

CCPS Incident Investigation Book, Third Edition

R.C. Stokes, BakerRisk Europe Ltd., Thornton Science Park, Pool Lane, Ince, CH2 4NU, UK

Q.A. Baker, M.P. Broadribb, T.V. Rodante, C.A. Grounds; Baker Engineering and Risk Consultants, Inc., 3330 Oakwell Court, Suite 100, San Antonio, TX 78218-3024, USA

CCPS undertook a project to update the *Guidelines for Investigating Chemical Process Incidents* book. The second edition of the book was published in 2003, fourteen years before this project was started. The book's focus is investigating process-related incidents. Whilst the book was written for chemical process safety incidents, the basic concepts and provided examples are equally applicable to other industries with hazardous situations like mining and manufacturing. A major revision in the book is an increased emphasis on investigating near-miss and minor incidents. Another goal for the book project was to make it globally applicable. The book was extensively reorganised and consolidated.

Introduction

CCPS undertook a project to update the *Guidelines for Investigating Chemical Process Incidents* bookⁱ. The second edition of the book was published in 2003, fourteen years before this project was started. There have been many developments during that 14 years including methodologies used to investigate process incidents, attitudes about investigation focus and practices, technological developments, regulatory agency expectations, and legal rulings regarding admissibility of evidence and expert opinions.

The book's focus is investigating process-related incidents. While the book was written for process safety incidents, the basic concepts and provided examples are equally applicable to other industries with hazardous situations such as mining and manufacturing. The book title was changed to *Guidelines for Investigating Process Safety Incidents*, dropping "chemical" from the title in recognition of the broad application of the book.

A major revision in the book is increased emphasis on investigating near-miss and minor incidents. A near-miss or minor incident that had the potential for significant damage or injury should be considered for a higher level of investigation commensurate with the potential consequence.

Another goal for the book project was to make it globally applicable. The new book edition provides flexibility in the investigation approach for varying regulatory, industry, cultural, and situational considerations. The result is a book that takes a truly global perspective not only geographically but also across industrial sectors and incident types.

The book was extensively reorganised and consolidated. The chapter order now follows the logical sequence that an operating company would follow to organise its investigation management system, respond to an incident, determine causal factors, determine root causes, develop recommendations, and communicate the findings. Subject matter was consolidated in chapters to provide readers with a single location for information on a subject, such as witness interviews, evidence collection or root cause analysis.

Role of the Book

Guidelines for Investigating Process Safety Incidents has a unique role in literature. It is the most extensive treatment of investigating incidents and accidents in processing facilities available to date. There are guides for investigating occupational injuries, such as the Health and Safety Executive's HSG 245, "Investigating Accidents and Incidents," although these guides are not specific to process safety incidents.ⁱⁱ Forensic investigations, particularly fires, are the subject of numerous papers and books. For example, the National Fire Protection Association publishes *Guide for Fire and Explosion Investigations*ⁱⁱⁱ, which focuses on the origin and cause of fires and explosions in residential and commercial situations. *Learning from incidents, accident and events*^{iv} published by the Energy Institute was written for the energy industry and provides a comprehensive overview of the entire investigation process, although the CCPS book explores the finer details of some of the tools and techniques that are available. API published Recommended Practice RP 585, *Pressure Equipment Integrity Incident Investigation*^v. While RP 585 was written for chemical processing situations, the focus is limited to pressure equipment integrity incidents. By contrast, *Guidelines for Investigating Process Safety Incidents* addresses any processing situation. "Incident" is defined very broadly as:

"An unusual, unplanned, or unexpected occurrence that either resulted in, or had the potential to result in a process upset with potential process condition excursions beyond operating limits, release of energy or materials, challenges to a protective barrier, or loss of stakeholder confidence in a company's reputation."

Accidents are a subset of incidents in the CCPS definition, with the definition of accidents being:

"An unplanned event or sequence of events that results in an undesirable consequence."

Near misses are also a subset of incidents, defined as:

"An incident in which an adverse consequence could potentially have resulted if circumstances (weather conditions, process safeguard response, adherence to procedure, etc.) had been slightly different."

Throughout this paper and the CCPS book, "incident" is used as the term that includes both accidents and near misses.

