Offshore Task 4.

Constraining Kick Signals through Advanced Multi-Phase Data

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3) Systems and Tech. Research

Offshore Project Review Meeting
10/26/20

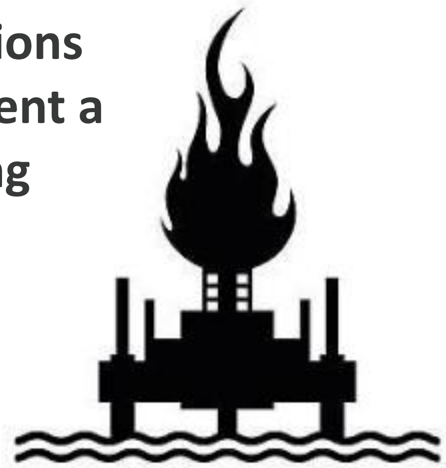
Motivation and Purpose

Task 4. Constraining Kick Signals via Advanced Multi-Phase Data

NATIONAL ENERGY TECHNOLOGY LABORATORY

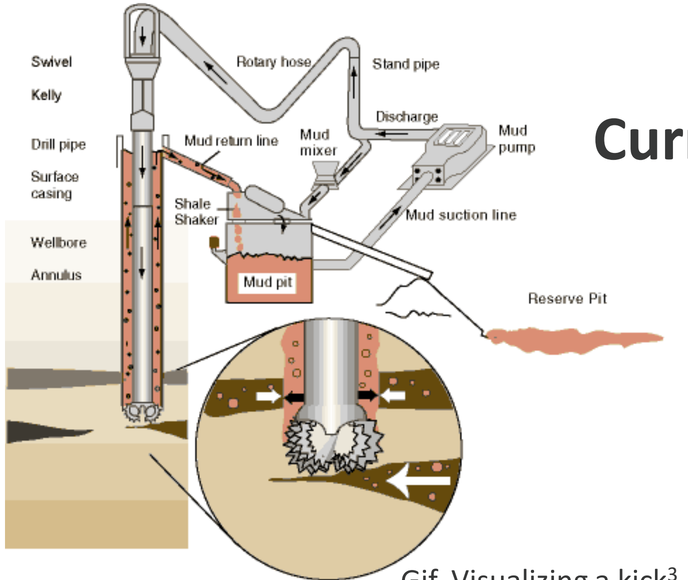
Unexpected formation fluid invasions into the borehole (“kicks”) represent a persistent threat during the drilling process.

Ecosystem damage
44% drilling non-productive time[1]
$8 billion/year losses[1]



58% of kicks occur during drilling[2]

Late kick detection is a major contributor to the occurrence of blowouts[2]



Gif. Visualizing a kick[3]

Current state-of-the art vs. This effort

Relies on monitoring at the surface : delayed response

Using geophysical signals from LWD sensors[4] : real-time

- *Acoustic velocity*
- *Conductivity/resistivity*

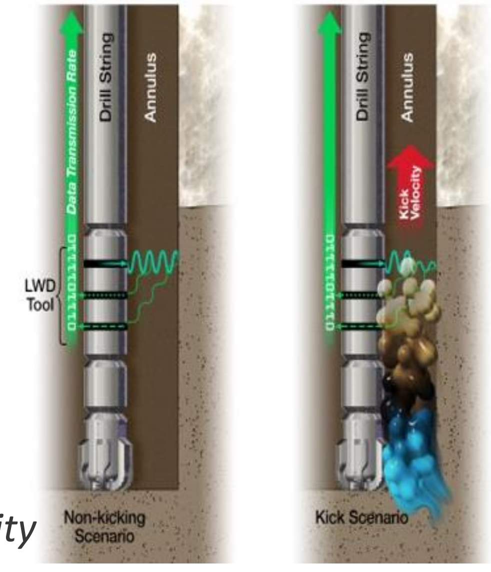


Fig. Conceptual response to kick[5]

1) https://www.landmark.solutions/Drillworks-Geomechanics accessed 02/20
2) Loss of Well Control Occurrence and Size Estimators, Exprosoft, 04/17
3) https://www.osha.gov/SLTC/etools/oilandgas/drilling/kickback_final.html
4) Rose, K., et. al., 2019, USPO #10253620
5) Tost, B., et. al., 2016, https://doi.org/10.2172/1327810

