Artificial Lift R&D Council

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# Impact of Ambyint's Machine Learning Closed Loop Optimization System on Horizontal Bakken Wells: Failure Analysis Case Study

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Ambyint

# Introductions



## Arsalan Adil

*Sr. Production Optimization Engineer*, **Ambyint**

**Background**

- *Sr. Petroleum Engineer*, **Flamingo Oil International**
- *Reservoir Simulation Engineer*, **IFP Beicip-Franlab**
- BA in Applied Mathematics and Comparative Literature from the City University of New York and MS in Petroleum Engineering from Heriot-Watt University

## Victoria Pons

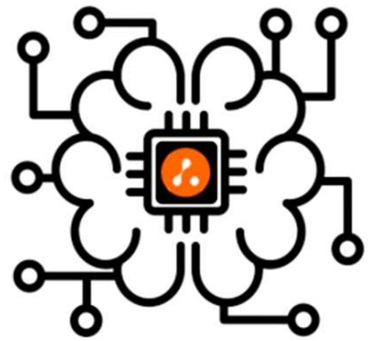
*CEO*, **Pons Energy Analytics**

**Background**

- *Senior Chief Scientist*, **Baker Hughes**
  - Steered the technical direction and customer focused product strategy for Well Manager, SROD, Production Link and deviated downhole tools
- *Senior Chief Scientist,* **Weatherford**
  - Pioneered new techniques for rod lift automation, artificial intelligence and data analytics as well as directed product strategy and direction as Artificial Lift SME for WellPilot and LOWIS
- *BS in Biology and Mathematics, MS and Ph. D. in Applied Mathematics from the University of Houston and holds* ***12 patents in the discipline of Artificial Lift and over 35 publications***

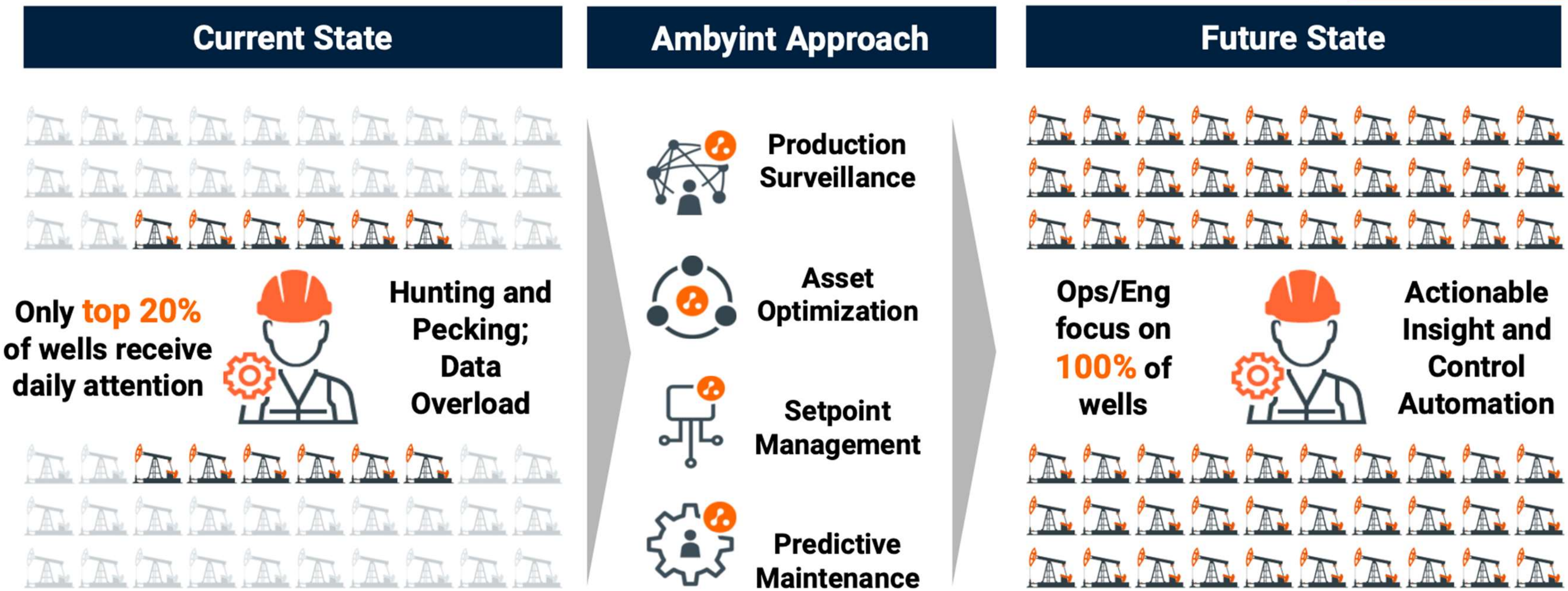
# Ambyint: Physics based AI critical to Production Optimization



| Physics | SME | AI |
|---|---|---|
|  |  |  |
| Physics-based > strictly data-driven optimization | SMEs with deep application expertise and field experience | Data science engineered for physics features of system |
| Best-in-class physics adapted for deviated / horizontal wells | Models, use cases and product built around operator priorities | Physics and SME leveraged to deliver AI-powered optimization |

