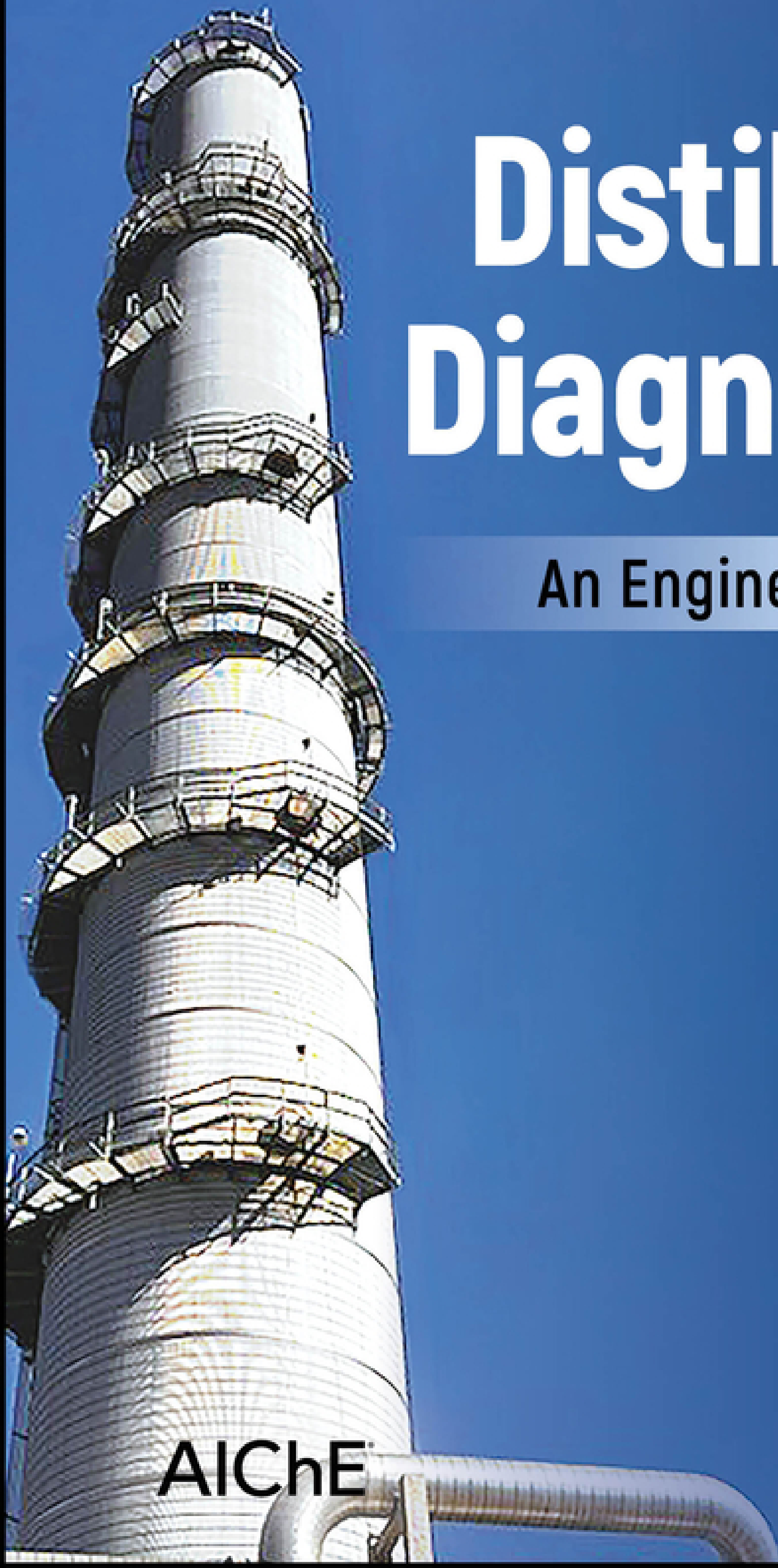

Distillation Diagnostics

An Engineer's Guidebook

Henry Z. Kister

AIChE

WILEY

Distillation Diagnostics

Distillation Diagnostics

An Engineer's Guidebook

Henry Z. Kister

Fluor Corporation, USA

AIChE
The Global Home of Chemical Engineers

WILEY

A Joint Publication of the American Institute of Chemical Engineers and John Wiley & Sons, Inc.

