An Oven Explosion –
Lessons Learned on PSM Concepts
(or “PSM: It’s not just for breakfast anymore”)

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PSM Concepts & Applicability

• Should some concepts of PSM be applied in all industries?

• Are codes enough?

• Should we accept the notion that suppliers always know their process and equipment better than us?

• Should we view combustion as something more than a mundane, ubiquitous process?
The Event

- September 15, 1998: Difficulties starting up new line.
- Once started, operations ramps up to full speed. Ovens ramp up to high fire settings.
- Within 12 minutes of ramp initiation, an explosion, heard for 6 miles, takes place.
Evolution or Managed Change?
Evolution or Managed Change?

Human Evolution
5 million years ago to the Present
Vertical Scale in Millions of Years

Proc. C
Proc. B, Mod 2
Proc. A, Mod 2
Proc. B, Mod 1
Proc. A, Mod 1

Process B
Process A
Societal Need
Sequence of Changes

• Orders a machine capable of X feet/minute
• Changes order to 1.5 X feet/minute
• Machine manufacturer changes burner requirements
• Burner manufacturer uses same burner, but increases gas flow to get higher rating
• No one changes combustion air fan capability
Sequence of Changes

- **Start up problem: Unstable low fire flame**
- **First Solution: Weighted Pressure Relief Valve on Combustion Air – Too Noisy!**
- **Second Solution: Combustion Air Trim Damper**
Flow could be anywhere in this box and satisfy the interlock
Same $d\mathbf{P}$ at Two Different Flows Possible

Trim Damper Affect on Fan Curve
The Burner
The Incident

21:15 Line shut down due to quality; burner at low fire

21:34 Line re-started, 12 minute ramp up to maximum speed. Burner demand set to high-fire

21:39 Leakage alarm – calculated number indicating pressure is high within oven. Operators should smell binder fumes. No smell reported. Thermal oxidizer temperature begins rising
The Incident


21:45:33 Operator clears alarm

21:46:04 Explosion occurs (pressure disturbance in Zone 1)
Explosion Venting

- **Recommended by FM & NFPA**
  - Only for ovens regardless if flammable vapors are generated or not
  - Does this mean we do not trust combustion safeguards?
- **Venting not provided**
Investigation

• *Identified, secured and tested the low combustion air pressure switch*

• *Confirmed valve positions and determined failure mode –* Combustion air trim damper was “fail last”

• *Found water in instrumentation lines*

• *Preserved lines and tested for effect of water on dPT*
### Affect of Water in the Instrumentation Line

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Amount of Water</th>
<th>dP Applied (in. WC.)</th>
<th>dP from DPT (in. WC.)</th>
<th>Error (in. WC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 ml.</td>
<td>4.1</td>
<td>4.1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>5 ml.</td>
<td>4.8</td>
<td>6.0</td>
<td>1.2</td>
</tr>
<tr>
<td>3</td>
<td>10 ml.</td>
<td>4.1</td>
<td>5.9</td>
<td>0.8</td>
</tr>
<tr>
<td>4</td>
<td>15 ml.</td>
<td>4.12</td>
<td>6.17</td>
<td>2.05</td>
</tr>
<tr>
<td>5</td>
<td>20 ml.</td>
<td>4.3</td>
<td>5.1</td>
<td>0.8</td>
</tr>
</tbody>
</table>
Conclusions

• **Failure to manage change:**
  - **Upsized burner from 30 MM to 40 MM BTU**
  - **Never increased fan rating**
  - **Original specification of 14:1 air/fuel ratio**
  - **Actual ability at high fire was 10:1**
Conclusions

- **Failure to manage change**: Due to flame instability at low fire, dP was reduced first by relief valve, then by trim damper.
- Fan curve truncated resulting in multi-point dP.
- Allowed trim damper to seek low flow position.
Conclusions

• **Failure to properly install:**
  – *Instrument locations changed to become accessible without building ladders/platforms*
  – *Tap points were higher than instruments*
  – *Condensate filled lines*
  – *Induced error*
  – *Corroded switch contact closed*
Conclusions

- Questionable design of burner
  - Seemed to meet code, but high fire flame was not monitored
  - Low fire flame monitored and stayed lit
  - Became ignition source of explosion
Conclusions

• We are not measuring meaningful parameter
  – Combustion air pressure limits do not mean we have sufficient air for combustion!

• We assume linkage will not slip or bind
  – Linkage slip has happened!
Conclusions

• *Should we measure air and fuel flow instead?*
  – *Ratio control and interlock systems?*
• *How about measuring combustibles in the exhaust?*
• *Can we make them reliable enough to preclude the need for venting?*
  – *ASME Code Case 2211?*
  – *SIL 1 or 2 needed?*