RANGE RESOURCES®

Marcellus Shale Production Facility Emissions: Leak Detection Field Study

NOVEMBER 9, 2017

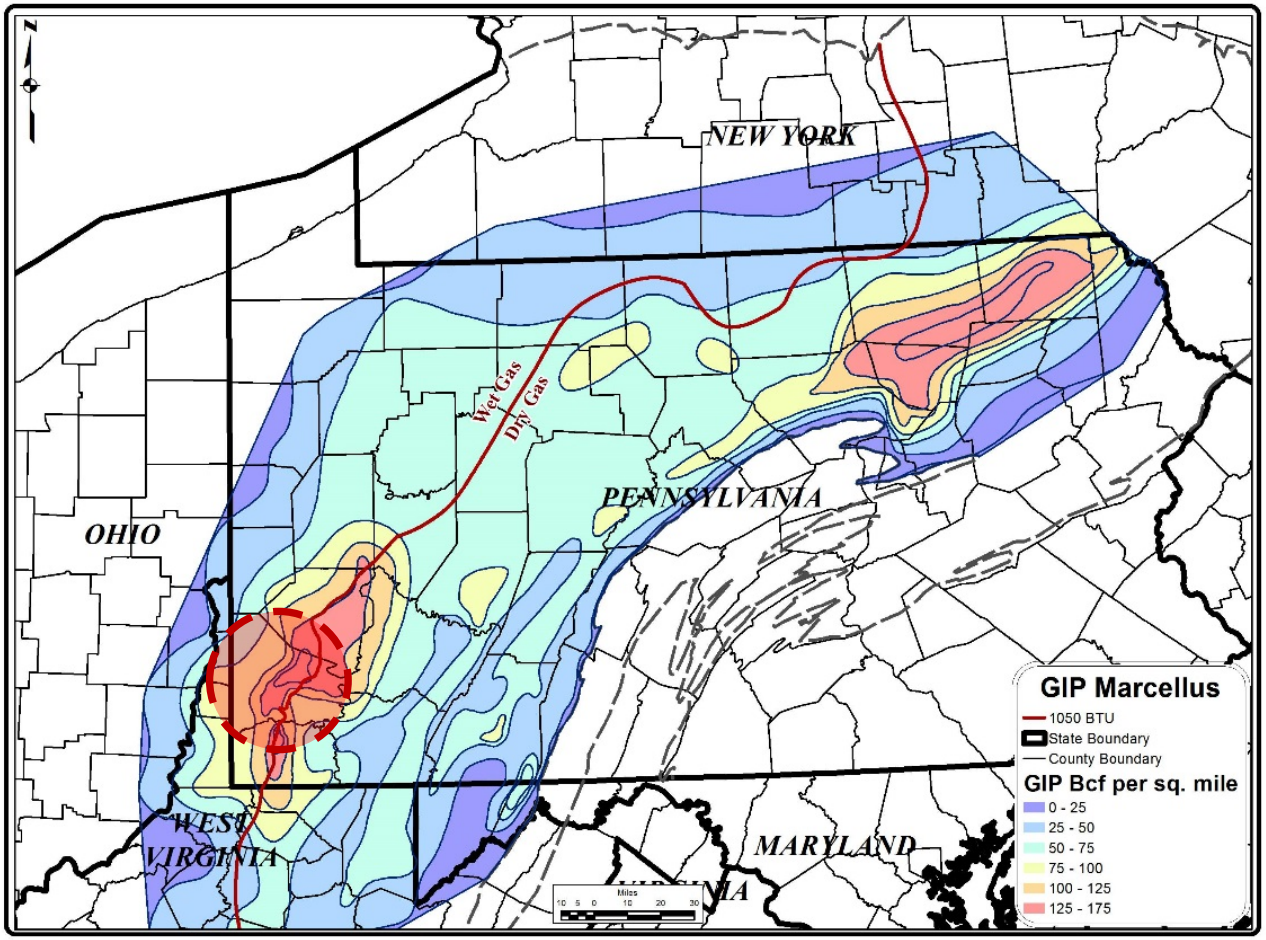
SUMMARY

- How many leaks? - Implementation of field-wide Leak Detection and Repair (LDAR) program generated ~68% reduction in fugitive leaks
- Where are leaks occurring? - Atmospheric stock tanks are the main contributor of emissions within a production facility
- Proper tank vent valves and set point selection are critical for reducing emissions & leak points

MOTIVATING FACTORS

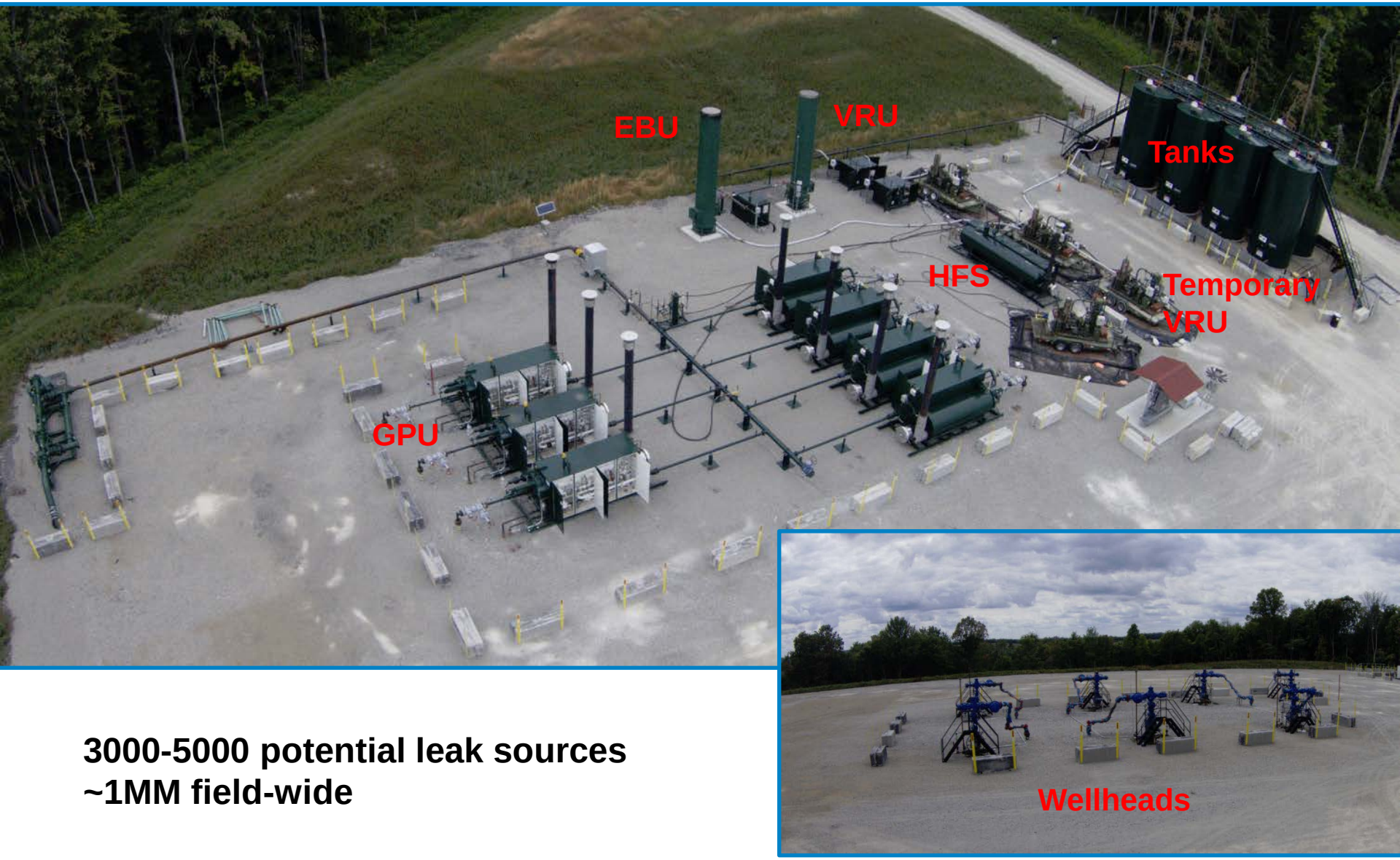
- Continued good environmental stewardship
- New regulations
- Public scrutiny
- Product loss

