Feedback from POPS-B explosion analysis

LIU-PSB Meeting 186  07 February 2017

Fulvio Boattini TE/EPC
Recall

April 2016: POPS storage capacitors went short circuited. An explosion resulted

POPS-B storage capacitors are in a building. An explosion risk analysis was triggered in November 2016.
B245 Storage capacitor location

Room: S-401
Parking area

Room: R-401
Entry area

Room: R-403

Stairs
B245 Explosion risk: aim of the Study

• Determine the effect of the explosion of one capacitor on the concrete structure;

• Eliminate all risks for personnel. Inside and outside the B245;

• Minimize effects on equipment. Restart after one explosion.

Analysis performed by external consultant: FCSolutionS
B245 Explosion risk: the approach

- A short circuit in the capacitor generates an arc;
  
  **Arc Energy calculation**

- The arc turns oil into gas (1lt $\rightarrow$ 100kJ);

  **Gas type and quantity calculation**

  \[ C_{10}H_{22} = 10.60H_2 + 0.06CH_4 + 0.23C_2H_2 + 0.02C_2H_4 + 9.43C \]

- Gases exit from capacitors and lead to secondary explosion;

  **Gas burning and CFD simulation**

- Secondary explosion generates pressure wave in the room.

  **Secondary explosion**

  **Structural analysis of concrete**
Arc Energy calculation

168 capacitor units divided into 5 blocks each protected by a single fuse.

Arc Energy = 1.5 MJ
Gas type and quantity calculation

Mainly Hydrogen and Acetylene

<table>
<thead>
<tr>
<th>Dati di base definizione scenario</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>energia d’arco</td>
<td>1.50 MJ</td>
</tr>
<tr>
<td>Rapporto energia olio/gas (decano eq)</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COMPOSIZIONE MISCELA</th>
<th>%Vgas</th>
<th>%Vtot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idrogeno</td>
<td>73.0</td>
<td>12.377</td>
</tr>
<tr>
<td>Acetilene</td>
<td>20.7</td>
<td>3.510</td>
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<tr>
<td>Metano</td>
<td>3.5</td>
<td>0.593</td>
</tr>
<tr>
<td>Etilene</td>
<td>2.1</td>
<td>0.356</td>
</tr>
<tr>
<td>Decano (olio eq)</td>
<td>0.000</td>
<td>0.000</td>
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</table>

<table>
<thead>
<tr>
<th>COSTANTI FISICHE</th>
<th>Vol/Amount</th>
<th>m3/Kmol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vol/Amount</td>
<td>22.415</td>
<td></td>
</tr>
<tr>
<td>rapporto VolN2/VolO2 in aria</td>
<td>3.83</td>
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</table>
Gas burning: “Well mixed”

- “Well mixed” approach;
  - “All the flammables produced during the primary explosion (hydrocarbons and oil mist) are supposed to come out from the enclosure and be perfectly mixed with air at stoichiometric concentration and ambient pressure”

Ignition source

The gas-oil mist cloud is placed on top of capacitors and ignited.
Gas burning: “Burst”

“Burst” Approach:

• “The enclosure is supposed to instantaneously disappear at failure pressure value (30bar). All flammables produced during the accident and the primary explosion phase (hydrocarbons and oil mist) are compressed in an initial volume, at pressure equal to failure pressure of the enclosure, and 100% concentration”

Case disappears and gas-oil mist is at failure pressure.

