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Book Review

THERMAL SAFETY OF CHEMICAL PROCESSES
Risk Assessment and Process Design

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Chemical industry is an important provider of products for population and industry (food, pharmaceutical, mechanic, electronic, textiles and so on). On the other hand, more than in other industries, accidents with critical consequences over humans and environment take place in chemical industry.

Thermal effects of reactions represent a special potential in producing some incidents or disasters in chemical plants. Taking no care on the safety aspects that seems to be insignificant at a first sight can lead to accidents.

The apparition of Prof Francis Stoessel's book represents a salutary event both for students and for designers and engineers in chemical industry. The present book addresses students, professional chemists, chemical engineers or engineers in process development and production of fine chemicals and pharmaceutical industries. The author has a long experience in the practice of safety assessment in industry and teaching students and professionals in this matter.

Step by step, the book guides those who perform risk analysis of chemical processes, develop new processes, or are responsible for chemical production, to understand the thermal aspects of processes and to perform a scientifically founded – but practically oriented – assessment of chemical process safety. This assessment may serve as a basis for the optimization or the development of thermally safe processes.

The book focuses on the thermal risks in chemical plant and is structured in three parts:

Part I presents the general aspects of thermal process safety.

In the *first chapter* the place of chemical industry in society is recognized, a review of the risk analysis of chemical processes and methods of hazard identification is discussed. The risk analysis is an important element to release a technically and economically efficient chemical process. The three common steps of risk analysis are: search for hazard, risk assessment and definition of risk-reducing measures. A successful risk analysis depends on three factors: the systematic and comprehensive hazard identification, the quality of the data used in the analysis and the experience of team in the risk analysis.

The *second chapter* reviews the thermodynamic and kinetic aspects of chemical reactions and presents the essential theoretical aspects for a fundamental understanding of runaway reactions. The author discusses the heat balance of reactors, the procedure for the evaluation of thermal risks and the most common calorimetric methods used in safety laboratories.

In the *third chapter*, a systematic assessment procedure is outlined. Based on the cooling scenario, dangerous characteristics are defined. The chapter closes with a practical procedure for the assessment of thermal risks.

The *fourth chapter* are dedicated to calorimetric measurement principles, classification of calorimeters and theirs operating modes.

Part II presents different reactor types (batch, semi-batch and continuous reactors), technical aspects of reactor safety and risk reducing measures.

Chapter 5 describes some aspects of reactor stability, the criteria for normal operating and for deviating conditions (such as cooling failure). Reactor safety requires a well understood heat balance and the control of the reactor temperature, so that a reactor will remain stable in case of mal operation. The concept of MTSR (maximum temperature of synthesis reaction) was introduced for this purpose.

In *Chapters 6 to 8* the aspects of reaction engineering for batch, semi-batch and continuous reactor are presented. The mass and heat balance, different strategies of temperature control and the recommendations for the design of thermally safe batch reactions is presented in sixth chapter. The principles of semi-batch reaction, the material and heat balances and the design of safe semi-batch reactors are analyzed in chapter 7.

The optimization of semi-batch reactors with respect to safety and economy and the presentation of feed strategy for maximizing the productivity under safety constraints are also considered. Continuous reactors offer advantages that make possible reactions that could not be carried out in discontinuous reactors. Two types of ideal continuous reactors (with full back mixing and with plug flow) and some special reactor types are considered. The mass and heat balances and the safety aspects for different situations are presented in chapter 8.

Chapter 9 illustrates technical aspects of reactor safety. The different heating and cooling techniques used for industrial reactors are reviewed. Also, how heating and cooling systems of reactors work, their performances and the implications on process safety are presented. A part of this chapter is dedicated to the overall resistance to heat transfer and the estimation of heat transfer coefficients. The last section is devoted to dynamic of the temperature control system and process design.

In *chapter 10* the typical protection measures are presented. The different categories of measures for runaway reactions are reviewed and discussed: eliminating, preventive, emergency measures. The eliminating measures have one point in common: they do not limit the effect of failures by adding protective equipment, but instead by process design or changing the process conditions.

Technical preventing measures refers to control of feed in semi-batch or continuous operations, emergency cooling (replaces the normal cooling system in case of failure), quenching, dumping and flooding, controlled depressurization, alarm systems. Time plays a primary role in the effectiveness of the measures. Emergency measures should be used as a last solution, when runaway cannot be prevented. Emergency pressure relief and containment are presented. A last section is devoted to the design of protection measures. The choice and design of technical protection measures depends by risk level and the critical classes help in selecting parameters need to be evaluated for each scenario.

Part III presents secondary reactions that are often involved in thermal explosions or runaway reactions.

Chapter 11 is devoted to secondary decomposition reactions, their characterization and evaluation of consequences when they get out of control. Reasons for triggering a secondary reaction may be diverse: too high a temperature, catalytic effects, presence of impurities.

The possible consequences of decomposition reactions are a high temperature increase, flammable or toxic gas release, solidification, foaming, carbonation. To any assessment of thermal risks priority must be determination of the decomposition energies. The probability of triggering the secondary decomposition reactions may be assessed using the concept of TMR_{ad} (Time to Maximum Rate). Also, the experimental characterization of the decomposition reactions is presented.

In *chapter 12* the autocatalytic reactions are discussed. Autocatalytic reaction is a chemical reaction in which a product functions as catalyst. The consequences of self - accelerating reactions may be a sudden rise of the temperature, a violent reaction and an important destructive power. For these reasons, is important to know if a decomposition reaction is of autocatalytic nature and the safety measures must be adapted to this type of reaction. For the autocatalytic reactions not only temperature is important but also the time.

Some models are presented for describe reaction behavior and heat release rate. Chemical and thermal analysis is presented for characterization of autocatalytic reactions. The last section presents the practical safety aspects of autocatalytic reactions.

Chapter 13 is dedicated to problem of heat confinement, in situations where heat transfer is reduced. Thermal confinement situations are encountered in storage and transport of reactive material, in failure of production equipment (cooling failure, loss of agitation and so on). Some typical industrial situations are considered: agitated jacketed vessel, unstirred storage tank containing a liquid and storage silo containing a solid. It must be noted that the nature of the materials, their thermal behavior and the dimensions of vessel must be considered in the assessment of heat confinement.

The heat balance are reconsidered from the viewpoint oh heat accumulation and for three mechanisms of heat transfer. Finally, the solution of heat accumulation problems are presented in six steps (decision tree).

Each chapter begins with a case study that represents the starting point in discussing a certain issue of chemical reaction development or some factors that have received less attention. Examples provided at the end of each chapter represents also lesson of how to approach chemical reactions and their thermal effects. At the end of each chapter, the exercises or case studies proposed, allowing to check understand of the subject matter.

One the basis idea of the book is simple: to develop a common and understandable language between specialists and non - specialists. For engineers involved with thermal safety of chemical processes, here is a basic guide for their practice of process safety.

Thermal Safety of Chemical Processes: Risk Assessment and Process Design maintains an all-important bridge between the academic media and the chemical industry and complete covers the techniques for maximizing the safety of chemical processes.

The approaching manner of the issues of thermal safety in chemical engineering and chemical plant design represents one of the reasons why this book should not be missing from the library collections of each chemical engineer or student preparing for this profession.

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