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Conventional plunger lift optimization

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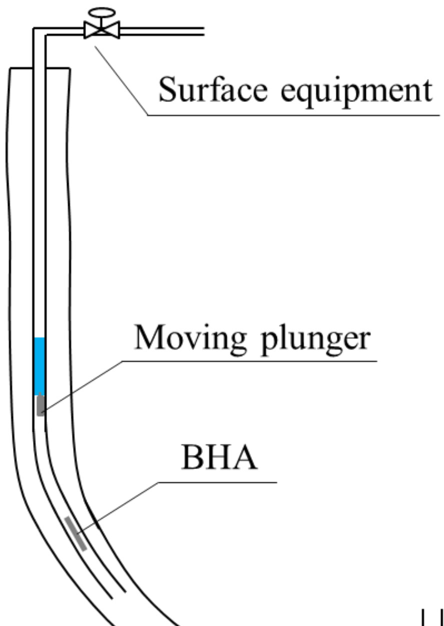
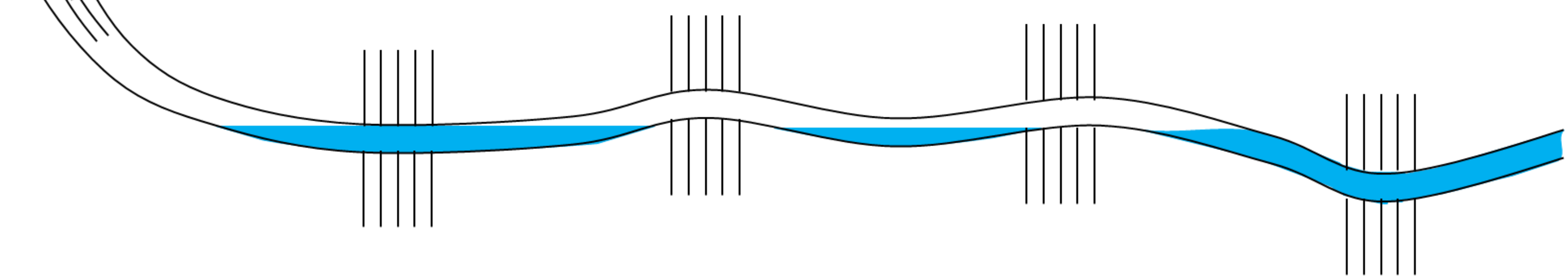
Outline

- Motivation
- Virtual Flow Metering
- Optimization
- Summary

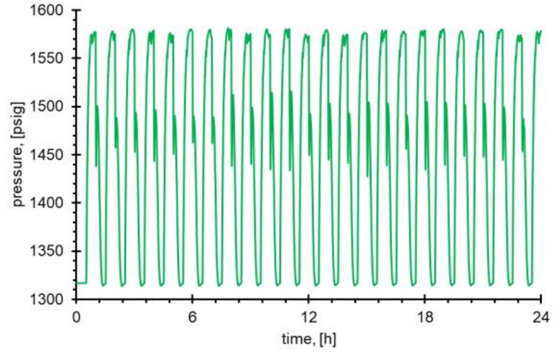
Motivation
Problem Complexity





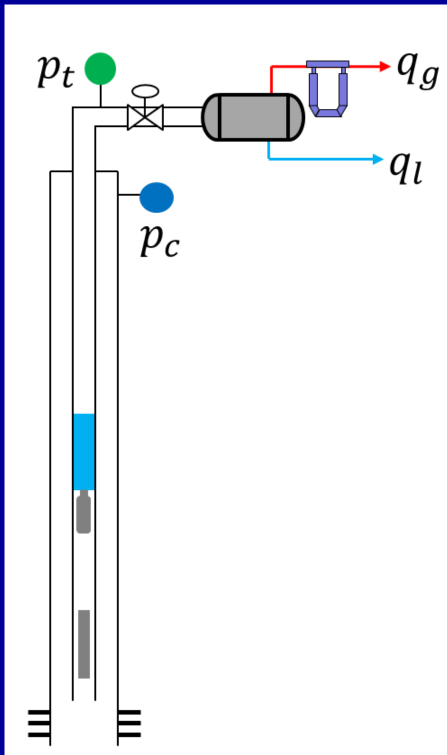
Vertical flow =
Transient plunger movement
+ Transient multiphase flow

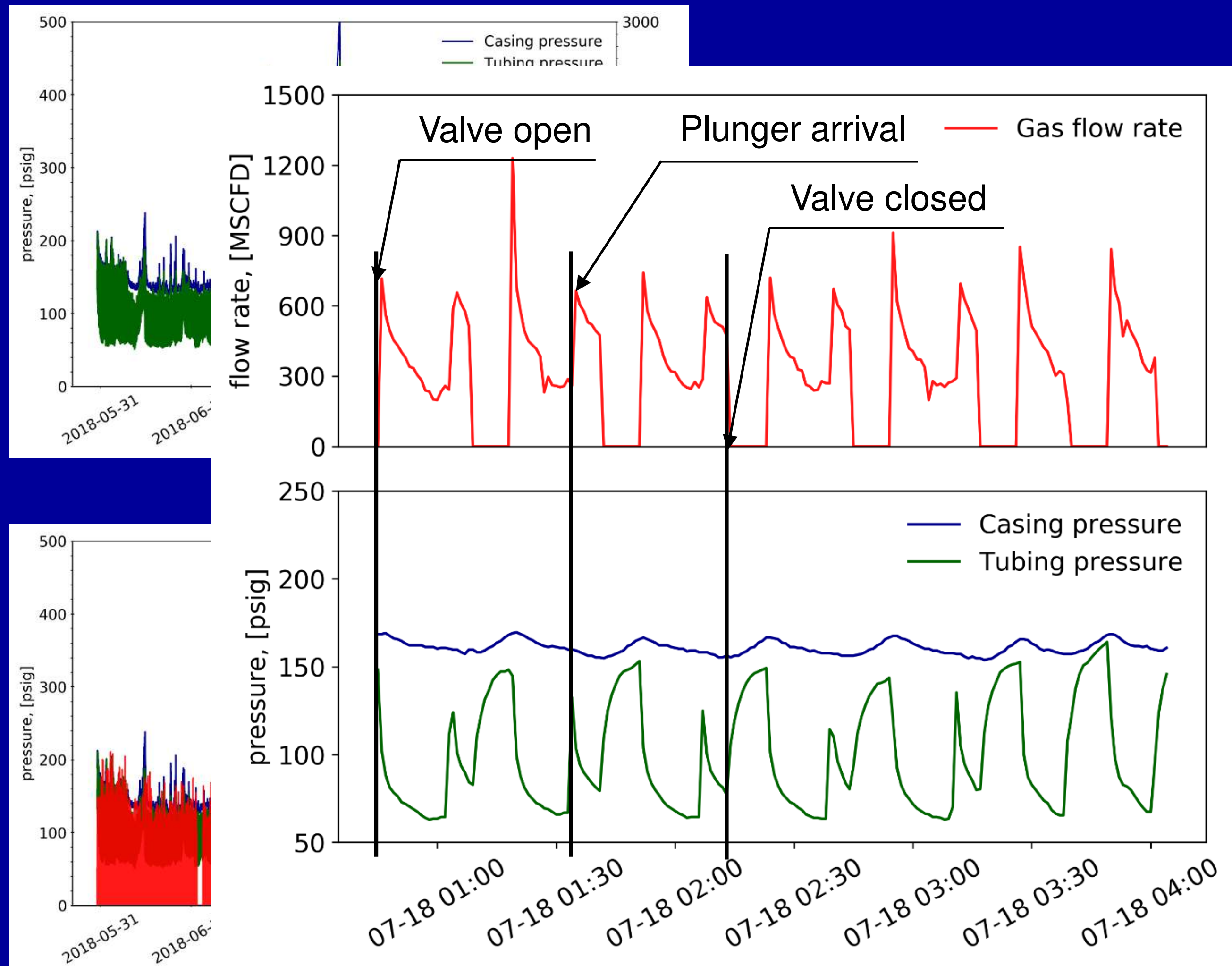
Lateral flow =
Unconventional IPR +
Transient multiphase flow