Ignition source
Gas burning: Results

Vents on the roof 2 x 1mt x 2mt (per room)

Vents on the side 2 x 1mt x 2mt (per room)

Six parameters sensitivity analysis: 60 analysis in total

<table>
<thead>
<tr>
<th>digit</th>
<th>#1</th>
<th>#2</th>
<th>#3</th>
<th>#4</th>
<th>#5</th>
<th>#6</th>
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<td>geometry</td>
<td>approach</td>
<td>cloudpos</td>
<td>ign delay</td>
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<tr>
<td>1</td>
<td>R401</td>
<td>R403</td>
<td>vent1roof</td>
<td>vent2roof</td>
<td>low-left</td>
<td>5msec</td>
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<tr>
<td>2</td>
<td></td>
<td></td>
<td>standard</td>
<td>setup P15</td>
<td>low-right</td>
<td>10msec</td>
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<tr>
<td>3</td>
<td>S401</td>
<td>vent1wall</td>
<td>up-right</td>
<td></td>
<td>20msec</td>
<td>4</td>
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<tr>
<td>4</td>
<td>vent2wall</td>
<td>up-left</td>
<td>central</td>
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<td>40msec</td>
<td>8</td>
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<tr>
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<td>16</td>
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<td>6</td>
<td>shield2</td>
<td></td>
<td></td>
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<td>bunker</td>
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<td>9</td>
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</table>
Gas burning: Results

“Well Mixed” room R-401.
With Vents, doors are replaced with blast resistant doors.

**Results** - Sensitivity on oil mist amount and venting scheme
- both 1 and 2 vents; well mixed approach

- **oil x1**
  - 0.12 bar
  - 1 vent 0.10 bar
  - 2 vents 0.09 bar

- **oil x4**
  - 0.12 bar
  - 1 vent 0.09 bar
  - 2 vents 0.08 bar

- **oil x16**
  - 0.11 bar
  - 1 vent 0.08 bar
  - 2 vents 0.07 bar

1 vent 0.11 bar
2 vents 0.09 bar

1 vent 0.10 bar
2 vents 0.09 bar

1 vent 0.09 bar
2 vents 0.08 bar

1 vent 0.08 bar
2 vents 0.07 bar

venting through doors (present solution)
venting through roof
venting through wall
Gas burning: Results

“Burst” room R-401.
With Vents, doors are replaced with blast resistant doors.

![Graph showing results of gas burning with vents.]

- 0.3 bar
- 1 vent 0.31 bar
- 2 vents 0.2 bar
- 1 vent 0.4 bar
- 2 vents 0.25 bar
Gas burning: Results

Venting through doors S-401

Venting through walls R-401 R-403

Venting through roof R-401 R-403

Direttiva Seveso 82/501/CEE

<table>
<thead>
<tr>
<th>Level</th>
<th>Stationary Radiation</th>
<th>Non – stationary Radiation</th>
<th>Overpressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>No effect</td>
<td>1.6 kW/m²</td>
<td>&lt; 125 kJ/m²</td>
<td>&lt; 30 mbar</td>
</tr>
<tr>
<td>Small effects</td>
<td>&lt; 3 – &lt; 5 kW/m²</td>
<td>125 – &lt; 200 kJ/m²</td>
<td>30 – &lt; 50 mbar</td>
</tr>
<tr>
<td>Reversible effects</td>
<td>5 – 7 kW/m²</td>
<td>200 – 350 kJ/m²</td>
<td>50 – 140 mbar</td>
</tr>
<tr>
<td>Irreversible effects</td>
<td>&gt; 7 kW/m²</td>
<td>&gt; 350 kJ/m²</td>
<td>&gt; 140 mbar</td>
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<tr>
<td>Lethality</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Venting through doors S-401 requires a wall.

Venting through walls R-401 & R-403 is better.
B245 Explosion risk: first conclusions

- Room S-401 is vented via the door;
  - A containment wall for people safety;

- Venting from the walls seems the best option for R-401 & R-403;

- Capacitor room doors replaced with blast resistant;
B245 Explosion risk: Planning

Complete on February 2017
- Choice of venting device and final dimensions;
- Structural analysis of the concrete structure;

Complete on April 2017
- As built drawings of modifications following explosion analysis;
- Specification of modification required by CV;

Complete on Septembre 2017
- Realization of all B245 modifications by a general contractor coordinated by SMB

CB: 76805 ?
Thank you for your attention
Questions?