PROBLEM SOLVING FOR PROCESS OPERATORS AND SPECIALISTS

PROBLEM SOLVING FOR PROCESS OPERATORS AND SPECIALISTS

Joseph M. Bonem

AIChE®

WILEY

A JOHN WILEY & SONS, INC., PUBLICATION

Copyright © 2011 by John Wiley & Sons, Inc. All rights reserved.

Published by John Wiley & Sons, Inc., Hoboken, New Jersey
Published simultaneously in Canada

No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, scanning, or otherwise, except as permitted under Section 107 or 108 of the 1976 United States Copyright Act, without either the prior written permission of the Publisher, or authorization through payment of the appropriate per-copy fee to the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923, 978-750-8400, fax 978-750-4470, or on the web at www.copyright.com. Requests to the Publisher for permission should be addressed to the Permissions Department, John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, 201-748-6011, fax 201-748-6008, or online at http://www.wiley.com/go/permission.

Limit of Liability/Disclaimer of Warranty: While the publisher and author have used their best efforts in preparing this book, they make no representations or warranties with respect to the accuracy or completeness of the contents of this book and specifically disclaim any implied warranties of merchantability or fitness for a particular purpose. No warranty may be created or extended by sales representatives or written sales materials. The advice and strategies contained herein may not be suitable for your situation. You should consult with a professional where appropriate. Neither the publisher nor author shall be liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or other damages.

For general information on our other products and services or for technical support, please contact our Customer Care Department within the United States at 877-762-2974, outside the United States at 317-572-3993 or fax 317-572-4002.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic formats. For more information about Wiley products, visit our web site at www.wiley.com.

Library of Congress Cataloging-in-Publication Data:

Bonem, Joseph M.
Problem solving for process operators and specialists / Joseph M Bonem.
p. cm.
Includes index.
ISBN 978-0-470-62774-7 (cloth)
1. Chemical engineering–Problems, exercises, etc. 2. Chemical engineering–Quality control. 3. Chemical processes–Mathematical models. 4. Problem solving. 5. Engineering mathematics–Formulae. I. Title.
TP168.B66 2011
660'.28–dc22

2010028354

Printed in Singapore

oBook ISBN: 978-0-470-93396-1
ePDF ISBN: 978-0-470-93395-4

10 9 8 7 6 5 4 3 2 1

This book is an attempt both to leave a legacy and to provide assistance to a group that I consider underpaid and undervalued: the process operations department in refineries and chemical plants. This group was invaluable to me when I began a career with a degree in chemical engineering. They taught me things that were not in books. I am hoping that through this book they can develop into true engineering problem solvers.

I am dedicating this book to these men and women who were so instrumental to helping me get started in a career that I found to be more than rewarding. They are all deceased now and their names are too numerous to mention. But I remember their names, faces, and the things that they taught me.

CONTENTS

PREFACE

During my career, I spent many hours solving chronic and/or severe chemical plant operating problems. These were problems that others, in the judgment of management, did not have the capability to solve. Some of the problems had resisted multiple attempts by others to find a solution. These problems appeared to be difficult to solve for one of two reasons. Those trying to solve them either did not have the capability or did not use the capability that they had to solve the problems. As I examined the reasons that I was successful in problem solving and others were not, I concluded that there was a common thread that linked all the unsuccessful problem solvers. The three aspects of the common thread were as follows:

- There was no disciplined problem-solving approach used by either the operators or the engineers. Thus both professions tended to "jump to conclusions." That is, they selected the first solution to a problem that they heard or thought about. Even worse than that, sometimes the problem that they were solving was really not the problem that was occurring. They did not take time to understand what problem they were trying to solve.
- They either did not have adequate training or did not use the training that they had to formulate theoretically correct working hypotheses. On one occasion, I observed an engineer correlating fractionation operation with the phase of the moon. This was a truly creative idea, but it had no relationship to reality.
- If a solution *appeared* to work, there was a tendency to immediately proclaim that the problem was solved. Many times the problem went away of its own accord only to resurface at a later date. I often heard the expression "We did a couple of things and the problem went away." As I heard this, I normally said either to myself or aloud, "If you don't know why it went away, there is a high probability that it will come back."

