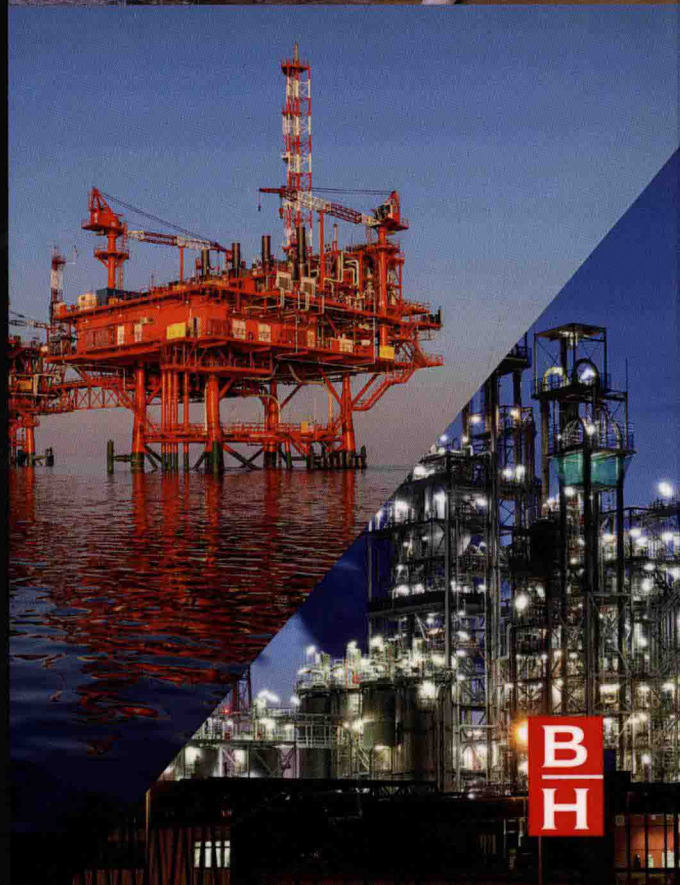
Risk Analysis and Control for Industrial Processes - Gas, Oil and Chemicals

A System Perspective for Assessing and Avoiding Low-Probability, High-Consequence Events



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Foreword

At the outset, I must say that this volume by Professor Hans Pasman on "Risk Analysis and Control for Industrial Processes, A System Perspective for Assessing and Avoiding Low Probability, High Consequence Events," is a very timely and much needed treatise. It is even more important given the need for process safety and sustainable development, and the need for a rational and constructive approach to risk assessment, risk management, and control against the backdrop of globalization.

Professor Pasman has been a visionary and trailblazer in the development and application of new methods and approaches in various areas of process safety and risk assessment. Over more than two decades of our professional association and friendship, I have always been impressed by his clarity of thought and great depth of expertise. This book is another indicator of Professor Pasman's stellar contributions to the theory and practice of the diverse and complex field of risk assessment.

The hunger for energy and the need for chemical products continue to fuel the growth of the chemical and petrochemical industries. Consequently, the risks and the hazards associated with the growth continue, and the challenges posed by technology, scale, and intensity of operations grows and changes. With the increasing complexity of chemical processes, interdependent chemical infrastructure, and the need for considering diverse issues such as safety, environment, cost, and social and cultural factors, challenges to process safety and risk assessment can no longer be solved by simple approaches. Process safety is at a crossroads with systems engineering, complex systems, and engineering for sustainable development. Assessments needed to address process safety challenges most often span a complex system requiring the application of sophisticated systems analysis. A complex systems approach allows the study of parts of a system that taken together cause the whole system to behave in a certain manner and how that behavior interacts with its environment.

Process safety is very closely linked to sustainable development. Risk assessments in the twenty-first century must bring together elements of manufacturing, design, and sustainable engineering in an integrated form. Interwoven through this new paradigm is the consideration of risk in every aspect. Another important aspect of risk assessments is the ability to deal with low probability—high consequence events.

Professor Pasman has been successful in taking a refreshing and poignant look at process safety and risk management; he has applied a systems approach in a holistic manner for the analysis and control of risks inherent to the operations of the processing industry and their products. He addresses risks in the chemical industry, processing of energy carriers such as oil and gas, metal and food processing, and storage and transportation of hazardous materials. The book also provides a very comprehensive review of methods used over the years to understand and manage risks. I sincerely

believe that the book has opened up a new vista and perspective on methodological improvements, necessary in the ever-increasing complexity of safe manufacturing and distribution in a competitive world.