# Ambyint: Methodical Approach Delivers Simplicity and Scalability



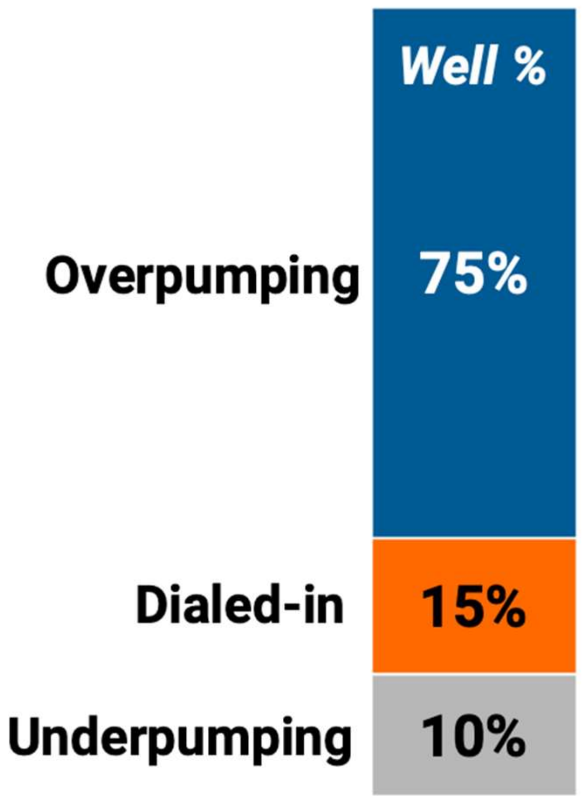



**Ambyint provides scalable, operational benefits for production teams**

# Ambyint: Using AI to Achieve Closed Loop Well Optimization at Scale

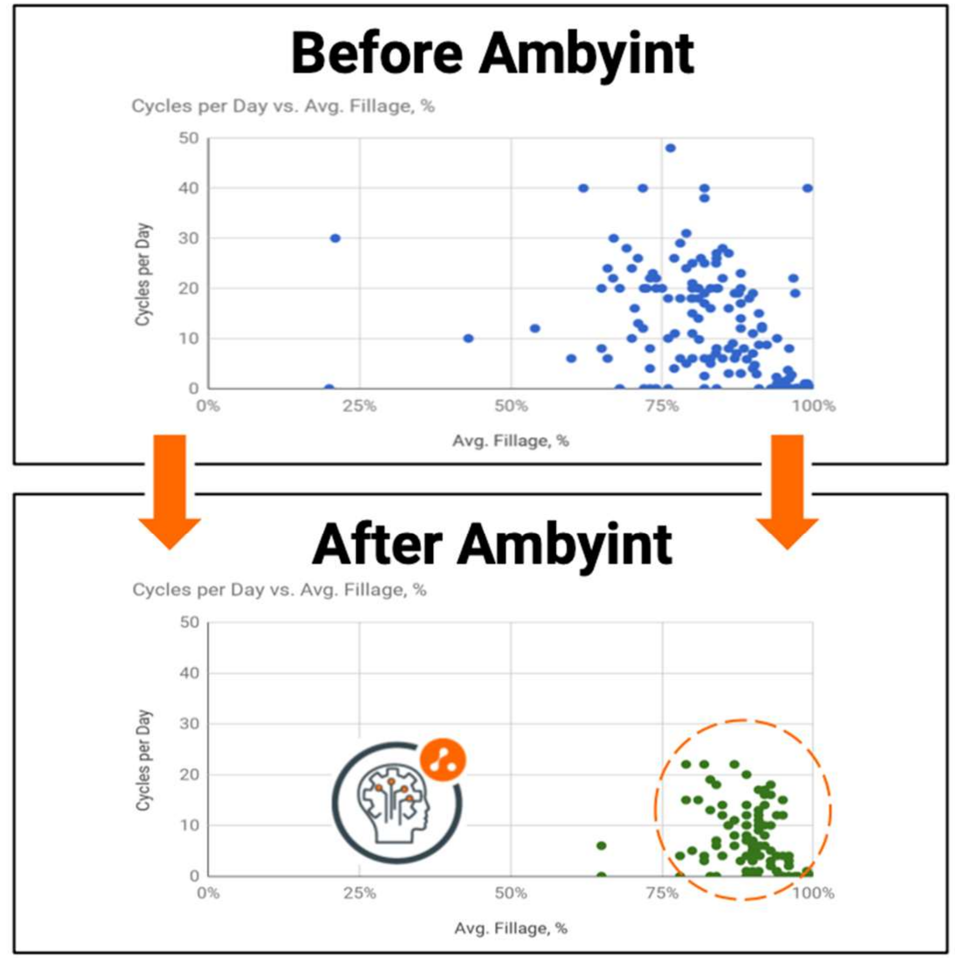


## Optimization Value Drivers




Reduce Failures
Reduce Workover Costs
Increase Efficiency
Reduce Electricity Costs

Increase Production




Note: breakdown based on empirical data from thousands of onshore wells

# Bakken Operator Case Study

Operator deployed Ambyint on 350 rod pump wells from 2017 – 2020 to autonomously optimize wells to:

- Increase production
- Reduce strokes
- Reduce failures
- Identify downhole conditions
- Increase pump fillage

Failure analysis was conducted on the Bakken case study where Ambyint adapted two models:

- Mean Time Between Failure - MTBF
- Failure Frequency - FF

# Data for Model

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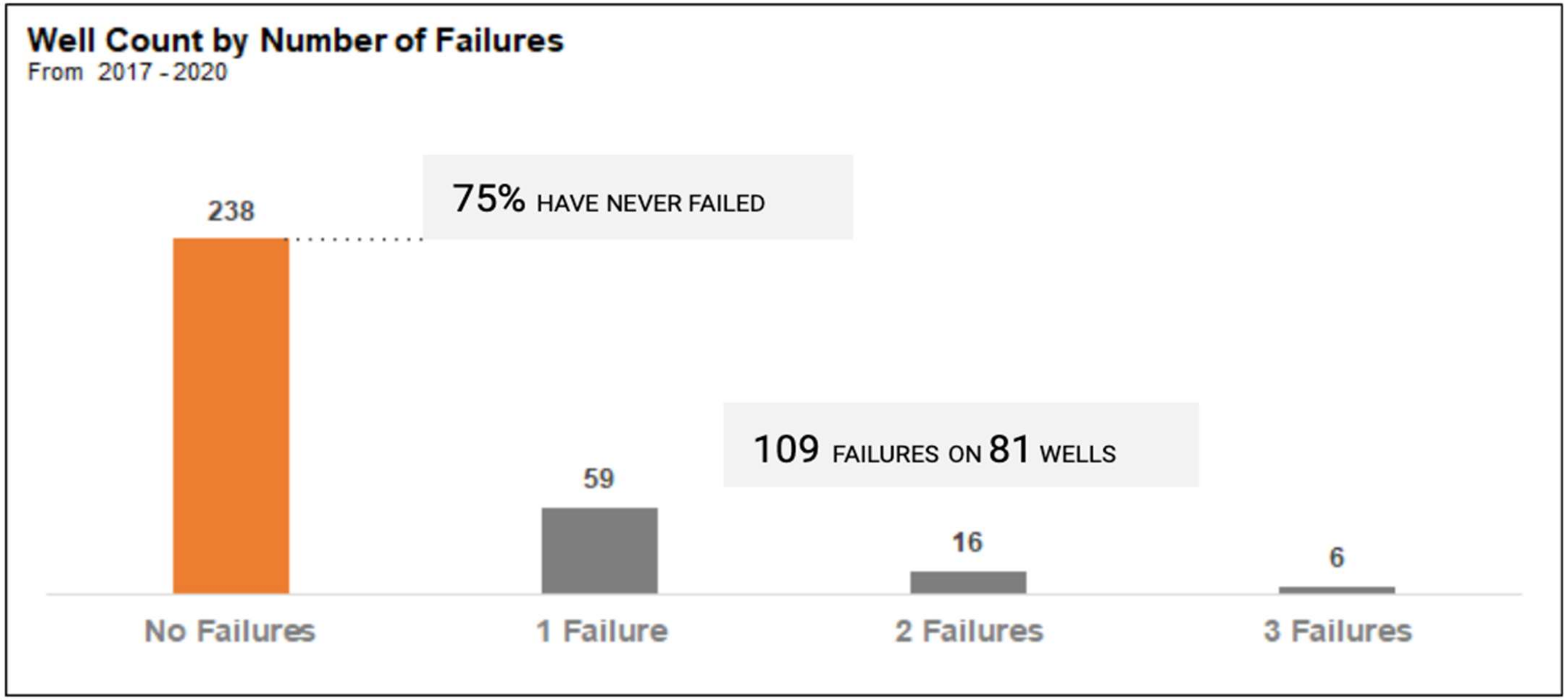
- Summary of Data Used for the Models
  - 319 wells
  - 1,675 lifespans from 2011 to 2020
  - Each failure was recorded with detailed event description: components failed, failure depth and failure mechanism in the operator failure log
- Scrubbed Failure Logs to Correct Errors
  - Incorrect install / failure dates that did not match up with each well's failure history (~300+ records had to be corrected)
  - Wells that had intermittent shut-ins (facilities repair, shut-in for drilling, frac jobs) had install dates that did not reflect install date as the last workover end date leading to lower (incorrect) runtimes for certain failures
  - Gaps in failure history for which no event was recorded
  - Runtimes were found to be inaccurate in several cases where SPM data was then used to validate if well was running or not (only for the time period well was on Ambyint)
  - Failure logs did not have all the Ambyint wells; 23 were found missing

# Case for Including Running Lifespans in Failure Analysis




- Only 25% of wells deployed on Ambyint failed, 75% were still running
- Need to have a criteria to include or exclude running lifespans

# Purpose of Case Study

**Objective:** Quantify and measure the impact of Ambyint in terms of increased runtime, decreased MTBF and decreased FF

**Hypothesis:** In the case of over-pumping, logically Ambyint should have a positive effect on wear and corrosion related failures due to lower pumping speeds, which imply smaller fluid velocities and reduced wear in the system

**Approach:** Comparing runtimes, MTBF and failure rate before and after Ambyint install

**Areas of Impacts:** Ambyint will have the most positive effect on wear, corrosion and corrosion enhanced wear and can delay end of life failures

**What can affect failure frequencies for Ambyint:**

- Ambyint well configuration set up must be complete and recommendations must be accepted
- Properly record & identify failure reason and failure component
- Corrective measures taken on repeated preventable failures
- Learn from past failures – Don’t repeat the same mistakes

**How do we know if Ambyint had an impact on well:**

- SPM data is positive
- # accepted recommendations > threshold
- Autonomous Set Point Management (ASPM) is active

# Modeling Definitions

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- "Lifespan"
  - Runtime record of a well with a specific install date / start date and end date. Can be either a 'Failure' or a 'Well Running' record
- Status Classification: "Pre-Ambyint", "On-Ambyint", "Split Lifespan", "Missing Lifespan"
  - **"Pre-Ambyint"** - Runtime records / lifespans on a well before Ambyint install
  - **"On-Ambyint"** - Runtime records / lifespans on a well after Ambyint install
  - **"Split Lifespan"** - Unique record (only 1 per well) where the runtime record is divided between 'On-Ambyint' AND 'Pre-Ambyint' based on ambyint install date; split lifespan can be classified a 'Failure' or as a 'Well Running'
  - **"Missing Lifespan"** - runtime records for which there is no event recorded; such lifespans occuring 'On-Ambyint' have been corrected using SPM data (if SPM data shows running its runtime is included and if SPM shows not running its considered as downtime)

| Well Name | Ambyint Install Date | Pre-Amb / On-Amb | % On Amb | Start | End | Duration | Pre-Amb | On-Ambyint | SPM_CHK | CLASS_CHK | Event | Color Code | OP Rec Accepted | UP Rec Accepted | Total Recs Accepted |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well # 1 | 11/29/2018 | Pre-Amb | | 12/11/2014 | 1/26/2015 | 46 | 46 | 0 | 0 | | Tubing Failure | | | | |
| | 11/29/2018 | | 14% | 1/26/2015 | 7/6/2019 | 1622 | 1403 | 219 | 176 | 137 | | | 0 | 0 | 0 |
| | 11/29/2018 | On-Amb | 100% | 7/6/2019 | 2/7/2020 | 216 | 0 | 216 | 216 | 216 | Rod Failure | | 0 | 2 | 2 |
| | 11/29/2018 | On-Amb | 100% | 2/23/2020 | 7/14/2020 | 142 | 0 | 142 | 135 | 140 | Well Running | | 6 | 0 | 6 |

Split Lifespan

Theoretical Run-time

Actual Run-time validated for 'On-Ambyint' lifespans

Missing Lifespan (runtime validated with SPM & Classification checks)