Simulation time: 24 h
- 6.5 min

Motivation Measurements

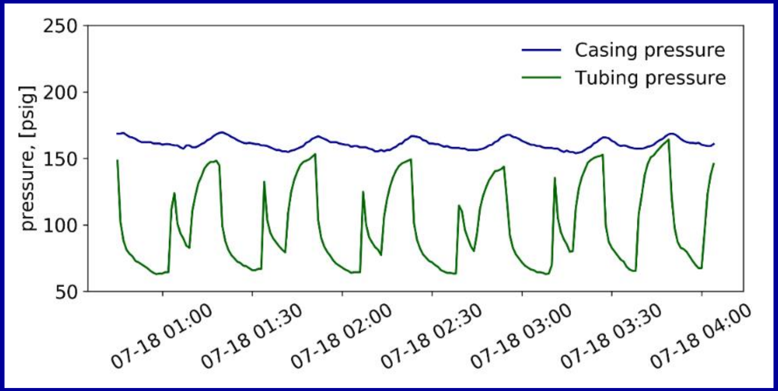


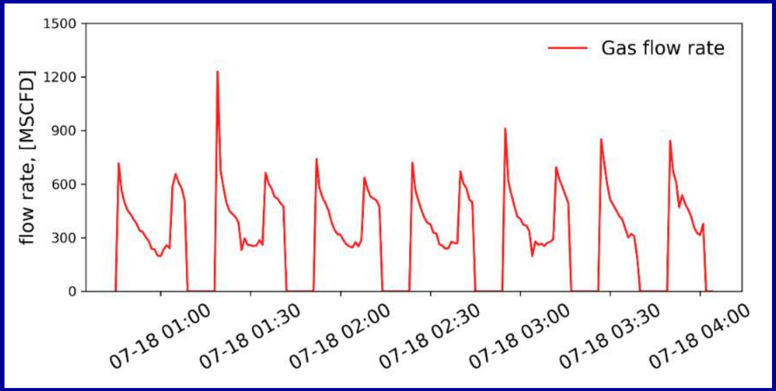


p_c - casing pressure
p_t - tubing pressure
q_g - gas flow rate
q_l - liquid flow rate

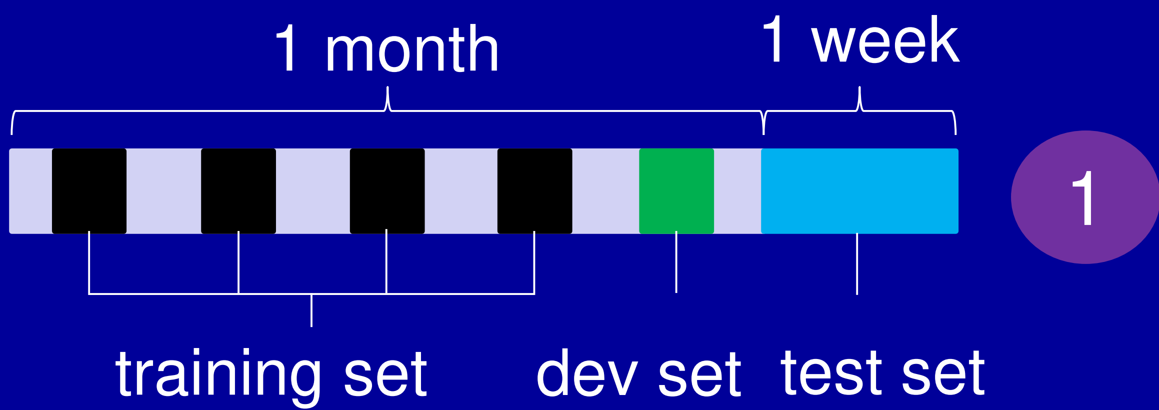
Virtual Flow Metering Problem Statement

Can we model gas flow rate data using pressure signals and arrival sensor data?

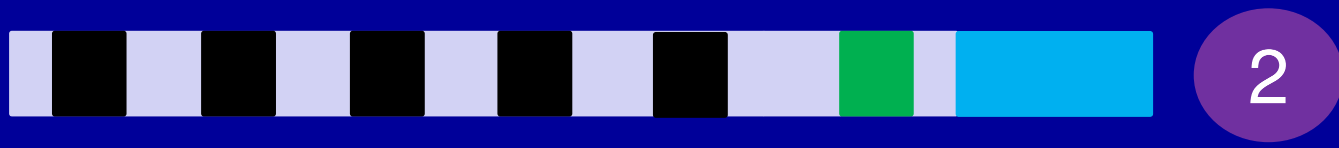




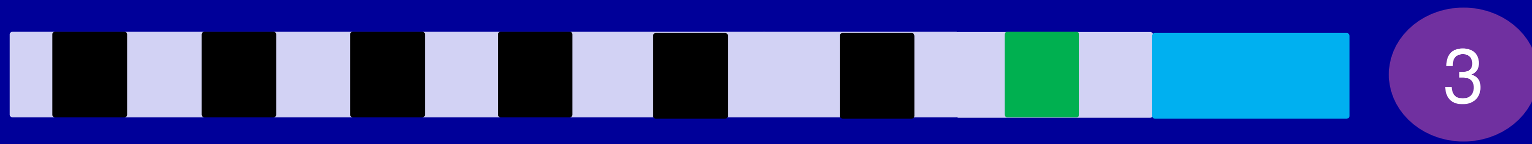
Virtual Flow Metering
Data Splitting Methodology



