Identification of Improvement Opportunities

Calculation Method Verification

Measurable Results
Emissions Reported by Category (Subpart W CH$_4$)

Identification of Improvement Opportunity

- Liquids unloading was the main contributor to 2018 Subpart W CH$_4$ emissions

- Occurs during process of unloading a well to allow for gas flow

- How can we reduce this number through engineering actions?
  - System contained unloading events
    - Plunger Lift
    - Capillary Strings
    - Pad Compression
1: Loading
Well production declines and eventually zero flows causing the well to load up.

2: Unloading
Well is shut and return to production by flowing to atmosphere, causing a “liquid unloading event”
Process Improvements Timeline

2017
- Begin testing plunger lift installs in middle of 2017.
- Identified 118 wells that required numerous manual liquid unloading events.
- Complete reduction in manual unloads on all operated plunger lift wells
- Total Systems Installed by year end 2017 = 16

2018
- Built on the success of 2017 and identified several other pads where manual unloads were a frequent requirement for flow.
- Observed uplift in production and reduction in manual unloading events.
- Total Systems Installed = 46, Total Systems = 62

2019
- Installed 60 more systems in Q1 2019
- Total Active Systems 108
- In addition to plunger lift systems, other means of emission reduction artificial lift systems were installed:
  - 4 Total Capillary strings by YE 2019
  - 3 pad compressors installed and operating by YE 2019 servicing 14 wells
Artificial Lift Success - Examples

Plunger Lift

Capillary String

Pad Compression
Liquid Unloading Calculation Verification

- **40 CFR Part 98 Subpart W lists 3 different calculation methods**
  - Calculation Method 1 – Equation W-7 using measured values
  - Calculation Method 2 – Equation W-8 for non plunger lift assist
  - Calculation Method 3 – Equation W-9 for plunger lift assist

- **Range Resources – Appalachia made piping changes to a Marcellus well in order to measure the vented gas during liquids unloading events in December 2018 to test the differences between Eq W-8 and W-7**

- **Two measurements were recorded**
  - Measurement 1 – Completed 12/13/18 resulting in Eq W-8 over estimating the emissions by 6.4%
  - Measurement 2 – Completed 12/29/18 resulting in Eq W-8 under estimating the emissions by 1.8%
  - Average of these two measurements results in a difference of 2.3% between calculated and measured.

- **Based on this confirmation it was decided that we would continue to use Eq W-8**
Identification - First Liquids Unloading Emissions Measurement

Venting Measurement #1 (12/13/18)

Start: 12:00 PM
Tubing 425 psia
Casing 640 psia

End: 1:09 PM
Tubing 430 psia
Casing 600 psia

Duration = 58 minutes
Vented Gas = 44.67 MCF
Calculated Eq W-8 = 47.48 MCF
*Calculation results in over estimation of venting by 6.4%
Identification - Second Liquids Unloading Emissions Measurement

Venting Measurement #2 (12/29/18)

Start: 12:00 PM
Tubing 440 psia
Casing 565 psia

End: 12:52 PM
Tubing 435 psia
Casing 535 psia

Duration = 53 minutes
Vented Gas = 42.66 MCF
Calculated Eq W-8 = 41.92 MCF
*Calculation results in under estimation of venting by 1.8%
Measurable Results

Range Resources CH4 Emission Reduction Trend for Basin 160A (Metric Tons /Year)

- 2018: 3,013 metric tons
- 2019 (EST): 1,471 metric tons
- 2020 (EST): 236 metric tons
Summary

- **RRC identified a series of opportunities to improve upon liquid unloading events throughout our NEPA asset.**
  - Installed 108 active plunger lift systems following 2017 GHG report
  - 4 total capillary strings installed by YE 2019
  - 3 pad compressors set and servicing 14 wells.

- **Confirmed to continue to use Eq W-8 to estimate emissions based upon verification through on-site piping changes.**

- **Throughout the last 3 years with initiative to reduce emissions based upon unloading events, we have seen a steady decline in emission numbers.**
  - **2017** – as reporting period initiated the program to reduce our emissions based upon liquid unloading events.
  - **2018** – built upon the success and creativity of the team to increase production, all the while reducing emissions through artificial lift alterations.
  - **2019** – addressed 90% of all the wells listed as having unloading events with with Plunger Lift, Capillary Strings, or pad compression, accounting for nearly 98% of our reportable emission calculations.
QUESTIONS?