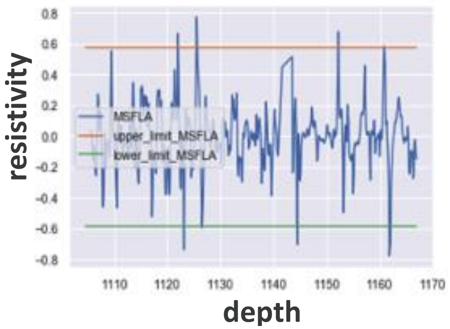
Goals/Approach

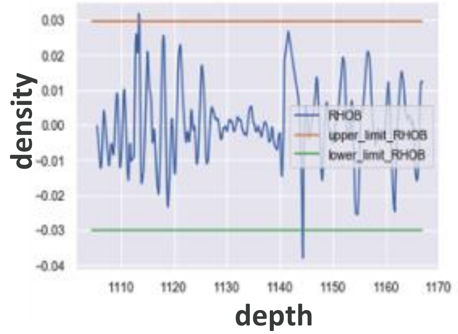
Task 4. Constraining Kick Signals through Advanced Multi-Phase Data

Challenge: Lacking data to develop an algorithm

2015: Received field **wireline** data from Saudi Aramco*
2017: Received field LWD data from Chevron via Schlumberger

*represents a post-drilling measurement technique not real-time while-drilling data





Saudi Aramco
Chevron Schlumberger

Our Approach: acquire data VIA experiments in a surrogate setup

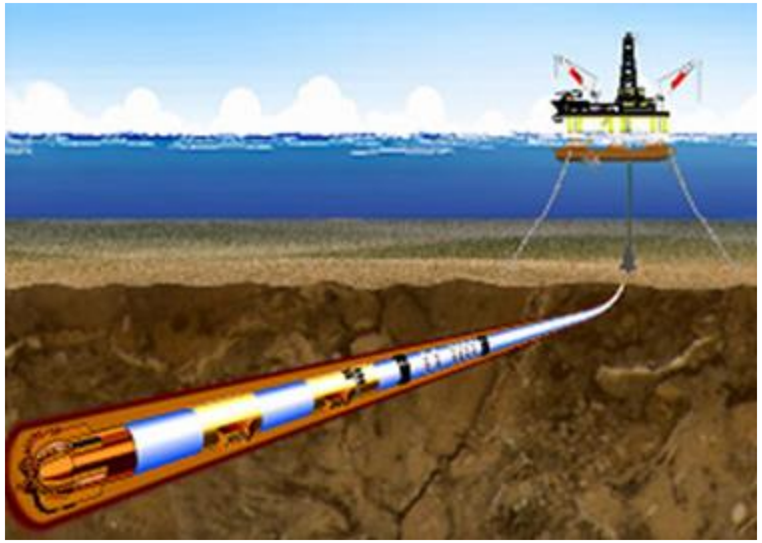


Fig. Conceptual wellbore operation[1]

- An annular flow cell to simulate a wellbore environment
- A sensor module to mimic capabilities of those found on while-drilling instrumentation