Fix ANN architecture using the initial training / dev / test sets



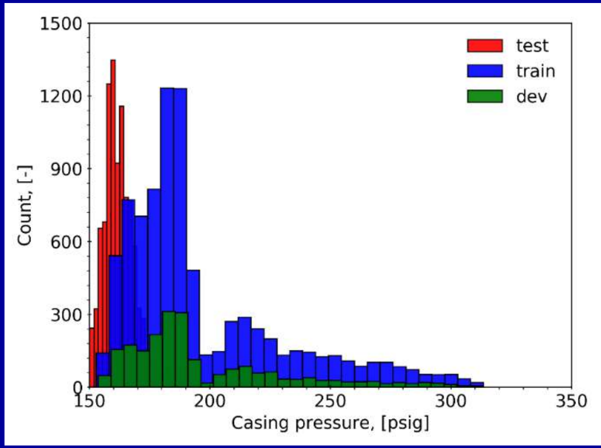
Tune the weights of the network using new training / dev / test sets

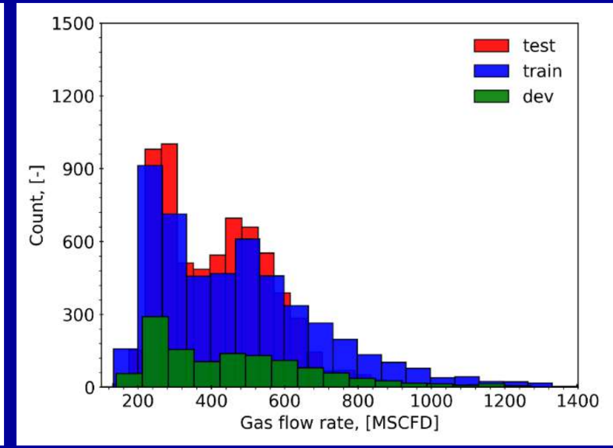


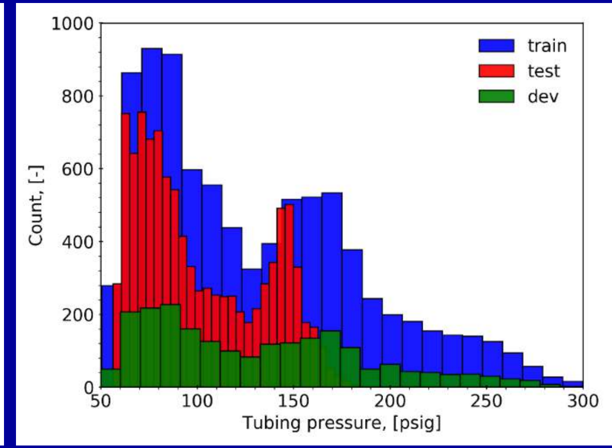
Reiterate step 2

Virtual Flow Metering
Data Distribution

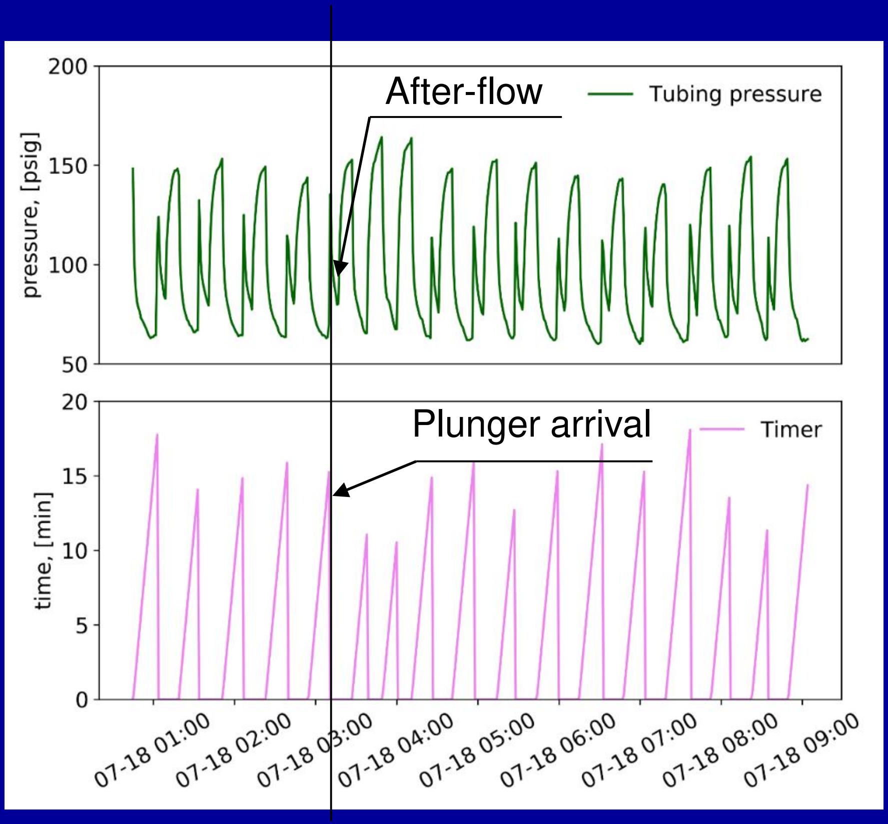
- Measured parameters

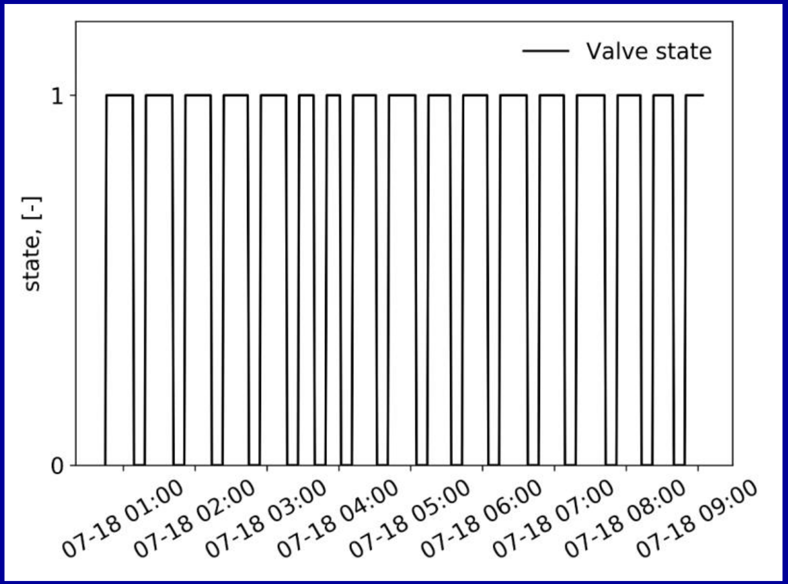




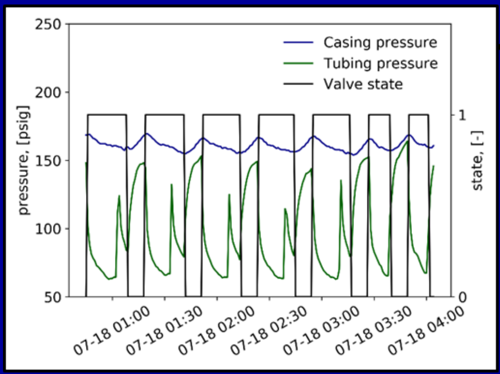


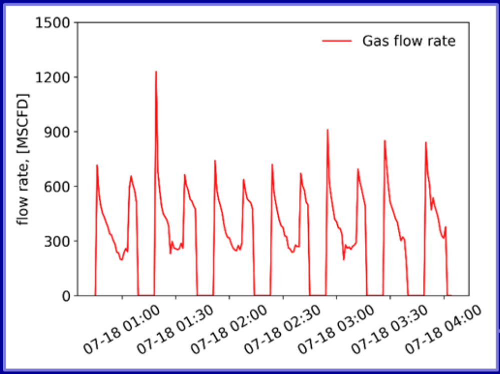
Virtual Flow Metering
Feature Transformation