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

Library of Congress Cataloging-in-Publication Data:

Names: Kister, Henry Z., author. | John Wiley & Sons, publisher.
Title: Distillation diagnostics : an engineer's guidebook / Henry Z Kister.

Description: Hoboken, New Jersey : Wiley, [2025] | Includes index.
Identifiers: LCCN 2024023262 (print) | LCCN 2024023263 (ebook) | ISBN 9781119640110 (hardback) | ISBN 9781119640158 (adobe pdf) | ISBN 9781119640127 (epub)
Subjects: LCSH: Distillation. | Distillation apparatus–Maintenance and repair.
Classification: LCC TP156.D5 K557 2025 (print) | LCC TP156.D5 (ebook) | DDC 665.5/32–dc23/eng/20240604
LC record available at https://lccn.loc.gov/2024023262
LC ebook record available at https://lccn.loc.gov/2024023263

Cover Design: Wiley

Set in 10/12pt TimesLTStd by Straive, Chennai, India

To my son, Abraham, and my daughter, Helen, who have been my love, blessings, and the lighthouses illuminating my path

Contents

Preface

For over a century, distillation, the "king of separations," has been by far the most common separation technique in refineries, petrochemical, chemical, and natural gas plants and will remain the prominent separation technique in the foreseeable future. Every chemical process has a reaction section and a separation section, with distillation usually dominating the latter. Three percent of the world's energy is tied in distillation. The dominance of distillation stems from its low capital compared to other techniques, scaling up well, and not introducing an extra agent that requires removal later.

The past half-century has seen tremendous advances in distillation technology. High-speed computers revolutionized the design, control, and operation of distillation towers. Invention and innovation in tower internals enhanced tower capacity and efficiency beyond previously conceived limits. Despite all these advances, the distillation failure rate has been on the rise and growing.

The great progress has not bypassed the distillation troubleshooting tools. Reliable pressure drop measurements, gamma scans, laser-guided pyrometers, and thermal cameras are tools that not-so-long-ago troubleshooters would only dream of. But again, despite this great progress, the ability of engineers to effectively diagnose and solve plant problems appears to be on the decline.

Why are we losing the problem-solving war? Despite the prominence of distillation in industry, academics prefer to focus on more trendy "cool" fields. The *Chemical Processing* editorial from March 2018 decries the lack of practical research on distillation in chemical engineering departments. In industry, mergers, cost-cuts, and the pandemic have retired most of the experienced troubleshooters and thinly spread the others. The literature offers little to bridge the experience gap. In the era of information explosion, databases, and computerized searches, finding the appropriate information in due time has become like finding a needle in an ever-growing haystack. To locate a useful reference, one needs to click away a huge volume of wayward leads.

The result is that distillation diagnostics is becoming a lost art. Engineers are given little practical guidance on how to correctly apply and get the most out of the diagnostic tools, so the tools are utilized sparsely and only on a very basic level. Problems are left undiagnosed or misdiagnosed. Solutions based on misdiagnoses are doomed to fail. Lacking a proper diagnosis, some engineers turn to so-called experts and end up being sold a bill of goods or sledge hammers to crack nuts. It is not uncommon to see an expensive new tower solving a problem that can be solved by replacing a faulty feed pipe for nickels and dimes.

The trend away from diagnosis could not have come at a worse time. We are being alarmed by adverse climate and environmental changes, are recognizing the importance of saving our planet, and are striving for a cleaner tomorrow. The engineering community is engaged in developing new technologies for reducing the carbon footprint, aspiring to "zero carbon" energy transition, carbon capture, and replacement of fossil fuels by renewables. Unfortunately, many of these technologies require massive new equipment and additional energy usage, neither of which helps achieve the prescribed goals of reducing carbon footprints.

