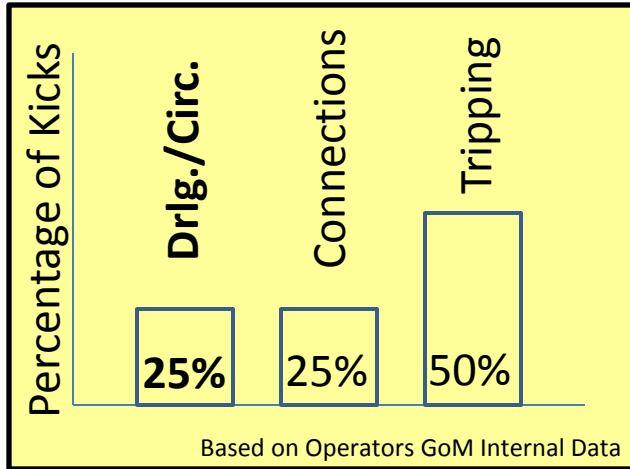


# Next Generation Kick Detection during Connections: Influx Detection at Pumps Stop (IDAPS) Software

**Brian Tarr, Shell**

# BACKGROUND

When Do Kicks Occur?

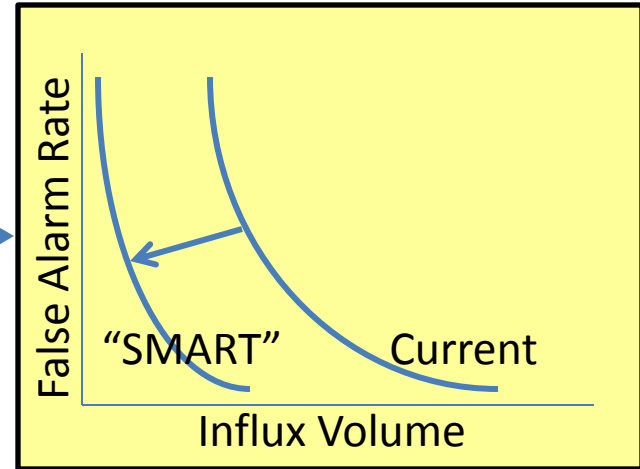


Focus of Current Rig Based Kick Alarm Systems:

1. Drilling/Circulating

Fault Tree Analysis

Smart Kick Detection System



SMART Kick Alarms for:

1. Drilling/Circulating
2. **Connections**
3. Tripping

## PERFORMANCE GOALS FOR IDAPS

1. Kick probability of detection (PD): Required PD  $> 0.95$ , Target PD = 1
2. Kick false alarm rate (FAR): Required FAR  $< 1/100$ , Target FAR  $< 1/1,000$
3. Time to detect (Td) a kick: Required Td  $< 240$  sec, Target Td  $< 120$  sec
4. Provide feedback if sensor data appears inconsistent
5. Adaptive to all well conditions
6. Use available surface sensor data
7. Simple to install and use