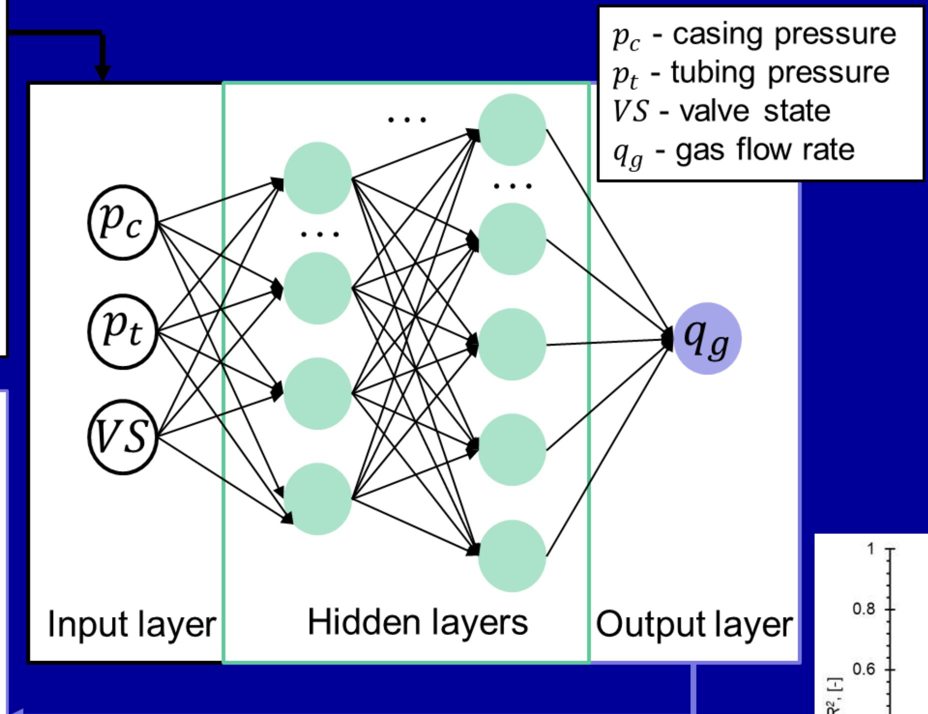




Virtual Flow Metering Model Selection

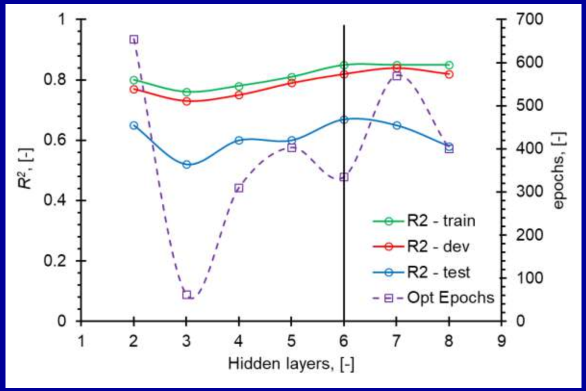




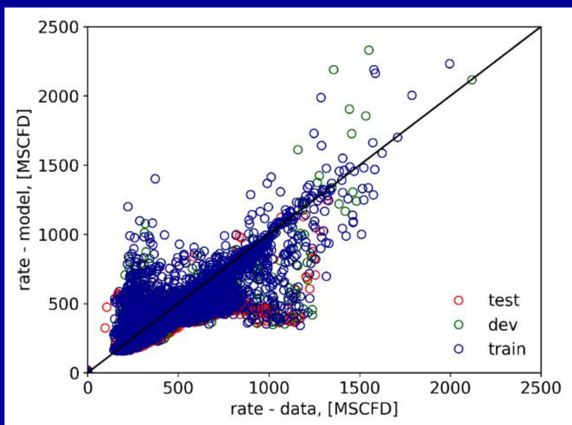


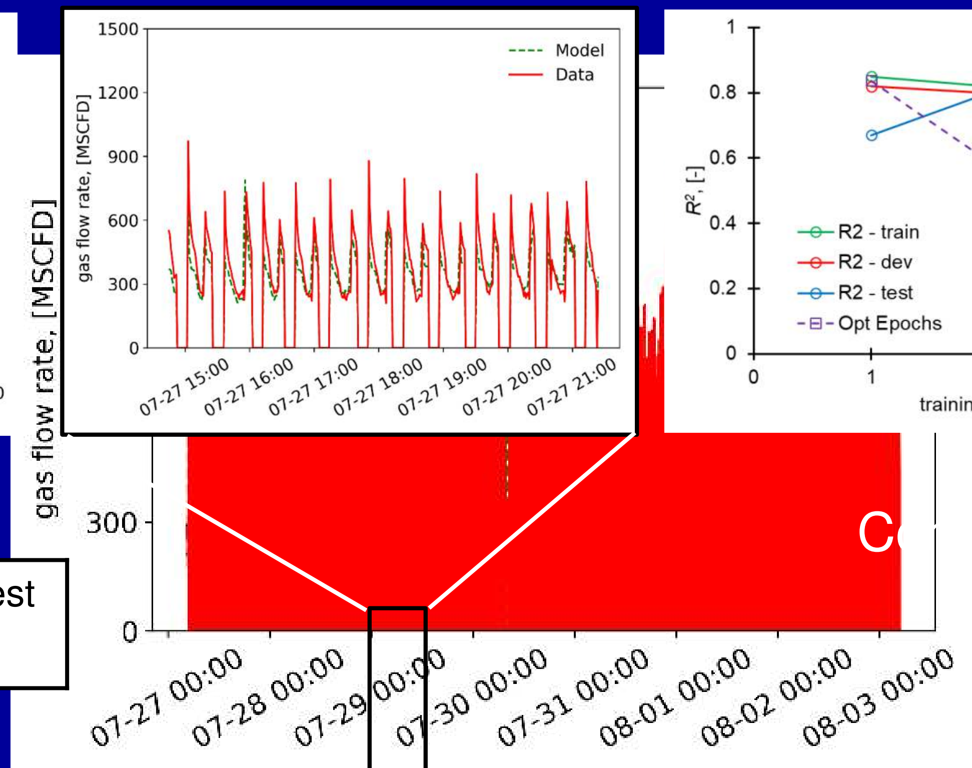
Hyperparameters – Andrianov (2018) plus additional tuning

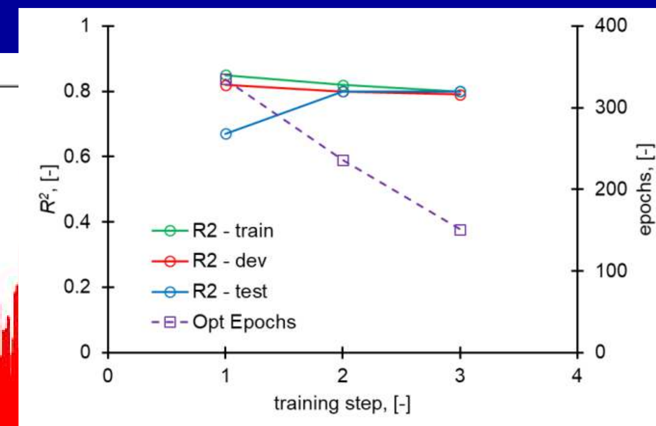
Nodes / layer	10
Hidden layers	6
Activation	ReLu
Learning rate	0.001
Reg-tion (l2)	0.1
Batch size	32
Optimizer	Adam



Virtual Flow Metering Model Results







R2 - train	R2 - dev	R2 - test
0.83	0.82	0.7

Step 1 results