# Modeling Definitions (continued)

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- Optimization Classification: ‘Non-Amb’ & ‘Amb’
  - **‘Non-Amb’** - Any lifespan that has no accepted recommendations; by default all ‘Pre-Amb’ lifespans qualify as ‘Non-Amb’, **however a ‘On-Amb’ lifespan that has no recs accepted will also be classified as ‘Non-Amb’**
  - **‘Amb’** - Any lifespan that has accepted recommendations generated by the Ambyint’s ASPM algorithm; by default these can never be ‘Pre-Amb’

| Well Name | Ambyint Install Date | Pre-Amb / On-Amb | % On Amb | Start | End | Duration | Pre-Amb | On-Amb | SPM_CHK | CLASS_CHK | Non-Amb | Amb | Event | Color Code | OP Rec Accepted | UP Rec Accepted | Total Recs Accepted |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well # 2 | 7/31/2019 | Pre-Amb | | 9/9/2015 | 6/23/2016 | 288 | 288 | 0 | | | 288 | | Rod & Tubing Failure | | | | |
| | 7/31/2019 | Pre-Amb | | 6/23/2016 | 6/24/2016 | 1 | 1 | 0 | | | | | Waiting on Rig | | | | |
| | 7/31/2019 | Pre-Amb | | 6/24/2016 | 6/27/2016 | 3 | 3 | 0 | | | | | Workover / Shut-in | | | | |
| | 7/31/2019 | | 4% | 6/27/2016 | 9/17/2019 | 1177 | 1129 | 48 | 49 | 48 | 1177 | | | | 0 | 0 | 0 |
| | 7/31/2019 | On-Amb | 100% | 9/17/2019 | 9/21/2019 | 4 | 0 | 4 | 0 | 4 | | | Workover / Shut-in | | 0 | 0 | 0 |
| | 7/31/2019 | On-Amb | 100% | 9/21/2019 | 10/21/2019 | 30 | 0 | 30 | 0 | 3 | | | | | 0 | 0 | 0 |
| | 7/31/2019 | On-Amb | 100% | 10/21/2019 | 10/22/2019 | 1 | 0 | 1 | 0 | | | | Workover / Shut-in | | 0 | 0 | 0 |
| | 7/31/2019 | On-Amb | 100% | 10/22/2019 | 11/16/2019 | 25 | 0 | 25 | 0 | | | | | | 0 | 0 | 0 |
| | 7/31/2019 | On-Amb | 100% | 11/16/2019 | 11/20/2019 | 4 | 0 | 4 | 1 | | | | Workover / Shut-in | | 0 | 0 | 0 |
| | 7/31/2019 | On-Amb | 100% | 11/20/2019 | 2/4/2020 | 76 | 0 | 76 | 75 | 76 | 76 | | Rod Failure | | 0 | 0 | 0 |
| | 7/31/2019 | On-Amb | 100% | 2/4/2020 | 8/31/2020 | 209 | 0 | 209 | 56 | 66 | | | Well Running | | 0 | 1 | 1 |

# Modeling Definitions (continued)

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- Early Failure Lifespans
  - Early failures are classified as wells with a runtime of less than 60 days.
  - Reason for early failure is most likely makeup and Handling failures
  - These failures skew the results of the analysis since these occurrences are outliers to the rest of the results
- Both ‘Amb’ and ‘Non-Amb’ lifespans of a well are treated equally
  - Early failures from either Pre-Amb or On-Amb data are discarded from the analysis since we are not considering Make-Up and Handling failures in this study

| Well | Ambyint Install Date | Pre-Amb / On-Amb | % On Amb | Start | End | Duration | Pre-Amb | On-Amb | SPM_CHK | CLASS_CHK | Non-Amb | Amb | Event | Color Code | OP Rec Accepted | UP Rec Accepted | Total Recs Accepted |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well # 1 | 8/16/2017 | Pre-Amb | | 9/22/2016 | 10/7/2016 | 15 | 15 | 0 | 0 | | | | Rod & Tubing Failure | | | | 0 |
| Well # 2 | 11/21/2018 | Pre-Amb | | 9/25/2015 | 10/9/2015 | 14 | 14 | 0 | | | | | Rod Failure (Part) | | | | |
| Well # 3 | 12/13/2018 | On-Amb | 100% | 3/1/2019 | 3/13/2019 | 12 | 0 | 12 | 12 | 12 | | | Rod & Tubing Failure | | 0 | 0 | 0 |
| Well # 4 | 12/14/2018 | Pre-Amb | | 1/29/2015 | 2/7/2015 | 9 | 9 | 0 | 0 | | | | Rod Failure (Part) | | | | |
| Well # 5 | 1/17/2018 | On-Amb | 100% | 8/31/2018 | 9/1/2018 | 1 | 0 | 1 | 1 | 1 | | | Rod Failure | | 0 | 0 | 0 |

# Mean Time Between Failures - Model



$$\textbf{MTBF} = \frac{Total\ Runtime}{Total\ \#\ of\ Runtimes}$$

$$= \frac{Runtime\ (1) + Runtime\ (2) ... + Runtime(n)}{n}$$

**<u>Objective</u>**

- **Compare true MTBF of 'Non-Amb' lifespans of a well vs. 'Amb' lifespans of a well**
- **Determine success of Ambyint based on longer average runtimes**

# MTBF Model – Positive Result

- **Well 'Running' lifespans can be included and counted as a failure only if it exceeds the average RT of previous failures**

<u>*Case I: 'Amb' 'Well Running' Lifespan Included*</u>

| Well Name | Ambyint Install Date | Pre-Amb / On-Amb | % On Amb | Start | End | Duration | Pre-Amb | On-Amb | SPM_CHK | CLASS_CHK | Non-Amb | Amb | Event | Color Code | OP Rec Accepted | UP Rec Accepted | Total Recs Accepted |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well # 3 | 1/17/2018 | Pre-Amb | | 11/23/2015 | 2/4/2017 | 439 | 439 | 0 | | | 439 | | Rod Failure | | | | |
| | 1/17/2018 | Pre-Amb | | 2/4/2017 | 2/5/2017 | 1 | 1 | 0 | | | | | Waiting on Rig | | | | |
| | 1/17/2018 | Pre-Amb | | 2/5/2017 | 2/6/2017 | 1 | 1 | 0 | | | | | Workover / Shut-in | | | | |
| | 1/17/2018 | | 30% | 2/6/2017 | 6/12/2018 | 491 | 345 | 146 | 147 | 85 | 345 | 146 | Rod & Tubing Failure | | 0 | 2 | 2 |
| | 1/17/2018 | On-Amb | 100% | 6/12/2018 | 6/16/2018 | 4 | 0 | 4 | 1 | 4 | | | Waiting on Rig | | 0 | 0 | 0 |
| | 1/17/2018 | On-Amb | 100% | 6/16/2018 | 6/19/2018 | 3 | 0 | 3 | 1 | 3 | | | Workover / Shut-in | | 0 | 0 | 0 |
| | 1/17/2018 | On-Amb | 100% | 6/19/2018 | 8/31/2020 | 804 | 0 | 804 | 647 | 590 | | 647 | Well Running | | 3 | 2 | 5 |

