Addressing the Process Safety Challenges associated with Heater Operations in the Process Industry

Paper presented on behalf of the Abnormal Situation Management® R&D Consortium

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Message

- Despite increase prevalence of SIS deployment for heater operations risks for significant process safety incidents still occur
- To mitigate risks, there is a need for practice area improvements in
  - Process Monitoring, Control and Support Applications
  - Skill and Knowledge Development

Founded in 1994

Creating a new paradigm for the operation of complex industrial plants, with solution concepts that improve Operations' ability to prevent and respond to abnormal situations.

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What is an Abnormal Situation?

- An industrial process is being disturbed and the automated control system can not cope
- Consequently, the operations team must intervene to supplement the control system.

An Abnormal Situation Impacts Process Safety

ASM Relation to PSM
Safety Pyramid Illustration

Process Safety Incidents

Abnormal Situation Incidents

Effective Operations Practices

Major Incidents
Incident above threshold for Process Safety Incident

Minor Incidents
Incident below impact threshold for PS Incident

Near Miss
System Failures that could lead to an incident

Unsafe Behaviors
Insufficient Operating Discipline

Illustration from:

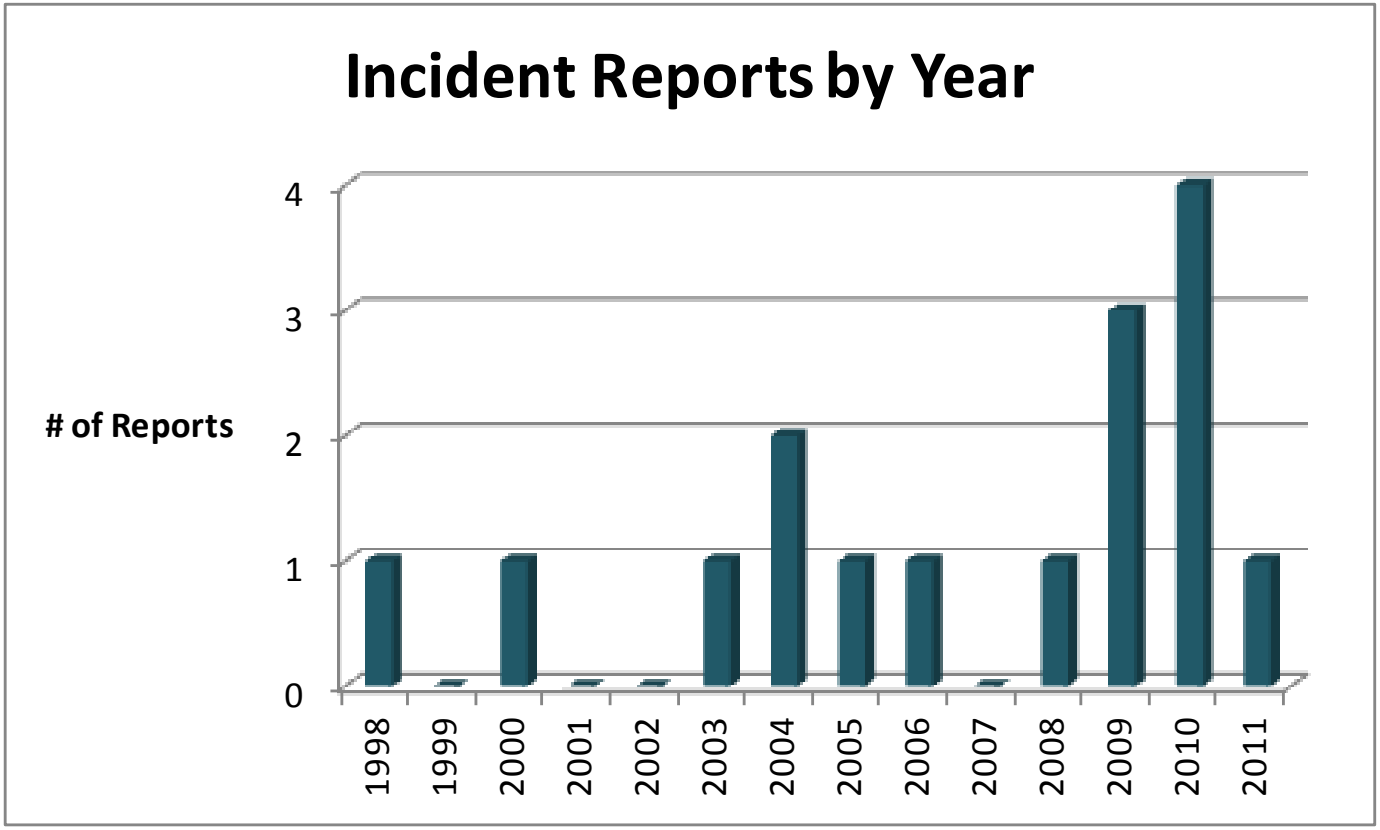
CCPS *Process Safety Leading and Lagging Metrics.*

