GUIDELINES FOR

PROCESS SAFETY DURING THE TRANSIENT OPERATING MODE

MANAGING RISKS DURING PROCESS START-UPS AND SHUT-DOWNS

An AIChE Technology Alliance
CCPS
Center for Chemical Process Safety

WILEY

Guidelines for Process Safety During the Transient Operating Mode:

Managing Risks during Process Start-ups and Shut-downs

Guidelines for Process Safety During the Transient Operating Mode:

Managing Risks during Process Start-ups and Shut-downs

Center for Chemical Process Safety

of the

American Institute of Chemical Engineers

New York, NY

WILEY

This edition first published 2021

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

Registered Office
John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, USA

Editorial Office
111 River Street, Hoboken, NJ 07030, USA

For details of our global editorial offices, customer services, and more information about Wiley products visit us at www.wiley.com.

Wiley also publishes its books in a variety of electronic formats and by print-on-demand. Some content that appears in standard print versions of this book may not be available in other formats.

Library of Congress Cataloging-in-Publication Data Applied for:
ISBN: 9781119529156

Cover Design: Wiley-AIChE
Cover Images: Silhouette, oil refinery © manyx31/iStock.com,
Stainless steel © Creativ Studio Heinemann/Getty Images,
Dow Chemical Operations, Stade, Germany/Courtesy of The Dow Chemical Company

10 9 8 7 6 5 4 3 2 1

This book is one in a series of process safety guidelines and concept books published by the Center for Chemical Process Safety (CCPS). Refer to www.wiley.com/go/ccps for full list of titles in this series.

It is sincerely hoped that the information presented in this document will lead to an even more impressive safety record for the entire industry; however, neither the American Institute of Chemical Engineers, its consultants, CCPS Technical Steering Committee and Subcommittee members, their employers, their employers' officers and directors, nor ioMosaic Corporation, and its employees and subcontractors warrant or represent, expressly or by implication, the correctness or accuracy of the content of the information presented in this document. As between (1) American Institute of Chemical Engineers, its consultants, CCPS Technical Steering Committee and Subcommittee members, their employers, their employers' officers and directors, and ioMosaic Corporation and its employees and subcontractors, and (2) the user of this document, the user accepts any legal liability or responsibility whatsoever for the consequence of its use or misuse

Table of Contents

Part I—Normal Operations

List of Figures

List of Tables

Acronyms and Abbreviations

AIChE	American Institute of Chemical Engineers
C	Consequence (*see Equation 10.1*)
CCPS	Center for Chemical Process Safety
ERP	Emergency Response Plan
ERT	Emergency Response Team
ESD	Emergency Shutdown Device
ESS	Emergency Shutdown System
F	Frequency (*see Equation 10.1*)
HAZOP	Hazards and Operability Study
HIRA	Hazards Identification and Risk Analysis
ITPM	Inspection, Testing, and Preventive Maintenance program
LOPA	Layer of Protection Analysis
LL	Lesson Learned
LS	Lesson Strength
LTI	Lost Time Injury
MOC	Management of Change
MTC	Medical Treatment Case
OD	Operational Discipline (*see Equation 10.1*)
ORR	Operational Readiness Review
PDCA	Plan, Do, Check, Act
PHA	Process Hazards Analysis
PPE	Personal Protective Equipment
PSSR	Pre-Startup Safety Review
R	Risk (*see Equation 10.1*)
RBPS	CCPS Risk Based Process Safety

SIMOPS	Simultaneous Operations
SIS	Safety Instrumented System
SWP	Safe Work Practice
US CSB	United States Chemical Safety and Hazard Investigation Board

Glossary

This Glossary contains some of the common terms in this guideline and some of the relevant process safety-related terms from the CCPS Process Safety Glossary. Refer to Table 2.1 for the glossary terms specific to normal, abnormal, and emergency operations, and to Table 2.2 for those specific to the transient operating modes. The terms in this guideline are current at the time of publication; refer to the CCPS website for updates to the CCPS Process Safety Glossary.