'Non-Amb' MTBF = $\frac{439 + 345}{2}$ = **392 days**

'Amb' MTBF = $\frac{146 + 647}{2}$ = **397 days**

'Well Running' RT > Avg. RT of 'Amb' failures; **included**
*(Note: split lifespan failures are counted as failures on 'Amb' & 'Non-Amb')*

**Result: Positive ('Amb' MTBF > 'Non-Amb' MTBF)**

# MTBF Model – Negative Result

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**_Case II: 'Amb' 'Well Running' Lifespan Excluded_**

| Well Name | Ambyint Install Date | Pre-Amb / On-Amb | % On Amb | Start | End | Duration | Pre-Amb | On-Amb | SPM_CHK | CLASS_CHK | Non-Amb | Amb | Event | Color Code | OP Rec Accepted | UP Rec Accepted | Total Recs Accepted |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well # 4 | 12/10/2018 | Pre-Amb | | 11/20/2013 | 7/20/2015 | 607 | 607 | 0 | | | 607 | | Tubing Failure | | | | |
| | 12/10/2018 | Pre-Amb | | 7/20/2015 | 10/4/2016 | 442 | 442 | 0 | | | | | | | | | |
| | 12/10/2018 | | 31% | 10/4/2016 | 12/4/2019 | 1156 | 797 | 359 | 360 | 300 | 797 | 359 | Rod & Tubing Failure | | 6 | 4 | 10 |
| | 12/10/2018 | On-Amb | 100% | 12/4/2019 | 12/27/2019 | 23 | 0 | 23 | 12 | 19 | | | Waiting on Rig | | 0 | 0 | 0 |
| | 12/10/2018 | On-Amb | 100% | 12/27/2019 | 12/31/2019 | 4 | 0 | 4 | 0 | | | | Workover / Shut-in | | 0 | 0 | 0 |
| | 12/10/2018 | On-Amb | 100% | 12/31/2019 | 8/31/2020 | 244 | 0 | 244 | 239 | 232 | | | Well Running | | 9 | 8 | 17 |

'Non-Amb' MTBF = $\frac{607 + 797}{2}$ = **702 days**

'Amb' MTBF = $\frac{359}{1}$ = **359 days**

'Well Running' RT < Avg. RT of 'Amb' failures; **excluded**

**Result: Negative ('Amb' MTBF < 'Non-Amb' MTBF)**

# MTBF Model – Inconclusive Result

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**Case III: 'Non-Amb' 'Well Running' Lifespan Excluded**

| Well Name | Ambyint Install Date | Pre-Amb / On-Amb | % On Amb | Start | End | Duration | Pre-Amb | On-Amb | SPM_CHK | CLASS_CHK | Non-Amb | Amb | Event | Color Code | OP Rec Accepted | UP Rec Accepted | Total Recs Accepted |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well # 5 | 7/23/2019 | Pre-Amb | | 9/7/2012 | 6/9/2015 | 1005 | 1005 | 0 | | | 1005 | | Rod Failure (Part) | | | | |
| | 7/23/2019 | Pre-Amb | | 6/14/2015 | 12/18/2015 | 187 | 187 | 0 | | | 187 | | Tubing Failure | | | | |
| | 7/23/2019 | Pre-Amb | | 12/18/2015 | 12/19/2015 | 1 | 1 | 0 | | | | | Waiting on Rig | | | | |
| | 7/23/2019 | Pre-Amb | | 12/19/2015 | 12/22/2015 | 3 | 3 | 0 | | | | | Workover / Shut-in | | | | |
| | 7/23/2019 | Pre-Amb | | 12/22/2015 | 1/5/2018 | 745 | 745 | 0 | | | 745 | | Rod & Tubing Failure | | | | |
| | 7/23/2019 | Pre-Amb | | 1/5/2018 | 7/2/2018 | 178 | 178 | 0 | | | | | Waiting on Rig | | | | |
| | 7/23/2019 | Pre-Amb | | 7/2/2018 | 7/7/2018 | 5 | 5 | 0 | | | | | Workover / Shut-in | | | | |
| | 7/23/2019 | | 52% | 7/7/2018 | 8/31/2020 | 786 | 381 | 405 | 402 | 388 | | | Well Running | | 3 | 2 | 5 |