During years of experience, I observed well-trained chemical engineers who had graduated in the upper part of their class having difficulty solving technical plant problems. I concluded that often these well-trained engineers were not really trained in subjects that would allow them to solve real-life plant process problems. They had minimal training in problem-solving techniques and much of their academic training was not directed at pragmatic solutions. For example, the academic world was teaching thermodynamics, but not how the theory applies to reciprocating or centrifugal compressors. With this limited amount of training in approaching real-world problems, the process engineer would often settle for a problem-solving approach based on logic with no calculations or, even worse, simple intuition. In addition, the pressures of a real-life problem-solving environment often caused him or her to take the approach of "trying something even if it doesn't work." Management rarely indicated that the engineer should take the time to make sure that the problem was solved correctly. Many times the belief of an operator and/or mechanic was taken as being the correct problem solution simply because the engineer did not have a good framework to develop any other possibility. Since the graduate engineer and operator now seemed to agree, management felt comfortable in implementing the "joint recommendation."

At the other extreme, I often saw well-trained, experienced operators taking one of two approaches when confronted with a problem.

- They would propose a solution that was based on experience only. If the problem was outside their realm of experience, they would withdraw and proclaim that their job was to "turn valves."
- They would propose an elaborate theory that had no scientific basis and was not based on any calculations.

Often, the solutions developed by the plant engineer or operator did not solve the problem. Even worse, the results of the attempted solutions were not documented and there was a strong possibility that the same problem solution would be tried again at a later date.

In an effort to mitigate the failure to solve industrial problems, a new series of techniques were developed that called for using teams to solve problems via interactive "brainstorming" approaches. I observed that the advantages of these teams were that they often brought a tremendous amount of data to bear on the problem and that they generated a long list of possible hypotheses. However, this approach was no more effective than the previous ones. The reason why this large amount of data failed to produce effective solutions was that there was no systematic analysis of the data. In addition, there was no stipulation that the possible hypotheses had to be theoretically feasible. Thus theoretically impossible hypotheses were treated with the same validity as the theoretically possible ones. The most likely outcome of such brainstorming sessions was that the solution with either the most votes or the loudest proponents was adopted as the recommended approach.

In spite of these less than perfect approaches, industrial problems are being solved by intuitive, logical approaches and/or brainstorming that do not involve calculations and/or data analysis. Most of these problems are being solved by experienced engineers and/or operators. However, these problems are generally not complex or chronic in nature. It is the chronic problems and/or those requiring an advanced analysis that this book addresses.

In addition to the factors discussed above, there are four macro demographic and economic trends that are emerging:

- As the "baby boomers" age and retire, the experience that is often of value in problem solving is not being replaced. Thus a more structured approach will become even more important in the next decade.
- In an effort to become more efficient, technical staffing in process plants is being reduced. Thus there is more emphasis on operators and process specialists being able to solve not only typical operating problems, but the severe and chronic problems.
- Process plants themselves are becoming larger and more complicated. Thus problems are more difficult to solve and there is more incentive for expediting a solution.
- Operators are much better schooled in the basic tools of the process industry such as chemistry and mathematics. With this basic training, they can be trained to do many of the more advanced chemical engineering calculations.

These macro trends lead to the premise of this book as follows:

> **There is a need to provide problem-solving training to a new generation of process operators who can be trained to do basic chemical engineering calculations rather than only relying on experience-based solutions.**

I have been encouraged to meet this goal as I have reflected on operators that have attended my problem-solving courses. While these courses were primarily developed for engineers, the operators in attendance could easily follow and participate as the problem-solving concepts were discussed. However, they lagged somewhat when actual calculations were presented. Thus I have included a separate chapter in this book to provide some basic chemical engineering concepts for someone with the equivalent of high school chemistry and algebra training. With this addition to a book or training seminar, it is my belief that a process operator or specialist will be able to comprehend the concepts presented throughout this book.