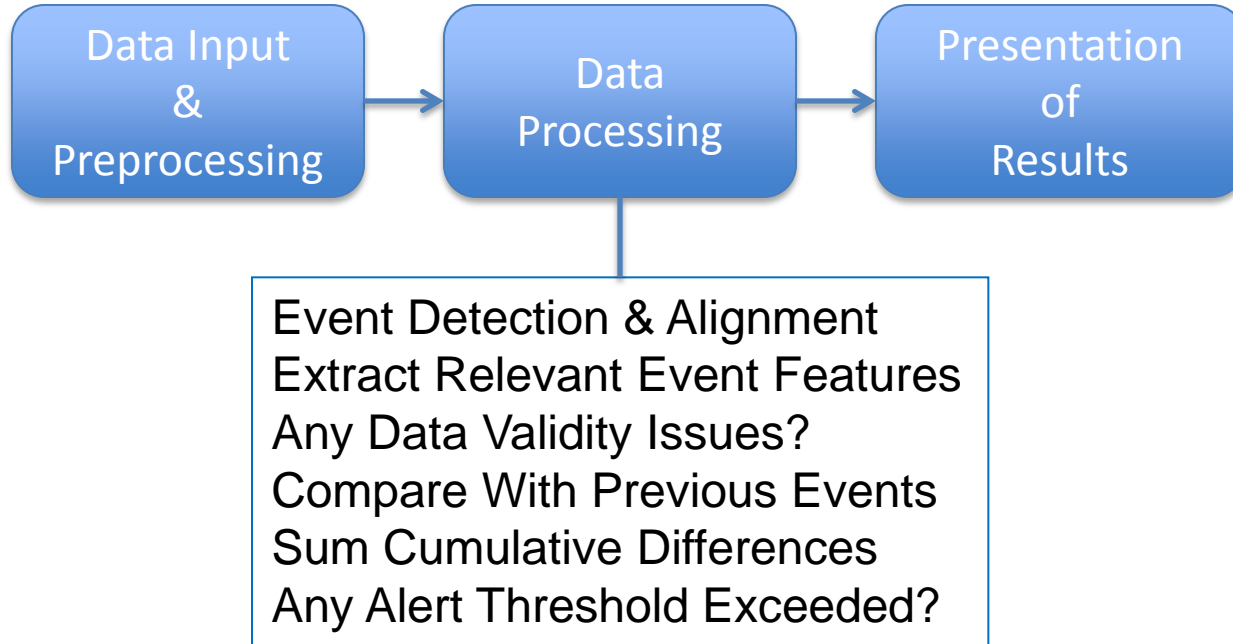


Good connection, no kick

Possible kick detected

Kick confirmed

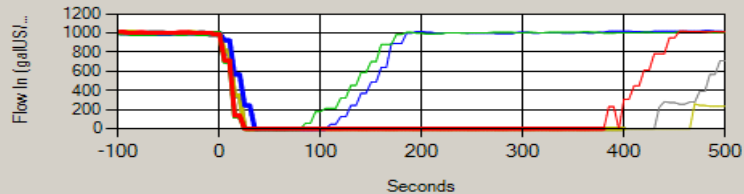
## IDAPS FUNCTIONAL DESIGN



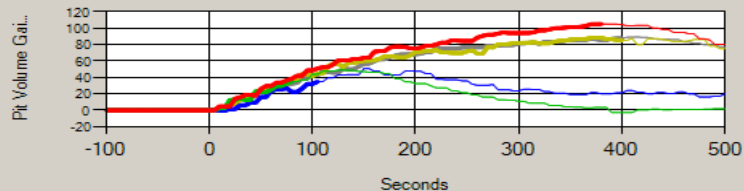
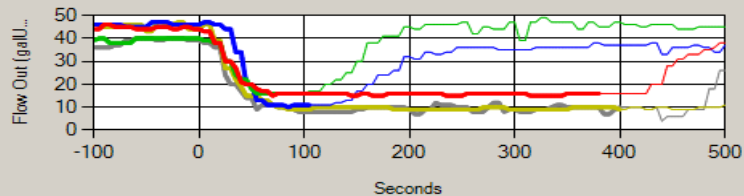
# IDAPS PUMPS-OFF EVENT COMPARISON DISPLAY

monstration Well: 1/17/2008 16:28:06 : Meas Hole/Bit Depth = 13608 / 13599 : On Bottom at pumps off

Event Data



Event 4	[2008-01-17 12:40:01]: 13407
Event 5	[2008-01-17 13:53:51]: 13503
Event 6	[2008-01-17 14:59:36]: 13554
Event 7	[2008-01-17 15:54:21]: 13516
Event 8	[2008-01-17 16:28:06]: 13599



Possible Influx Detected  
Probability: Medium

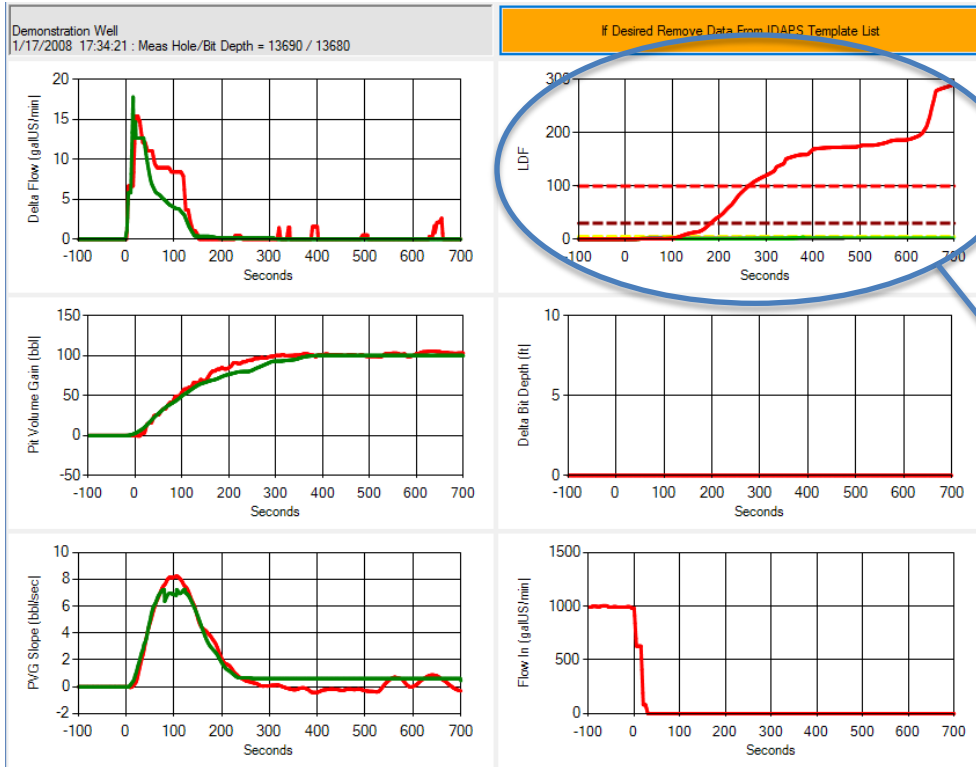
Possible sensor errors detected  
Paddle stuck flow measurement  
Range: 122 - 400  
Influx indicated medium confidence  
Range: 237 - 400  
**Abnormal amount of flow back to pit**  
Range: 280 - 381