$$\text{'Non-Amb' MTBF} = \frac{1005 + 187 + 745}{3} = 646 \text{ days}$$

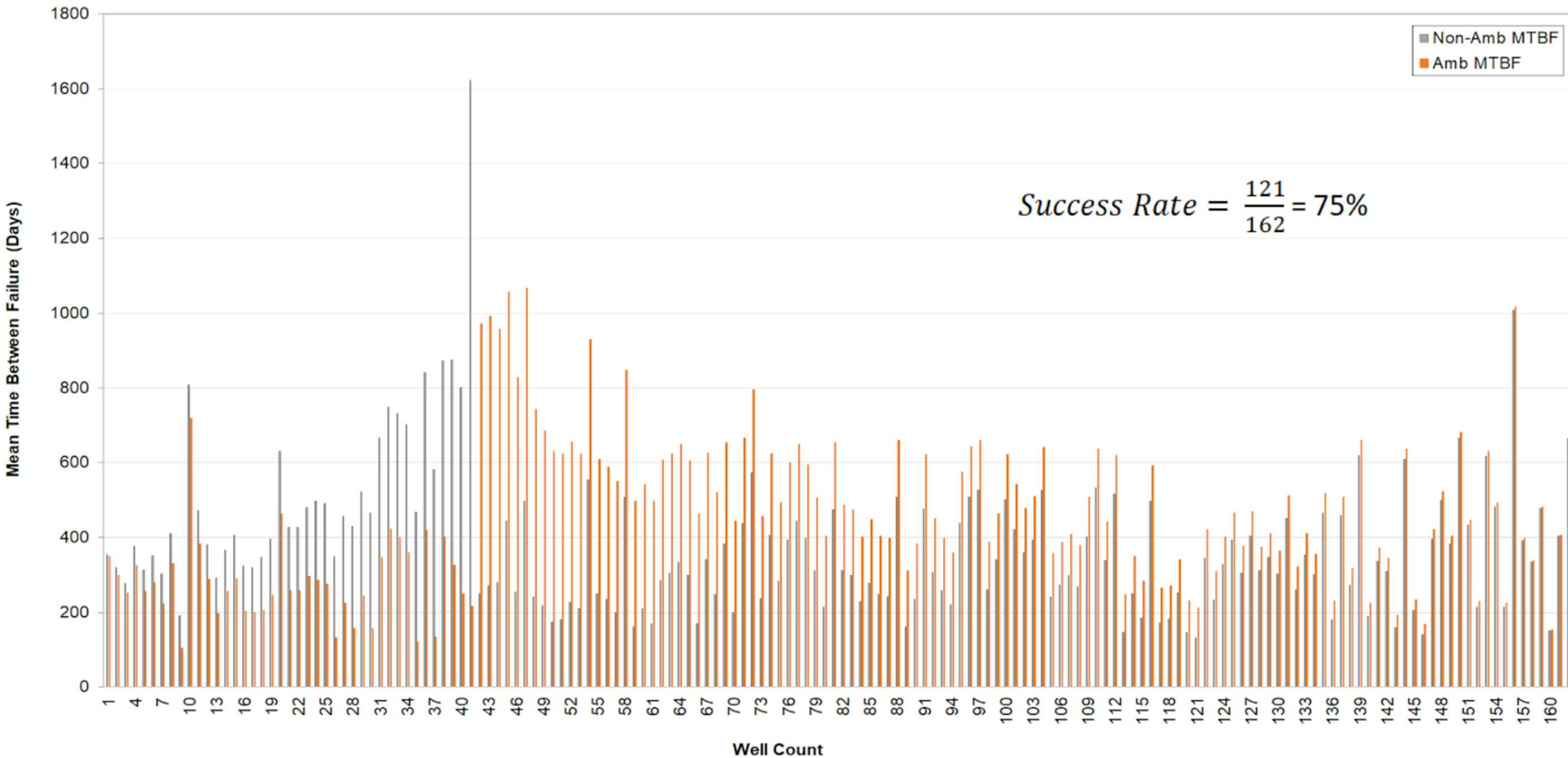
'Non-Amb' 'Well Running' RT < Avg. RT of 'Non-Amb' failures; **excluded**

'Amb' MTBF = 0

No 'Amb' failure

**Result: Inconclusive (need more runtime / failure to determine Ambyint's impact as positive / negative)**

# Histogram for MTBF Model



# MTBF Model - Results

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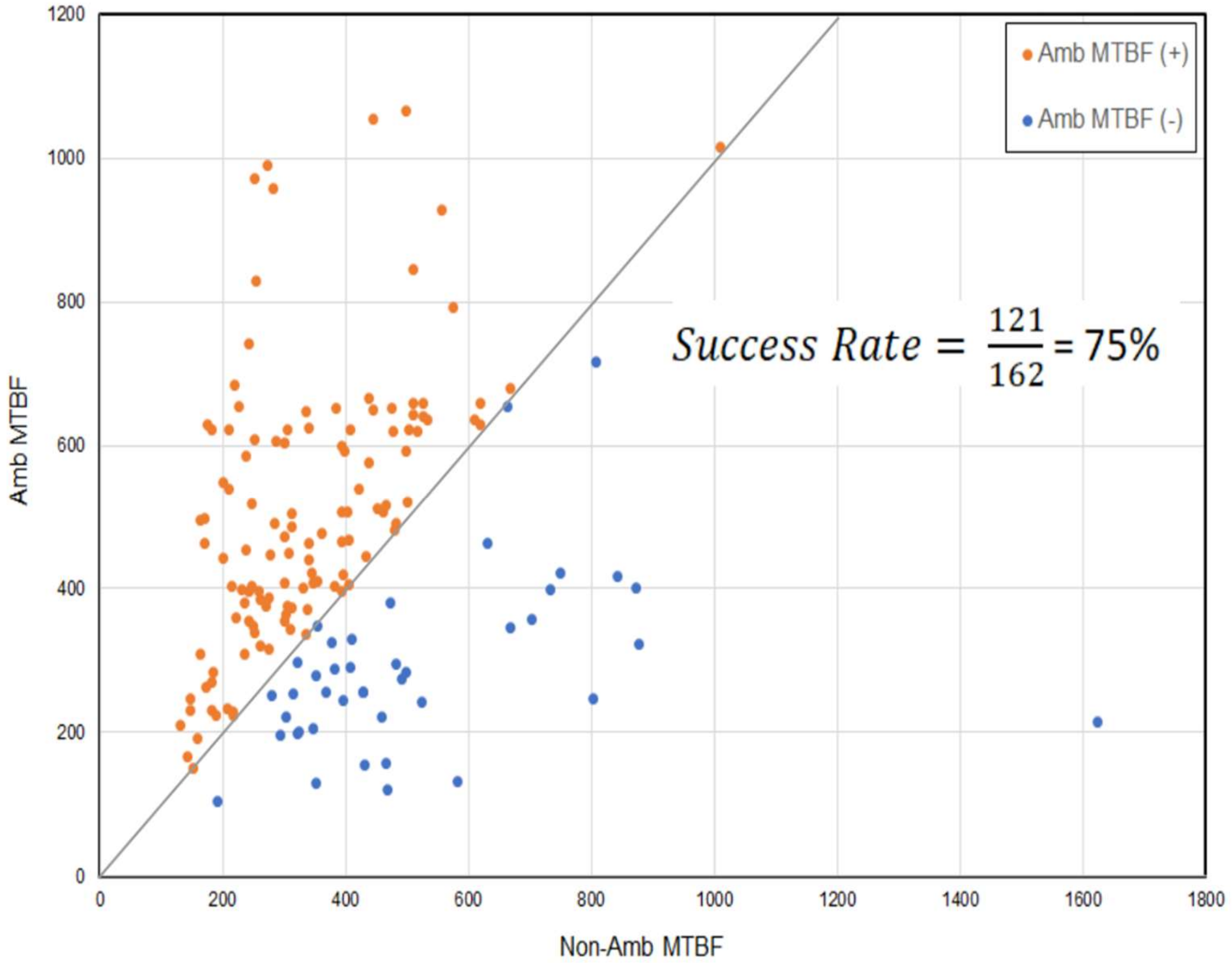


| MTBF Model Results | Well Count |
|---|---|
| Positive | 121 |
| Negative | 41 |
| Inconclusive | 144 |
| Null (No SPM data) | 13 |
| Total | 319 |

| | Non-Amb | Amb | % Diff. |
|---|---|---|---|
| Median MTBF | 343 | 411 | +20% |
| Average MTBF | 382 | 451 | +18% |