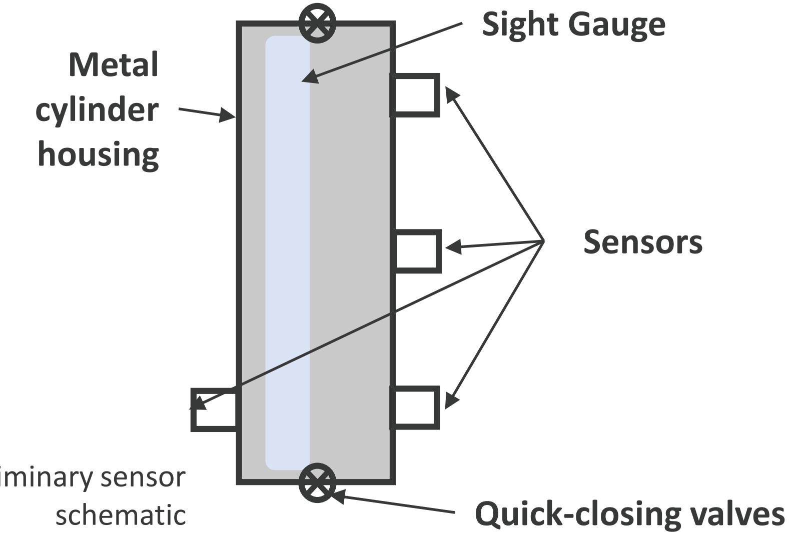
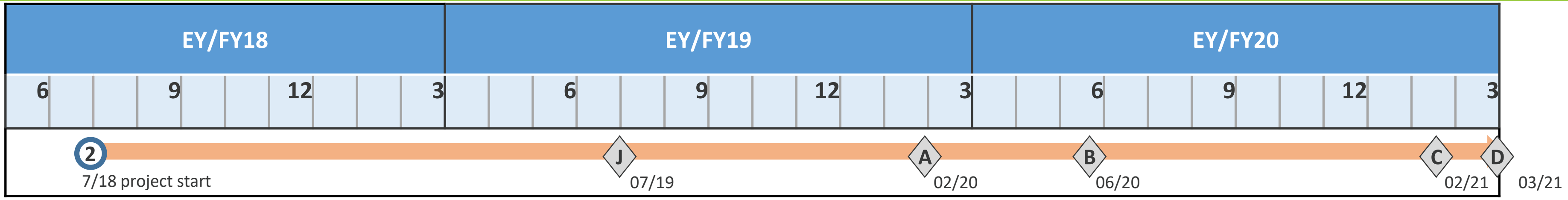


Fig. Preliminary sensor schematic

1) https://www.rigzone.com/training/insight.asp?insight_id=296&c_id=

Overview of Current Status Task 4



C: database for air:water flow at ambient conditions
D: shakedown of elevated experiment

Photo: Top of exp. flow loop

- Re-designed ambient exp. apparatus constructed and operational*
  - * COVID pandemic restricts access to OSU (March 2020 – June 2020)
- Finalized design of elevated experiments w/ LSU.
- **Shakedown reveals that current sensors do not respond to changes in gas content (July 2020)****
  - ** Unreliable sensors suspends elevated conditions experiment activity
- Designing surrogate sensor(s) w/ LSU (new/ongoing)
  - -opportunity to develop field signals in lab
- Implemented a sequence anomaly detection algorithm to identify kicks

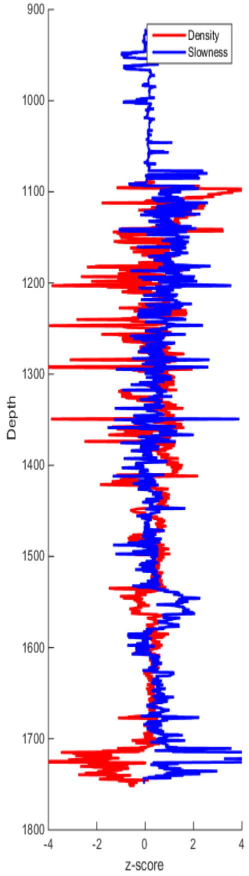
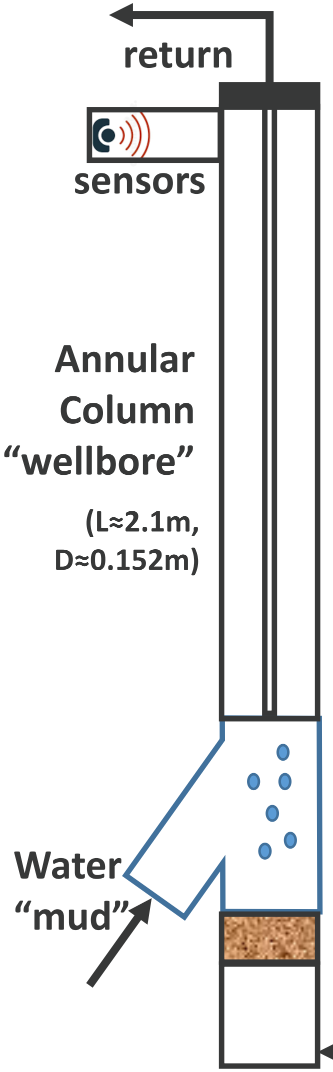