M. Sam Mannan
Regents Professor and Director
Mary Kay O'Connor Process Safety Center
Texas A&M University
College Station, Texas, USA

Preface

Meanwhile, when the sun rises, the fog will not be harmful,
—free translation of Daniel Chodowiecki's explanation of his etching symbolizing the Enlightenment (1791)

SCOPE, MOTIVATION, OBJECTIVES, AND CONTENTS OF THE BOOK

The existence of mankind on this world in the present magnitude and growth and at a reasonable level of comfort is only physically possible thanks to the process industry providing us energy and fuels, construction and electronic materials, fertilizers and food, textiles, pharmaceuticals, coatings, drinking water, and so forth. This dependence will further grow, certainly when the standard of living in the developing countries reaches that of developed ones. However, industrialization comes with certain risks. Most dreadful are risks of *high consequence, low probability* events involving hazardous materials, which can be widely ranging in nature and effect. Many examples of major accident hazards have already been observed. High consequence means catastrophic losses, sometimes with huge loss of human life including various kinds of other harm, and losses to the means, infrastructures, and environments on which our lives depend. The human body is rather vulnerable to mechanical impact and shock, extreme temperatures, and a long list of gaseous, liquid, and solid substances that over certain concentration thresholds are lethally toxic to our system. We do not need to mention high intensities or doses of heat, nuclear, and electro-magnetic radiation. Walking into an enclosure with low oxygen concentration in the air is not healthy as well and may cause acute death. On the other hand, low probability of occurrence is very low. Indeed, the considered event may not happen in our lifetime. Measured in a probability over a certain time duration the event may be not less frequent than the impact of a comet, but this does not mean it cannot show up; it still can happen tomorrow! Yet if its precursor trail is detected, we gain the opportunity to influence and reduce its probability of occurrence.

Risk analysis as an approach and collection of methods to foster safe ways of achieving production goals has developed since the 1960s. It has roots in the nuclear power community of academia, regulators, and industry and has spread to various engineering disciplines and beyond to management, medicine, economy, and finance. Basically, nuclear power risk analysts founded the leading forum of Probabilistic Safety Assessment and Management conferences operating since the early 1990s. Even more general and perhaps less technical oriented are the aims of the Society for Risk Analysis, which is active in organizing meetings in various parts of the world. Risk management practice applying the methods of risk analysis became a

must in the many aspects of business life and finance, and even further evolved to risk governance of company boards and governments.

The process industry, though, in its early development was plagued by mishaps from sometimes unknown chemical and physical mechanisms, and it was keen to establish safe approaches. Beginning in the 1960s under the auspices of chemical engineering institutions, loss prevention symposia have been organized in the United States and Europe, and some years later in Asia. These symposia have been instrumental in developing concepts and methods for hazard and risk analysis, and know-how for optimal organization and safety management, while adopting elements from elsewhere. They still give much attention to sharing knowledge on material properties, damaging mechanisms due to spills and unintentional releases, and preventive and protective measures.

This book endeavors to address all those leading or being employed in the industry and those involved in care for safety of the industry who prefer an overview and to see a timeline of developments. The book is intended especially to address students, in particular engineers, and to challenge them to advance the field further. Hopefully, the overview it offers will also be consulted by policy and decision makers, as it shows in risk prediction the strengths and weaknesses of science and engineering. For those who are less technically interested, each chapter is preceded by a summary.

The book is meant as a contribution to enhance process safety and risk and uncertainty management; it tries to apply a system approach and to cover in a holistic way the analysis and control of risks inherent to the operations of the processing industry and their products. It therefore focuses on the chemical industry, processing of energy carriers such as oil and gas, metal and foodstuff processing, and storage and transportation of hazardous materials. It briefly reviews experiences collected over the years and existing methods to understand and manage risks. The main aim is, however, to open a further future perspective of methodological improvements, necessary in the ever-increasing complexity of getting products safely manufactured and distributed in a competitive world. Knowledge of the human factor, organizational and technical aspects shall be merged and interaction in a sociotechnical system must be analyzed for improved risk control to avert mishaps.