- **Inconclusive and null results are not included for this analysis**

# Failure Frequency Model

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$$\textbf{Failure Frequency (FF)} = \frac{Total\ \#\ of\ Failures}{Total\ Runtime\ in\ Years}$$

$$= \frac{Failure\ (1) + Failure\ (2) \ldots + Failure\ (n)}{[Runtime\ (1) + Runtime\ (2) \ldots + Runtime\ (n)\ ]/365}$$

**Objective**

- **Compare true FF of ‘Non-Amb’ lifespans of a well vs. ‘Amb’ lifespans of a well**
- **Determine success of Ambyint based on lower failure frequency**

# Failure Frequency (FF) Model – Positive Result



- ‘Well Running’ lifespans are always included and never counted as failures

| Well Name | Ambyint Install Date | Pre-Amb / On-Amb | % On Amb | Start | End | Duration | Pre-Amb | On-Amb | SPM_CHK | CLASS_CHK | Non-Amb | Amb | Event | Color Code | OP Rec Accepted | UP Rec Accepted | Total Recs Accepted |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well # 1 | 1/17/2018 | Pre-Amb | | 11/23/2015 | 2/4/2017 | 439 | 439 | 0 | | | 439 | | Rod Failure | | | | |
| | 1/17/2018 | Pre-Amb | | 2/4/2017 | 2/5/2017 | 1 | 1 | 0 | | | | | Waiting on Rig | | | | |
| | 1/17/2018 | Pre-Amb | | 2/5/2017 | 2/6/2017 | 1 | 1 | 0 | | | | | Workover / Shut-in | | | | |
| | 1/17/2018 | | 30% | 2/6/2017 | 6/12/2018 | 491 | 345 | 146 | 147 | 85 | 345 | 146 | Rod & Tubing Failure | | 0 | 2 | 2 |
| | 1/17/2018 | On-Amb | 100% | 6/12/2018 | 6/16/2018 | 4 | 0 | 4 | 1 | 4 | | | Waiting on Rig | | 0 | 0 | 0 |
| | 1/17/2018 | On-Amb | 100% | 6/16/2018 | 6/19/2018 | 3 | 0 | 3 | 1 | 3 | | | Workover / Shut-in | | 0 | 0 | 0 |
| | 1/17/2018 | On-Amb | 100% | 6/19/2018 | 8/31/2020 | 804 | 0 | 804 | 647 | 590 | | 647 | Well Running | | 3 | 2 | 5 |

$$\text{‘Non-Amb’ FF} = \frac{2}{[439 + 345] / 365} = \mathbf{0.9}$$

$$\text{‘Amb’ FF} = \frac{1}{[146 + 647] / 365} = \mathbf{0.5}$$

‘Well Running’ RT **included** in total runtime

**Result: Positive (‘Amb’ FF < ‘Non-Amb’ FF)**

# Failure Frequency (FF) – Negative Result

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| Well Name | Ambyint Install Date | Pre-Amb / On-Amb | % On Amb | Start | End | Duration | Pre-Amb | On-Amb | SPM_CHK | CLASS_CHK | Non-Amb | Amb | Event | Color Code | OP Rec Accepted | UP Rec Accepted | Total Recs Accepted |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well # 2 | 12/10/2018 | Pre-Amb | | 11/20/2013 | 7/20/2015 | 607 | 607 | 0 | | | 607 | | Tubing Failure | | | | |
| | 12/10/2018 | Pre-Amb | | 7/20/2015 | 10/4/2016 | 442 | 442 | 0 | | | | | | | | | |
| | 12/10/2018 | | 31% | 10/4/2016 | 12/4/2019 | 1156 | 797 | 359 | 360 | 300 | 797 | 359 | Rod & Tubing Failure | | 6 | 4 | 10 |
| | 12/10/2018 | On-Amb | 100% | 12/4/2019 | 12/27/2019 | 23 | 0 | 23 | 12 | 19 | | | Waiting on Rig | | 0 | 0 | 0 |
| | 12/10/2018 | On-Amb | 100% | 12/27/2019 | 12/31/2019 | 4 | 0 | 4 | 0 | | | | Workover / Shut-in | | 0 | 0 | 0 |
| | 12/10/2018 | On-Amb | 100% | 12/31/2019 | 8/31/2020 | 244 | 0 | 244 | 239 | 232 | | | Well Running | | 9 | 8 | 17 |

'Non-Amb' FF $= \frac{2}{[607 + 797] / 365} =$ **0.5**

'Amb' FF $= \frac{1}{[359 + 239] / 365} =$ **0.6**

'Well Running' RT **included** in total runtime

**Result: Negative ('Amb' FF > 'Non-Amb' FF)**

# Failure Frequency (FF) – Inconclusive Result

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| Well Name | Ambyint Install Date | Pre-Amb / On-Amb | % On Amb | Start | End | Duration | Pre-Amb | On-Amb | SPM_CHK | CLASS_CHK | Non-Amb | Amb | Event | Color Code | OP Rec Accepted | UP Rec Accepted | Total Recs Accepted |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well # 3 | 7/23/2019 | Pre-Amb | | 9/7/2012 | 6/9/2015 | 1005 | 1005 | 0 | | | 1005 | | Rod Failure (Part) | | | | |
| | 7/23/2019 | Pre-Amb | | 6/14/2015 | 12/18/2015 | 187 | 187 | 0 | | | 187 | | Tubing Failure | | | | |
| | 7/23/2019 | Pre-Amb | | 12/18/2015 | 12/19/2015 | 1 | 1 | 0 | | | | | Waiting on Rig | | | | |
| | 7/23/2019 | Pre-Amb | | 12/19/2015 | 12/22/2015 | 3 | 3 | 0 | | | | | Workover / Shut-in | | | | |
| | 7/23/2019 | Pre-Amb | | 12/22/2015 | 1/5/2018 | 745 | 745 | 0 | | | 745 | | Rod & Tubing Failure | | | | |
| | 7/23/2019 | Pre-Amb | | 1/5/2018 | 7/2/2018 | 178 | 178 | 0 | | | | | Waiting on Rig | | | | |
| | 7/23/2019 | Pre-Amb | | 7/2/2018 | 7/7/2018 | 5 | 5 | 0 | | | | | Workover / Shut-in | | | | |
| | 7/23/2019 | | 52% | 7/7/2018 | 8/31/2020 | 786 | 381 | 405 | 402 | 388 | | | Well Running | | 3 | 2 | 5 |