Fig. Wireline data currently used to test algorithm

Experiment Update (1/4): Ambient Setup

An opportunity to observe and measure perturbations



- Annular configuration (realistic wellbore)
- Ambient conditions (T/P)
- Simple fluids (air/water)
- Representative dimensions

Custom-machined aluminum diffuser plate holder


Photo. Berea sandstone[1]

Sensors inserted crossflow

- Ultrasonic acoustic velocity
- Electrical conductivity by electrode

1) https://www.bereasandstonecores.com/

Experimental Update (2/4): Elevated Setup

Emulate more realistic conditions: bridging information gap

Elevated Facilities

SwRI vs LSU PERTT Lab

- – Temporary setup
- – Contractor relationship
- – **Cost prohibitive**

- \+ Large supporting infrastructure
  - \+ Semi-permanent : no penalty to build/decommission
- ★ Industry contacts & history of petroleum research
- \+ Collaborator relationship
- \+ Potential access to two research wells

Photos. PERTT facilities[1]

LWD Sensors

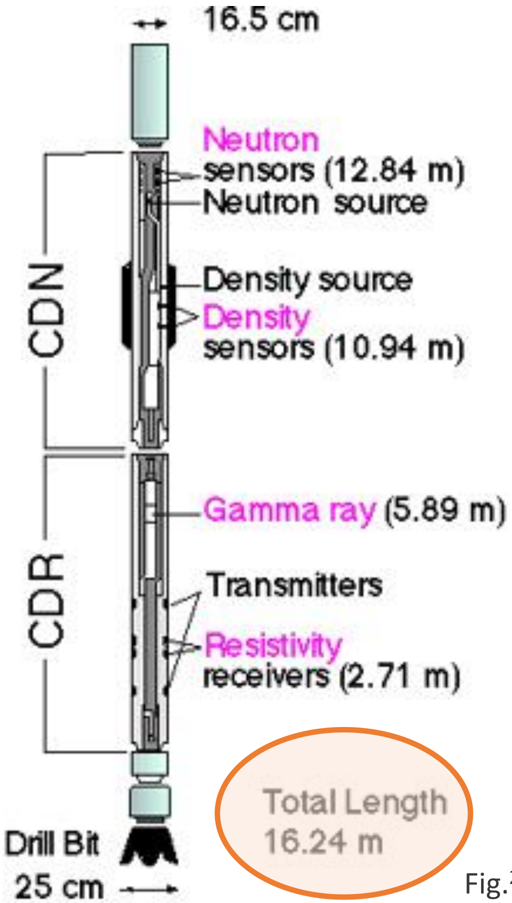


Fig.[2]

Properties

- Acoustic using audible frequency *range* (20 Hz – 20 kHz)
- Electrical using induction (400 kHz and 2 MHz)

Challenges

- Too expensive to buy/rent
- Large & heavy (e.g. crane) : adds to costs
- Reticence/inflexibility

Sensors needed to provide data to test the detection method are not readily available

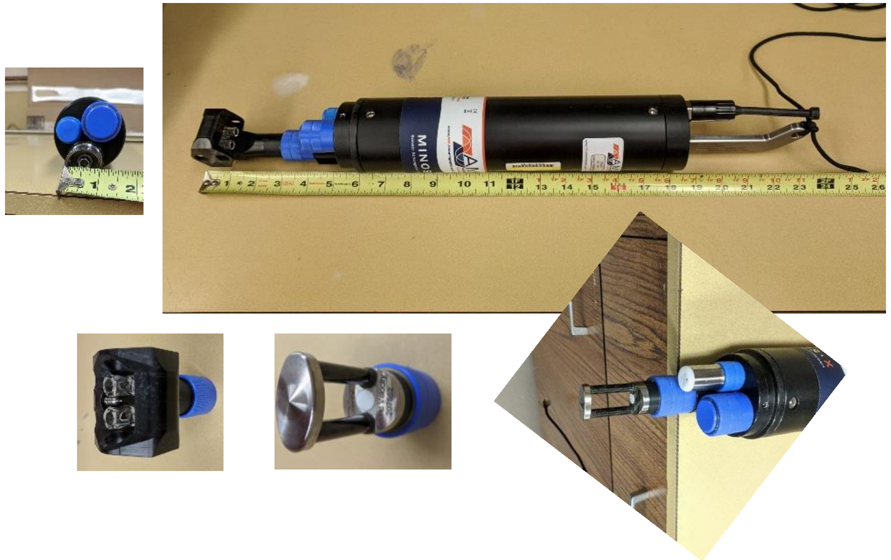
1) Feo, G., et al, 2020. Sensors, 10.3390/s20010267
2) https://mlp.ldeo.columbia.edu/wp-content/uploads/2016/06/cdr-cdn-1-1.jpeg