LEAK DETECTION AND REPAIR (LDAR) – AREA OF STUDY



Dry Gas + Wet Gas (60° API+)
~1000 horizontal wells

TYPICAL SITE LAYOUT



3000-5000 potential leak sources
~1MM field-wide

DEFINITION OF A LEAK

Any venting of gas or vapors to atmosphere when:

1. Outside design parameters or equipment set points

2. And visible with an optical gas imaging camera

Example: Leaking Weighted Thief Hatch (older industry standard)

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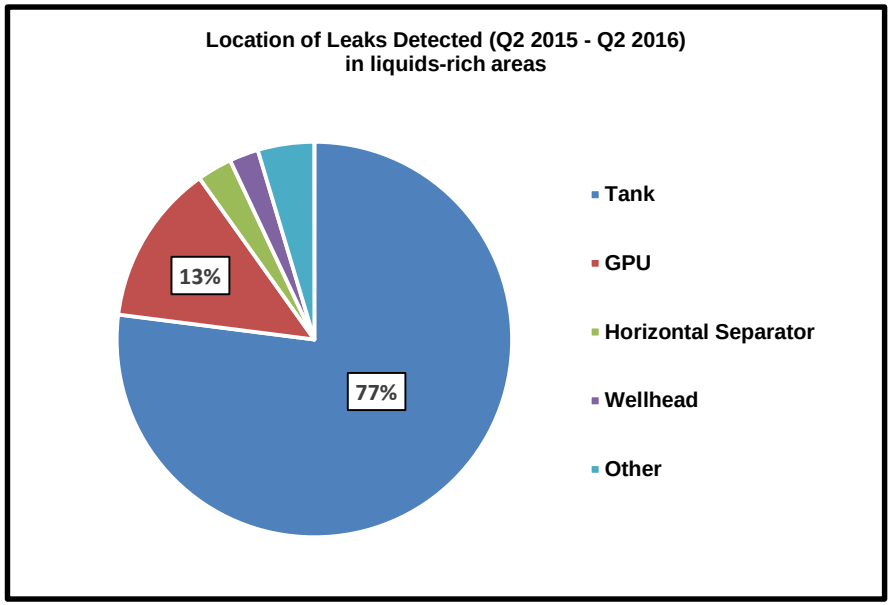
2. And visible with an optical gas imaging camera

Example: Leaking Stainless Fitting (solenoid)

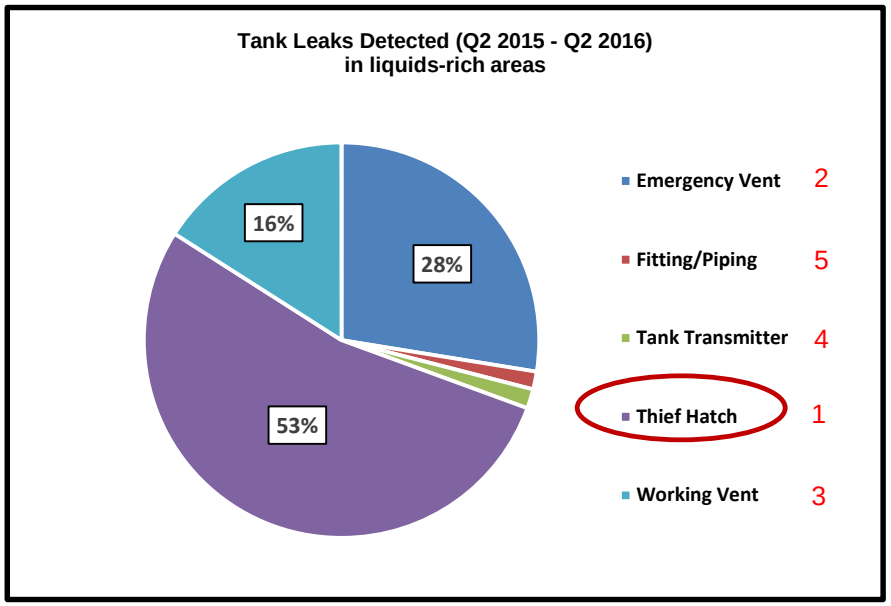
WHERE ARE LEAKS OCCURRING?

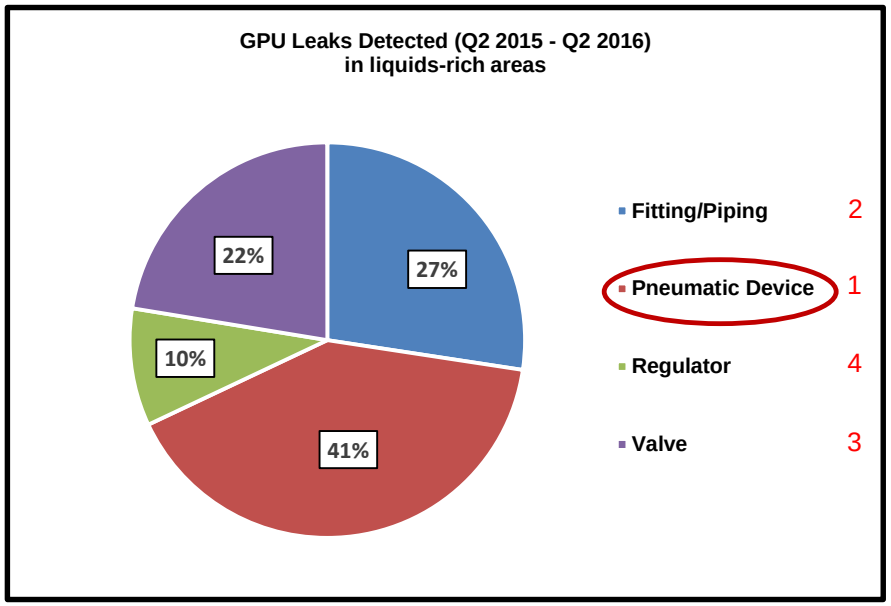


Key takeaways:

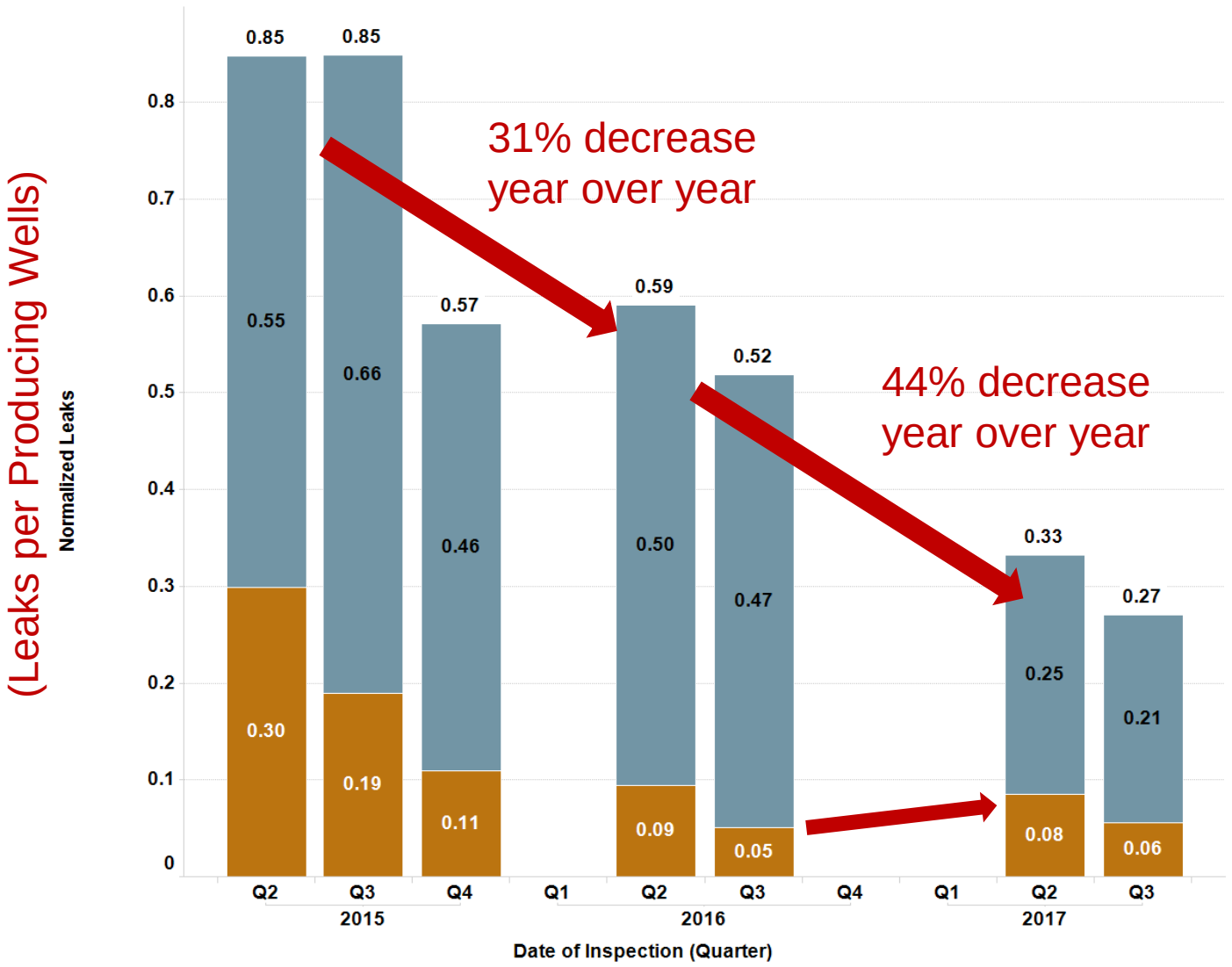
- Total leaks over 1-year period
- 77% of leaks are tank related (i.e. PRVs, thief hatches)
- 13% from Gas Production Units (GPU)

WHERE ARE LEAKS OCCURRING?





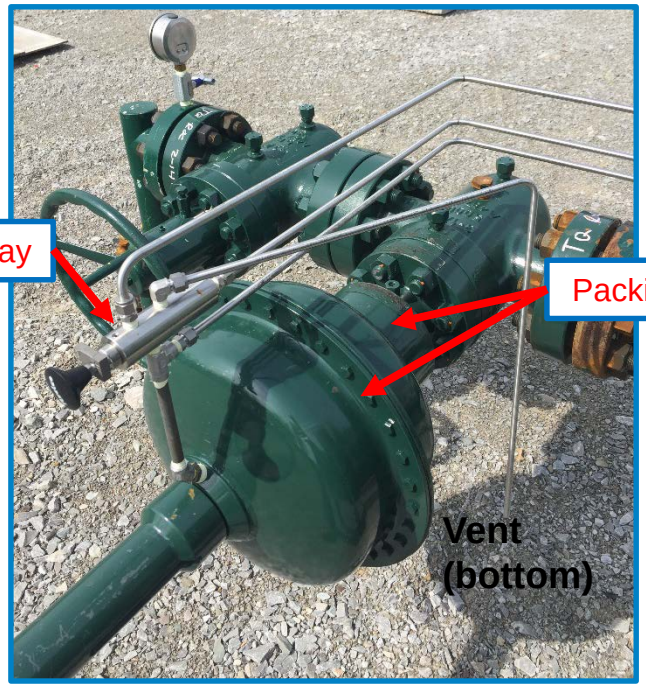
REDUCTION IN OPTICAL GAS IMAGING LEAKS

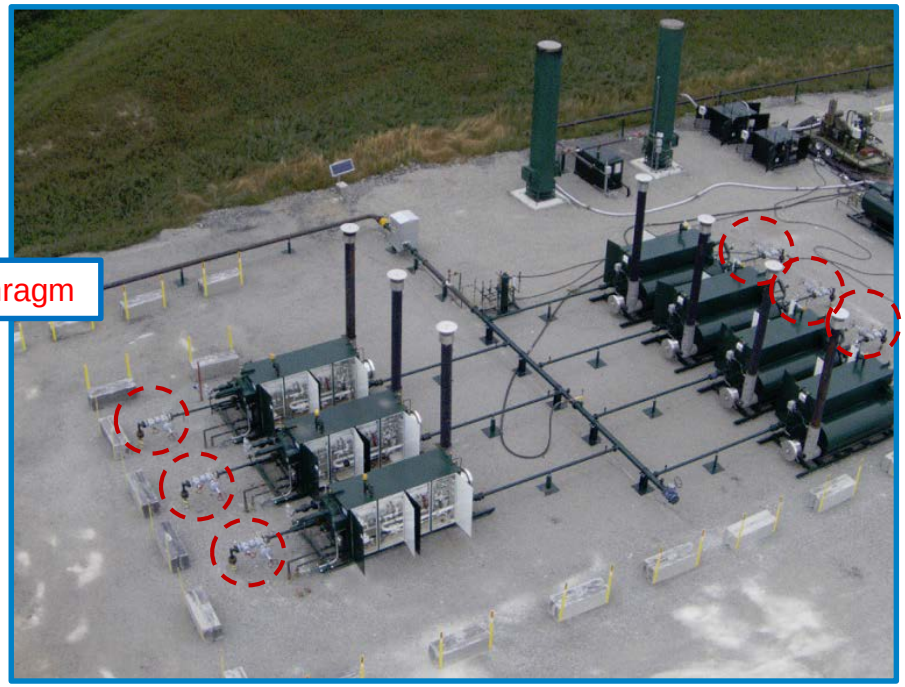


Why the increase with non-tank leaks?

