Abnormal Situation Management and the Human Side of Process Safety

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

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Key Message

• In recent years, many organizations have been striving to improve process safety management performance.

• One opportunity for improving process safety performance is to reduce the probability of human error through effective abnormal situation management practices.
Challenges associated with human side of process safety have been a focus of the Abnormal Situation Management® (ASM) Consortium for the past fifteen years.

www.asmconsortium.org
Abnormal Situation Management®
A Joint Research and Development Consortium

Founded in 1994

Enable operating teams to proactively manage their plants to maximize safety and minimize environmental impact while allowing the processes to be pushed to their optimal limits.

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Abnormal Situation Definition

- 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.
- Impacts **profitability** in multiple ways:

  - Product Quality
  - Equipment Damage
  - Loss of Life
  - Product Thruput
  - Personal Injury
  - Job Satisfaction
ASM Relation to PSM
Safety Pyramid Illustration

Process Safety Incidents

Abnormal Situation Incidents

Effective Operations Practices

Major Incidents
Incidents above threshold for Process Safety Incident

Minor Incidents
Incidents below impact threshold for PS Incident

Near Miss
System Failures that could lead to an incident

Unsafe Behaviors
Insufficient Operating Discipline


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# Managing Abnormal Situations

**Operational Modes and Critical Systems Perspective**

<table>
<thead>
<tr>
<th>Operational Modes:</th>
<th>Plant States:</th>
<th>Critical Systems:</th>
<th>Operational Goals:</th>
<th>Plant Activities:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency</td>
<td>Disaster</td>
<td>Area Emergency Response System</td>
<td>Minimize Impact</td>
<td>Firefighting</td>
</tr>
<tr>
<td></td>
<td>Accident</td>
<td>Site Emergency Response System</td>
<td></td>
<td>First Aid</td>
</tr>
<tr>
<td></td>
<td>Out of Control</td>
<td>Physical and Mechanical Containment System</td>
<td>Bring to Safe State</td>
<td>Rescue</td>
</tr>
<tr>
<td>Abnormal</td>
<td>Abnormal</td>
<td>Safety Shutdown, Protective Systems, Hardwired Emergency Alarms</td>
<td>Return to Normal</td>
<td>Manual Control &amp; Troubleshooting</td>
</tr>
<tr>
<td>Normal</td>
<td>Normal</td>
<td>DCS Alarm System</td>
<td>Keep Normal</td>
<td>Preventative Monitoring &amp; Testing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Decision Support System, Process Equipment, DCS, Automatic Controls, Plant Management Systems</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**ERTC 15th Annual Meeting**

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Managing Abnormal Situations
Human Supervisory Control

• This model operationalizes the human processing elements in the operator’s supervisory control responsibilities for managing abnormal situations

**Adaptation of Supervisory Control Activity models of Jens Rasmussen and David Woods - CMA.**
Sources of Abnormal Events

People:
- Fail to detect problems in reams of data
- Are required to make hasty interventions
- May be unable to make consistent responses
- May be unable to communicate well

Established in literature; confirmed by 18 plant studies - US, Canada, & Europe
Making the Business Case

Unexpected Events Cost 3-8% of Capacity

~ $10 Billion annually in lost production!

Source: ASM Consortium Research

Plant Operating Target

Optimization efforts

Operational Constraints

Plant Capacity Limit

Plant Incidents

Summarized Production Data

Source: ASM Consortium Research
Persistent Paradoxes

• **Paradox of Automation**
  – Better automation leads to more sophisticated processes.
  – More sophisticated processes leads to more opportunities for error.
  – We tend to “fix” the increasing errors with still more automation.

• **Paradox of Reliability**
  – Better equipment reliability leads to fewer operator interventions.
  – Fewer operator intervention leads to fewer opportunities to learn from experience.
  – Less experiential knowledge and skill leads to more human errors.
  – We attempt to “fix” the increasing human error with equipment reliability improvements.

• **Consequently, when things go wrong, people have difficulty intervening to correct the problem.**

• **Need to better understand how to break the cycles and support human intervention activities**
ASM Incident Analysis Study
Project Objectives

• Understand relation between ineffective operations practices and process industry incidents
  – Systematically analyze incidents to determine common operational practice failure modes
  – Identify root causes of common operational practice failure modes
  – Why do failures occur across incidents

This research study was sponsored by the Abnormal Situation Management® (ASM®) Consortium.

