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Case Study: Safety Device failure results in tanker BLEVE

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An 11,000 gal delivery truck carrying liquid propane (LPG) arrives Saturday (10/6/2007) around 1:00PM to off-load propane.

The propane was destined for two storage tanks at the foundry, which had their vapor and liquid lines connected.

- This enabled filling both through a common liquid inlet line.

The storage tanks and cargo trailer were equipped with relief vents.

The storage tanks were protected from the unloading area by a concrete wall.
Unloading Area

Small Propane Storage Tank

Large Propane Storage Tank

Storage Tank Relief Vent

Liquid Valve - CLOSED

Vapor Valve - CLOSED

Concrete Wall

Liquid Hose

Vapor Return Hose

Propane Truck

Propane Truck relief vents
Background Cont.

◊ The fitting on the liquid delivery line was discovered separated from the flexible hose.

◊ The driver requested help from foundry staff to “repair” the line.

◊ Two pairs of (four total) hose clamps were used to secure the liquid line.

◊ The driver then charged the liquid line with propane, engaging the PTO.
Liquid and Vapor lines

Vapor Valve - CLOSED

Liquid Internal Valve - OPEN

Liquid Valve - OPEN
Internal Liquid Valve

- 600GPM Internal Excessive Flow Valve

- SIMULATED TANKER BOTTOM

- Pump

- Discharge Piping

- Hose Ball Valve. This valve was OPEN and being used by the driver.

- Ball Valve
  - Left side of the truck. This valve was CLOSED.

- NO FLOW
Moments before opening the globe valve to the storage tanks, the repaired fitting failed and engulfed the truck in a “white cloud” of propane.

The cloud of escaping propane was then ignited.

A fire began to burn under the truck which lasted for approximately 7 minutes before a BLEVE occurred.

The internal valve mounted in the belly of the truck was manually actuated, and equipped with a thermal fuse assembly.
Background Cont.

◊ From videos taken during the fire, prior to the BLEVE, the thermal fuse assembly can be seen immersed in direct flames.

◊ The thermal fuse assembly does not close the valve prior to the BLEVE.

◊ The internal excess flow valve does not shut until after the BLEVE has occurred.
The Fuse Assembly Operation

◊ The fuse assembly should provide adequate force to the release bar to close the valve when it is subjected to a temperature of 250°F.

◊ A fusible link melts which causes a spring to push against a nylon plunger which pushes against the release bar.
Force direction
Trailer Remains
Pre-BLEVE
The BLEVE
BLEVE
Valve Positions

600GPM Internal Excessive Flow Valve

SIMULATED TANKER BOTTOM

Pump

Discharge Piping

Hose Ball Valve. This valve was OPEN and being used by the driver.

Ball Valve
Left side of the truck. This valve was CLOSED.

Ball Valve
Internal Valve Operation
The internal valve was redesigned in 2003.
The redesign changes were significant, and the fuse assembly spring should have been changed.
The amount of force put on the release bar and the stop screw increased 30% on the redesigned valve.
The spring force in the fuse assembly was not increased to compensate for this change.
The spring force in release spring was not decreased to compensate for this change.
The redesigned internal valve was on the subject truck.
Redesigned Internal Valve
Fuse Assembly Operation

◊ Proper Fuse Assembly operation is highly dependant on:

- The friction force between fuse assembly cylinder and the nylon piston
- The friction between release bar and the knurled nut
- Annealing of the release spring
- Relaxation of the fuse assembly spring
- The force placed on the knurled nut by the handle
- The amount of engagement of the knurled nut on the release bar
Fuse Assembly Testing
Fuse Assembly Testing
Fusible Assembly Force

- Heat Gun FA 13
- Heat Gun FA 14
- Butane Torch FA 15
- Butane Torch FA 16
- Propane Torch FA 17
- Propane Torch FA 18
- Full Flame Burn FA 19
- Full Flame Burn FA 20
- Full Flame Burn FA 21

Force (lbs) vs. Time (s)
Why didn’t the valve close?

◊ The fusible assembly on the internal valve should have closed the valve after 20 seconds of fire exposure.

◊ The internal valve was redesigned in 2003. Both designs were tested by two separate forensic engineering companies, who conducted pull tests on the valves.