http://www.aiche.org/ccps/metrics/index.aspx

ASM Research Objective

- Identify challenges and contributing factors associated with heater operations, such as
  - Human Machine Interface (HMI) design
  - Safety Instrumented System (SIS) complexity
  - Operator Competency

Approach



- Analyzed 16 major heater incident reports from member companies
- In 2012, most incidents were less than 10 years old

Heater Incident Reports
Impacts

- All had potential for injury or loss of life
  - 31% with injuries and/or fatalities
- All had equipment damage
  - 38% with extensive or significant
- Many with production outage
  - 31% had 2 day to 4 months
  - 50% did not indicate
- Only 4 reported Cost Impact
  - $1MM to $100MM

Heater Incident Reports
Characteristics

- **69%** of incidents involved Startup operations (11 of 16)
- **69%** of the incidents involved heaters with a SIS implementation (11 of 16)
- **38%** of incidents identified controls in manual or bypassed as a contributing factor (6 of 16)

Heater Incident Analysis
Failure Analysis Methodology

Incident Reports

TapRoot root cause analysis method for each report

Event Flow Chart

Failures

Root Causes

Repeat for each incident report

Common Failure Modes

Based on ASM *Effective Operations Practices*

ASMC clustering analysis method across all reports

Root Cause Manifestations

"How its root causes occur"

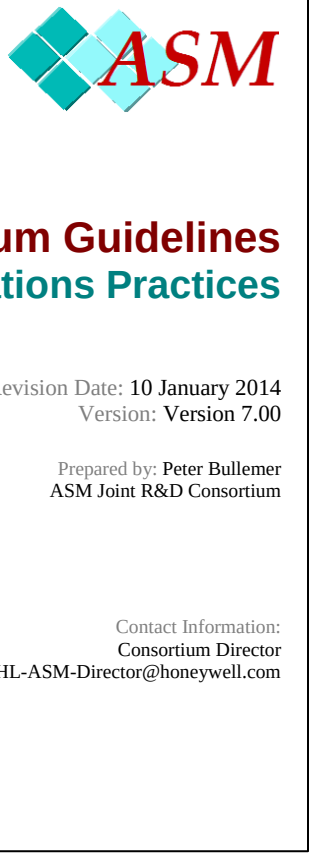
Solution Concepts

"Ways to mitigate risk"

Bullemer, P.T. and Laberge, J.C. (2010). Common operations failure modes in the process industries. *Journal of Loss Prevention in the Process Industries,* 23(6), 928-935.

Terminology

- **Failure** is a practice flaw that, if corrected, could have prevented the incident or mitigated its impact
  - What went wrong in the words of the investigators
  - Example: Supervisor not accessible
- **Common failure modes** are shared operational practice failures across incidents
  - Failures map to ASM *Effective Operations Practices* Guidelines
  - Example: Ineffective first-line supervision



Heater Incident Analysis
Failures by Practice Area

#	Operations Practice Category	Total Failures	% of Failures
1	Understanding Abnormal Situations	4	4%
2	**Org. Roles, Resp., & Work Processes**	**35**	**29%**
3	**Knowledge and Skill Development**	**16**	**13%**
4	Communications	4	4%
5	**Procedures**	**15**	**13%**
6	Work Environment	0	0%
7	**Proc. Monitor, Ctrl, & Support Apps**	**39**	**33%**
	Other	6	5%
	Total	119	100%