The CCPS book is a guideline, meaning that it includes suggested methodologies. The book presents a variety of methodologies for each subject area, such as timeline development, causal factor determination and root cause determination. It is anticipated that companies will choose methodologies that best fit their processes, culture, investigation experience level, resources and other considerations. It is also anticipated that companies will use different approaches based on the severity of the event. The guideline was written to encourage companies to develop a program best suited to their needs, including differing investigation levels based on potential incident severity.

The third edition of the CCPS book was written for several audiences. Company management was one audience. The first four chapters of the book (Introduction, Incident Causation, Overview of Investigation Methodologies, and Designing an Incident Investigation Management System) were written with company management in mind. The novice investigator is another audience who can use the book as a guide for learning the entire investigation process. Lastly, the audience of experienced investigators will find the book a helpful reference when they need information on a specific subject or a refresher on a topic. For both novice and experienced investigators, helpful checklists were included.

The CCPS book is not a forensic text, nor is it a legal reference. The third edition omitted many passages pertaining to legal issues from prior editions, many of which were obsolete and US-centric. Given the global focus of the book, it was impossible to include legal considerations for all venues. As a result, the third edition encourages readers to consult legal counsel about regulatory and legal considerations for the jurisdiction of the incident.

Human factors was the subject of the greatest revisions during writing of the book. As Trevor Kletz stated, “For a long time, people were saying that most accidents were due to human error and this is true in a sense but it’s not very helpful. It’s a bit like saying that falls are due to gravity”^{vi}. Historically, incident investigations have provided only cursory treatment of human factors contributions to incidents. By probing why something happened, underlying causes may be identified and meaningful changes undertaken to prevent potential future incidents. A new chapter has been added to this edition identifying human factors concepts and incorporating human factors into the incident investigation process. Human factors is a topic in its own right and CCPS has started a project on human factors and will have a new publication on the subject in the near future. As a result, the chapter on human factors in the incident investigation book was limited to an overview of the subject.

Major Changes to the Book

Terminology

Considerable effort was spent clarifying terminology in the book (e.g., what is an incident versus an accident). This was not merely a matter of semantics. The structure of some investigation methodologies changed with terminology revisions. For example, the second edition of the book used the terms immediate causes, contributing causes, enabling causes and root causes. These terms were confusing and have widely different meanings among references and companies. The third edition of the book simplified the terminology to use only two terms: causal factors and root causes. They are defined as:

Causal factor - A major unplanned, unintended contributor to an incident (a negative event or undesirable condition), that if eliminated would have either prevented the occurrence of the incident, or reduced its severity or frequency.

Root cause - A fundamental, underlying, system-related reason why an incident occurred that identifies a correctable failure(s) in management systems. There is typically more than one root cause for every process safety incident.

Near Miss

Considerable emphasis was added throughout the book to investigating near misses. The CCPS book follows the lead of API RP 585^v in treating a near miss as an incident. This is a significant philosophical shift as many companies have treated near misses as events that did not have to be investigated like accidents. The CCPS book encourages investigating near misses with the same rigor as accidents based on *potential severity* of the near miss.

Categorisation of Incidents

A separate chapter was written for notification and classifying and selecting the investigation level for process safety incidents. A major change in the book was categorisation of incidents based on the *potential damage or injury*, not just the actual damage or injury. In this new approach, a near miss that potentially could have been a severe accident would be investigated in the same way as a major accident. The authors and CCPS subcommittee members had numerous accounts of investigations in which plant personnel felt “lucky” that the incident was not more severe, such as the wind blowing a toxic plume from a seal leak away from a group of workers. Had the wind been in a different direction, the workers could have been badly injured.

The combination of treating near misses as incidents and categorising incidents based on potential severity supports the philosophy of investigating small incidents so that corrective actions can be taken to prevent larger incidents. The book advocates for additional attention to investigating near misses and small incidents.

Objectivity of Investigations

The third edition adds the scientific method to objectively, systematically, and scientifically determine the causal factors. The scientific method has become a requirement for expert testimony in the United States due to court rulings. NRPA 921 has been revised substantially in the past decade to base fire and explosion investigations on the scientific method.ⁱⁱⁱ The CCPS book defines the scientific method as:

“Principles and procedures for the systematic pursuit of knowledge involving the recognition and formulation of a problem, the collection of data through observation and experiment, and the formulation and testing of hypotheses.”