One simple technology is being forgotten: correct diagnostics. In his book *Process Engineering for a Small Planet* (Wiley, 2010), Norman Lieberman demonstrates how poor troubleshooting and wasteful practices guzzle energy, generate carbon dioxide, and waste the earth's precious resources. In Chapter 1 of his book, Lieberman describes a case in which a correct diagnosis would have led to modifying trays and downcomers in a fractionator, and adding mist injection to the overhead compressor, which could have circumvented erecting a giant new fractionator with a new oversized overhead compressor. Just the energy usage due to the compressor oversizing was estimated to waste the amount of crude oil that 400 families use daily. Fabricating the new steelwork and structures consumed additional immense amounts of energy and emitted tons of carbon dioxide, all of which were unnecessary.

In another example (Chapter 2), four uninstalled tray manways induced the escape of a large quantity of diesel in the bottom of a crude fractionator. To vaporize it took 40 MM Btu/h, which is equivalent to the fuel consumption of a quarter of a million 400 horsepower motor cars driving around the clock. Lieberman diagnosed the problem and recommended re-installing the manways, but the implemented solution was to build a new larger heater, wasting not only energy but also concrete, steel, nickel, and chromium needed for the heater and its tubes, the mining and production of which only adds to the carbon footprint. Lieberman presents a book full of similar experiences.

This book builds up on Lieberman's initiative with a multitude of distillation examples. In one (Chapter 8), a packed stripper was erected to turn a wastewater stream into cooling water makeup. The entering wastewater poured above the oversized hats of the liquid distributor. In the little space between the hats, the vapor sped up and carried the liquid over. Two different consultants studied the problem. The first offered an incorrect diagnosis and a failed fix. The second performed an extensive simulation study, incorrectly concluding that a larger-diameter tower was needed. The plant gave up and junked the tower, with the water still going to the sewer. Good troubleshooting and hat or feed pipe modifications costing nickels and dimes would have saved precious water, reduced sewage, and prevented turning a good tower into scrap metal.

My previous book, *Distillation Troubleshooting*, focused on case studies and the lessons learned. This book goes further, providing the tools to correctly diagnose and solve operating problems, avoid the wasteful practices, and make the most of existing equipment. It travels through the multitude of invaluable tools available for diagnosing tower problems, providing application guidelines derived from the school of hard knocks. The book describes what each tool can and cannot do, provides insight into how different ideas and theories can be tested using these tools, shares the experience of how to correctly interpret the results provided by each technique, and guides troubleshooters to a multitude of additional tests that they can perform to get closer to a correct diagnosis and an effective fix. The only other place where its information is available is in the heads of experienced troubleshooters.

The techniques are illustrated with real case studies from my experience of 45 years as well as from the experiences of many of my colleagues and those presented in the literature. Every technique is accompanied with an extensive list of "do and don'ts" based on the author's and industry's experience. This guidance can make the difference between success and failure, and between good and bad results.

The case studies and lessons learned are described to the best of the author's and the contributors' knowledge and in good faith, but may not always correctly reflect the problems and solutions. Many times I thought I had the answer, only to be humbled by a new light or another experience later. The experiences and lessons in this book are not meant to be followed blindly. They are meant to be stories told in good faith and to the best of knowledge and understanding of the author or contributors, which hopefully give troubleshooters ideas to think about. We welcome any comments that either affirm or challenge our perception or understanding.

If an incident that happened in your plant is described, you may notice that some details could have changed. Sometimes, this was done to make it more difficult to tell where the incident occurred. At times, it was done to simplify the story without affecting the key lessons. Sometimes, it happened long ago and memories of some details faded away. Sometimes, and most likely, this incident did not happen in your plant at all. Another plant had a similar incident.

The book emphasizes the "do-it-yourself" approach. It endeavors to place the tools and good application guides in the practitioner's hands, eliminating reliance on the so-called experts. People who attend my seminar classes come out with knowledge on how to apply the tools and express concern about forgetting this knowledge over the years. They express wishes to have a book like this so they can refresh their memories in the future. This is that book. It is my hope that the book will lead the readers to correct diagnostics and effective fixes to tower problems, and to trouble-free operation.

If you can successfully solve only one problem using the techniques in this book, the savings to your company will be enough to pay for thousands of copies of the book. But far beyond the savings, you will be taking a step in the right direction of saving our small planet and ushering in a cleaner tomorrow.

