

Chemical Process Safety

Learning from Case Histories

Fourth Edition

Roy E. Sanders



ELSEVIER

AMSTERDAM • BOSTON • HEIDELBERG • LONDON • NEW YORK • OXFORD
PARIS • SAN DIEGO • SAN FRANCISCO • SINGAPORE • SYDNEY • TOKYO

Butterworth-Heinemann is an imprint of Elsevier



Contents

Preface	xv
Acknowledgments	xvii
1 Perspective, perspective, perspective	1
Introduction	1
The media rarely focuses on the benefits of the chemical industry	1
A glance at the history of chemical manufacturing before the industrial revolution	2
The modern industrial chemical industry modifies our way of living	4
Risks are not necessarily how they are perceived	5
Natural pesticides	11
Plant employee safety versus life-style choices	12
The chemical industry's excellent safety record	13
Who has the most dangerous jobs?	14
What events resulted in fatal occupational injuries in 2012?	18
Just how dangerous is it to work in a US chemical plant?	19
How are the chemical and refinery industries doing today when it comes to major losses? And what should we do in the future?	19
Process safety culture	20
References	20
2 Good intentions	23
Modifications made with good intentions	23
A tank truck catastrophically fails	23
Siphoning destroys a tender tank	27
Tank roof splits from overfilling	31
A well-intended change yields a storage tank collapse	31
A water drain line is altered and a reactor explodes	37
An air system is improved and a vessel blows up	39
A new air system improved economics, but jeopardized safety	43
Another incident with nitrogen backup for a compressed air supply	43
The hazards of nitrogen asphyxiation	44
Concerns for safety on a refrigerated ethylene tank	46
Beware of impurities, stabilizers, or substitute chemicals	48
Good intentions on certain new protection systems lead to troubles	49
A gas compressor is protected from dirt, but the plant catches fire	50
A replacement check valve installed – one detail overlooked	50
What was one of the immediate causes of the fire?	52

What did investigators recommend?	52
Another good intentions project: new tanks are destroyed and the neighborhood is disrupted	53
Another tragic incident involving hydrogen sulfide takes the lives of two workers	58
Closing thoughts on sewers	59
Carbon absorption incidents show history repeats	59
The lighter side	60
A review of good intentions	60
References	61
3 Focusing on water and steam: the ever-present and sometimes evil twins	63
Hydro-test goes awry	64
A flooded column collapses as water is being drained from the system	68
Water reacting with strong chemicals	71
Easy-to-use steam heat can push equipment beyond safe design limits	73
Heating water in a confined system	74
Steam condenses and a mega-vessel is destroyed during commissioning	75
A tragedy develops when hot oil is pumped upon a layer of water	79
Discussion and recommendations	83
References	85
4 Major US incidents in the twenty-first century	87
Unfortunately – there is often a certain sameness in process incidents	87
Delaware City, Delaware, incident	88
Rouseville, Pennsylvania, incident	88
Buffalo, New York, incident	89
Learning opportunities from major incidents in the twenty-first century	89
President Obama signs an Executive Order relating to process safety management	90
An explosion in a plastics manufacturing facility in Illinois results in five deaths, plant closure and eventual tear down of the facility	91
A glimpse of the PVC plastic facility, the loss of life and property	93
PVC reactor layout and most likely incident scenario	94
Not learning from incidents	96
Key findings on the Illiopolis PVC plant incident	97
The CSB recommendations submitted to Formosa Plastics USA	98
The March 2005 Texas City, Texas, refinery incident – the most tragic US refinery accident of the decade	99
Besides poor safety culture – what happened prior to the release?	100