Figure 1 depicts the steps involved in the scientific method as it is applied to a process safety incident investigation. As with any type of scientific reasoning method, the process begins with defining the problem to be solved. For example, the problem could be determining the cause of loss of containment that led to a flammable material release and fire.

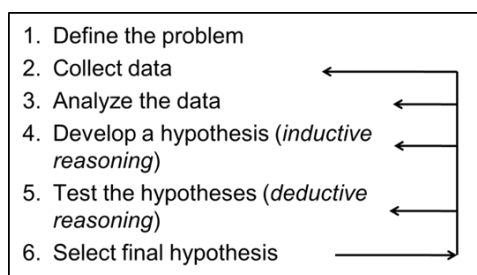


Figure 1. Scientific Method Process

The benefit of the scientific method for a process safety incident investigation is that the hypotheses are rooted in data collected during the investigation including observations, measurements, electronic data, witness accounts, and any other sources of data for the incident. That is, hypotheses are suggested by facts. Just because a hypothesis is suggested by a fact does not make the hypothesis true. For example, a valve on a bypass leg for a control valve was observed to be closed following a fire and operators reported checking the valve as part of a shutdown procedure to ensure that it was closed. However, when the valve was later tested in a laboratory, it was found to be slightly open, allowing vapours to pass. Hypotheses must be tested to ascertain validity. This testing step is crucial to the success of an investigation. Many investigations suffer from a lack of objectivity since focus on the investigation team's favourite hypothesis (see investigator bias below) is difficult to avoid. Another shortcoming of many investigations is not considering multiple hypotheses. Skipping the testing step can lead to an incorrect cause determination. Without the correct causal factor, root causes will not address the fundamental problems and recommendations will not prevent a repeat incident.

Investigator bias received expanded treatment in the CCPS book as part of the effort to improve objectivity of investigations. A common problem for investigators is confirmation bias. It is human nature to begin seeking evidence that confirms a hypothesis that an investigator develops. Investigators do not inherently seek evidence to disprove their hypotheses. The result is investigators who are fixated on their favourite hypotheses. The book suggests that investigators should actively attempt to disprove every hypothesis. Only if a hypothesis can stand up to attempts to disprove it should the hypothesis be considered valid.

Organisation of the Book

The third edition was a major re-write of the CCPS book, which was reorganised to follow the order in which a company would organise an investigation program and a team would conduct an investigation. The overall flow of the book is shown in Figure 2. Subjects were consolidated into single chapters so that readers could easily find material on a subject, such as analysing evidence or determining root cause.

The first three chapters provide an overview of process safety incident investigations targeted primarily at novice investigators and company management. The fourth chapter on designing an investigation system is intended to aid company management to understand the organisational needs as well as management's roles.

The fifth to thirteenth chapters concern investigating an incident, starting with initial notification and culminating in reporting. These chapters are the references for investigators with numerous techniques to conduct all phase of an investigation. The depth of discussion provided by these chapters for process safety incident investigation sets the CCPS book apart from other references.

Implementing recommendations is also discussed in the book. While taking corrective actions is not an investigative step, the subject was addressed in the book in order to clarify responsibilities for implementation as discussed below.

- Overview of investigations
 - Introduction to investigations
 - Incident causation
 - Overview of investigation methodologies
- Designing an investigation management system
- Responding to an incident
 - Initial notification and classification of an incident
 - Building an investigation team
 - Gathering data
 - Analyzing data
 - Determining causal factors
 - Determining root causes
 - Developing recommendations
 - Preparing a report
- Implementing recommendations
- Improving the investigation program
- Sharing lessons learned

Figure 2. Organisation of the Book

Continuous improvement of the investigation program is addressed in the book. Companies with successful investigation programs learn from each investigation and improve their processes. Many companies have developed their own methodologies as variants of methodologies presented in the book. Improving the skill level of investigators is part of this program.