Term	Definition
Conduct of Operations (COO)	An element in the CCPS RBPS model. The embodiment of an organization's values and principles in management systems that are developed, implemented, and maintained to (1) structure operational tasks in a manner consistent with the organization's risk tolerance, (2) ensure that every task is performed deliberately and correctly, and (3) minimize variations in performance. See Operational Discipline.
Consequence (C)	The undesirable result of the impact of a loss event, usually measured in health and safety effects, environmental impacts, loss of property, and business interruption costs. See Equation 10.1.
Deviation	A process condition outside of established design limits, safe operating limits, or standard operating procedures.
Emergency Shutdown Device (ESD)	A device that is designed to shut-down the system to a safe condition on command from the Emergency Shutdown System.

Term	Definition
Emergency Shutdown System (ESS)	The safety system that overrides the action of the basic control system when predetermined conditions are violated.
Frequency (F)	Number of occurrences of an event per unit time (e.g., 1 event in 1000 yr. = 1 x 10-3 events/yr.). Interchangeable with "likelihood". See Equation 10.1.
Hazards Identification and Risk Analysis (HIRA)	A collective term that encompasses all activities involved in identifying hazards and evaluating risk at facilities, throughout their life cycle, to make certain that risks to employees, the public, or the environment are consistently controlled within the organization's risk tolerance.
Inspection, Testing, and Preventive Maintenance (ITPM) Program	Scheduled proactive maintenance activities intended to (1) assess the current condition and/or rate of degradation of equipment, (2) test the operation/functionality of equipment, and/or (3) prevent equipment failure by restoring equipment condition.
Loss event	Point in time in an abnormal situation when an irreversible physical event occurs that has the potential for loss and harm impacts.
Operational Discipline (OD)	The performance of all tasks correctly every time. *Note:* OD is the execution of the CCPS RBPS Conduct of Operations (COO) element by

Term	Definition
	individuals within the organization. See effect on Risk in Equation 10.1.
Outage	See Turnaround.
Pickling	A metal surface treatment used to remove impurities, such as inorganic contaminants, rust or scale from ferrous metals, copper, precious metals and aluminum alloys. A solution called pickle liquor, which usually contains acid, is used to remove the surface impurities.
Plan, Do, Check, Act (PDCA)	A four-step process for quality improvement. In the first step (Plan), a way to bring about improvement is developed. In the second step (Do), the plan is carried out. In the third step (Check), what was predicted is compared to what was observed in the previous step. In the last step (Adjust), plans are revised to eliminate performance gaps.
Risk	A measure of human injury, environmental damage, or economic loss in terms of both the incident likelihood (frequency) and the magnitude of the loss or injury. *Note:* A simplified version of this relationship expresses risk as the product of the frequency and the consequence's impact (i.e., Risk = Frequency x Consequence). See Equation 10.1.

Term	Definition
Risk Based Process Safety (RBPS)	The Center for Chemical Process Safety's (CCPS) process safety management system approach that uses risk-based strategies and implementation tactics that are commensurate with the Risk Based Process Safety (no hyphen) need for process safety activities, availability of resources, and existing process safety culture to design, correct, and improve process safety management activities.
Risk matrix	A tabular approach for presenting risk tolerance criteria, typically involving graduated scales of incident likelihood on the Y-axis and incident consequences on the X-Axis. Each cell in the table (at intersecting values of incident likelihood and incident consequences) represents a particular level of risk.
Safety Instrumented System (SIS)	A separate and independent combination of sensors, logic solvers, final elements, and support systems that are designed and managed to achieve a specified safety integrity level. Note: A SIS may implement one or more Safety Instrumented Functions (SIFs).

Term	Definition
Shutdown (S/D)	A process by which an operating plant or system is brought to a safe and non-operating mode. *Note for this guideline:* Equivalent to the multiple shut-down transient operating modes discussed in this book (Table 2.2).
Significant loss event	Point in time in an abnormal situation when an irreversible physical event occurs that causes loss and harm impacts. *Note:* Companies can specify "significant" depending on the relative impact to people, the environment, property, and business interruption—their "risk tolerance." See Risk matrix.
Standby mode	Hardware operation that is normally not running but should be ready to run, e.g., an emergency diesel generator. *Note for this guideline*: When troubleshooting equipment during an abnormal situation, specific equipment may be placed in a temporary "standby" or "warm circulation" mode while the troubleshooting efforts are underway.
Turnaround	A scheduled shutdown period when planned inspection, testing, and preventive maintenance (ITPM), as well as corrective maintenance such as modifications, replacements, or repairs is performed. *Note:* Often referred to as a shutdown (Per this guideline: no hyphen) or an outage.