- **Averaging 30-40 new non-tank leaks per quarter**
- **Have reached a 'maintenance mode' – fixing new leaks**

NON-TANK LEAKS – MAIN CONTRIBUTORS





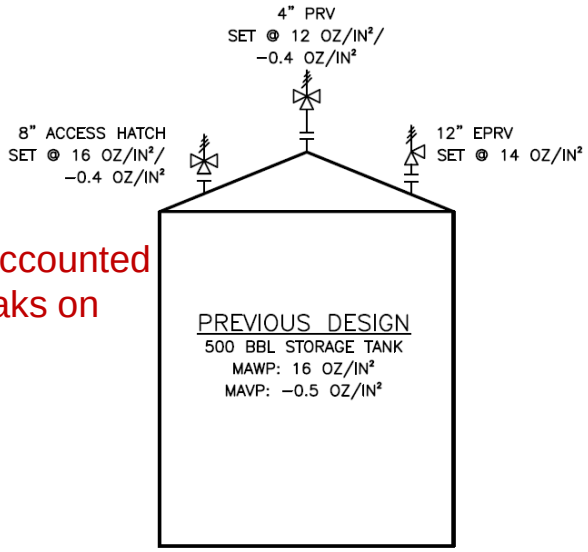
Secondary pneumatic ESD at GPU w/ Relay

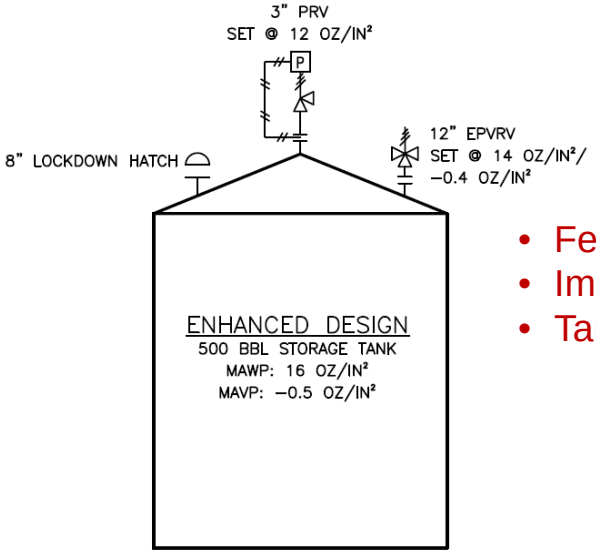
Relay – degradation of seal, which leads to leaking - elastomer upgrade

Pneumatic ESD – either packing or actuator diaphragm – elastomer upgrade/OGI testing prior to installation

TANK VENTING DESIGN

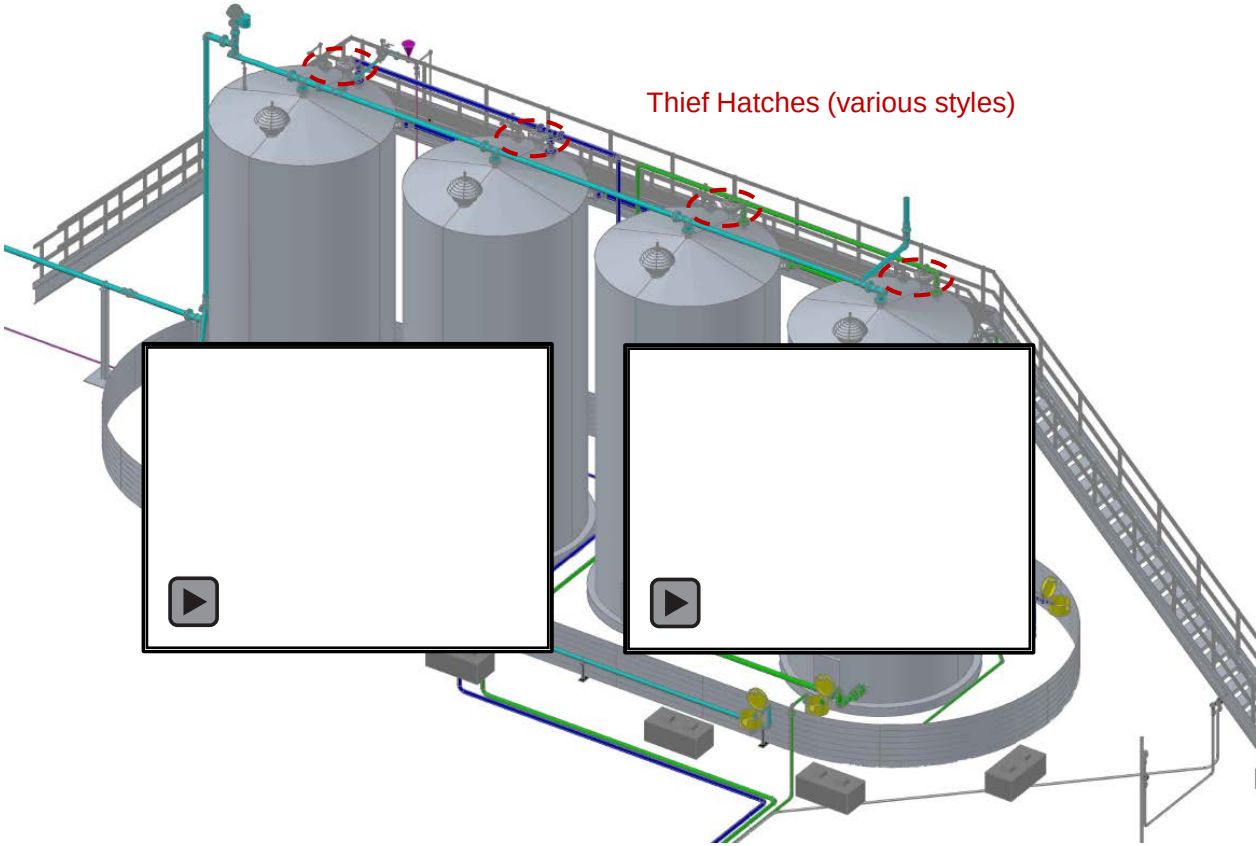
Thief hatch - Accounted for >50% of leaks on tanks





- Fewer leak sources
- Improved sealing
- Tank protection

PREVIOUS TANK VENTING DESIGN



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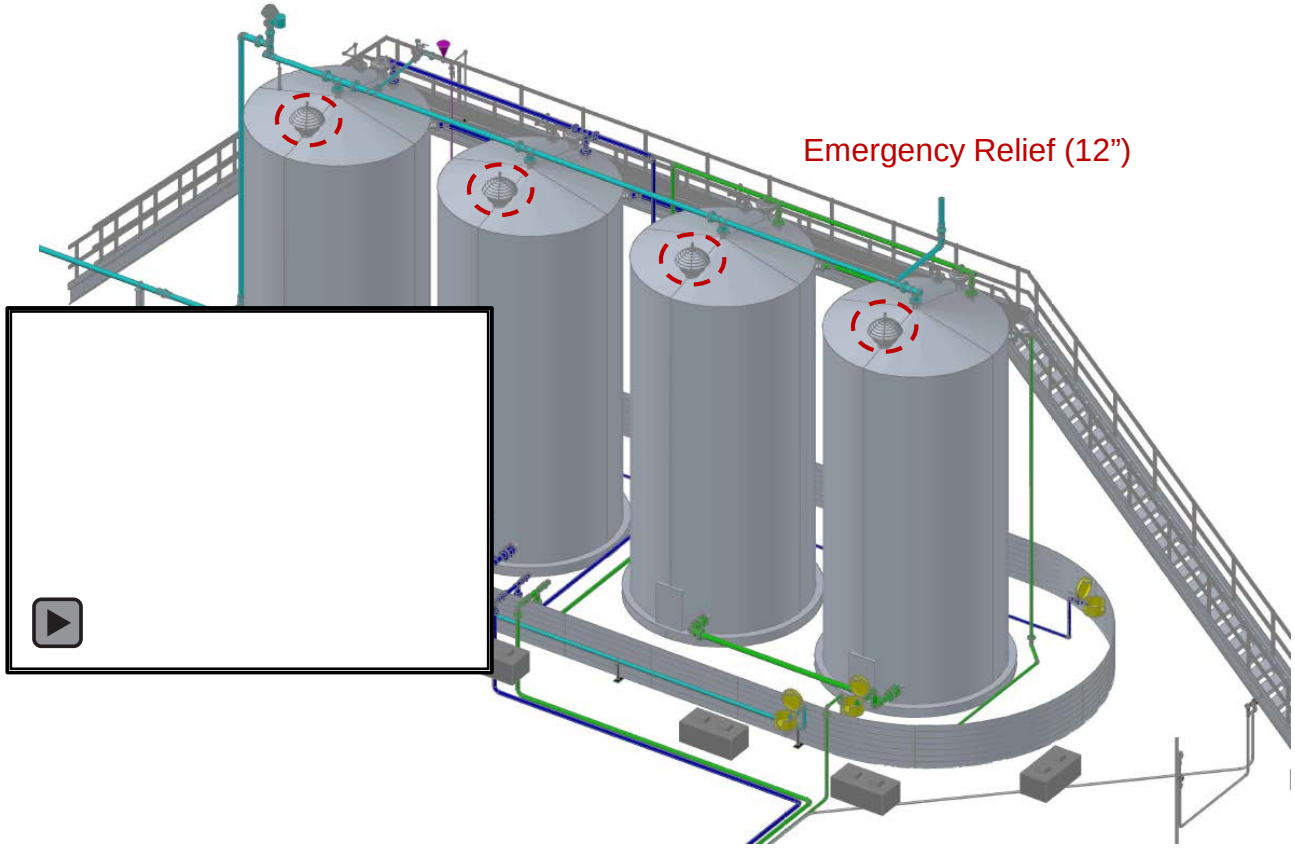