- 88% of failures attributed to 4 categories

Heater Incident Analysis

Top 10 Operations Failures

Rank	Top 10 Failure Common Failure Modes	%
1	**Fail to ensure adequate support for operator situation awareness through the integrated use of overview, detail, and trend monitoring displays**	**9%**
2	**Fail to implement & communicate comprehensive hazard analysis**	9%
3	**Fail to establish effective first line leadership roles**	8%
4	**Fail to use design guidelines & standards for console applications**	8%
4	**Fail to establish maintenance for CR applications**	8%
6	**Fail to implement comprehensive Management of Change**	7%
7	**Fail to establish effective initial and refresher training**	7%
8	**Fail to ensure that all applications are fit for purpose**	5%
9	**Fail to conduct training on situation management and team collaboration skills for abnormal situations**	4%
10	**Fail to ensure compliance with policy on the use of procedures**	4%

- Top 10 failures account for 67% of all operations practice failures
- Similar to the Top 10 for analysis of 32 incidents with four exceptions (2009 MKOC Symposium)

Terminology

- Root cause **manifestations** are the specific expression or indication of a root cause in an incident
  - 'How' operational failure modes are expressed in real operations settings – are the root cause details aggregated across incidents
  - Basis for creating audit checklist to proactively look for operational risks
  - Example: *Supervisor not in control room to discuss problems* is an example manifestation for the *No Supervision* common root cause and the *Ineffective First Line Leadership Role* common failure mode

- **Failure to Ensure Support for Operator Situation Awareness**
  - Key indicators and alarms to indicate the health of the heater were not available to the console operator such as loss of feed, fuel rich or flameout conditions (10)
  - Appropriate response required operator to integrate status across multiple parameters simultaneously (2)
  - Site did not have formal practice to communicate SOL excursions to operators (1)
  - Key indicator for health of the furnace was not conveniently located near the local panel where field operators made field adjustments (1)

(#) Number of root causes related to common manifestation

Common Manifestations
Proc. Monitoring, Ctrl & Support Apps

- **Failure to Establish Maintenance to ensure applications work as intended**
  - Controllers did not control process in auto mode (2)
  - No formal practice to assess need and adequacy of preventative maintenance based on equipment reliability or criticality of equipment for operations (2)
  - Industry substandard inspection methods fail to detect critical conditions (2)
  - Lack of effective maintenance on field labeling to ensure accurate information is available to field operations (1)
  - Maintenance program did not prevent recurring problems (1)
  - Maintenance program did not result in timely replacement of important instrumentation (1)

(#) Number of root causes related to common manifestation

- **Failure to ensure applications are fit before commissioning**
  - Operability verification checks not performed following installation (6)
  - Industry substandard inspection methods fail to detect critical conditions (1)
  - Insufficient review of electrical and instrumentation package from vendor (1)

(#) Number of root causes related to common manifestation

Common Manifestations
Knowledge & Skill Development

- **Failure to conduct training for situation awareness and team collaboration skills**
  - Members of the shift team lacked effective troubleshooting skills (2)
  - The shift team did not establish effective team situation awareness on all of their upset response activities (2)
  - The shift team failed to maintain overall situation awareness focusing on single problem (2)

(#) Number of root causes related to common manifestation

- **Training Practices**
  - Customized training module on the typical heater operating risks specific to each heater in terms of indication of scenario, recommended actions and warnings on what not to do
  - Shift team training on heater operations led by Industry expert in heater operation training
- **Procedure practices**
  - Start-up procedures for different conditions (e.g., cold start-up, hot start-up with pilots, hot start-up with no pilots)
  - Use of a risk-based classification methodology for procedure format and use

Member Site Visits
Better Practices

- **Understanding Abnormal Situations practices**
  - Continuous improvement culture and implementing solutions for near-miss root causes
- **HMI Design practices**
  - Inclusion of critical parameters for heater operation in the console span-of-control overview (Level 1)
  - Integration of SIS instrumentation status into the main operating displays (Level 2)