$$\text{'Non-Amb' FF} = \frac{3}{[1005 + 187 + 745] / 365} = \mathbf{0.6}$$

$$\text{'Amb' FF} = \frac{0}{[405] / 365} = \mathbf{0.0}$$

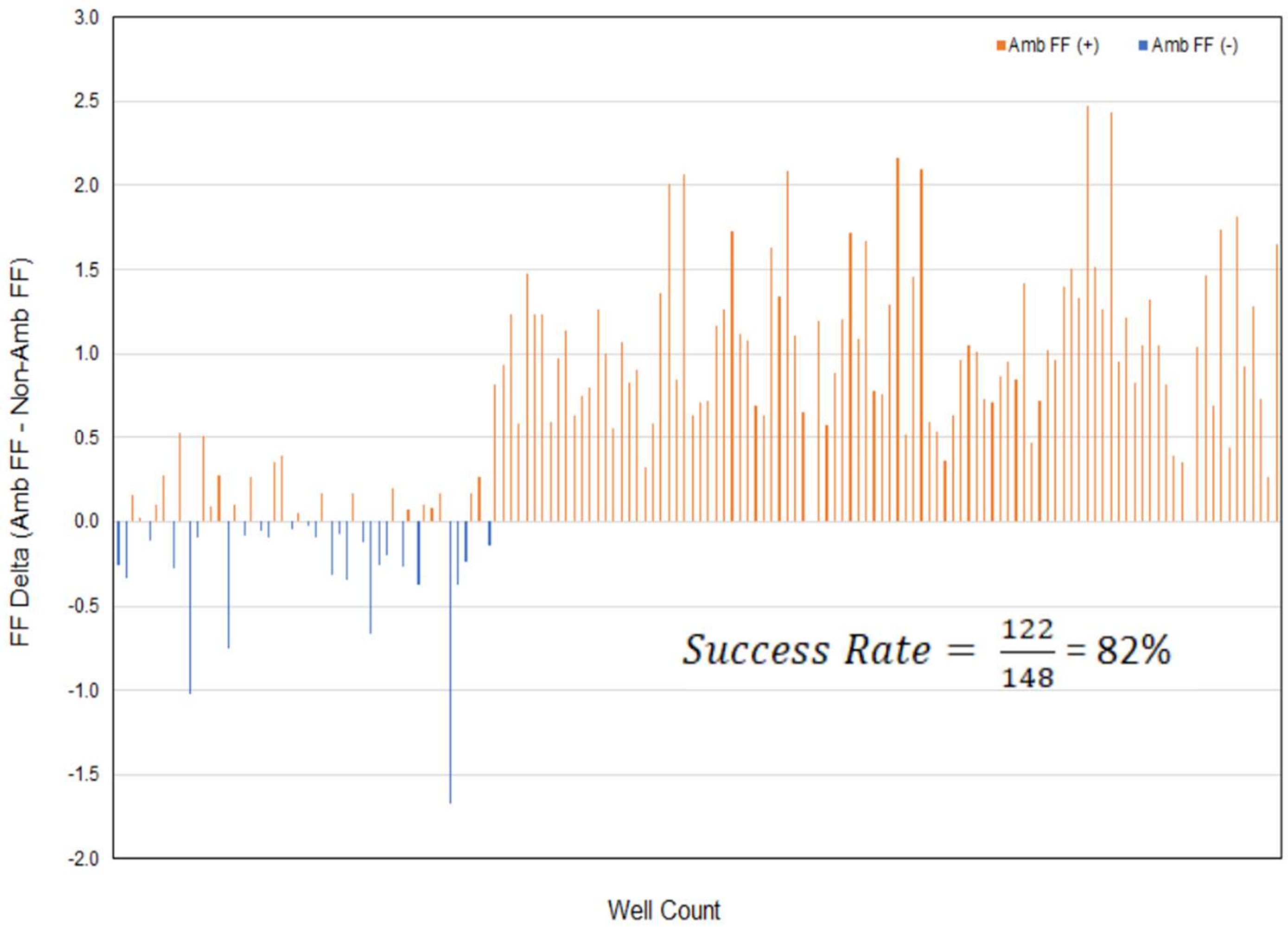
'Well Running' RT **included** in total runtime

**Result: Inconclusive (No Failure on Ambyint)**

# Failure Frequency (FF) Model - Results



**FF Model Results**




| FF Model Results | Well Count |
|---|---|
| Positive | 122 |
| Negative | 26 |
| Inconclusive | 158 |

| | Non-Amb | Amb | % Diff. |
|---|---|---|---|
| Median Runtime | 351 | 524 | +49% |
| Average Runtime | 395 | 531 | +34% |

# Conclusion

- This case study focuses on evaluating impact of Ambyint's autonomous optimization of rod pump wells on failure reduction deployed in the Bakken from 2017-2020:
  - MTBF Model: **18% improvement in failures - Avg. MTBF**
  - Failure Frequency Model: **34% improvement in failures - Avg. FF**
- The adapted methodologies increase accuracy of failure analysis:
  - Well level as opposed to group / field level analysis of failures, better accuracy
  - Inclusion of 'running lifespans' and exclusion of early (anomalous) lifespans
  - Can be applied to ***any*** operational / design parameter to evaluate its impact on well runtime ***regardless of lift type***, e.g. chemical treatments, downhole design changes, new workflows etc.

# Thank You

https://www.ambyint.com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