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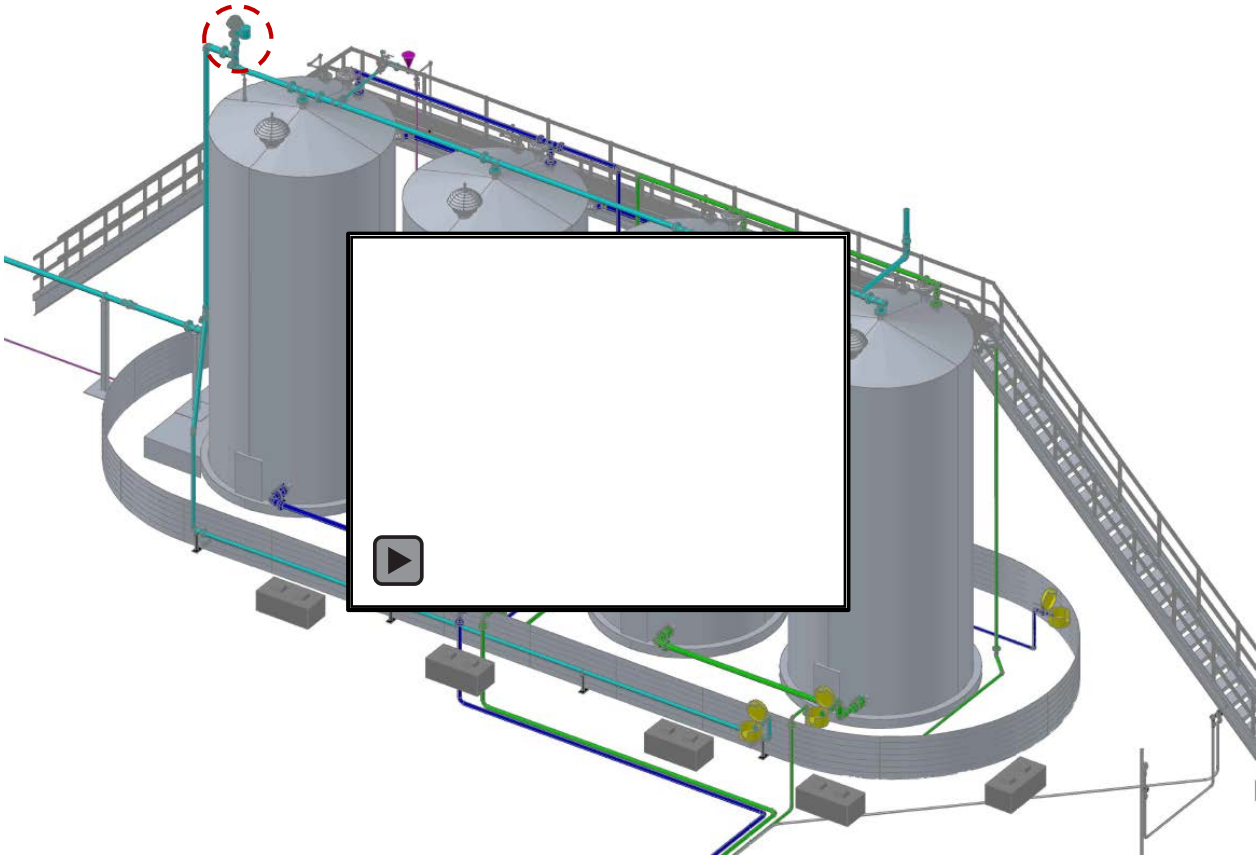
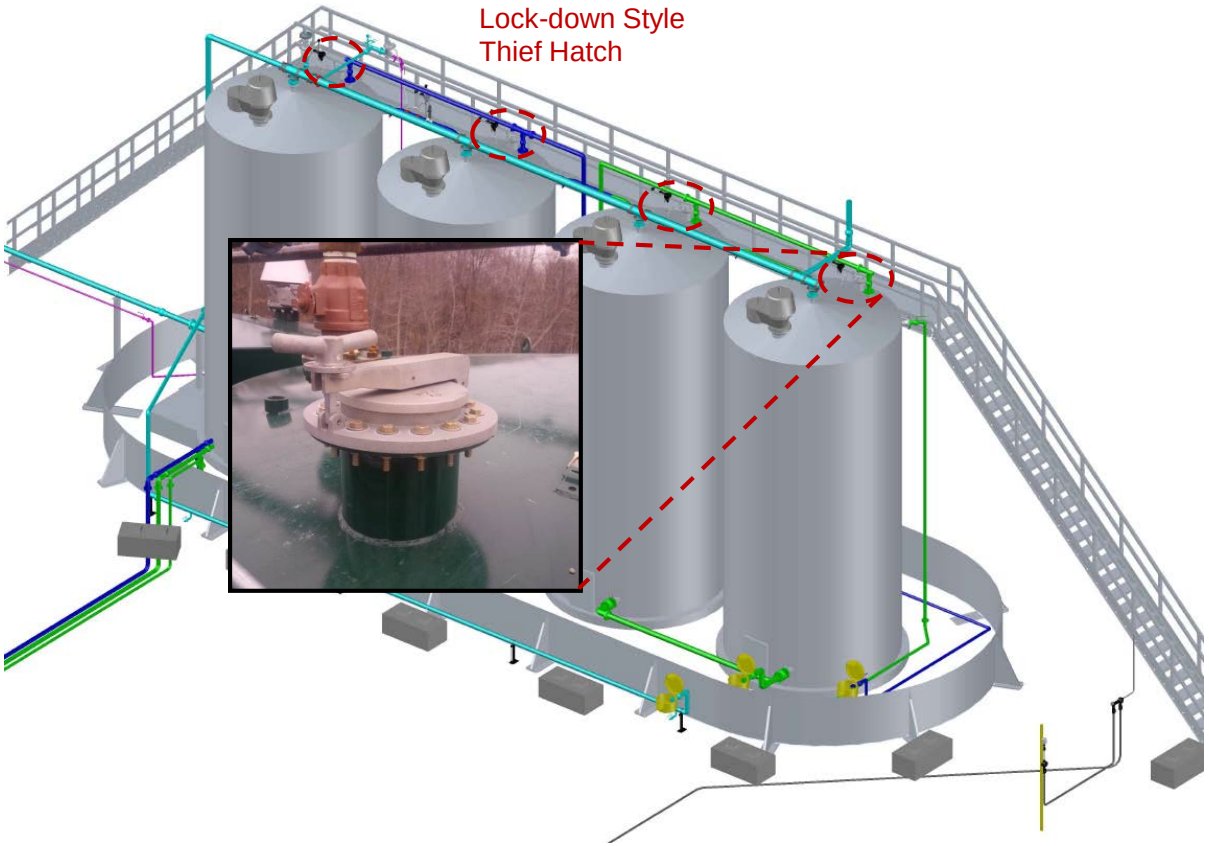