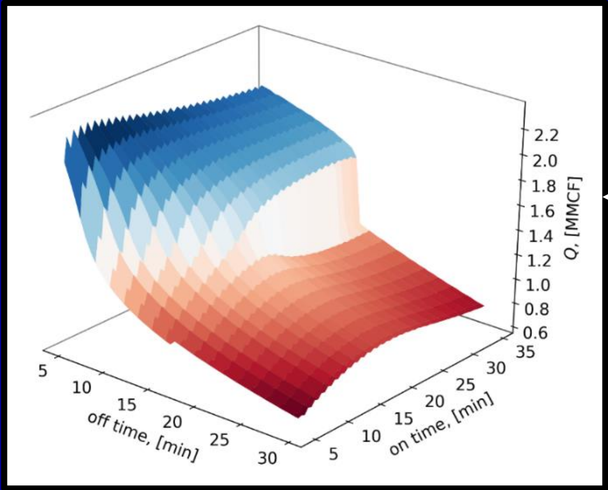
Compiled results

Virtual Flow Metering Summary

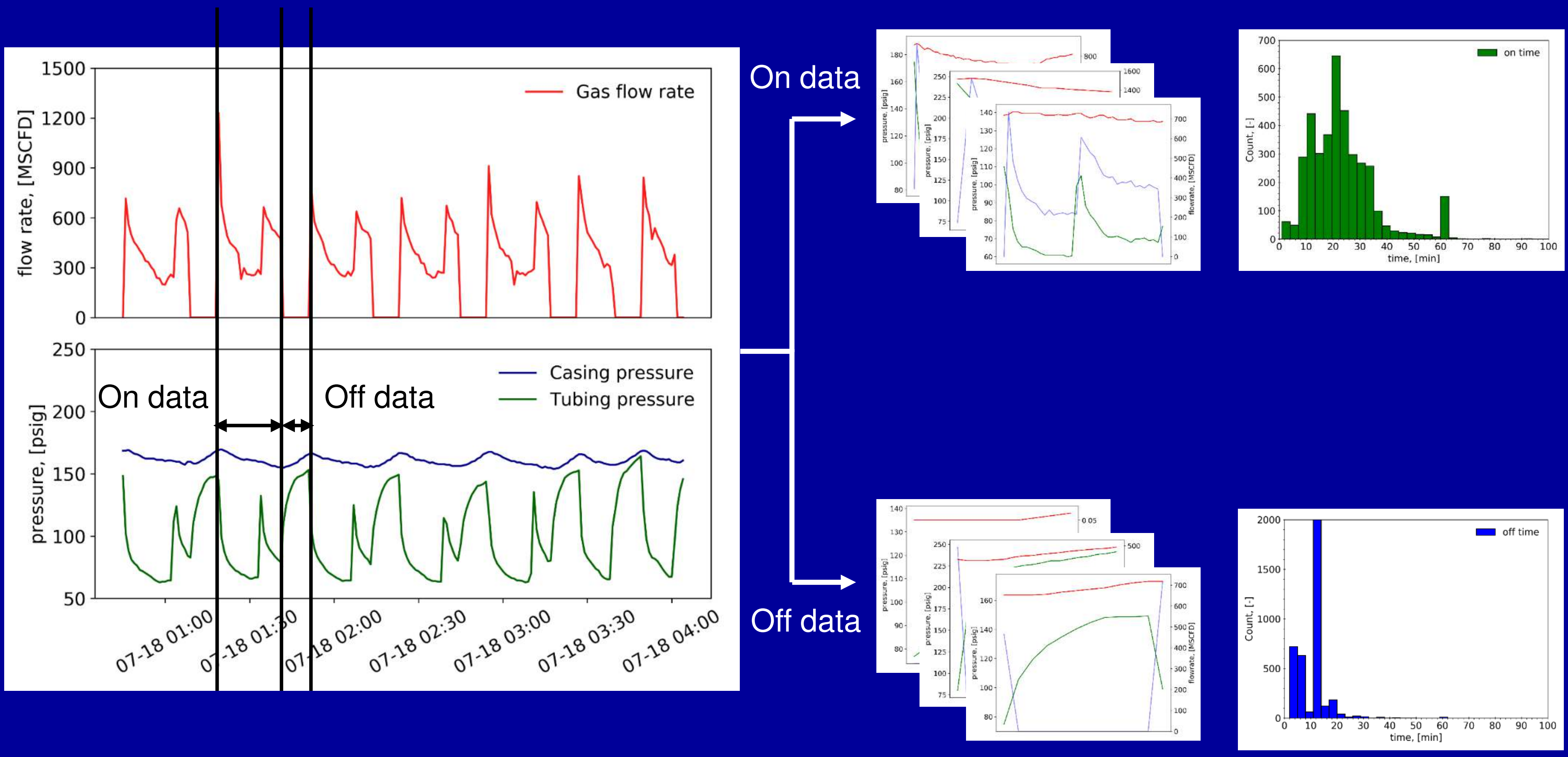
- Pressure and arrival sensor data are sufficient to model gas flow rate
- Model needs to be calibrated
  - Fix calibrated network architecture based on the first training set
  - Perform routine production tests
  - Model becomes better with increased training data set
- Predicted flow rates can be used for allocation purposes
- After-flow time can be optimized based on predicted flow rate

