Tank Vapor Recovery Safety in Design

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Overview

- Assess Common Tank Failure Mechanisms
- Review Best Practices in Design of VRU Systems
  - Piping Considerations
  - System Design Considerations
  - Operation of the Stack Valve
- Make Gas Concerns
  - Make up or Make Worse!!
- Suction Design Best Practices
- Compressor Design for VRU Service
Safety Considerations
Tank Failure Modes

- Corrosion – Roof and Floor
- Collapse – Vacuum
- Hydraulic Failure – Closed System Overflow
- BLEVE – Boiling Liquid Expanding Vapor Explosion
- Over-pressure - Frangible Joint vs. External Rafters
Tank Corrosion

Roof Corrosion

Floor Under Deposit Corrosion

Solution - Seal tank.
- Operate TVRU system at positive pressure.
- Avoid installing TVRU Drain Tanks

Solution – Inspect, Prep, and Coat floor and shell three feet up from the tank bottom

Source: Robert Asato, Ph.D, Leeward Community College. Used by Permission.
Source: Metallurgical Viability, Inc. Used by Permission.
Tank Vacuum Collapse

Simultaneous Operations

Painters on Roof
Hydrotest Crew on Ground

Solution - Communicate

Source: Walter Driedger – is not the photographer, he credits API
Tank Hydraulic Rupture
Closed Overflow System

Normal Operation

Start Overflow

Roof Hydraulic Rupture

Solution – Balance Line
Tank Boiling Liquid Expanding Vapor Explosion (BLEVE)

Steam Heater TCV fails open or Coil Ruptures

Solution:

- Steam Shutdown Valve (fail close) on inlet to tank coils or thermo panes
- High temperature shutdown monitoring temperature located high in water phase, not oil emulsion
Tank Over-pressure

Frangible Roof Joint

External Rafters

Shell to Roof Failure

Shell to Floor Failure
Typical VRU Design in an OCP

- Large pipe sizing and 316L Stainless Steel
- Long piping support spans with min deflection
- Eliminate sources of Oxygen IGF & Drain Tanks
- Press transmitter near furthest large gas source
- Oxygen sensor to mitigate corrosion and HEL
- Stack valve to mitigate Varec reseating leaks
- Cooling with cold potable water atomizer
- Make-up gas at inlet of compressor
- Oil-flooded rotary screw compressor
- More than one destination for TVRU gas
Vapor Recovery System Key Considerations

- VRU System Should be Plant Specific
  - One Size does not “fit All”
- Prioritize Recommendations based on
  - Tank Permit Requirements
  - Location of Flare or Export Gas System
  - Toxic Gas Release Mitigation – Ultrafab/Sulfatreat
  - Resources, Cost and Schedule
- Provide Training Pertaining to the Proper Design and Operation
  - Only as Good as the Operators
- Majority of VRU related deficiencies are the result of Poor Design
VRU Piping Design Best Practices

- **Design Piping to Minimize Pressure Drop**
  - Max Pressure Drop from Furthest or Largest Producing Gas Source should be \( \leq 0.5'' \) W.C at twice the maximum flow.

- **Construct system piping from 316L stainless steel thin wall schedule 10 piping,**
  - Large diameter 316L sch 10 is light weight with large section modulus allowing for 50 ft pipe support spans with minimal deflection/pocketing.
  - No need to design pipe support spacing for hydrotest loads, instead use low pressure (30 psig) service test with nitrogen and soap bubble test.

- **Concerns With Using Carbon Steel Piping**
  - Oxygen can form Iron Oxide Scale
  - Hydrogen sulfide can form Iron Sulfide Scale
  - Carbon Dioxide and Water can cause pitting corrosion.
**VRU Stack Valve Design**

- Stack valve should be centrally located
  - This will allow venting at one safe location that can be controlled and measured for reporting purposes.
  - This prevents individual tank PVSVs from opening.

- Stack Valve should be a tight shut-off high performance butterfly Valve
  - PVSV sealing surfaces do not seal tight after relieving which is the purpose of having a Valve upstream of the Varec.