ENHANCED TANK VENTING DESIGN



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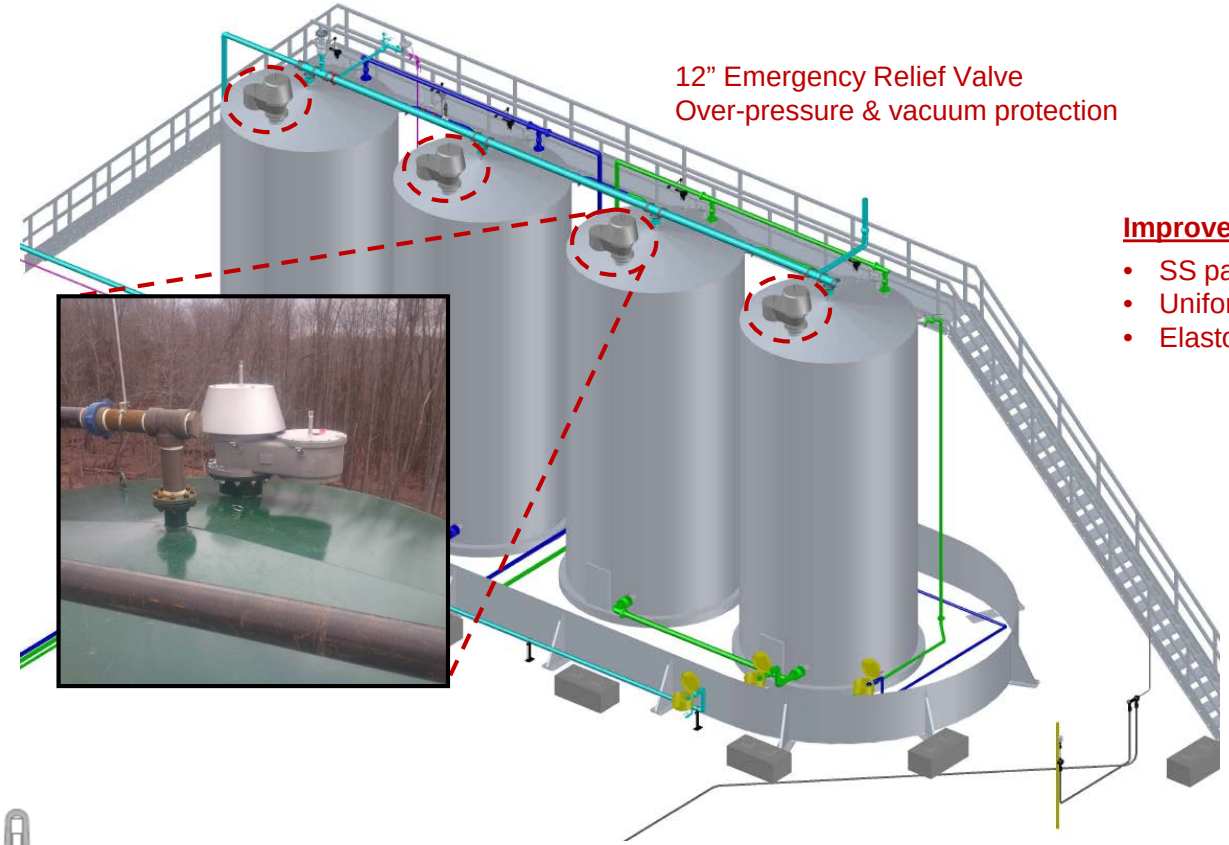
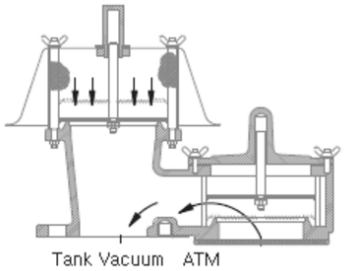


12” Emergency Relief Valve
Over-pressure & vacuum protection

Improvements:

- SS pallet seat vs. aluminum
- Uniform weight distribution
- Elastomer selection



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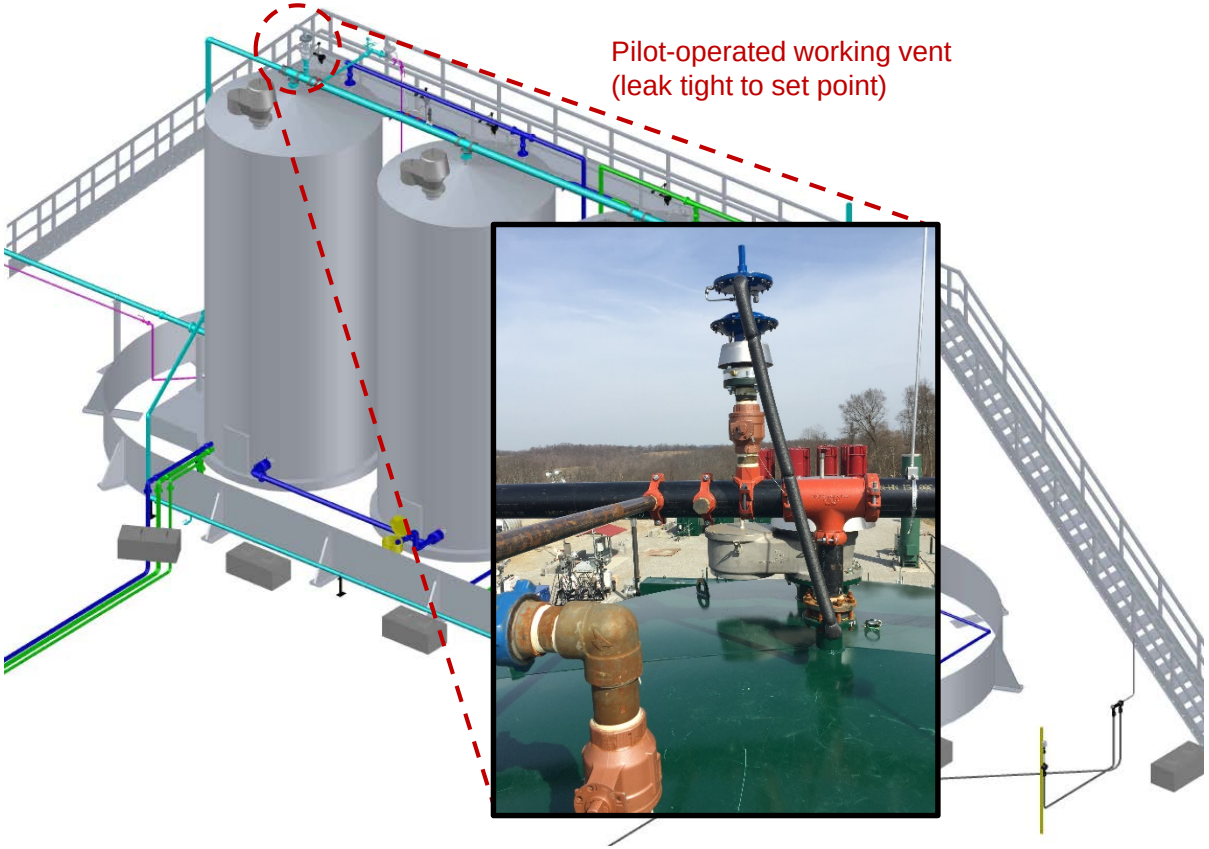
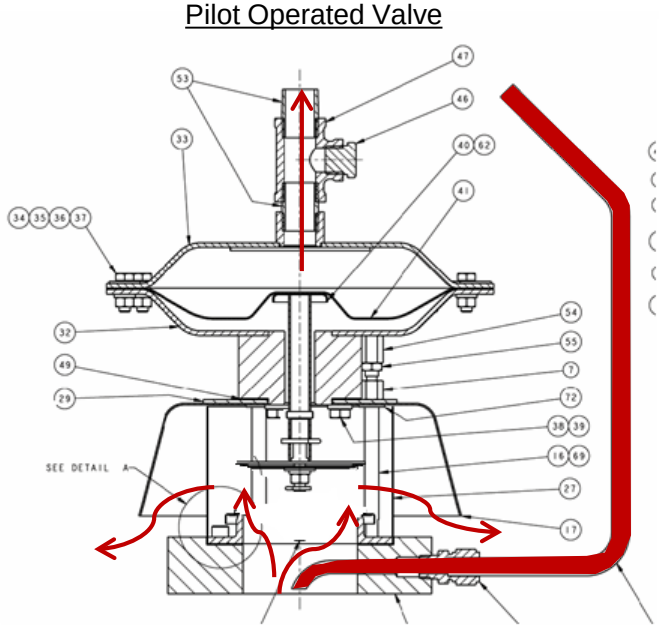