HENRY Z. KISTER

May 2024

List of Acronyms

AIChE	American Institute of Chemical Engineers
AGO	Atmospheric gas oil
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
ATB	Atmospheric tower bottoms
BPA	Bottom pumparound
BPD	Barrels per day
BPH	Barrels per hour
BPSD	Barrels per stream day
BTM	Bottom
CAT	Computer aided tomography
CFD	Computational fluid dynamics
COND	Condensate
COT	Coil outlet temperature
COV	Coefficient of variation
CW	Cooling water
dP	Differential pressure (pressure drop)
ED	Extractive distillation
FCC	Fluid catalytic cracking
FI	Flow indicator
FRI	Fractionation Research Inc (or Institute)
FRN	Full range naphtha
HAZOP	Hazard and operability analysis
HCO	Heavy cycle oil
HCU	Hydrocracker Unit
HETP	Height equivalent to a theoretical plate
HF	Hydrogen fluoride
HN	Heavy naphtha
HP	High pressure
HSE	Health, Safety, and Environment
HVB	Hot vapor bypass
HVGO	Heavy vacuum gas oil
ID	Internal diameter
IPA	Intermediate pumparound
IR	Infrared
LCO	Light cycle oil
LED	Light Emitting Diode
LI	Level indicator

LN	Light naphtha
LNG	Liquefied natural gas
LV	Liquid volume
LVGO	Light vacuum gas oil
MBPD	Thousand BPD
MCB	Main Column Bottoms
MDEA	Methyldiethanol amine
MEA	Monoethanol amine
MP	Medium pressure
MPA	Mid pumparound
MRI	Magnetic resonance imaging
MSCFH	Standard cubic feet per hour × 1000
OSHA	The Occupational Safety and Health Administration
OVHD	Overhead
P&ID	Process and instrumentation diagram
PA	Pumparound
PFD	Process flow diagram
PI	Pressure indicator
PPR	Polypropylene return
STM	Steam
TAR	Turnaround
TI	Temperature indicator
TPA	Top pumparound
TRC	Temperature recorder/controller
VCFC	Vapor crossflow channeling
VLE	Vapor–liquid equilibrium
VLLE	Vapor–liquid-liquid equilibrium
VTB	Vacuum tower bottoms

Acknowledgments

Many of the experiences and case histories reported in this book have been invaluable contributions from colleagues and friends who kindly and enthusiastically supported this book. Many of the contributors elected to remain anonymous. Kind thanks are due to all contributors, you have done a magnificent service to our beloved science of distillation and to the industry. Special thanks to those whose names do not appear in print. To those behind-the-scenes friends, the author extends special appreciation and gratitude.

Writing this book required breaking away from everyday work and family demands. Special thanks are due to Fluor Corporation, particularly to my supervisors, Curt Graham, Maureen Price, Jeff Scherffius, Jennifer Foelske, and Bill Parente, for their backing, support, and encouragement of this book-writing endeavor, going to great lengths to make it happen. Warmhearted gratitude to my wife Susana for her love, dedication, and devotion to our family, guiding our children to walk in G-d's path and do the right thing, and encouraging them to excellence.

Recognition is due to my mentors who, over the years, encouraged my work; immensely contributed to my achievements; and taught me much about distillation and engineering: to my life-long mentor, Dr. Walter Stupin, who warmly mentored and encouraged my work, throughout my career at C F Braun and later at Fluor, being a ceaseless source of inspiration behind my books and technical achievements, and who taught me a lot of what I know about distillation; Curt Graham and Paul Walker, Fluor, whose warm encouragement, guidance, and support were the perfect motivators for professional excellence and achievement; Professor Ian Doig, University of NSW, who inspired me over the years, showed me the practical side of distillation, and guided me over a crisis early in my career; Professor James Fair, distillation guru, University of Texas, who warmly encouraged my books and distillation work; Reno Zack, who enthusiastically encouraged and inspired my achievements throughout my career at C F Braun; Dick Harris and Trevor Whalley, who taught me about practical distillation and encouraged my work and professional pursuits at ICI Australia. Thanks are due to my colleagues Garry Jacobs and Carlos Trompiz (Fluor), Ron Olsson (Celanese), Daryl Hanson (Valero), Christine Long (Chevron), and troubleshooting guru Norman Lieberman, all of whom taught me a lot by sharing their vast experiences and expertise. The list could go on, and I express special thanks to all who encouraged, inspired, and contributed to my work over the years. Much of my mentors' and colleagues' teachings found its way to the following pages.