- Stack Valve opens under the following conditions:
  - VRU Shutdown and/or pressure reaches 3.0” w.c.
  - VRU Discharge pressure is high due to no VRU gas outlet
  - Oxygen content in VRU gas is at 10% of the HEL

- Stack Valve assists operations with recording of deviation

\[
\frac{(Q_1 + Q_2)}{2} \times (T_2 - T_1)
\]

"w.c."
VRU System Design Best Practices

- Piping should be sized to limit pressure drop to 0.5” w.c. between compressor suction and all equipment connections, at a minimum of two times nominal flow.

<table>
<thead>
<tr>
<th></th>
<th>in W.C</th>
<th>psig</th>
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<tbody>
<tr>
<td>Tank Design Pressure</td>
<td>3.5</td>
<td>0.13</td>
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<tr>
<td>Stack Valve Relief Pressure</td>
<td>3.0</td>
<td>0.11</td>
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<tr>
<td>VRU Suction Pressure</td>
<td>2.0</td>
<td>0.07</td>
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<tr>
<td>VRU Recycle Valve Pressure</td>
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<td>0.04</td>
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<tr>
<td>VRU Make Up Gas Valve Pressure</td>
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<td>0.02</td>
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<tr>
<td>Tank Design Vacuum Valve</td>
<td>-0.8</td>
<td>-0.03</td>
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- Gas rate fluctuations from field due to POP’s and terrain induced slugging, day-to-night and seasonal temperature changes must be considered in the design.

*Note: Compressor Capacity Control, Recycle Valve, and Make-up Gas are all trying to control pressure at their set-points based on a single pressure transmitter located at the furthest tank and/or the largest gas source.
VRU Make-up Gas Considerations

- Make-up Gas helps to maintain positive pressure on tanks when the tank liquid level drops.
- Assuming that the piping system is sized properly, produced gas from one tank can serve as make-up gas to another tank.
- Make-up Gas competes with Produced Gas for capacity in the VRU piping system and Compressor.
- Make-up Gas is only required at the inlet of the VRU compressor suction scrubber.
VRU Typical Suction Design Deficiencies

- Cold Potable Water Atomizer
- Inlet Air Cooler
- (3") Diaphragm Seals and Welded Capillaries attached to Hermetically sealed Pressure and Level Transmitters
- 2" w.c. no negative pressure
- Compressor Suction Scrubber
- No Pocketing
- TVRU Compressor
- Scrubber Level Control Valve
- Condensate Pump
- 5 psig
- 5 psig
VRU Compressor Design Recommendations

- VRU compressors Not Ideal
  - Sliding vane, liquid ring, and Reciprocating are
  - Limited to a single stage compression ratio of 3.0 (30 psig discharge pressure) due to heat of compression
  - Compressor will shutdown on high discharge temperature.
  - More Staged Will Require Larger Foot print.

- VRU Compressor Recommended
  - Oil-flooded Rotary Screw Compressor
  - Single stage compression ratio of 8.0 (100 psig discharge pressure) due to the heat of compression being absorbed in the oil.
  - Minimized Leaks – Less Moving Parts
  - Liquid Flooded – Can Tolerate some Liquid Carry over.
Other Considerations

- Consideration must be given to downstream pressure drops on equipment such as coolers, sulfa-scrub columns, sulfa-treat columns, iron sulfide blockage, and the final pressure at the destination such as steam generators, casing gas collection system, disposal wells, or flare.

- Ensure more than one destination for VRU discharge gas such as steam generator, disposal well, flare, etc.
Key Considerations for VRU System

- Pipe sizing and materials
- Large piping support spans with minimal deflection
- No pocketing of piping
- Stack valve centrally located to mitigate tank Varec re-seating leaks
- Eliminate sources of Oxygen to VRU (i.e.: Flotation Cells and Drain Tanks)
- Oxygen sensor to mitigate corrosion and address higher explosion limit
- Pressure transmitter located on furthest and/or largest gas source
- Make-up gas at inlet of compressor
- Cooling with cold potable water atomizer
- Scrubber Condensate pump with level control valve
- Large diaphragm seals and welded capillaries
- Oil-flooded rotary screw compressor—high compression ratio
- More than one destination for TVRU gas
Questions or Comments?