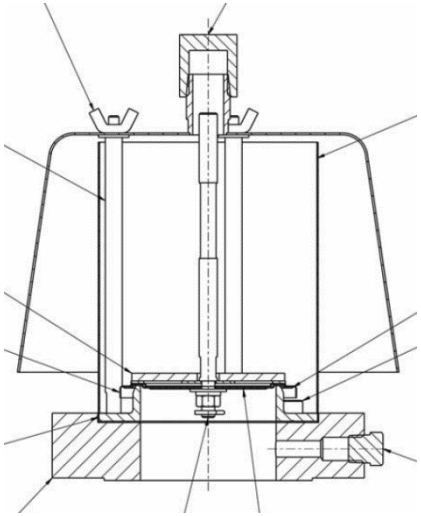
PILOT OPERATED VALVES

Pilot Operated Valve



Seat load increases with increasing tank pressure and is at maximum just below set point.

Weight Operated Valve



Seat load decreases with increasing tank pressure and is at minimum just below set point.

TANK VENTING DESIGN – LEAK TIGHT

THIEF HATCH REPLACEMENT EXAMPLE

Challenges:

1. “Bubble-tight” seal required
2. Maintain flow capacity
3. Provide pressure/vacuum relief and tank access

Designed for Range

TANK VALVE MAINTENANCE

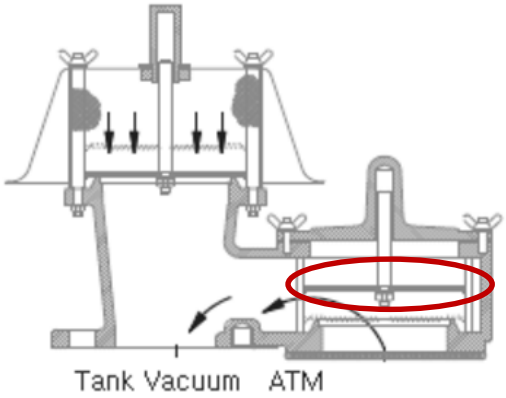
- Leaks will develop over time (even on the *best* valve technology)
- However - Any leaks on new tank valves can be corrected by cleaning and/or replacing diaphragms
- Parts are readily available to correct leaks
- Future work needed on diaphragm elastomer longevity

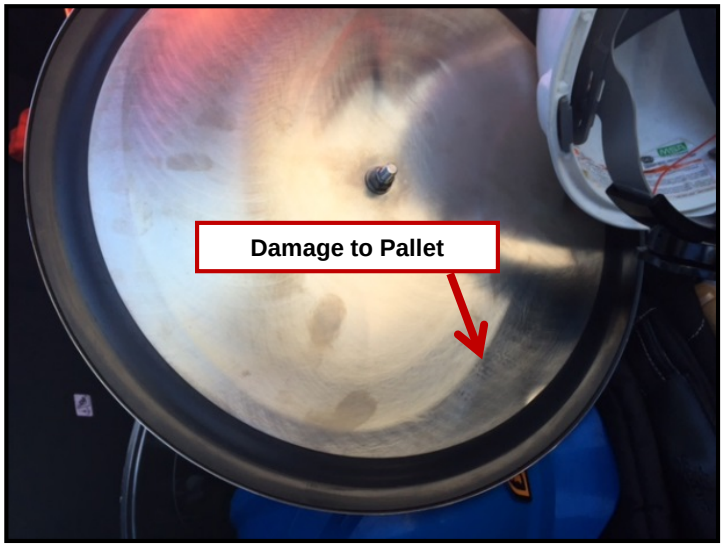
EPVRV – for newer tanks

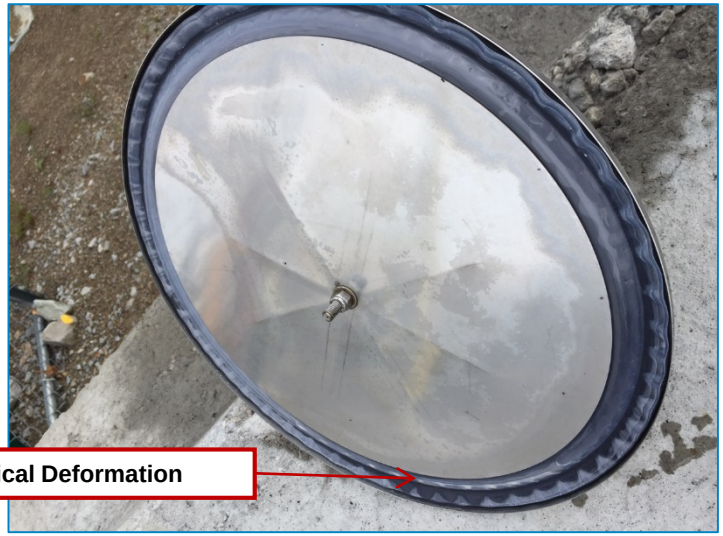
Weighted hatch – for older tanks

ATTENTION TO DETAIL

Pressure Sealing Washers







CONCLUSIONS

- Possible to significantly reduce fugitive leaks over a relatively short period of time for upstream O&G
- Focus on atmospheric stock tank valve design is essential – almost 80% of fugitive leaks are at the tank battery
- Leaks from other sources are minor and easily corrected (only 1 new leak per ~25 wells per quarter)

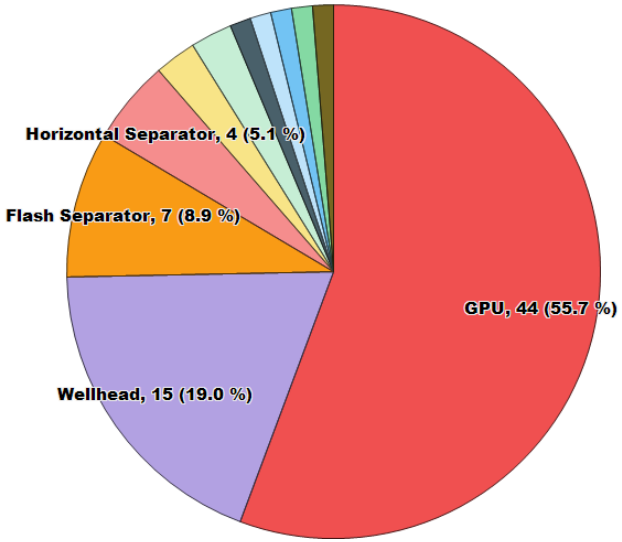
QUESTIONS?