Optimization Problem Statement

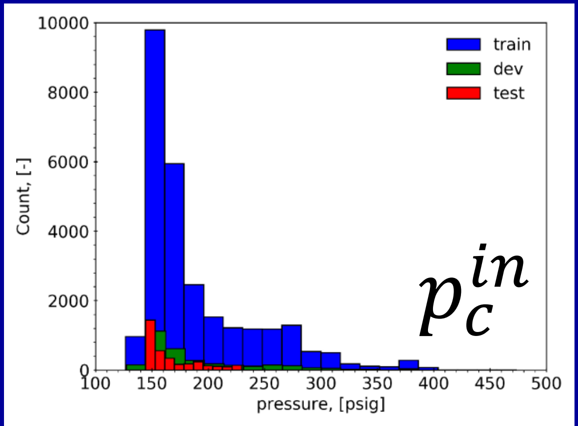
Can we model casing pressure and gas flow rate using controller set points and initial conditions?

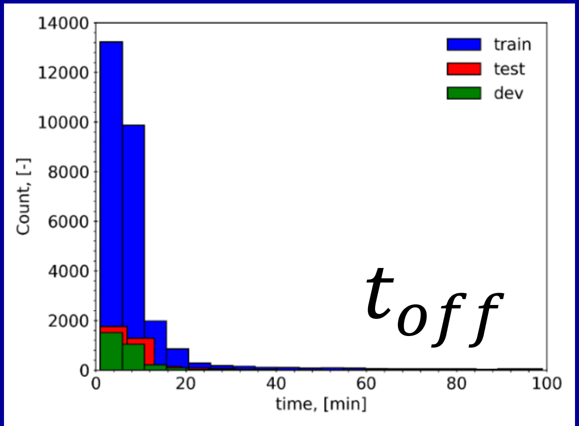


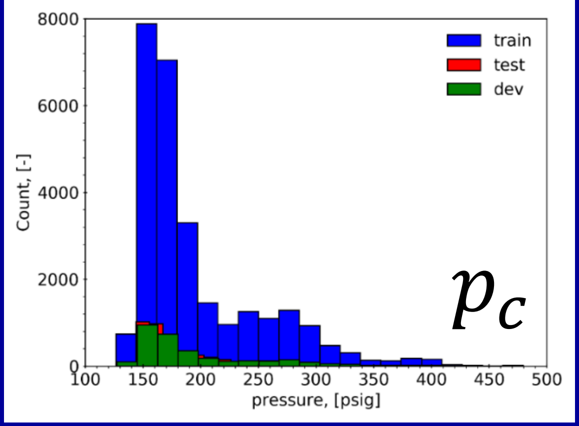
Optimization
Data Preparation



Optimization
Modeling "off" data



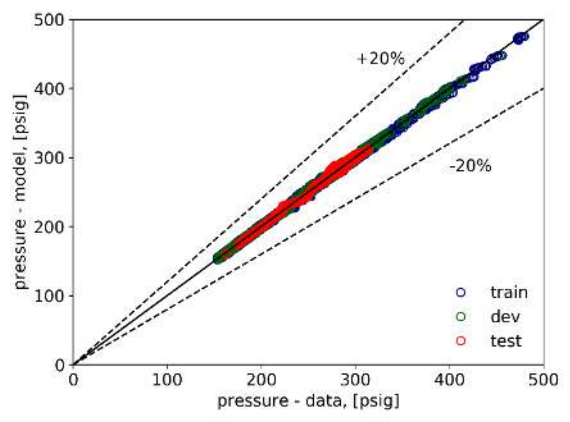




Input	t_{off}	p_c^{in}	~~p_t^{in}~~
Output		p_c	

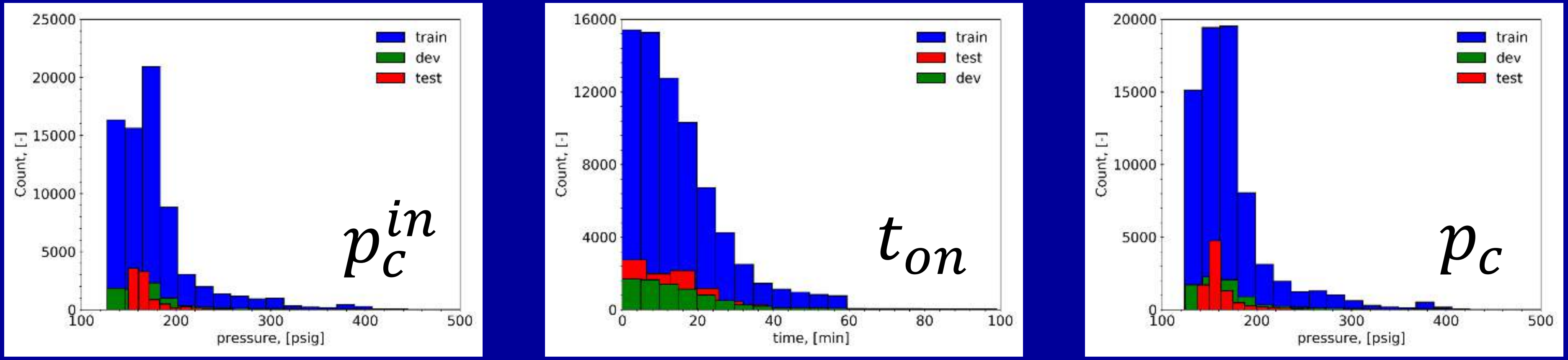
$\rho\,(p_c, p_t) = 0.84$

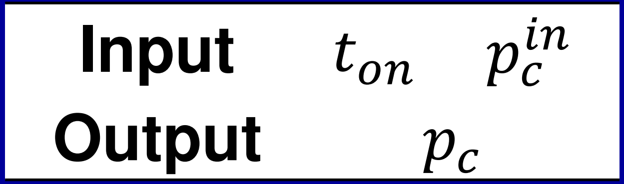
R2 - train	R2 - dev	R2 - test
0.98	0.98	0.93

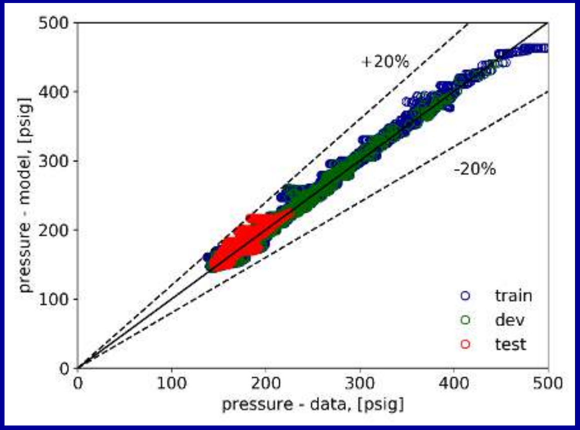


Nodes	[6, 6, 3]