Special thanks are due to my mother, Dr. Helen Kister, and my father, Dr. John Kister, may their memories be blessed, who dedicated their lives to me, guided me to do things right, enthusiastically supported my work throughout my life, and have been there for me every moment of the day. Their prayers have remained with me even after they left this world. Thanks also for always encouraging me to excel and teaching me to diagnose and critically evaluate problems.

Special thanks are due to Tracerco, in particular to the dedication of Margaret Bletsch and Lowell Pless, who contributed wonderful expertise, experiences, and images for the radioactive troubleshooting sections of this book and assisted me in fitting them to the audience.

Chapter 1

Troubleshooting Steps

"In our industry we have many more troublemakers than troubleshooters"
—(Professor Zarko Olujic, presentation to AIChE)

Troubleshooting, revamping, and eliminating waste offer huge benefits in reducing capital investment, downtime, carbon dioxide emissions, and energy consumption. Unfortunately, the attention paid to this resource in the energy-transition era has been too little to reflect its tremendous potential.

A multitude of examples in Norman Lieberman's book *Process Engineering for a Small Planet* (287) demonstrate how poor troubleshooting leads to wasteful practices that guzzle energy, increase the carbon footprint, and deplete the earth's precious resources. The chemical process industry (CPI) has been paying dearly for downtime, lost production, substandard product quality, raw material problems, safety and environmental issues, and excessive energy consumption due to ineffective troubleshooting of abnormal situations (16). In 1997, a consortium estimated that the annual loss for the CPI due to ineffective abnormal situation management was US $10 billion (16).

Correct diagnosis is at the heart of problem identification and implementing a correct, cost-effective solution. An incorrect diagnosis breeds ineffective solutions that prolong the agony and escalate the costs. This chapter focuses on the systematic diagnostic steps. The following chapters will describe the multitude of techniques that have been found effective for diagnosing distillation problems.

A well-known sales axiom states that 20% of the customers bring in 80% of the business. A sales strategy tailored for this axiom concentrates the effort on these 20% without neglecting the others. Distillation diagnostics follow an analogous axiom. A person engaged in diagnosing column problems must develop a good understanding of the factors that cause the vast majority of column malfunctions and the techniques available for narrowing in on their root causes. While a good knowledge and understanding of the broader field of distillation is beneficial, the diagnosis often requires only a shallow knowledge of this broader field.

It is well accepted that diagnosing problems is a primary job function of operating engineers, supervisors, and process operators. Far too few realize that distillation diagnostics start at the design phase. Any designer wishing to achieve a trouble-free column design and operation must be as familiar with diagnostic techniques, many of which are applicable during the design (and more so at the revamp) phase.

Expansive surveys of the causes of column malfunctions were described in previous studies (196, 198, 201). Abundant resources are available to distinguish good from poor practices and to

Distillation Diagnostics: An Engineer's Guidebook, First Edition. Henry Z. Kister.

avoid and overcome troublesome design and operations (e.g., 192, 285, 286, 293). What is often missing is the connect. How does one link field observations with the known tower malfunctions in order to develop an effective remedy? This book is all about the link: translating field observations into diagnoses and cures.

Following a brief survey of the primary causes of tower malfunctions, this chapter looks at the basic diagnostic: the systematic strategy for diagnosing distillation problems and the dos and don'ts for formulating and testing theories. Finally, it reviews the techniques for testing these theories and for focusing on the most likely root cause.

1.1 CAUSES OF COLUMN MALFUNCTIONS

Close to 1500 case histories of malfunctioning columns were extracted from the literature and abstracted in Ref. 201. Most of these malfunctions were analyzed in Ref. 198 and classified according to their principal causes. A summary of the common causes of column malfunctions is provided in Table 1.1. If one assumes that these case histories make up a representative sample, then the analysis presented below has statistical significance. Accordingly, Table 1.1 can provide a useful guide to the factors most likely to cause column malfunctions and can direct troubleshooters toward the most likely problem areas.