◊ The initial testing at CASE Forensics and MDE showed that the spring in the fuse assembly was not strong enough to reliably close the valve.
# Fusible Assembly Spring Testing

## Not heated

<table>
<thead>
<tr>
<th>Fuse assembly spring #</th>
<th>Compressive force (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>24.6</td>
</tr>
<tr>
<td>2</td>
<td>26.2</td>
</tr>
<tr>
<td>3</td>
<td>26.5</td>
</tr>
<tr>
<td>4</td>
<td>27.1</td>
</tr>
<tr>
<td>5</td>
<td>27.9</td>
</tr>
<tr>
<td>6</td>
<td>26.9</td>
</tr>
<tr>
<td>7</td>
<td>26.5</td>
</tr>
<tr>
<td>8</td>
<td>26.8</td>
</tr>
<tr>
<td>9</td>
<td>27.3</td>
</tr>
<tr>
<td>10</td>
<td>26.9</td>
</tr>
<tr>
<td>11</td>
<td>26.9</td>
</tr>
<tr>
<td>12</td>
<td>27.6</td>
</tr>
</tbody>
</table>

## Heated

<table>
<thead>
<tr>
<th>Fusible Assembly spring #</th>
<th>Heat method</th>
<th>Force exerted by fusible assembly spring (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>Heat Gun</td>
<td>27.6</td>
</tr>
<tr>
<td>14</td>
<td>Heat Gun</td>
<td>27.7</td>
</tr>
<tr>
<td>15</td>
<td>Butane Torch</td>
<td>27.9</td>
</tr>
<tr>
<td>16</td>
<td>Butane Torch</td>
<td>28.3</td>
</tr>
<tr>
<td>17</td>
<td>Propane Torch</td>
<td>28.6</td>
</tr>
<tr>
<td>18</td>
<td>Propane Torch</td>
<td>28.4</td>
</tr>
<tr>
<td>19</td>
<td>Large Propane Flame</td>
<td>27</td>
</tr>
<tr>
<td>20</td>
<td>Large Propane Flame</td>
<td>30.1</td>
</tr>
<tr>
<td>21</td>
<td>Large Propane Flame</td>
<td>29.4</td>
</tr>
</tbody>
</table>

**Range:**

- Not heated: 24.6 - 27.6
- Heated: 27 - 30.1
# Disassembled Spring testing

<table>
<thead>
<tr>
<th>Spring</th>
<th>Compression force (lb)</th>
<th>Compression force (lb)</th>
<th>Compressive force (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Subject Valve</td>
<td>Exemplar</td>
<td>Redesigned Valve</td>
</tr>
<tr>
<td>Release lever</td>
<td>43.2</td>
<td>57.6</td>
<td>30.7</td>
</tr>
<tr>
<td>Excess flow</td>
<td>165.2</td>
<td>158</td>
<td>115.2</td>
</tr>
</tbody>
</table>

![Image showing excess flow spring and release lever spring]
Road Conditions - Variability

◊ A road test was conducted (for approximately 3 months) to determine the relative effect of road use (dirt and grime, motion) on the force required to close the valve.
## Road Test - Results

<table>
<thead>
<tr>
<th>Force required</th>
<th>Force available</th>
</tr>
</thead>
<tbody>
<tr>
<td>average = 42.7 lbs</td>
<td>Fusible assembly provides 24-30 lbs of force</td>
</tr>
<tr>
<td>st. dev = 6.8 lbs</td>
<td></td>
</tr>
<tr>
<td>max = 57 lbs</td>
<td></td>
</tr>
<tr>
<td>min = 24 lbs</td>
<td></td>
</tr>
</tbody>
</table>
**The Fuse Assembly has NO Safety Factor**

◊ The subject fuse assembly has been shown not to have properly operated at CASE Forensics on many occasions.

◊ MDE Engineering has had similar results.

◊ The fuse assembly in old style valve likely did not actuate reliably upon heating.

◊ This is the **FINAL** device required to stop the flow of liquid propane in the event of a fire.

◊ The fuse assembly should **ALWAYS** close the valve when it is heated to temperatures above 250°F.

◊ The fuse spring **does not include an appropriate safety factor** and is **undersized**.
Safety Factor

\[
\text{Safety factor} = \frac{\text{material strength}}{\text{design load}}
\]

- A safety factor is the ratio of the material strength proportional to the design load.
- Common safety factors for mechanically functioning safety devices range from (3-4).
- In this case, the design load exceeded the material strength.
Conclusions

◊ The fusible assembly on the internal valve did not function adequately to close the internal valve

◊ The fusible assembly may never have reliably worked on the old style internal valve

◊ The fusible assembly on the redesigned valve does not function reliably, and does not include a factor of safety sufficient to ensure reliable operation
QUESTIONS?