Understanding Overpressure Scenarios and RAGAGEP

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Presentation topics

- Pressure vessel failure
- RAGAGEP to manage overpressure risk
- Deviation from RAGAGEP (in PHA)
- Closing a residual risk gap for overpressure
- Human error related to overpressure protection

**Objective**: Provide a survey of essential elements to manage overpressure risk in process industries
Pressure vessel failure data

- CCPS PERD
- Lees LP
- IEEE-500
- TNO Purple Book
- Smith and Warwick

Data indicate $1 \times 10^{-4}$ to $1 \times 10^{-5}$ (per year) likelihood of catastrophic failure.
Pressure vessel failure

“I cannot bring to mind any process vessels that were definitely over-pressured and failed because a relief valve did not open.”
Norman Lieberman, *A working Guide to Process Equipment*

An anecdotal statement that subjectively validates the low failure frequency
Pressure vessel failure

Pressure vessel failures (causes) and probability distribution

1. “Residual” failures ..........(≈1/3)
2. Corrosion ..................(≈1/3)
3. Brittle Fracture ..........(≈1/3)
4. Deformation failure ......(2%)

(API-521 scenarios)
Pressure vessel failure API-521 scenarios

Hydraulic Overpressure

MAWP

Undesired Rxn

HP Source

Blocked Outlet - Vapor

Tube rupture

Blocked Outlet - Liquid
RAGAGEP to manage overpressure risk

- ASME Boiler and Pressure Vessel Code, Section VIII, Pressure Vessels (c.1911)
- API STD 520 (1955)
- API STD 521 (1969)
- CCPS publications
- Engineering design books
Deviation from RAGAGEP (in PHA)

Is the pressure vessel (and piping) protected by a PRV?

- “Open communication” rule for PRV
- PRV vs “System design”

ASME VIII U-1 (h), U-1 (j);
ASME VIII UG-133 (c), Appendix M M-5
ASME VIII UG-135 (d)(1), (d)(2)
ASME VIII UG-140 (formerly code case 2211)
Deviation from RAGAGEP (in PHA)

Is a PSE (rupture disk)/ PRV combination used?

- Backpressure (leaking PSE)
- PRV credit
- Monitor installation

ASME VIII UG-127 (b) (4)
Deviation from RAGAGEP (in PHA)

Related to Test Pressure:
1.3x MAWP –or–
1.5x MAWP (pre-1999)

Is PRV used to protect heat exchanger?

- Intent is to protect exchanger shell or channel head (for tube rupture case)
- Pressure protect the lower rated side if 10/13ths rule (2/3 rule) not satisfied
Deviation from RAGAGEP (in PHA)

Is hydraulic overpressure considered?

- It is not uncommon to find a PRV study has documented the liquid overfill case (API-521) as not credible based on operator response (10-30 min)
- Older PRVs may not be certified for liquid service

API 521 4.2.5 and 4.4.7
Deviation from RAGAGEP (in PHA)

Are secondary consequences considered?

- Disposal

1. The valve will open some day
2. When the valve opens, the vessel will be liquid full
3. The liquid will be at its B.P. at the pressure at which the relief valve opens
4. Assume source of ignition

API 521 6.3
ASME VIII UG-135
Deviation from RAGAGEP (in PHA) API-521 4.2.3

Is “double-jeopardy” claimed?

- Concept is used in API-521 to exclude multiple simultaneous (and independent) failures from relief design basis
- Concept is used in PHA as well to exclude multiple failure scenarios
- Example

#1st Failure
Valve malfunction open

#2nd Failure
Valve malfunction open

HP pipeline gas

FO

API 521 4.2.3

600# users

150# users

71st Annual Instrumentation and Automation Symposium for the Process Industries
Failures that are revealed (obvious), [e.g., impact production], and will be restored in a timely manner are candidates for “double-jeopardy”
Deviation from RAGAGEP (in PHA)

API-521 4.2.3

Calculate simultaneous failure frequency:

- \((F_1 \times P_2) + (F_2 \times P_1)\)
- \((1/10\,\text{yr} \times 1/10\,\text{yr} \times 8\,\text{hrs} \times 1\,\text{yr}/8760\,\text{hrs}) + \ldots\)
- \(= 1\times10^{-5}/\text{yr}\)
Deviation from RAGAGEP (in PHA)