What happened immediately after the release?	104
Besides poor safety culture – what are some key technical findings of the Chemical Safety Board?	105
Besides poor safety culture – what are some key organizational findings of the Chemical Safety Board?	107
BP shares their investigation findings on key issues	108
BP Texas City violations and settlement agreements	109
An independent blue ribbon panel investigates BP's North American operations	110
A foreword on the findings published by the Baker Panel – broadens the impact	110
The summary of the Baker Panel findings	111
Corporate safety culture	111
Refinery tragedy in Anacortes, Washington	112
Introduction to the Anacortes refinery incident	112
Details on the Tesoro refinery incident	113
Why the catastrophic rupture? The technical focus	114
Other Chemical Safety Board findings	115
The CSB video "Tesoro Tragedy – Behind the Curve"	116
CSB sweeping game changing recommendations for the US environmental agency	117
CSB recommendations for the State of Washington	118
CSB recommendations for the American Petroleum Institute	118
The Washington Department of Labor and Industries issues citations	118
Ammonium nitrate catastrophe in West, Texas April 17, 2013 – fifteen perish	119
Major incidents in the twenty-first century	121
References	121
5 Two highly destructive twenty-first century vapor cloud explosions: one in the United Kingdom and the other in Venezuela	125
Buncefield UK fuel storage and transfer depot explosion and fires 2005	125
Introduction to the Buncefield incident and impact in the area	126
A look at some details prior to the explosion and massive fire	127
The economic costs of the Buncefield incident	131
Fuel concerns after the explosion and fires	133
Instrumentation and control systems	134
Buncefield report recommendations	134
Recommendations for design and operation of fuel storage sites	135
Summary comments on the Buncefield incident	136
A catastrophic explosion at Amuay refinery in Venezuela	137
Immediate events leading up to the explosion	137

A closer look at details at the Amuay refinery incident	138
Petroleos de Venezuela (or PDVSA) leak source study	139
RMG presented their view promptly after the incident	140
"The Economist" speaks to some underlying issues	140
The Manufacturing Center in Energy orientation (COENER) report	141
One strongly critical media report speaks about the Amuay refinery operations	141
The Amuay refinery based upon an insurance report	143
Blunt recommendations by the Manufacturing Center in Energy	144
Conclusions and recommendations for the Amuay disaster	145
Vapor cloud explosions – closing comments	145
When it comes to vapor clouds what can you do?	145
References	146
6 Preparation for maintenance	149
Some problems when preparing for maintenance	149
A tank vent is routed to a water-filled drum to "Avoid" problems	151
Preparing to paint large tanks	152
Preparing a brine sludge dissolving system for maintenance	153
What happened in the brine system?	153
A violent eruption from a tank being prepared for maintenance	155
An explosion while preparing to replace a valve in an ice cream plant	156
A chemical cleaning operation kills sparrows, but improves procedures	159
Other cleaning, washing, steaming, and purging operations	160
A tragedy when preparing for valve maintenance	161
A review of changes made to prepare for maintenance	163
References	164
7 Maintenance-induced accidents and process piping problems	165
Planning and communication	167
Repaired reboiler passes the hydro-test and later creates a fire	168
A tank explodes during welding repairs after passing a flammable gas test	169
A phenol tank's roof lifts as repairs are made	170
Catastrophic failures of storage tanks as reported by the Environmental Protection Agency	171
Hot work on tank catwalk results in a contractor's death, injuries, and a costly off-site environmental insult	172
Sulfuric acid tank background basics	174
Unsafe condition report and hot work permit shortcomings	175
The management of change shortcomings in sulfuric acid tank incident	175
Root causes as defined by the CSB	177
Similar tragic incidents involving hot work to tanks provided within the CSB full report Delaware City	177

A closer look a details at the Amuay refinery incident	138
Petroleos de Venezuela (or PDVSA) leak source study	139
RMG presented their view promptly after the incident	140
"The Economist" speaks to some underlying issues	140
The Manufacturing Center in Energy orientation (COENER) report	141
One strongly critical media report speaks about the Amuay refinery operations	141
The Amuay refinery based upon an insurance report	143
Blunt recommendations by the Manufacturing Center in Energy	144
Conclusions and recommendations for the Amuay disaster	145
Vapor cloud explosions – closing comments	145
When it comes to vapor clouds what can you do?	145
References	146
6 Preparation for maintenance	149
Some problems when preparing for maintenance	149
A tank vent is routed to a water-filled drum to "Avoid" problems	151
Preparing to paint large tanks	151
Preparing a brine sludge dissolving system for maintenance	152
What happened in the brine system?	153
A violent eruption from a tank being prepared for maintenance	153
An explosion while preparing to replace a valve	155
in an ice cream plant	156
A chemical cleaning operation kills sparrows, but improves procedures	159
Other cleaning, washing, steaming, and purging operations	160
A tragedy when preparing for valve maintenance	161
A review of changes made to prepare for maintenance	163
References	164
7 Maintenance-induced accidents and process piping problems	165
Planning and communication	167
Repaired reboiler passes the hydro-test and later creates a fire	167
A tank explodes during welding repairs after passing a flammable gas test	168
A phenol tank's roof lifts as repairs are made	169
Catastrophic failures of storage tanks as reported by the Environmental Protection Agency	170
Hot work on tank catwalk results in a contractor's death, injuries, and a costly off-site environmental insult	171
Sulfuric acid tank background basics	172
Unsafe condition report and hot work permit shortcomings	174
The management of change shortcomings in sulfuric acid tank incident	175
Root causes as defined by the CSB	175
Similar tragic incidents involving hot work to tanks provided within the CSB full report Delaware City	177