NON-TANK LEAKS – WHY THE INCREASE?

- **Two quarters without inspections/leak corrected prior to Q2 2017 – More leaks started during that timeframe**
- **Q2 2016 and Q2 2017 leak distributions are very similar**
- **Data shows 30-40 new non-tanks leaks per quarter**

KEY TAKEAWAY – Field is approaching a “maintenance mode” for non-tank leaks

Q2 2016



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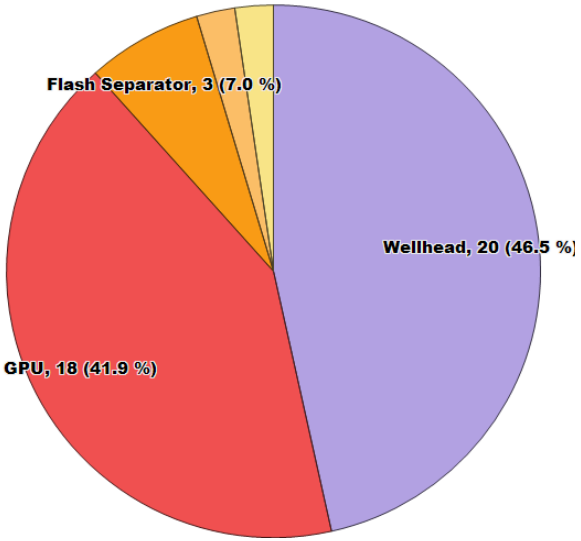
No prior quarter inspection

Q3 2016



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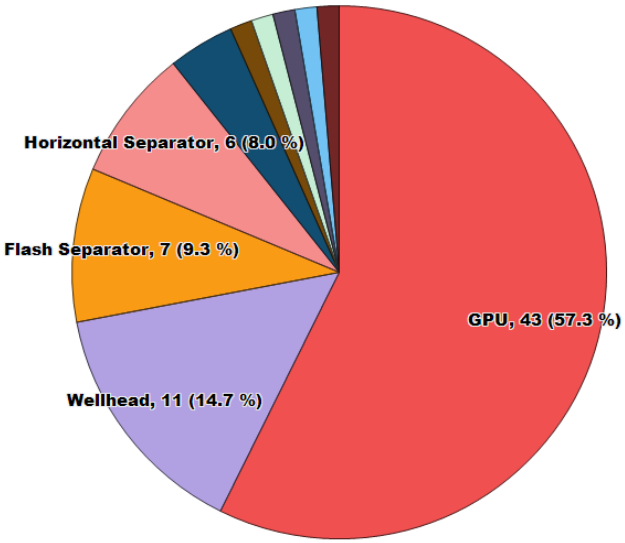
Q2 2017



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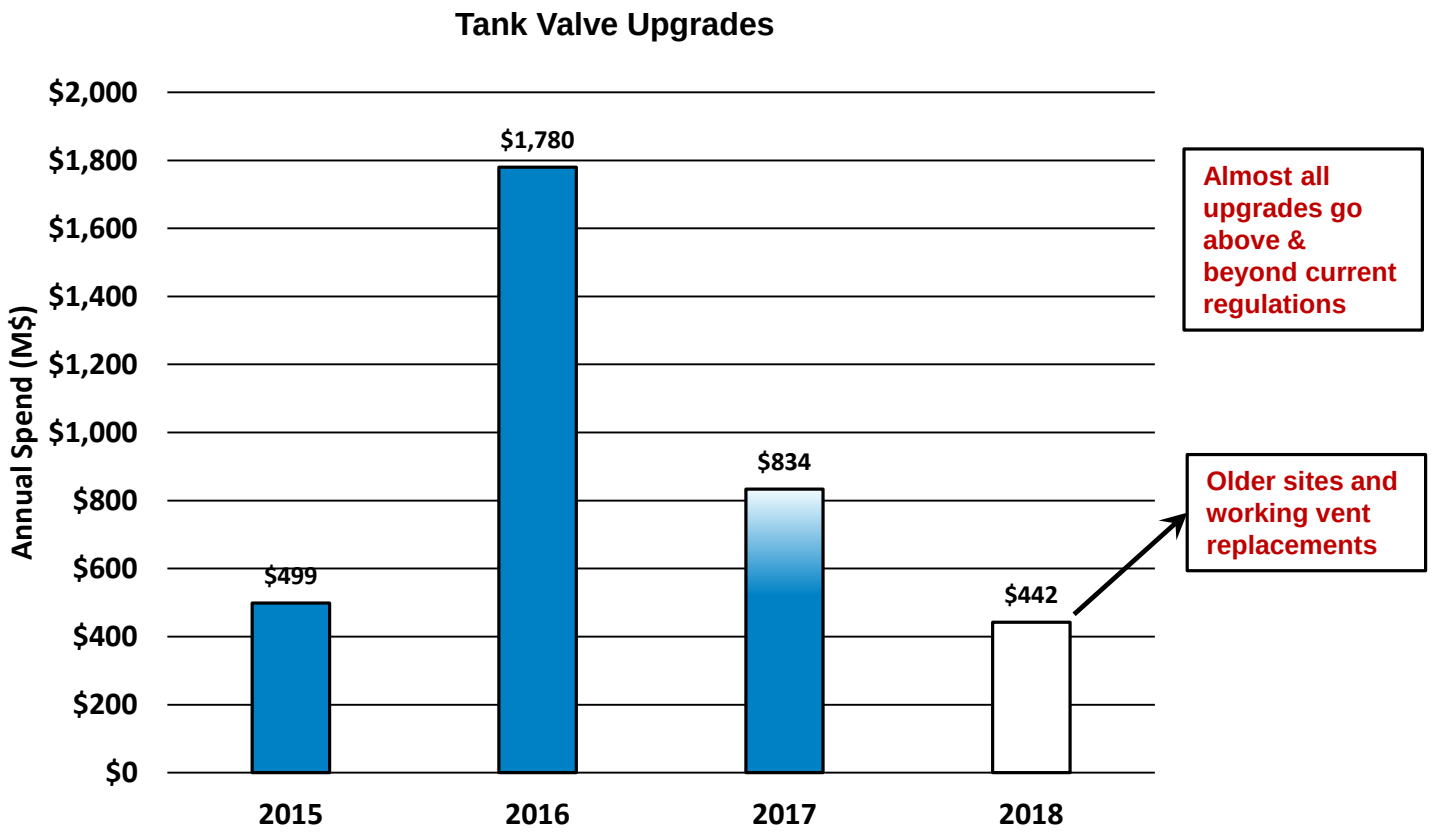
No prior quarter inspection

COST OF LEAK REDUCTION



2015 → 2018 = $3.5MM

2015 → 2018 = $3.5MM + maintenance/labor

~$4.7MM

ATTENTION TO DETAIL

‘Rippling’ effect caused by mechanical deformation – often installed on vacuum pallets

Test concluded = > 7 months without leak

OGI Concentration

“Optical gas imaging equipment is capable of imaging a gas that is half methane, half propane at a concentration of 10,000 ppm at a flowrate of ≤60g/hr from a quarter inch diameter orifice”