The general guidelines in Table 1.1 often do not apply to a specific column or even plant. For instance, foaming is not high up in the table; however, in amine absorbers, it is a very common trouble spot. The author therefore warns against blindly applying these guidelines in any specific situation.

The total number of cases in each category is shown in the column headed "Cases." The other three columns show the split of these cases according to industry categories, namely refining, chemicals, and olefins/gas plants.

An analysis of Table 1.1 suggests the following:

- Plugging, tower base, tower internals damage, instrument and control problems, startup and/or shutdown difficulties, points of transition (tower base, packing distributors, intermediate draws, feeds), and assembly mishaps are the major causes of column malfunctions. They make up nearly two-thirds of the reported incidents. Familiarity with these problems, therefore, constitutes the "bread and butter" of distillation and absorption troubleshooters.
- Primary design is a very wide topic, encompassing vapor–liquid equilibrium, stage-to-stage calculations, reflux-stages relationship, unique features of multicomponent distillation, tray and packing capacities and efficiencies, scale-up, column diameter and height determination, type of tray, and size and material of packing. This topic represents most of our distillation know-how and occupies the bulk of most of the distillation texts (e.g., 34, 193, 299, 451, 492). While this topic is paramount for designing and optimizing distillation columns, it plays only a minor role in operations and troubleshooting in distillation. As shown in Table 1.1, only one column malfunction among fourteen is incurred in the primary design. The actual figure is probably higher for a first-of-its-kind separation, but lower for an established separation. Due to the bulkiness of this topic and its low likelihood to cause malfunctions, and due to the excellent coverage that the topic receives in several texts (e.g., 34, 193, 299, 451, 492), it is only lightly touched upon in this book.
- The above statements must not be interpreted to suggest that troubleshooters need not be familiar with the primary design. Quite the contrary. A good troubleshooter must have a solid understanding of primary design because it provides the foundation of distillation

Table 1.1 Most common causes of column malfunctions. (From Kister, H. Z., Transactions of the Institution of Chemical Engineers, 81, Part A, p. 5, January 2003. Reprinted Courtesy of the Institution of Chemical Engineers in the UK.)

No.	Cause	Total cases	Refinery cases	Chemical cases	Olefins/ gas cases
1	Plugging, coking	**121**	68	32	16
2	Tower base and reboiler return	**103**	51	22	11
3	Tower internals damage (excluding explosion, fire, implosion)	**84**	35	33	6
4	Abnormal operation incidents (startup, shutdown, commissioning)	**84**	35	31	12
5	Assembly mishaps	**75**	23	16	11
6	Packing liquid distributors	**74**	18	40	6
7	Intermediate draws (including chimney trays)	**68**	50	10	3
8	Misleading measurements	**64**	31	9	13
9	Reboilers	**62**	28	13	15
10	Chemical explosions	**53**	11	34	9
11	Foaming	**51**	19	11	15
12	Simulations	**47**	13	28	6
13	Leaks	**41**	13	19	7
14	Composition control difficulties	**33**	11	17	5
15	Condensers that did not work	**31**	14	13	2
16	Control assembly	**29**	7	14	7
17	Pressure and condenser controls	**29**	18	3	2
18	Overpressure relief	**24**	10	7	2
19	Feed inlets to tray towers	**18**	11	3	3
20	Fires (excluding explosions)	**18**	11	3	4
21	Intermediate component accumulation	**17**	6	4	7
22	Chemicals release to the atmosphere	**17**	6	10	1
23	Subcooling problems	**16**	8	5	1
24	Low liquid loads in tray towers	**14**	6	2	3
25	Reboiler and preheater controls	**14**	6	–	5
26	Two liquid phases	**13**	3	9	1
27	Heat integration issues	**13**	5	2	6
28	Poor packing efficiency (excluding maldistribution/support/hold-down)	**12**	4	3	2
29	Troublesome tray layouts	**12**	5	2	–
30	Tray weep	**11**	6	1	3
31	Packing supports and hold-downs	**11**	4	2	2

know-how. However, the above statements do suggest that in general, when troubleshooters examine the primary design for the cause of a column malfunction, they have less than one chance out of ten of finding it there.