Experiment Update (3/4): Sensors

Shakedown showed existing sensor(s) failed to respond

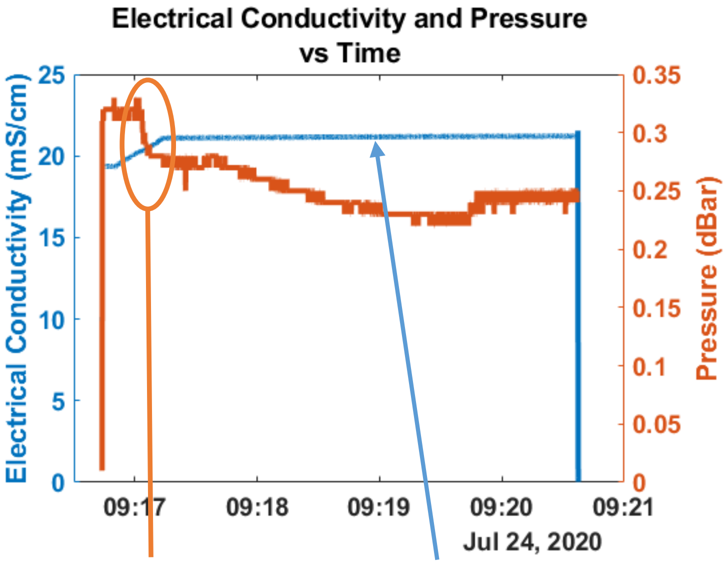
AML Sensors

- Purchased in 2018
- Rugged, immersible, wireless, intrinsic controls



- Acoustics w/ ultrasonic frequency (4 MHz)
- Electrical via set of electrodes (direct contact)

Mid-July shakedown:



Gas injection starts, gas flow rate increasing with time

Conductivity sensor does not respond to gas

Lessons:

- Larger spacing between transmitter and receiver for both devices
- Lower acoustic measurement frequency

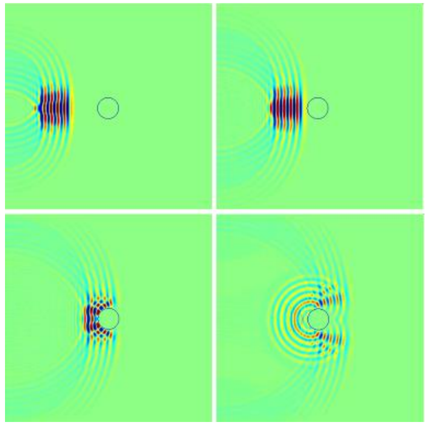


Fig.[1]

Scattering becomes significant when bubble size >> wavelength

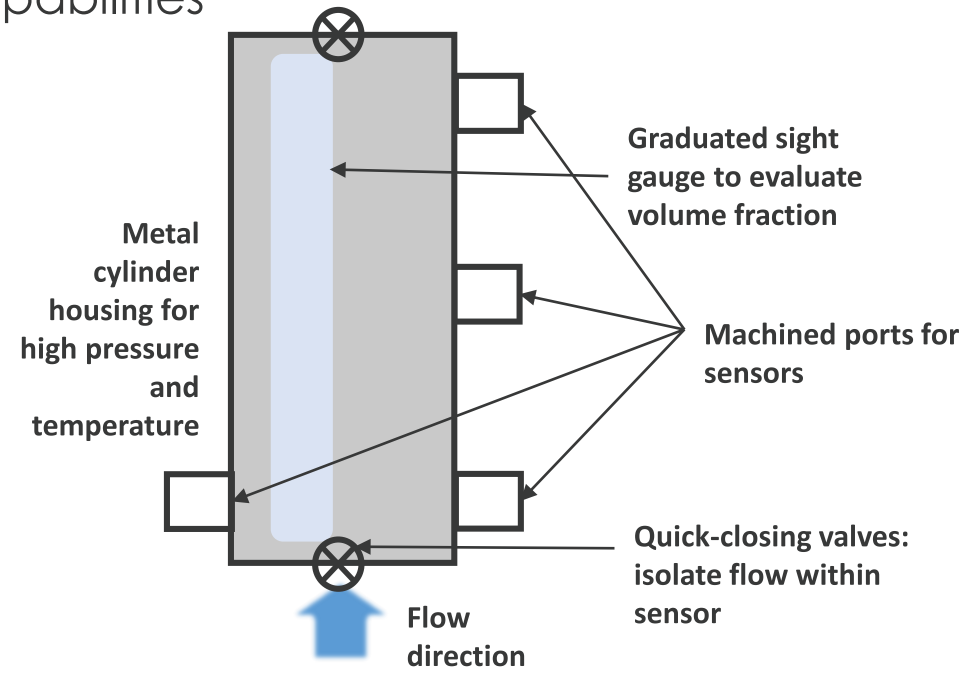
1) https://www.mathworks.com/matlabcentral/mlc-downloads/downloads/submissions/12097/versions/1/screenshot.gif