Investigation Methodologies and Tools

A wide variety of methodologies and tools are published for incident investigations. It can be overwhelming for investigators to wade through literature to gain an understanding of the options. The CCPS book was prepared as a reference source in which numerous methodologies and tools are described and referenced. Figure 3 provides an overview of the categories of tools covered in the book. The tools have become more structured over time as investigators and organisations have become more proficient at process safety incident investigations. Logic Trees and Predefined Trees are the tools for determining root cause. In addition, 5 Whys is a methodology added to the third edition determine root cause.

It should be mentioned that most organisations use combinations of tools when conducting an investigation, not just a single tool as shown in Figure 3. For example, the authors frequently use a timeline or sequence diagram to organise the sequence of events and connectivity among events, the scientific method to develop and test hypotheses, and a pre-defined tree to determine root causes.

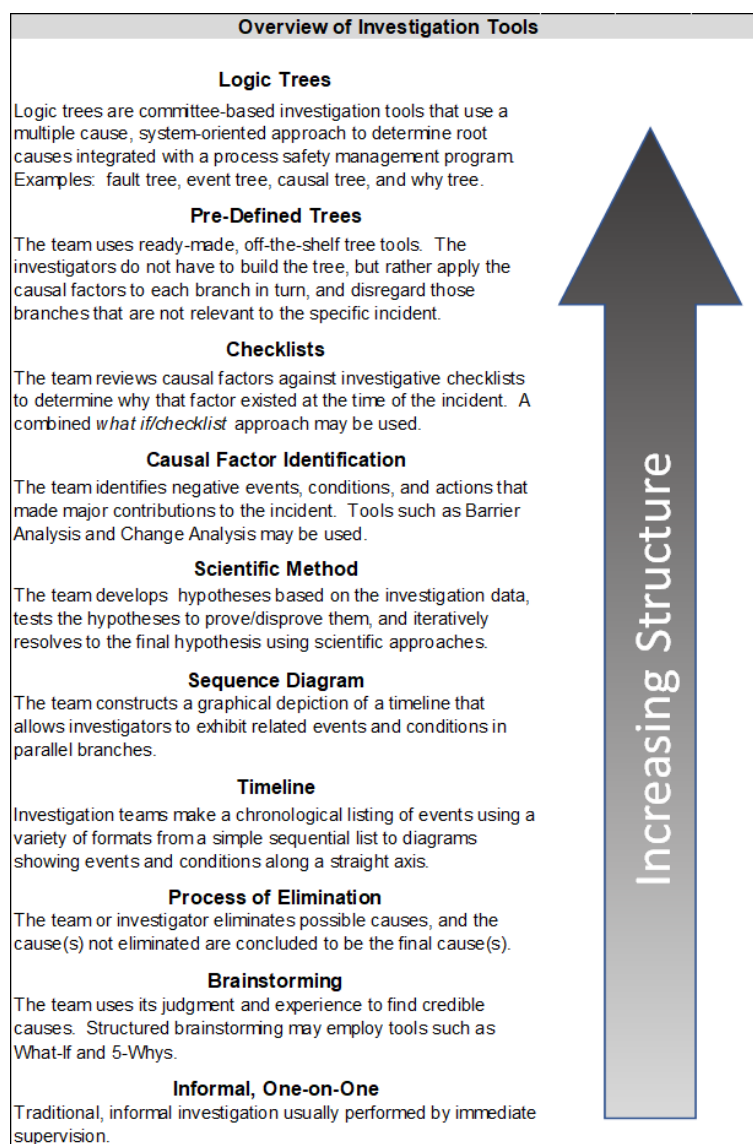


Figure 3. Investigation Tools from Unstructured to Highly Structured

Implementing Recommendations

Implementing recommendations is also discussed in the book. The investigation process identifies causal factors and root causes and develops recommendations; the latter typically in collaboration with the management team. Endorsement and implementation of the recommendations are not part of the investigation team's responsibility; those are management's role. The book clarifies the roles of the investigation team and management.

Another issue that was clarified was the investigation team's role in restarting a process that was shut down due to an incident. The book clarified that it is management's decision whether to restart a process, not the investigation team. The investigation team develops recommendations including performance criteria for the recommendations. It is then up to management to decide implementation priority, equivalency of potential alternatives, staging implementation, and performance metrics. It is recognised that major accident investigations may take considerable time to complete, and some processes may be ready to restart before the investigation is complete. Interim reports and recommendations may be needed in such circumstances.