I cannot claim that the techniques discussed in this book will allow the process operator or specialist to achieve perfection in the area of problem solving. However, I can say that these techniques have worked for me throughout a long career of industrial problem solving. The chemical engineering fundamentals discussed in the book are presented from the perspective of the problem solver as opposed to the perspective of a process designer or that of someone in the academic world. There are shortcuts and simplifying assumptions that are used. These may not be theoretically precise, but they are more than adequate for problem-solving activities. There are without a doubt additional chemical engineering fundamentals that should be covered. However, I have selected those areas that I felt would be of most value to the industrial problem solver.

My industrial experience indicates that there are three requirements to successfully solving complex problems. They are as follows:

1. You must have verifiable data.
2. You must use a structured problem-solving approach that includes a statement of what problem you are trying to solve. This requires rigid discipline. As discussed in Chapter 1, we often fail at simple problem solving because we tend to rely on intuition or experience-based solutions as opposed to a more rigorous, structured problem-solving approach.
3. You must use sound engineering skills to develop a simple working hypothesis.

If any one of these three is absent, unsatisfactory results may occur. For example, a logical solution to a problem is of no value if it is not based on sound data or if the conclusion violates a fundamental premise of engineering. Conversely, a sophisticated computer simulation program is of little value unless it is directed toward solving the correct problem in an expeditious fashion.

Multiple surveys and interviews throughout the United States have listed "problem-solving skills" and "vocational-technical skills" in the top 10 skills that employers wish their employees had. This book deals with these two skills as follows:

1. The three essential problem-solving skills (Daily Monitoring System, Disciplined Problem-Solving Approach, and Determining Optimum Technical Depth) are discussed and guidelines are provided for successful implementation of each of these.
2. Vocational-technical skills are enhanced by equipment descriptions, helpful hints, and practical knowledge that will expand the problem solver's capabilities and academic training. The helpful hints and practical knowledge include calculation techniques that are presented without lengthy derivations and proofs.

Several example problems are included throughout this book in order to illustrate the concepts and techniques discussed. Some of the example problems are included in the chapters devoted to specific aspects of process engineering. The remainder are included in Chapter 14. This chapter is meant to deal with a series of problems that involve multiple aspects of process engineering problem solving.

The problems in the book are, for the most part, real problems. The failures and successes described have actually occurred. The problem-solving techniques described in this book were responsible for the successes. Failures were often due to not using the techniques described. Occasionally, fictitious problems are created to help illustrate important concepts or calculation techniques.

The English set of units has been used throughout the book. The English units and their abbreviations are described at the end of each chapter. A table of conversion factors to scientific units is provided in the Appendix.

Throughout the book, I have used the term "problem solver" to mean the individual with direct responsibility for solving the problem under consideration. I have also used the masculine pronoun "he" knowing full well that there are talented female problem solvers as well.

I have borrowed heavily from my previous book, *Process Engineering Problem Solving*. After publication of the earlier book, I was often asked about the utilization of the principles described in the book by other engineering disciplines or by operators/mechanics. It is my firm belief that the problem-solving principles (Daily Monitoring System, Disciplined Problem-Solving Approach, and Determining Optimum Technical Depth) described in the earlier book can be used by other engineering disciplines or operators/mechanics. This became the incentive to write a book specifically for process operators. An operator cannot be expected to have the academic skills to formulate a full range of process hypotheses. However, because of the pragmatic approach used in this book, it is likely that an operator/mechanic could readily learn how to do the calculations required to formulate a majority of the theoretically correct hypotheses required to solve problems in a process plant. Problem solving throughout this book is referred to as "engineering problem solving" even though the book is intended for operators. The term "engineering problem solving" is used since the proposed approach uses engineering calculations that can be learned by operators.

While this book and my previous book were written for those working in industry, I have been told by others that the early chapters of the books have wide application. These people have suggested to me that these chapters have application to any vocation requiring a disciplined approach to problem solving, such as criminal or fire investigation and medicine.

Joseph M. Bonem