Member Site Visits
Challenges

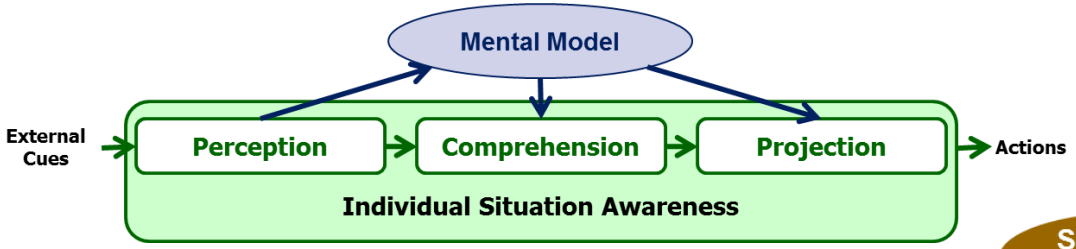
- **Reliability**
  - Mechanical reliability for stack and fan dampers (i.e., sticking dampers or dampers that slam shut)
    - » Impacts efficiency and optimization of the heater operation during normal operation
  - Instrumentation reliability, particularly SIS instrumentation, which ends up being bypassed, during normal operation
- **Start-up conditions & Instrumentation**
  - For non-natural draft furnaces in which pilot burners are knocked out and the SIS trips out the heater
  - For non-natural draft furnaces with combustible analyzers and unreliable lighting methods on pilot or main burners

Member Site Visits
Challenges

- **Continuous Improvement**
  - Communicating the successive lessons learned following each SIS deployment – to the next units but also the preceding units
    - » e.g., change in physical speed at which FG PVs are closed / opened
- **HMI Design**
  - Effective Level 2 HMI design for heater operation that covers the full operation of the heater (e.g., pass flows, fuel gas, air, SIS indication, and/or steam generation, SCR)
  - Effective depiction of permissive status for start-up

Risk Mitigation Strategies

- **Need to Improve Individual and Team Situation Awareness during Startup activities**
  - Improve the quality and content of Operating Displays
  - Identify and develop effective training methods for individual and team competencies for abnormal situation management
    - » Including the role of first line leadership



Risk Mitigation Strategies

- **Need to Improve the Quality of Safety Instrumented System (SIS) Deployment and Maintenance**
  - Improve the quality of inspections and operability checks for SIS instrumentation and controls
  - Establish effective practices for mitigating hazards for ‘non-normal’ start-up conditions

Conclusions

- Despite increase prevalence of SIS deployment for heater operations, risks for significant process safety incidents still occur
- Analysis of 16 major heater incidents revealed operations practice failure mode profile distinct from larger pool of major process safety incidents
- Findings suggest need for improvement in
  - Situation awareness during heater startups
  - Quality of SIS deployment and maintenance

Questions & Answers

- **Please ask questions or offer comments**

Abstract

- The Abnormal Situation Management® Consortium (ASMC) funded a study to investigate challenges associated with heater operations. The study team analyzed 16 member company incident reports using the TapRoot® methodology to identify root causes associated with heater operations failures. The main finding was the operations failure mode profile for heater-related incidents was different from the profile found in a larger pool of 32 process industry incidents that did not specifically involve heater operations.
- Specifically, the investigation found a higher prevalence of operations failures due to: (1) Inadequate human-machine interface to support situation awareness, (2) Inadequate operator training for abnormal situation management and team collaboration skills, (3) failure to insure automation applications are fit for purpose before commissioning, and (4) failure to establish maintenance program to ensure automation applications are performing as intended.
- In addition, the study team visited three member company sites to investigate challenges associated with heater operations. The site visit findings validated the incident investigation findings as well as revealed some additional challenges during day-to-day operations not associated with incidents.
- Specific risk mitigation strategies, from improvements to operator interface design to team competencies and communication to hazard identification, are discussed to address the identified process safety challenges associated with heater operations.