1.2 COLUMN TROUBLESHOOTING – A CASE HISTORY

In Sections 1.3 and 1.4, the systematic approach recommended for diagnosing distillation problems is presented. The recommended sequence of steps is illustrated with reference to the case history described below.[1]

The following story is not a myth; it really happened. One morning as I sat quietly at my desk in corporate headquarters, the boss dropped by to see me. He had some unpleasant news. One of the company's refinery managers was planning to visit our office to discuss the quality of some of the new plants that had been built in his refinery. As an example of how not to design a unit, he had chosen a new gas plant for which I had done the process design. The refinery manager had but one complaint: "The gas plant would not operate."

I was immediately dispatched to the refinery to determine which aspect of my design was at fault. If nothing else, I should learn what I did wrong so as not to repeat the error.

Upon arriving at the refinery, I met with the operating supervisors. They informed me that, while the process design was fine, the gas plant's operation was unstable because of faulty instrumentation. However, the refinery's lead instrument engineer would soon have the problem resolved.

Later, I met with unit operating personnel. They were more specific. They observed that the pumparound circulating pump (see Figure 1.1a) was defective. Whenever they raised hot oil flow to the debutanizer reboiler, the gas plant would become destabilized. Reboiler heat-duty and reflux rates would become erratic. Most noticeably, the hot-oil circulating pump's discharge pressure would fluctuate wildly. They felt that a new pump requiring less net positive suction head was needed.

Both these contradictory reports left me cold. Anyway, the key to successful troubleshooting is personal observation. So I decided to make a field test.

When I arrived at the gas plant, both the absorber and debutanizer towers were running smoothly but not well. Figure 1.1b shows the configuration of the gas plant. The debutanizer reflux rate was so low it precluded significant fractionation. Also, the debutanizer pressure was about 100 psi below design. Only a small amount of vapor, but no liquid, was being produced from the reflux drum. Since the purpose of the gas plant was to recover propane and butane as a liquid, the refinery manager's statement that the gas plant would not operate was accurate.

As a first step, I introduced myself to the chief operator and explained the purpose of my visit. Having received permission to run my test, I switched all instruments on the gas-plant control panel from automatic over to local manual. In sequence, I then increased the lean oil flow to the absorber, the debutanizer reflux rate, and the hot-oil flow to the debutanizer reboiler.

1 Reproduced from Norman P. Lieberman, *Troubleshooting Process Operations* (4th ed., PennWell Books, Tulsa 2009). This case history is a classic example of how to perform a systematic troubleshooting investigation. The permission of PennWell Books and Norman P. Lieberman for reproducing this material is gratefully acknowledged.