The Chemical Safety Board offers safety advice on Hot Work within a 14 min video	178
Another tank explosion during maintenance hot work	179
Repair activity to a piping spool results in a massive leak from a sphere	179
The Phillips 66 incident: tragedy in Pasadena, Texas	182
A massive fire, BLEVEs, and \$5 million damages after a mechanic improperly removes a valve actuator	185
Misdirected precautions on a reactor system isolation plug valve result in a vapor cloud explosion	189
A hidden blind surprises the operators	191
Poor judgment by mechanics allowed a bad steam leak to result in a minor explosion	194
The Flixborough disaster and the lessons we should never forget	196
Do piping systems contribute to major accidents?	199
Beware of other piping issues	201
Specific piping system problems reported as major incidents	202
Four case histories of catastrophic pipe failures	202
An 8-in. pipeline ruptures and an explosion occurs – December 24, 1989	203
Piping problems review	204
Concluding thoughts on maintenance – induced accidents and process piping problems	205
References	206
8 One-minute modifications: small, quick changes in a plant can create bad memories	209
Explosion occurs after an analyzer is repaired	209
When cooling methods were changed, a tragedy occurred	209
Instrument air backup is disconnected	210
A furnace temperature safeguard is altered	210
It appeared to be icicles hanging in a small plant	215
Another costly gasket error	218
While compressed asbestos gaskets are phased out, other leaks will occur	218
Other piping gasket substitution problems	219
New stud bolts fail unexpectedly	220
A “Repaired” hose fails triggering a major fire	222
Hurricane procedures are improperly applied to a tank conservation vent lid	223
Painters create troubles	225
Pipefitters can create troubles when reinstalling relief valves	226
Another pipefitter’s error	227
Lack of respect for an open vent as a vacuum-relief device results in a partial tank collapse	228
Just a bucket of water destroys a tank	229
Lack of respect for an open vent as a pressure-relief device costs two lives	231
One-minute modifications review	232
References	233

9	Accidents involving compressors, hoses, and pumps	235
	Reciprocating compressors	235
	A piece of compressor water jacket is launched	240
	The misuse of hoses can quickly create problems	241
	The Chemical Safety Board investigates a chlorine unloading hose failure	242
	The Chemical Safety Board investigated a phosgene hose failure with a fatality	243
	Fatality from a ruptured hose in HF service	244
	Hose mishaps frequently lead to loss of containment – maybe more than we think	245
	The water hose at the Flixborough disaster	246
	Hoses used to warm equipment	246
	Three-Mile Island Incident involved a hose	247
	The Bhopal Tragedy was initiated by use of a hose	247
	Improper purge hose set up for maintenance creates major problems	251
	High-pressure hydrogen inadvertently backs into the nitrogen system and an explosion occurs	252
	A nitric acid delivery to the wrong tank makes front-page news	252
	How do you prevent such an incident?	253
	Other truck delivery incidents	253
	An operator averts a sulfuric acid unloading tragedy	254
	Hoses cannot take excessive abuse	254
	What is the advice from practitioners?	256
	Centrifugal pumps	256
	River water pump piping explodes	262
	Severe pump explosions surprise employees	264
	A large condensate pump explodes	264
	Closing thoughts on pump explosions.	264
	Courtesy of the “Beacon”	266
	Afterthoughts	266
	References	266
10	Failure to use, consult, or understand specifications	269
	Lack of well-defined, rigid operating instructions cost \$100,000 in property damages	269
	Other thoughts on fired heaters	272
	Low-pressure tank fabrication specifications were <i>not</i> followed	273
	Explosion relief for low-pressure tanks	274
	Tinkering with pressured vessel-closure bolts ends with a harmless bang	275
	Piping specifications were not utilized	278
	Pump repairs potentially endanger the plant, but are corrected in time to prevent newspaper headlines	284
	Plastic pumps installed to pump flammable liquids	286
	Weak walls wanted – but alternate attachments contributed to the damage	286
	References	288