Hidden layers	3
Activation	ReLu
Learning rate	0.001
Reg-tion (l2)	0.1
Batch size	32
Optimizer	Adam

Optimization
Modeling "on" data – pressure



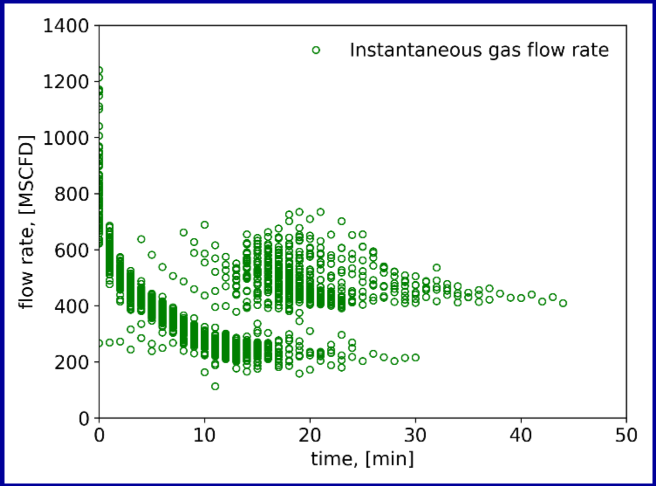




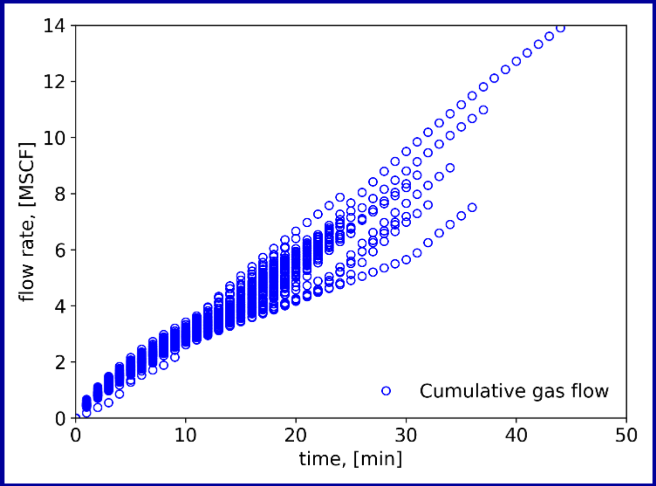
R2 - train	R2 - dev	R2 - test
0.95	0.93	0.75

Nodes	[9, 3]
Hidden layers	2
Activation	ReLu
Learning rate	0.001
Reg-tion (l2)	0.1
Batch size	32
Optimizer	Adam

Optimization
Modeling "on" data – gas production

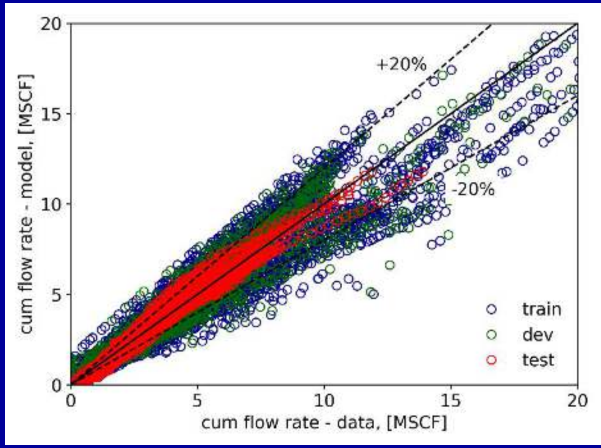


Integrate every cycle



Input	t_{on}	p_c^{in}	p_c
Output		Q_g	

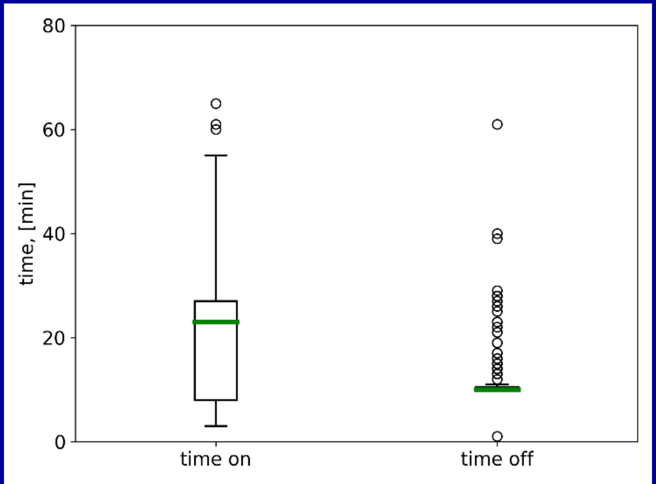
R2 - train	R2 - dev	R2 - test
0.97	0.96	0.92