Experimental Update (4/4): Next Steps

Sensors to replicate LWD/MWD capabilities

Key Elements

- Wideband acoustics - hydrophones
- Electromagnetic induction
- Temperature/pressure sensors
- Graduated Sight Gauge
- Quick-closing Valves



Other Features

- Multiple receivers
- Inline arrangement
- Flexibility

Custom sensor(s) to emulate those used in the field

Updated Approach

LSU PERTT Lab

Design, build, calibrate, verify sensor → Test sensor in other conditions (assess) → Use data to test detection algorithm (optimize) → Field deployment

U.S. DEPARTMENT OF ENERGY

Sensitivity Analysis

Numerical compliment to develop understanding of expected response

Predicted acoustic response to varying kick volume

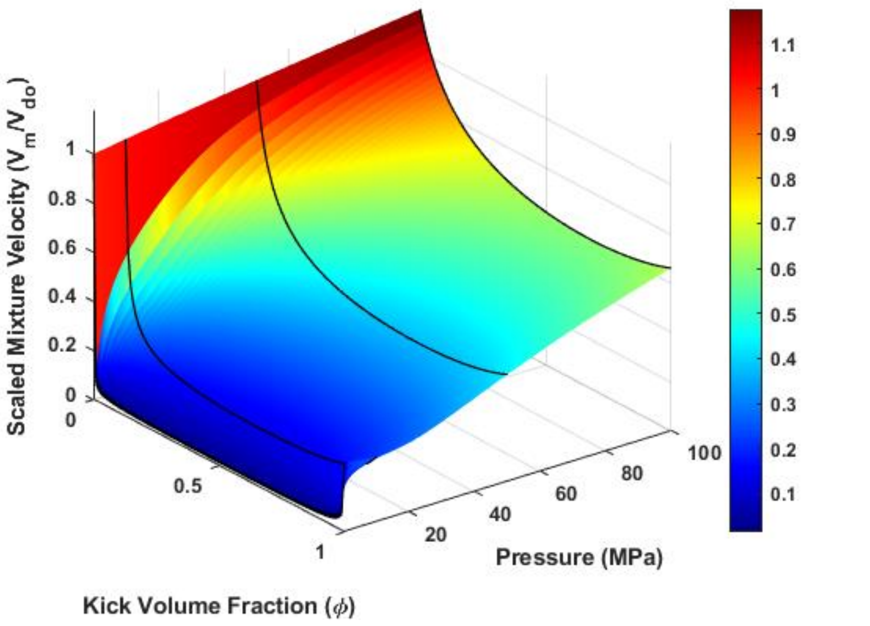
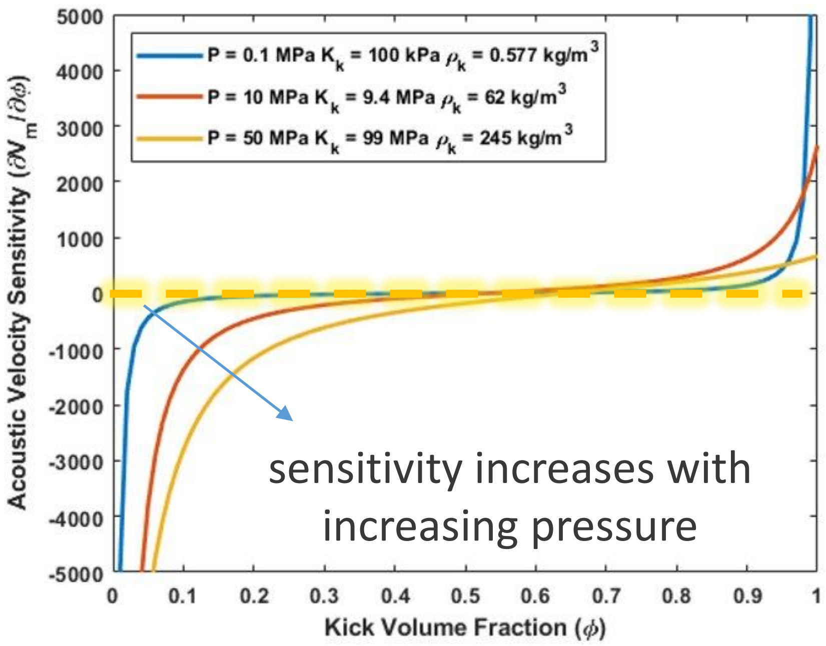


