determined and thus good engineering judgement is required to determine what information is crucial. The author presents, through his many industry case studies, an abundance of information for each in terms of data, background, photos, and drawings from which a student may draw to determine the best course of action. Mr. Sabol has organized the case studies with a number of special exercises for students or for student teams to perform. The actual resolution for each practical case study is also given for discussion.

I think that the author can be confident that there will be many grateful professors, students and engineering managers who will have gained a broader necessary perspective of real world engineering and the associated multidiscipline approach required to solve the large scale problems frequently encountered in industry.

Dr. William C. Schneider*
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Texas A&M University
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* Dr. William C. Schneider is presently an Endowed Professor of Engineering, teaching courses in engineering mechanics and engineering design to graduate and undergraduate students at Texas A& M University. He has a wealth of practical experience gained from 38 years performing critical analysis and design at the NASA Johnson Space Center. Some of his spacecraft components are still on the moon; he has 14 US patents and numerous NASA medals for his achievements. He had sign-off authority for the US space-shuttle flights.

Preface

Being an engineer, husband and father rank highly among my endeavors. I have had great mentors throughout my professional and personal life; and have tried to be a good mentor to those I worked with, and to those close to me. This book is perhaps a completion of that attempt to mentor others to become better engineers.

When I ask someone, "How do you solve a problem?" they look at me and ask anything ranging from "Don't you know?" to "What problem?" I don't know the answer either. What I do know is that the more problems I solve the better I am at solving problems. Thus, experience is a valuable teacher. The trouble is, experience takes time.

Reducing the time to gain experience in real-world problem solving is therefore a goal of this work. I have taken from my career the most memorable projects. They are memorable because they were difficult. Memorable because I learned something from each one. Although they may seem difficult, there are paths through the data and seemingly unconnected points that reside in our engineering education. My hope is that these scenarios open doors to problem solving and life beyond the university that will pay dividends in the reader's career as a mechanical engineer.

The cases in this book are experiences, altered to avoid identification with any owner. Names are excluded. Locations are not mentioned and in many cases transposed across oceans to disguise the original project. It is not my intent to identify anyone but to present a situation that provides a learning opportunity. I anticipate that each chapter, including the problems and outside readings, can be completed in one week as part of a supplement to course studies.

There are people and institutions that have made this book possible, and I would like to acknowledge a few of them. To the contributors of artwork, Mitsubishi-Hitachi Power Systems Americas, EPRI, Doosan, ERCOT, ThermoFlow, Fram, Nooter/Eriksen, Atco, General Electric, Siemens, ASME, Crane, DeWalt, Dresser, Alstom, Triad Instruments, and owners that permitted the use of photographs, I am deeply grateful. Being able to show size, scale, and details of equipment characteristics is a valuable contribution. Thank you.

My engineering and professional mentors are too numerous to recall; however, a few deserve a mention. Charles, it was great to work with you and create a first of its kind. Keith, you directed a mentor/mentee relationship that changed the company, and protected it in a

unique project that resulted in a considerable new opportunity. Who says Fortran is dead? Reid, "you can have only one first priority," "everyone has a contribution to make," and "there are only two decisions you make in your life" are valuable life lessons that will stay with me. Mike taught me how to appreciate everyone's opinion, to seek them out, and incorporate everyone's knowledge. George helped me understand that there is no greater joy than to enjoy what you do. Jo showed me how to progress the work and how to motivate people.

A special thanks to Steve Turns at Penn State. Your feedback was a breakthrough for this book. Also a special thanks to my publisher. Paul, thanks for believing in the book as much as I did, and in my ability to create it.

Stuart Sabol PE, PMP

Introduction

This volume of *Case Studies in Mechanical Engineering* strives to bring real-life experiences to students, recent graduates, and those seeking to continue their education either formally or on their own. These particular cases depart from traditional engineering case studies in that they are not evaluations of failures, and do not try to explore the field of engineering ethics. Instead, the author has drawn from his years of engineering to present those cases that affected his career and brought about new understandings in the field and practice of mechanical engineering. All deal with engineering's impact on a company's earnings and profit.