Use of HIPPS (SIS) in lieu of PRV

- ASME VIII UG-140
  (formerly code case 2211)

Issues

- SIL target for HIPPS
  - UG-140 no PRV (SIL 3)
  - UG-140 w/ PRV \textit{and} system design (per LOPA)
  - API-521 (existing vessel) (per LOPA)

- Human error/ Human factors
Residual risk gap for overpressure

A residual or “nuisance” risk gap is created in LOPA the following way:

\[ 1 \times 10^{-4} = (1 \times 10^{-1}) \times (1 \times 10^{-2}) \times \text{gap} \]

Target = ICF x PSV x (gap)

- Gap ≤ 10 (one IPL)
- Why is this a “nuisance” gap and what can be done?
Residual risk gap for overpressure

(API-521 or PHA) Causes of Overpressure

- Control system failure (BPCS) – generic 1/10
- Human error – generic 1/10 to 1/100

PRV IPL credits

- Generic (2 IPL credits)
- Should be calibrated with TMELs to close API-521 overpressure scenario?
Residual risk gap for overpressure

- How to close the gap
- “Sharpen the pencil”
Human error related to overpressure protection

- PRV vs a HIPPS (SIS)
- To get an instrumented system as reliable as a PRV requires redundancy and more testing (i.e., increased complexity)
### Human error related to overpressure protection

<table>
<thead>
<tr>
<th>Human Contact Point</th>
<th>PRV</th>
<th>HIPPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardware design</td>
<td>Controlling case Size orifice</td>
<td>Sensor, Logic solver, Final element</td>
</tr>
<tr>
<td>Software design</td>
<td></td>
<td>Application logic</td>
</tr>
<tr>
<td>Safety system design</td>
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<td>SRS</td>
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<tr>
<td>Construction package</td>
<td>Piping design</td>
<td>Electrical design</td>
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<tr>
<td>Construction package</td>
<td></td>
<td>Instrument design</td>
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<tr>
<td>Construction package</td>
<td></td>
<td>Installation design</td>
</tr>
<tr>
<td>Testing/ restoration</td>
<td>Bench test</td>
<td>FAT, SAT, PT x 3 subsystems</td>
</tr>
<tr>
<td>Administrative control</td>
<td>Manage physical bypass w/ CLO valves</td>
<td>Manage physical and electronic bypass x 3 subsystems</td>
</tr>
<tr>
<td>Documentation</td>
<td>Relief valve folder</td>
<td>10-100 order mag. greater</td>
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<tr>
<td>Suppliers</td>
<td>1</td>
<td>5+</td>
</tr>
</tbody>
</table>
Human error related to overpressure protection

How can we achieve 1e-4 human error probability? (O&M phases)

1) Control human factors related to SIS
2) Provide “recovery factors” for human error
3) Reduce dependencies
Human error related to overpressure protection

“Top 10” SIS Human Factors (O&M phases) based on lessons learned from quantitative HRA

- Procedures (quality)
- Procedures (using them)
- Safety communications (across shift change)
- Practice (minimize cognitive demand)
- Reliance on memory (between steps)
- Motivation (competency = understanding)
- Fatigue.. 12 hr shifts (manage per API-755)
- Administrative control systems
Human error related to overpressure protection

- Recovery factors (O&M phases)
- Managing “restoration” of HIPPS / SIS following ITPM
- Low hanging fruit (ensure proper restoration following ITPM …)
  - Second check following ITPM
  - Periodic check between ITPM
  - CLO root valves to SIS/ IPLs
Human error related to overpressure protection

Reduce dependencies (O&M phase)

1. Awareness of one’s own errors
   ✓ Provide feedback
     • Statuses, positions, indications

2. Checking someone else’s work
   ✓ Active inspections (with check-list)
   ✓ Passive inspections (walk-around, scan the console, etc.)
   ✓ PSF (performance shaping factors)
     • It is better not to know whose work is being checked
Presentation summary

We’ve looked at:

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