Fig. water with natural gas at $T = 77℃$

Predicted sensitivity of response to *change* in kick volume



Provide insight into: what volume of kick is discernable / level of sensor accuracy needed

Next: resistivity modeling and incorporating sensor accuracy

Presented at Offshore Technology Conference. May, 2020*

OFFSHORE TECHNOLOGY CONFERENCE 2020 #OTC2020

1) Tost et al., Digital presentation https://www.onepetro.org/presentation/OTC-30831-PT) and Conf. Proceedings: https://doi.org/10.4043/30831-MS.

Algorithm Update: Initial Approach

Develop data analysis techniques for a kick detection algorithm

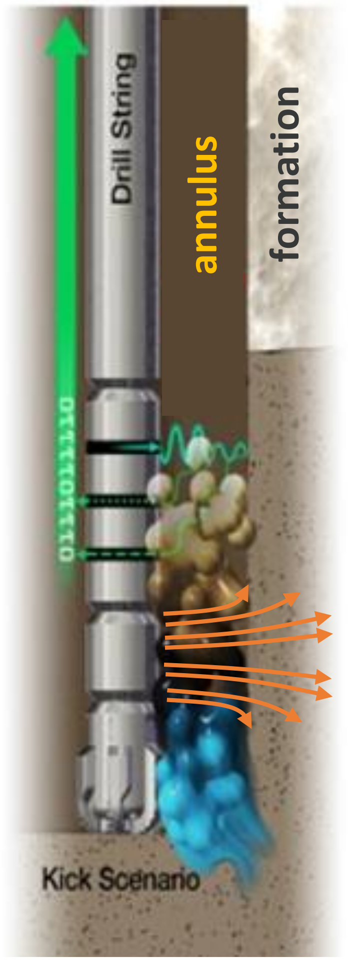


Fig. Illustration of wellbore environment[1]

Challenges

- Lack of real datasets
- Existing dataset(s) are not ideal:
  - wireline data – not real-time LWD data
  - focused on formation – not annular space