Lessons Learned

The third edition of the CCPS book expanded on the topic of learning from incident investigations. The book separately addresses learning at the local level where the incident occurred, sharing the lessons more broadly in the company, sharing lessons with industry, and receiving lessons from industry. The challenges of sharing lessons externally due to regulatory and litigation situations are acknowledged; nonetheless, the intention is to improve safety in the company and industry whenever possible.

Conclusions

The third edition of the CCPS book *Guidelines for Investigating Process Safety Incidents* provides a major update to literature concerning incident investigations specific to process safety incidents. The book has an extensive treatment of the entire subject including organising an investigation program, selecting a team, performing the investigation, determining root causes and implementing recommendations. A major change in philosophy advanced in the book is to treat near misses as incidents and deciding on the level of investigation based on the potential severity of the incident. The scientific method was added to the book to improve objectivity of investigations. Roles of the investigation team and management in implementing recommendations and deciding on restarting processes were clarified. Sharing lessons learned both internally and externally was expanded.

Acknowledgments

The third edition of the CCPS book *Guidelines for Investigating Process* was a collaborative effort.

BakerRisk authored the document. BakerRisk has developed an international reputation in the area of incident investigations and is recognised for incident investigation services, from site investigation and proving/disproving accident scenarios, through to development of the plans and safety programs for post-accident operations.

The support and contribution from the CCPS Incident Investigation Subcommittee, the CCPS Staff Consultant, and peer reviewers was greatly appreciated.

Michael Broadribb, Baker Engineering and Risk Consultants, Inc.
Laurie Brown, Eastman Chemical Company
Chonai Cheung, Contra Costa County
Eddie Dalton, BASF
Carolina Del Din, PSRG
Jerry Forest, Celanese, Subcommittee Chair
Scott Guinn, Chevron Corporation
Christopher Headen, Cargill
Kathleen Kas, Dow Chemical Company
Mark Paradies, System Improvements, Inc.
Nestor Paralicci, Andeavor
Muddassir Penkar, Evonik Canada Inc.
Morgan Reed, Exponent
Meg Reese, Occidental Chemical Corp.
Marc Rothschild, DuPont
Joy Shah, Reliance Industries Ltd
Dan Sliva, CCPS Staff Advisor
Robert (Bob) Stankovich, Eli Lilly
Lee Vanden Heuvel, ABS Consulting
Terry Waldrop, AIG
Scott Wallace, Olin
Della Wong, Canadian Natural Resources

Dan Sliva was the CCPS staff liaison and was responsible for overall administration of the project.

CCPS and the author also gratefully acknowledges the comments and suggestions received from the following peer reviewers:

Amy Brethat, NOVA Chemicals Corporation
Steven D. Emerson, Emerson Analysis
Patrick Fortune, Suncor Energy
Walter L. Frank, Frank Risk Solutions, Inc.
Barry Guillory, Louisiana State University
Jerry L. Jones, CFEISBC Global
Gerald A. King, Armstrong Teasdale LLP
Susan M. Lee, Andeavor
William (Bill) D. Mosier, Syngenta Crop Protection, LLC
Mike Munsil, PSRG
Pamela Nelson, Solvay Group
Katherine Pearson, BP Americas
S. Gill Sigmon, AdvanSix

ⁱ Anon, *Guidelines for Investigating Chemical Process Incidents*, Center for Chemical Process Safety, American Institute of Chemical Engineers, ISBN 0-8169-0897-4, 2003

ⁱⁱ Anon, "Investigating Accidents and Incidents," Health and Safety Executive, HSG 245, 02/2014

ⁱⁱⁱ Anon, "Guide for Fire and Explosion Investigations," National Fire Protection Association, NFPA 921, ISBN 978-145591602-3, Quincy, MA, USA, 2017

^{iv} Anon, "Learning from incidents, accident and events," Energy Institute, 1st edition, London, August 2016

^v Anon, "Pressure Equipment Integrity Incident Investigation," RP 585, American Petroleum Institute, Washington, DC, USA, 2014

^{vi} Birkbeck, Human Factors in Accident Investigation, Health and Safety Executive, UK, PowerPoint presentation, <https://www.scribd.com/presentation/245279725/Human-Factors>.