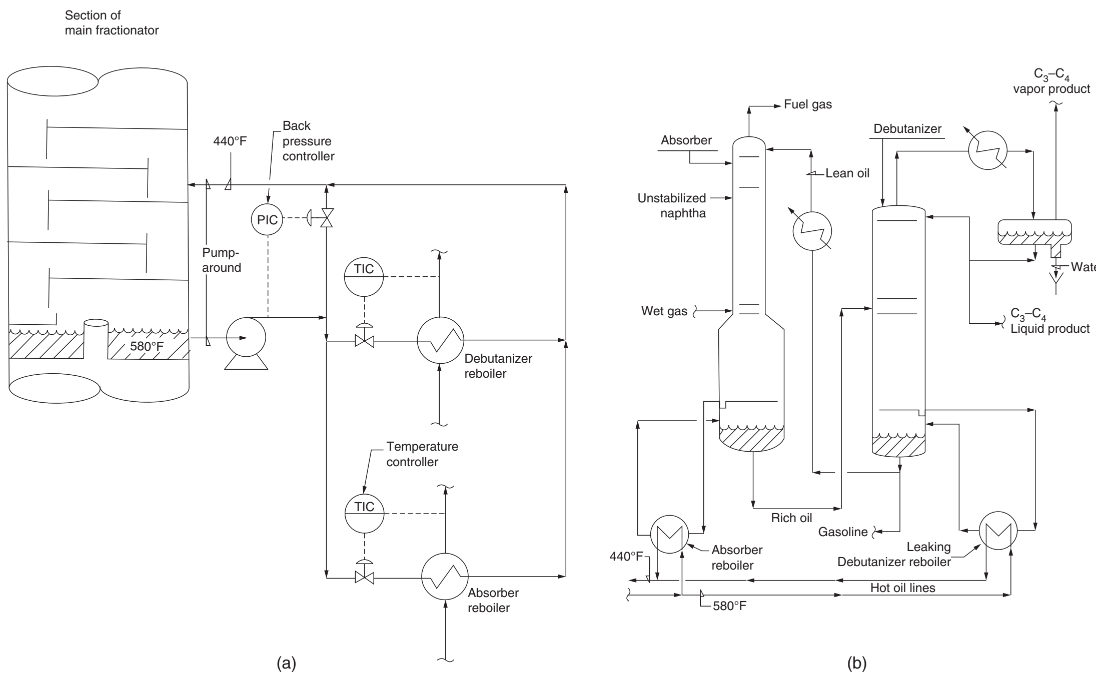

Figure 1.1 Column troubleshooting case history. (a) Hot oil from the fractionator supplies heat to gas plant reboilers. (b) Leaking debutanizer reboiler upsets gas plant. (From Lieberman, N. P., "Troubleshooting Process Operations," Ed. 4, PennWell Books, Tulsa, OK, 2009. Reprinted with permission.)

The gas plant began to behave properly. The hot-oil circulating pump was putting out a steady flow and pressure. Still, the plant was only producing a vapor product from the debutanizer reflux drum. This was because the debutanizer operating pressure was too low to condense the C_3–C_4 product. By slowly closing the reflux drum vapor vent valve, I gradually increased the debutanizer pressure from 100 psig toward its design operating pressure of 200 psig.

Suddenly, at 130 psig, the hot-oil flow to the debutanizer's reboiler began to waiver. At 135 psig the debutanizer pressure and the hot-oil flow plummeted. This made absolutely no sense. How could the debutanizer pressure influence hot-oil flow?

To regain control of the gas plant, I cut reflux to the debutanizer and lean-oil flow to the absorber. I was now back where I started. The thought of impending failure loomed.

I repeated this sequence twice more. On each occasion, all went well until the debutanizer pressure increased. By this time it was 3 a.m. Was it also time to give up and go home?

Just then, I noticed a commotion at the main fractionator control panel. The operators there stated that the fractionator was flooding again—for the third time that night. The naphtha production from the fractionator had just doubled for no apparent reason.

In every troubleshooting assignment there always occurs that special moment, the moment of insight. All of the bits and pieces fall into place, and the truth is revealed in its stark simplicity.

I cut the debutanizer pressure back to 100 psig and immediately the flooding in the main fractionator subsided. The operators then closed the inlet block valve to the hot-oil side of the reboiler and opened up a drain. Naphtha poured out instead of gas oil. This showed that the debutanizer reboiler had a tube leak.

Whenever the debutanizer pressure reached 130 psig, the reboiler pressure exceeded the hot-oil pressure. The relatively low-boiling naphtha then flowed into the hot oil and flashed. This generated a large volume of vapor that then backed hot oil out of the reboiler. The naphtha vapors passed on into the main fractionator and flooded this tower. Thus, the cause of the gas plant instability was neither a process design error, instrument malfunction, nor pumping deficiency. It was a quite ordinary reboiler tube failure.

1.3 STRATEGY FOR TROUBLESHOOTING DISTILLATION PROBLEMS

In almost any troubleshooting assignment, it is desirable to solve a problem as fast as possible with the least expense. Surprisingly, this objective is often only partially achieved, the obstacle being a poor (often nonexistent) strategy for diagnosing the problem.

While devising a troubleshooting strategy, it is useful to think in terms of a "doctor and patient" analogy. The doctor's strategy for diagnosing an illness is well established and easily understood by most people. Applying a similar strategy to diagnosing distillation problems often constitutes the most effective and least expensive course of action.

The sequence of steps listed below is often considered optimum for tackling a troubleshooting problem. It is based on the author's experience as well as the experience of others (112, 116, 161, 166, 286, 293, 318, 411, 498). The step headings refer to the doctor and patient analogy. Actions described in Lieberman's case history (Section 1.2) are referenced to demonstrate the optimum sequence of steps. A good troubleshooting strategy always proceeds stepwise, starting with the simple and obvious.