Necessarily, the book has its limits. It does not provide a complete detailed overview of all that has been written about the subject in a technical sense as that is the objective of Lees' Loss Prevention in the Process Industries, not even in a condensed way as in Lees' Process Safety Essentials. The latter book is certainly very useful for those who want to know more on certain aspects. But, this book selects and briefly summarizes knowledge on major hazards and acute effects in a balanced way on all those aspects that are of significance for fostering process and plant safety. This approach is followed with regard to both technical and organizational aspects, including regulatory and human factor ones. All relevant aspects of which the author is aware of are touched upon with some references for those who desire further details. The book is in part established material, yet delves into new developments and methods up until the end of 2014 with a promise for improved future risk control.

With regard to examples and regulatory aspects, most of what is discussed already occurs in or is applicable to the United States and Europe. The issue of security is only mentioned in a few instances because many generic aspects of it are covered by process safety and risk reduction measures. Unfortunately, we must live with many acronyms. These have been noted and defined repeatedly; I hope this is helpful but not irritating.

The process safety "building" has many doors and rooms filled with experience, system engineering, risk assessment, management, and human factors. I have tried to connect the rooms, because so far the field consists largely of a collection of specialties.

Hans J. Pasman

Acknowledgments

Thoughts about what shall be written and how to write them need reaction from colleagues with critical minds. I was fortunate to find friends who did not necessarily agree with what I had drafted. The text with an initial Dutch flavor was first Americanized and then converted to English—English but kept in American spelling. Meanwhile, comments were made and suggestions given with regard to the content, improving its quality.

Firstly, I would like to acknowledge the invaluable support of Dr William (Bill) J. Rogers, who teaches risk management and probabilistic methodology at the Mary Kay O'Connor Process Safety Center (MKOPSC) of the Artie McFerrin Chemical Engineering Department of Texas A&M University, College Station, Texas. Bill was inspiratory, a theory provider, and supporter in systems approach to process safety and predictive risk analysis. Dealing with uncertainty is key in this problem field. I enjoyed the many discussions (and also the concerts he organized). Secondly, Dr Simon P. Waldram of Waldram Consultants Ltd, also a research fellow at MKOPSC, formerly a professor at the University of London, was my chemical-physical conscience. Apart from making critical comments, he also gave the text a true English touch. Dr Paul H. J. J. Swuste, associate professor of the Safety Science Group of the Delft University of Technology, the Netherlands, with a background in biochemistry but extensive experience in occupational safety and safety management, supported me in the long-term main lines of safety thinking and kept me straight in the human factor and organizational aspects. Further, thanks to Ms. Trish Kerin, BEng, Director IChemE Safety Center, Institution of Chemical Engineers, in Melbourne, who after her industrial experience made very useful practical comments on the manuscript.

In addition, I would like to thank Dr M. Sam Mannan, PE, CSP, DHC, Director of MKOPSC and Regents Professor at Texas A&M University, for his moral support and Dr Sonny Sachdeva and Joshua Richardson of MKOPSC who managed and obtained the copyright permissions.

Lastly, I want to thank my wife, Ina, my partner in life, who has steadfastly stuck by my side, as well as my children and grandkids who missed seeing "opa" for quite some periods.

I graduated in chemical technology and started my career at Shell, but during military service was transferred to TNO, the Dutch National Research organization. Apart from defense research, I necessarily learned much about process safety by investigating numerous disastrous accidents in the late 1960s and early 1970s by directing development of experimental methods and performance of risky experiments of various kinds to explain what happened in these accidents. I have been a member and then 10 years chairman of the European (EFCE) Working Party on Loss Prevention since its beginning in 1972, as well as helped to found the European Process Safety Centre. As well, I thank all my former colleagues at TNO, at the Delft University of Technology where I have been teaching chemical risk management,

and of the Working Party for their cooperation and support. Although we have now a wealth of computational models providing the basis of system risk analysis, it is unfortunate that young generations can only obtain limited (but safe!) *experimental* experience, both in the chemical and physical senses but also in human and organizational functioning. Experimenting is expensive and models are a way of studying a problem. But, a model remains only a model that must be tested, and the mechanisms threatening process safety are complex and vary widely. The looming mishap is always hidden in the tails of the distributions.

Finally, I would like to admit that if Ms. Fiona Geraghty of Elsevier had not challenged me, I would never have started writing this book. My hope is that it will contribute to a sound understanding of how to manage industrial process risks.

Hans J. Pasman

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