Acknowledgments

The American Institute of Chemical Engineers (AIChE) and the Center for Chemical Process Safety (CCPS) express their appreciation and gratitude to all members of the *Guidelines for Process Safety During the Transient Operating Mode* Subcommittee for their generous efforts in the development and preparation of this important guideline. CCPS also wishes to thank the subcommittee members' respective companies for supporting their involvement during the different phases in this project.

Subcommittee Members (2016-2018):

Theresa Broussard, Chair	Chevron Corporation
Susan Bayley	Linde Process Plants, Inc.
Don Connolley	BP Corporation NA, Inc.
Eddie Dalton	BASF Corporation
Reyyan Koc Karabocek	ExxonMobil
Pamela Nelson	Solvay
Jitesh Patel	New Jersey DEP
Scott Schiller	BakerRisk
Dan Sliva	CCPS Staff Consultant
Sandeep Vipra	Reliance
Elliot Wolf	Chemours

The collective industrial experience and know-how of the subcommittee members makes this guideline especially valuable to those who develop and manage process safety programs and management systems.

Before publication, all CCPS guidelines are subjected to a peer review process. CCPS gratefully acknowledges the thoughtful comments and suggestions of the peer reviewers. Their work enhanced the accuracy and clarity of this guideline.

Initial manuscript peer reviewers (2018):

Daniel Callahan	Stepan
Charles Foshee	Chevron
Jennifer Mize	Eastman
Al Morrison	Chevron

Although the peer reviewers provided comments and suggestions, they were not asked to endorse this guideline and did not review the final manuscript before its release.

The book committee wishes to express their appreciation to Elena Prats and Kathy Anderson, ioMosaic Corporation, for their contributions in preparing the guideline's draft manuscript. Sincere appreciation is extended to Dr. Bruce K. Vaughen, PE, CCPSC, of CCPS for his contribution in restructuring the book committee's efforts, addressing the final comments from both the book's committee and peer reviewers, and in creating the final, published manuscript.

Before publication of the final manuscript for this guideline, an additional technical review of each of the chapter's drafts and the restructured and enhanced manuscript provided additional insights that were incorporated into the final, published manuscript. Much appreciation is extended to the final reviewers for their time.

Restructured draft and final manuscript reviewers (2020):

Theresa Broussard, Chair	Chevron Corporation
Dan Sliva	CCPS Staff Consultant
Jennifer Bitz	CCPS, Project Manager
Pete Lodal	Eastman
Dr. Anil Gokhale, PE	CCPS Project Director

Special appreciation is extended to Kiezha Ferrell for copy editing the draft of the final manuscript.

Dedication

This guideline is dedicated to those who have been injured or lost their lives, and their families, as a result of incidents that occurred during transition times in the industries handling hazardous materials and energies. Hazards and risk management approaches continue to improve facilities based on the learnings from these incidents. Since there is a better understanding of some of the human performance-related issues today, improved engineering and administrative controls have been established to help prevent these type of incidents from occurring again. This guideline puts forth a framework that applies the Risk Based Process Safety (RBPS) principals to activities specifically associated with the transient operating mode. It is the hope of the authors that the risk reduction approaches provided in this guideline can be integrated and implemented within the existing process safety and risk management systems in organizations striving toward world-class process safety performance.

> *"Do not let the world's adversity stifle your enthusiasm, nor blind your vision. The struggle towards excellence should ever be conducted on the high plains of self-confidence, a sense of purpose, and positive thought. Go forth with a desire to accomplish…with a desire to contribute to our society."*
>
> Ronald E. McNair, 1950 - 1986
> NASA Astronaut - Space Shuttle Challenger