Each case is a study based on actual problems solved by engineers in industry. The names of the facilities and participants in the cases are absent, and the facts have been altered, but the lessons remain intact. Some of the case studies have been assembled from different projects or events that took place over several years. Most have been shortened or simplified to present a set of cases, each of which can be completed in a reasonable amount of time. The case studies thus provide a glimpse of how real-world engineering differs from traditional textbook problems and how engineering can impact management and the corporate bottom line.

Cases 1 through 3 are introductory. The first case study provides details of steam turbines, their design, and their operating characteristics. It provides a lesson in thermodynamic analysis, and its relevance to actual hardware. The second case study links commercial and engineering disciplines with the added dimension of time pressure and decision making. The third introduces manufacturer corrections from test to standard conditions for gas turbines combined with normal wear and tear, paradigm shifts, capital improvements and management decision-making processes.

Cases 4 and 5 explore aspects of detailed design. Case 4 studies the details of ASME flow elements in liquid and two-phase applications, thermodynamics, uncertainty evaluations, and computer programming. Case 5 dives deeper into applications of two-phase flashing flow with the problem of setting equipment elevations, pump characteristics, and detailed hydraulic calculations.

Case 6 develops a tool to analyze system availability and reliability.

Cases 7 and 8 deal with environmental subjects and an engineer's role in society and higher level decision making. Case 7 requires balancing of combustion calculations, and decision making. Case 8 explores fundamental market behavior and how a company's decisions can be impacted by taxes and governmental intervention.

Cases 9 and 10 deal with the application of engineering fundamentals combined with more abstract concepts. Case 9 combines knowledge of heat-transfer characteristics and detailed fluid system design, with quality-assurance requirements for engineers, and owners, and corporate responsibility. Case 10 develops a maintenance strategy for large equipment and complex systems, expanding the current state of the art in maintenance planning.

Case 11 explores the roles and responsibilities of an engineer responsible for a design team. The case illustrates developments, leadership and management tools that can be applied to a generic project engineering assignment.

Case 12 is a short study of engineering in daily life: how advancements are possible even in trades that have evolved over millennia, highlighting the necessity of using creativity and improving accuracy and quality.

In these studies, career decisions, standard practices, and engineering improvements are combined with decision-making and presentation skills to advance the traditional textbook approach to engineering beyond the classroom.

Each case study contains several exercises that can be used as in-class or homework activities. The cases may be approached as team activities. Solutions to the exercises, and detailed discussion, are included in each chapter.

Contents

Case 1

Steam Turbine Performance Degradation

A private investor-owned power company owns 15 GW of capacity including conventional fossil-fired generation and natural-gas fired combined cycle gas turbine power plants spread throughout the United States. The company competes in several unregulated power markets and takes seriously its ability to provide safe, reliable, low-cost power compared to its competitors while meeting all environmental permit requirements. Quarterly senior management reviews include reports on worker and contractor safety performance, the reliability and efficiency of the facilities, as well as any exceedances of environmental permits. The company spent time and resources establishing guidelines and procedures for regular performance monitoring at its generating facilities, including results analysis. These guidelines are routinely reinforced at every level of the organization with training for new recruits and refresher courses for midlevel management.

The performance-monitoring procedures and guidelines include techniques to analyze the test data based on industry guidelines, particularly ASME PTC Committee (2010) and technical papers from noted industry experts such as Cotton and Schofield (1970). For the company's steam turbines, the condition of the various stages is related to changes in stage pressures at standard conditions knowing how the throttle flow to the machine has changed. The methods are based on the fact that, for a large multistage condensing turbine, all stages, except the first and last, operate with a constant pressure ratio (p_2/p_1.) This allows the general flow equation for flow through a converging-diverging nozzle for stages beyond the first stage to be simplified to equation (1.1)

$$\dot{m} = \Phi \cdot \sqrt{\frac{P}{\upsilon}} \tag{1.1}$$

Case Studies in Mechanical Engineering: Decision Making, Thermodynamics, Fluid Mechanics and Heat Transfer, First Edition. Stuart Sabol.

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