11	“Imagine If” modifications and practical problem solving	289
	“Imagine If” modifications – let us not exaggerate the dangers as we perform safety studies	289
	New fire-fighting agent meets opposition – “Could Kill Men as Well as Fires”	289
	A process safety management quiz	290
	New fiber production methods questioned	293
	Practical problem solving	294
	The physics student and his mischievous methods	295
	References	296
12	The role of mechanical integrity in chemical process safety	297
	Mechanical integrity in a chemical plant	297
	A regulatory view of mechanical integrity	298
	Mechanical integrity programs must be tailored to the specific site	299
	Mechanical integrity in design and installation	300
	Equipment covered by mechanical integrity	300
	Regulatory enforcement of mechanical integrity	302
	What is all this about RAGAGEP?	303
	Struggling with mechanical integrity	304
	Written procedures and training	304
	Classification of equipment by hazard potential	305
	Mechanical integrity programs for pumps/compressors	306
	Mechanical integrity programs for piping, pressure vessels, storage tanks, and process piping	312
	Inspecting pressure vessels, storage tanks, and piping	316
	Inspection of pressure vessels and storage tanks	316
	Mechanical programs for safety-critical instruments and safety relief valves	329
	The critical role of safety relief valves	329
	“In-house” testing safety relief valves	331
	Mechanical integrity program for process safety interlocks and alarms	339
	Protective process safety interlocks at a DuPont plant	340
	Another company – a different emphasis on safety critical instrument systems	341
	Another approach – prooftesting at a Louisiana plant	342
	Additional information on mechanical integrity	350
	References	351
13	Effectively managing change within the chemical industry	353
	Introduction	353
	Preliminary thoughts on managing change	353
	Are management of change systems like snowflakes?	354
	A reality check provided by previous chapters	355
	Keeping MOC systems simple	357

Losing tribal knowledge	357
Some historical approaches to plant changes	358
The US OSHA PSM Standard addresses "management of change"	358
Principles of an effective management of change system that prevents uncontrolled change and satisfies OSHA	360
An overall process description to create or improve a management of change system	361
Clear definitions are imperative	362
Key steps for an effective management of change system for a medium or large organization	364
Key steps for an effective management of change system for a small company	370
Multidisciplinary committee can provide an in-depth look when identifying hazards	372
Operational variances for maintenance need a close examination too	374
Variances, exceptions, and special cases of change	375
Should the MOC system be paperless?	377
Over two dozen plants share their MOC practices	378
Management of change approvals, documentation, and auditing	381
Closing thoughts on management of change policy	382
The Center for Chemical Process Safety	385
Recommendations and regulations after 1988	385
References	388
14 Investigating and sharing near misses and unfortunate accidents	391
Introduction	391
What does the regulation say about incident investigations?	391
Plant cultures can affect investigations	393
More guidelines on the culture of incident reporting	395
An OSHA program coordinator's view	395
Layers of incident causes	396
A furnace tube failure case history is revisited	396
Process safety incident investigation techniques	398
Applying root cause analysis	399
Some chemical manufacturers' approaches to incident investigation	400
What is a root cause?	401
STAMP – a new accident causality model	404
Some thoughts on process safety incident investigation techniques	406
Complying with the OSHA element on incident investigation	406
Report approval, report distribution, sharing the findings, corrective action tracking, and report retention	410
Conclusions	411
References	412

15	Keep a sense of vulnerability for safety sake: seven recommendations for keeping a sense of vulnerability at your chemical processing or refining site	415
	Opening thoughts on unease and who should it impact	415
	How do you create a sense of unease or vulnerability?	416
	A focused effort is essential	417
	Success can blind us of reality	418
	Seven recommendations to reduce your vulnerability	418
	Why not step back in time?	424
	References	425
16	A strong safety culture is essential: it is essential to develop a strong safety culture	427
	Process safety culture has been recognized and accepted in recent years	427
	Foundation for development of safety culture	428
	About 65 companies shared to shape the earlier definition of "Safety Culture" in 2003	429
	What is process safety culture? Perhaps – it is the root cause of the decade!	429
	A dozen features essential to developing a durable safety culture within PSM	432
	API RP 754 describes the "Purpose of Indicators" as [17]	441
	Is safety culture really important?	442
	References	443
17	Sources of helpful information for practicing chemical process safety	445
	Key cost free process safety resources at your finger tips	445
	Process safety resources via consultants, professional associations and trade associations via the web	451
	Excellent books addressing chemical process safety – from a process engineer's viewpoint	460
	Two of the best process safety videos which focus on learning from case histories	463
	References	464
	Index	465