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ASM Incident Analysis Study
Common Operations Failures

Top 10 Operations Failures

<table>
<thead>
<tr>
<th>Operation</th>
<th>#</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazard analysis/ communication</td>
<td>79</td>
<td>15%</td>
</tr>
<tr>
<td>First-line leadership</td>
<td>65</td>
<td>12%</td>
</tr>
<tr>
<td>Continuous improvement</td>
<td>60</td>
<td>11%</td>
</tr>
<tr>
<td>Safety culture</td>
<td>36</td>
<td>7%</td>
</tr>
<tr>
<td>Initial and refresher training</td>
<td>30</td>
<td>6%</td>
</tr>
<tr>
<td>Task communications</td>
<td>29</td>
<td>5%</td>
</tr>
<tr>
<td>Comprehensive MOC</td>
<td>28</td>
<td>5%</td>
</tr>
<tr>
<td>Cross functional communication</td>
<td>23</td>
<td>4%</td>
</tr>
<tr>
<td>Compliance with procedures</td>
<td>15</td>
<td>3%</td>
</tr>
<tr>
<td>Design guidelines and standards</td>
<td>14</td>
<td>3%</td>
</tr>
<tr>
<td>Other failure modes</td>
<td>160</td>
<td>30%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>539</td>
<td></td>
</tr>
</tbody>
</table>

- 32 incidents were analyzed using TapRoot incident investigation methodology

<table>
<thead>
<tr>
<th></th>
<th>Public</th>
<th>Site</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>14</td>
<td>7</td>
<td>21</td>
</tr>
<tr>
<td>Non USA</td>
<td>6</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>20</td>
<td>12</td>
<td>32</td>
</tr>
</tbody>
</table>

- Top 10 covered 70% of identified operations practice failures
### Root Cause Analysis Study
Impact by Practice Areas

#### Effective Operations

<table>
<thead>
<tr>
<th>Practice Area</th>
<th>% of Failures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding Abnormal Situations</td>
<td>4%</td>
</tr>
<tr>
<td>Organization Roles, Resp. &amp; Work Processes</td>
<td>53%</td>
</tr>
<tr>
<td>Knowledge &amp; Skill Development</td>
<td>7%</td>
</tr>
<tr>
<td>Communications</td>
<td>17%</td>
</tr>
<tr>
<td>Procedures</td>
<td>8%</td>
</tr>
<tr>
<td>Work Environment</td>
<td>1%</td>
</tr>
<tr>
<td>Process Monitoring, Ctrl, &amp; Support Applications</td>
<td>10%</td>
</tr>
</tbody>
</table>

- Based on a total of **539 practice failures** across 32 incident reports
Human reliability improvements require focus on more than technology.

We need to identify the problems that have to be solved and only then search for solutions:

- Culture,
- Organization,
- Work place,
- Work process,
- and
- Technology

**ASM Solution Framework**

- Understanding Abnormal Situations
- Organization Roles, Responsibilities & Work Processes
- Communications
- Knowledge & Skill Development
- Procedures
- Process Monitoring, Control & Support Applications
- Work Environment
Summary of Research Program

- 2009-10 Research Roadmap Analysis Findings vs. Past Research Outcomes illustrates areas of emphasis

Research Opportunity X Research Outcomes Produced

<table>
<thead>
<tr>
<th>Procedures</th>
<th>Monitoring/Control</th>
<th>Understanding</th>
<th>Knowledge/Skill</th>
<th>Organization</th>
<th>Communications</th>
<th>Environment</th>
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</thead>
<tbody>
<tr>
<td># Problems</td>
<td># Research Needs</td>
<td># Research Outcomes</td>
<td># Problems</td>
<td># Research Needs</td>
<td># Research Outcomes</td>
<td># Problems</td>
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<td>19</td>
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<td>29</td>
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<td>8</td>
<td>13</td>
<td>8</td>
<td>5</td>
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<tr>
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<td>8</td>
<td>8</td>
<td>19</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>31</td>
<td>31</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>13</td>
<td>5</td>
</tr>
</tbody>
</table>

Highest Rank Importance

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Understanding Abnormal Situations

Vision

• Shared understanding of abnormal situation causes and impacts, widely communicated across the site, in order to efficiently and accurately inform continuous improvement programs that mitigate and reduce abnormal situations.

• Example project: Business Justification and Metrics Development
  – Develop a conceptual cause and effect framework for analysis of impact of operations practices on operator and plant performance
Organization Roles, Responsibilities & Work Processes Vision

- Management systems, work practices, organizational structures, and a continuous improvement culture that supports prevention and mitigation of abnormal situations.

- **Example project:** Root Cause Analysis of Industry Incident Reports
  - Develop understanding of operations practice failures in 32 industry incident reports
  - Create plant manager’s audit checklist
Knowledge & Skill Development Vision

- Knowledge and skill development establishes and maintains the competencies needed for effective abnormal situation response.

- Knowledge and skill development is a continuous process that is supported by a performance evaluation framework that identifies training opportunities and enables sustainable operator performance over time.

- Example project: Use of Simulators to Train ASM Competencies
  - Demonstrate effective use of simulators to train ASM competencies
Knowledge & Skill Development
Research Roadmap

Competency Framework
2010

Sustained Performance
2012

Metrics
2014

Knowledge Management
2016

Predictive Training
2018

2020

2020+

Competency Driven, Sustainable, Needs Based ASM Training
Communications Vision

• Successful communication enables situation awareness under normal, abnormal and emergency situations.

