Understanding and Managing the Risk During the Transient Operating Mode: 

*Start-ups and Shut-downs*

Purdue Process Safety and Assurance Center (P2SAC)  
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Outline

• The operating and transient operating modes  
• Results from the incident review  
• Understanding risk during transient operating modes  
• The impact of asset integrity  
• The impact of operational discipline  
• How to effectively manage the risk  
• Conclusion
The Operating Modes

- Deviation from Target Operating Region
- Operating Mode
- Normal
- Abnormal
- Emergency

The Transient Operating Modes (Overview)

- Deviation from Target Operating Region
- Operating Mode
- Normal
- Abnormal
- Emergency

Ten Transient Operating Modes:

- Shut-downs
- Start-ups afterwards

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>Abnormal</th>
<th>Emergency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shut-downs</td>
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</table>
The Ten Transient Operating Modes (Overview)

1) Shut-down (Normal)
2) Start-up (Normal)
3) Shut-down designed for a process shut-down
4) Start-up after a process shutdown
5) Shut-down designed for a facility shut-down
6) Start-up after a facility shut-down

7) Shut-down for an unscheduled shut-down
8) Start-up after an unscheduled shut-down
9) Shut-down activated for an emergency shutdown
10) Start-up after an emergency shutdown
Depictions of The Transient Operating Modes

- Normal operations
  - Normal start-up and normal shut-down
  - Process and facility shutdowns
  - Start-up after process and facility shutdowns

- Abnormal operations
- Emergency operations

Normal Start-up and Shut-down: Continuous Process

<table>
<thead>
<tr>
<th>Pressure (bar)</th>
<th>At-rest, safe idle state</th>
<th>Normal Start-up</th>
<th>Normal Operation</th>
<th>Normal Shut-down</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 (15)</td>
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<td></td>
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<td>2.1 (30)</td>
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Upper Quality Limit
Process Aim
Lower Quality Limit
Shutdown-related Start-ups and Shut-downs

At-rest, idle state

Normal Operation

Normal Shut-down

Facility afterwards

Normal Operation

Pressure

bar (psi)

4.1 (60)

1.01 (14.7)

Time

Transient Operating Mode

Activities during the Shutdown

Shutdowns

Process Aim

Depictions of the Transient Operating Modes

- Normal operations
- Abnormal operations
  - Recovery
  - Unscheduled shut-down
  - Start-up afterwards
- Emergency operations
Recovery from Abnormal Operations

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<th>Pressure (bar (psi))</th>
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<td>4.1 (60)</td>
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Normal Shut-down during Abnormal Operations

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Depictions of the Transient Operating Modes

- Normal operations
- Abnormal operations
  - Emergency operations
    - Emergency shut-downs
    - Start-up afterwards

Emergency Shut-down during Abnormal Operations

- At-rest, safe idle state
- Normal Start-up
- Normal Operation
- Emergency Shut-down

Pressures:
- Lower Safety Limit
- Upper Safety Limit

Process Aim:
- Exceeded
  - Upper Safety Limit

Time
Outline

• The operating and transient operating modes
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Results from the Incident Review

Transient Operating Mode

Time

Process Aim

At-rest, idle state
Normal Operations

Upper Equipment Design Limit

Incident

Start-up
Shut-down

Process or Facility Shutdowns
Abnormal Operations
Results from the Incident Review

Transient Operating Mode

Time

Process Aim

Normal Operations

Process or Facility Shutdowns

Abnormal Operations

Shut-down

Start-up

Upper Equipment Design Limit

At-rest, idle state

Did not count during Process or Facility Shutdowns

Incident

Incident

Incident

Incident

WHY?

Emergency Operations

Results from the Incident Review
Understanding Risk: The Risk Matrix

Risk = \( F \times C \)

How Risk is Managed During Normal Operations

Evaluated Risk

Managed Risk

\( R_1 > R_2 \)
How Risk is Managed During the Transient Operating Mode

Outline

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Impact of Asset Integrity on the Equipment Life Cycle

- **Birth**
  - Design
  - Fabricate
  - Construct
  - Install

- **Use**
  - Commission
  - Operate
  - Maintain

- **End of Life**
  - Decommission

Maintain/Sustain equipment integrity

Inspection, Testing, and Preventive Maintenance (ITPM)

The Impact of Operational Discipline During the Transient Operating Mode

<table>
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<tr>
<th>Frequency (F)</th>
<th>Consequence (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>High</td>
</tr>
<tr>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td></td>
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Actual Risk

- **High**
- **Low**

Perceived Risk

Incident

Risk = \( \frac{F \times C}{OD} \)

\( R_3 > R_2 \)
Outline

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How to Effectively Manage the Risk
During the Transient Operating Mode

Risk managed with engineering and administrative controls

Engineering controls: Focus on equipment
Administrative controls: Focus on procedures

The Hierarchy of Controls:
Engineering controls
Then
Administrative controls

Less Effective
Results Mapped to the Elements and Pillars in the RBPS Model

Risk Based Process Safety (RBPS)

Columns are Elements

Twenty Elements

Elements (Columns) supported by Pillars

Four Pillars

Process Safety and Risk Management Model

Summary: How to Effectively Manage the Risk

Sustain Engineering Controls:
Asset Integrity and Reliability

Pillar III
Manage Risk
**Summary: How to Effectively Manage the Risk**

**Sustain Administrative Controls:**
- Shut-down and Start-up Operating Procedures
- Asset Integrity and Reliability (ITPM) Program
- Management of Change (MOC) Program
- Emergency Response

**Conclusion: Good OD Examples for Pillar III, Manage Risk**

**Administrative controls in Asset Integrity**

- **Ensuring** an effective Inspection, Testing and Preventive Maintenance (ITPM) program for all *safeguards*
- **Resourcing** maintenance teams adequately in preparation for process or facility shutdowns
- **Adhering** to the scheduling planned maintenance on critical *safeguards*
- **Using** qualified personnel to inspect, test, and refurbish *safeguards*, as needed before start-ups or commissioning
Conclusion: Effect on the Safe Operating Zone During the Transient Operating Mode


During the Transient Operating Mode

Aim

- Normal Operations
- Shut-down
- Start-up
- Shut-down

Process

- At-rest, idle state
- Upper Equipment
  - Design Limit
- Incident
- Incident
- Incident

Time

Questions?