Change in signals due to lithology of formation vs a kick in annulus

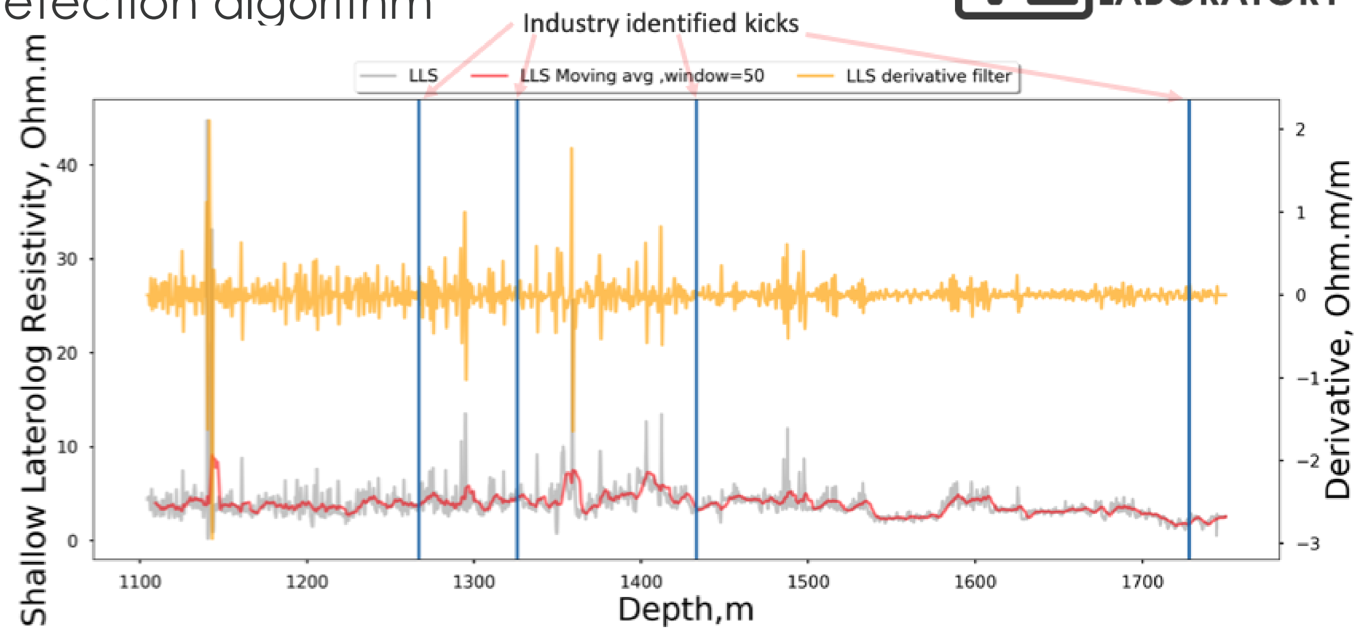


Fig 1. Filters applied to *wireline* data

⚠ Demonstrates technique only

- Moving average filter suppresses the peaks[2]
- Derivative filter magnifies the effect of noises[2]
- The method is indiscriminate*

**Kick TCF project is focused on commercializing kick detection algorithm using real-world data in collaboration with Aramco Services Inc.

Next: additional algorithm work and signal analysis**

1) Adapted from Tost, B., et. al., 2016, https://doi.org/10.2172/1327810
2) Cornell CS 6670 Lecture on filters

Summary and Next Steps

Task 4. Constraining Kick Signals via Advanced Multi-Phase Data

In the absence of field data - develop representative data at low cost

- ✓ A multiphase flow experiment was built that simulates a kick in a wellbore environment (with simplifications):
  - ➢ Constrained to simple fluids in ambient conditions
  - ➢ Existing sensors found inadequate
- ✓ Examined certain physical property response(s) through simple models
  - ➢ Bulk density and acoustic velocity
- ✓ Implemented and applied an improved algorithm for kick detection based on sequential data mining method

- ✓ An experimental facility for simulating this scenario under more realistic conditions was identified and planned:
  - ➢ Delayed due to lack of suitable sensors

Next step: develop custom sensors as a surrogate to those in the field

Next step: identify and evaluate resistivity model

Next step: incorporate segmentation strategy; explore application of supervised learning methods; investigate identification of an annular contribution

Key Takeaways

- **No comparable laboratory setup to *produce and detect* geophysical signals of a fluid kick in a simulated wellbore system**
  - Low cost
  - Available to research and industry
  - Cultivate a needed dataset
    - understand mixture responses
    - testbed for algorithm development

Visit at:
https://edx.netl.doe.gov/offshore/portfolio-items/advanced-low-cost-downhole-kick-detection/

Recent Publication/Presentation:
Tost B., et al., Conf. Proceedings: https://doi.org/10.4043/30831-MS and digital presentation at: https://www.onepetro.org/presentation/OTC-30831-PT).

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Disclaimer & Acknowledgement

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- Acknowledgement: Parts of this technical effort were performed in support of the National Energy Technology Laboratory's ongoing research under the Offshore Unconventional Resources – DE FE-1022409 by NETL's Research and Innovation Center, including work performed by Leidos Research Support Team staff under the RSS contract 89243318CFE000003.