• Communications practices allow operational and functional team members to efficiently perceive, orient, evaluate and act on information in context to the current team goals and constraints.

• Team members coordinate with respect to goals and activities, through the use of effective information media to ensure continuity in work conditions.

• *Example project:* Use of checklist to improve shift handover communications
  – Assess impact of handover checklist with structured electronic logbook
Procedures Vision

• Procedure content (whether automated or manual) is up-to-date and provides the guidance and instruction needed to minimize, avoid and recover from deviations in operating intent, including unexpected outcomes and abnormal situations.

• A comprehensive usage policy and procedure development, deployment, analysis, and lifecycle management practices enable effective procedure use in appropriate situations.

• Example project: Procedure Execution Failure Modes during Abnormal Situations
  
  – Understand how and why failures occur
  – Identify solutions to mitigate failures

<table>
<thead>
<tr>
<th>Common Manifestations</th>
<th>#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inappropriate action</td>
<td>15</td>
</tr>
<tr>
<td>Fail to detect abnormal condition</td>
<td>12</td>
</tr>
<tr>
<td>Lack understanding of impact</td>
<td>8</td>
</tr>
<tr>
<td>Fail to detect abnormal situation</td>
<td>4</td>
</tr>
<tr>
<td>Unaware of hazard</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
</tr>
</tbody>
</table>
Procedures Research Roadmap

Procedures Risk Assessment
Procedure Authoring
Automated Procedures
Procedure Execution

Procedure Data Models
2010

Procedure Deviation
2012

Lifecycle Management
2014

Dynamic Procedures
2016

Proactive Procedures
2020

2020+

‘Smart’, Robust, Context Sensitive, Integrated Procedures

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Work Environment Vision

- The work environment enhances operations team situation awareness within their scope of responsibility, operator alertness, efficient work practices, collaborative interactions (including with other disciplines) and abnormal situation prevention and response.

- **Example project: Vigilance Decrement on Alertness**
  - Understand time course of alertness loss with console operations activity
Process Monitoring, Control, & Support Applications Vision

- A comprehensive and **user-centered** set of applications and tools that enables a **single point of access to the information** needed for operations **team situation awareness** and effective prevention and response to abnormal situations.

- **Example project:** Visual Thesaurus
  - Develop feasible and effective visualization techniques for console-wide overview displays
Process Monitoring, Control, & Support Apps. Research Roadmap

- Interaction Requirements
  - Operations ‘Cockpit’
  - 2010
  - 2012
- Proactive Monitoring
  - 2014
- Integrated UI
- Automation Design
  - 2016
- Decision Support
  - 2018
- Adaptive Automation
  - 2020
- User-Centered, Integrated, Adaptive Applications
  - 2020+

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ASM Guideline Documents

ASM Consortium Guidelines
Effective Operator Display Design 2008

ASM Consortium Guidelines
Effective Alarm Management Practices 2009

ASM Consortium Guidelines
Effective Procedural Practices 2010

Available on www.createspace.com

- Recently published for use in process industries
- Emphasis on effective prevention and response to abnormal situations
- Based on observed effective practices in member production facilities
- Includes learning from research projects
ASM Publications

- **Understanding Abnormal Situations**

- **Organizational roles, responsibilities and processes**

- **Knowledge and Skill Development**
• **Communications**

• **Procedures**

• **Environment**
• Process Monitoring, Control & Support Applications


Concluding Comment

• The ability of a plant to **effectively prevent and respond to abnormal situations** is a key element to reducing the impact of process safety incidents.

• Human reliability improvements require focus on more than technology;

• Address the influence of
  – Culture,
  – Organization,
  – Work place,
  – Work process,
  – and
  – Technology
Thank You!

Questions and/or Comments?

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Visit www.ASMConsortium.org for more information including membership

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Abstract

• In recent years, many organizations have been striving to improve process safety management performance. One aspect of improving process safety performance is to reduce the probability of human error.

• The challenges associated with human side of process safety have been a focus of the Abnormal Situation Management® (ASM) Consortium for the past fifteen years.

• The mission of the ASM Consortium, a group of 13 companies and universities in the process control industry, is to enable operating teams to proactively manage their plants to maximize safety and minimize environmental impact while allowing the processes to be pushed to their optimal limits.

• This paper presents findings on sources of operational failures and a solution framework developed to address the challenges to human reliability. The solution framework consists of seven operation practice areas that influence the effectiveness of abnormal situation management and the likelihood of process safety incidents.

• The ability of a plant to effectively prevent and respond to abnormal situations is a key element to reducing the impact of process safety incidents.

• Since 1994, the ASM Consortium has been striving to improve ASM practices through their active Research & Development program.