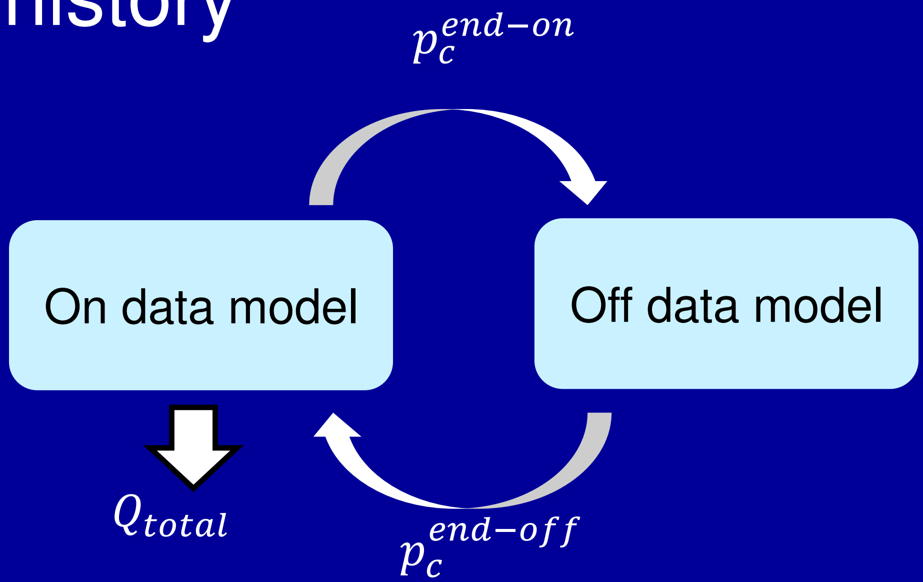


Nodes	[6, 6]
Hidden layers	2
Activation	ReLu
Learning rate	0.001
Reg-tion (l2)	0.1
Batch size	32
Optimizer	Adam

Optimization Modeling – cycle

- Final model validation: model final week of production history



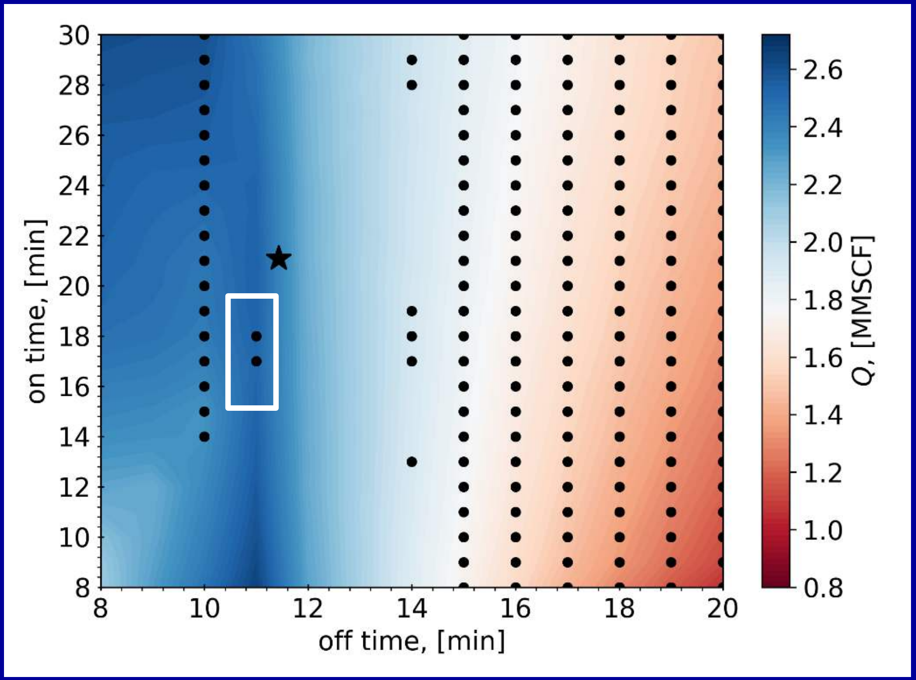


	Cumulative gas production, [MSCF]
Data	1840.8
Model	1699.0

Error 7.7 %

Optimization
Response surface

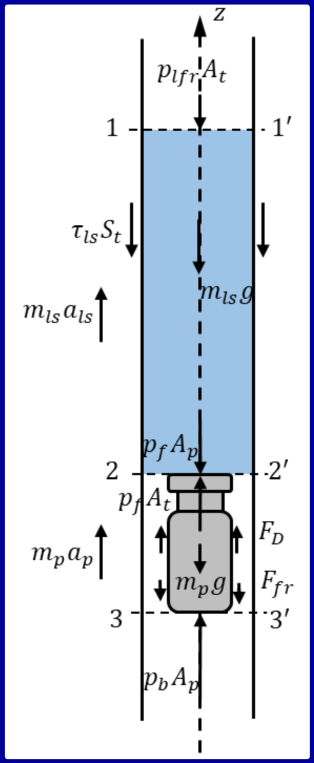
- Calculate cumulative gas production under different on / off times
- Constrain the results by the fall and upstroke plunger performance (Lea, 1982; Nadkrynechny et al., 2013)
- Improvement by 8.5%



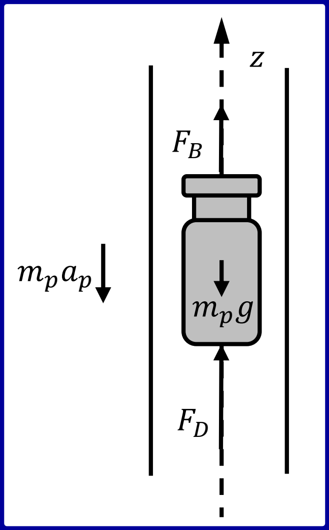
$$t_{upstroke} < t_{on}$$
$$t_{fall} < t_{off}$$

Optimization Constraints

$t_{upstroke} < t_{on}$: use Lea (1982) model with equivalent casing size → calibrate casing size to match upstroke time



$t_{fall} < t_{off}$: use Nadkrynechny et al. (2013) approach to model fall → use dynamic pressure buildup from the data-driven model



Optimization Summary

- Integrating “on” and “off” models predicts cumulative production with 7.7% error
- “Off” time should be minimized
- “On” time should be around 17 min
- Understanding plunger lift physics dictate the limitations of the optimization results
- Optimization increase gas production by 8.5%
- Model can complement existing alarm systems on SCADA

Questions? Suggestions?

Thank you for your attention!

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