Possible influx issues detected  
-- 184: Probability = Low  
Continuing flow out excessive  
Pit volume slope excessive  
Pit volume gain excessive  
-- 236: Probability = Medium  
Continuing flow out excessive  
Pit volume slope excessive  
Pit volume gain excessive

If Desired Remove Data From IDAPS  
Template List

Show Influx Analysis

IDAPS event processing terminated due to flow in.



## IDAPS EVENT ANALYSIS DISPLAY

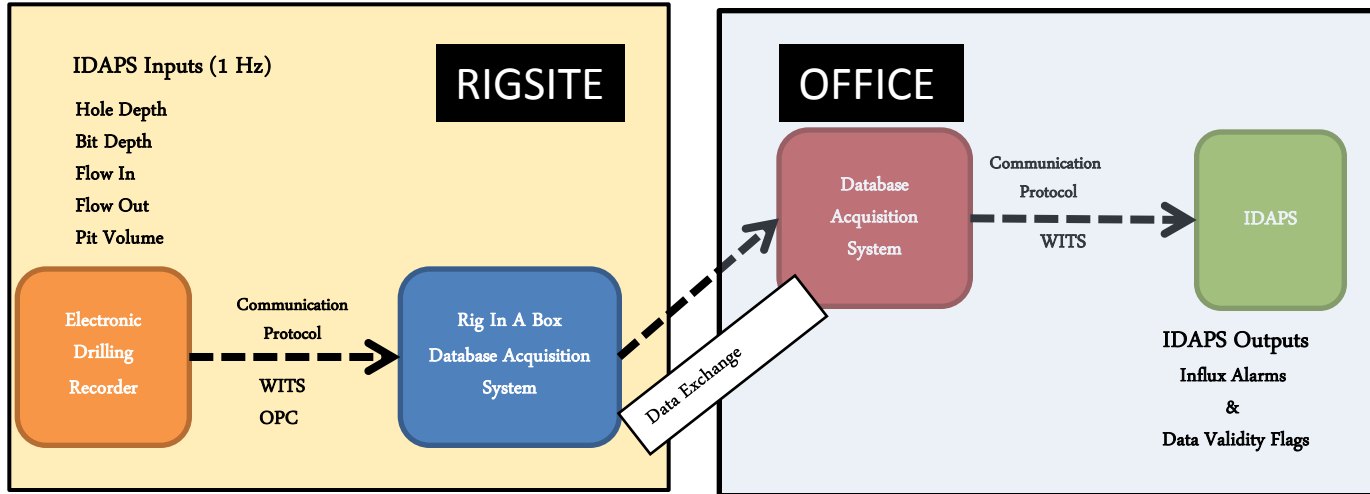
— Current pumps-off event

— Comparison Signature  
(derived from prior events)

$$\text{Likelihood Derived Factor (LDF)} \\ = A (V1 \times V2 \times V3 \times V4) + B \times V1 \\ + C \times V2 + D \times V4$$

V1 to V4 = Cumulative sum Variables  
A to D = Constants

# IDAPS DATA FLOW DIAGRAM



## IDAPS Validation Using Historical Data Set

Filename	Event Number	Comments	Estimated Influx Volume [bbl]
Well1	16	Verified Influx	15
Well2	25	Suspected Influx	10
Well3	29	Verified Influx	22
Well4	12	Verified Influx	8.5
Well5	30	Verified Influx	14
Well6	17	Suspected Influx	10
Well7	12	Possible Influx	16
Well8	17	Possible Influx	N/A
Well9	8	Possible Influx	35
Well10	18	Suspected Influx	17
Well11	12	Suspected Influx	20


**All 4 Verified Kicks Detected**  
 PD = 1.0

**Only 7 IDAPS False Alarms**  
**in 1362 connections**  
 FAR = 1 per 195 Connections

Time to “confirmed” alarm  
 ranged from 84 to 263 seconds



# IDAPS TESTING

## Functional Testing

Unit  
Testing

Integration  
Testing

System  
Testing

Acceptance  
Testing

## Non-Functional Testing

Performance  
Testing

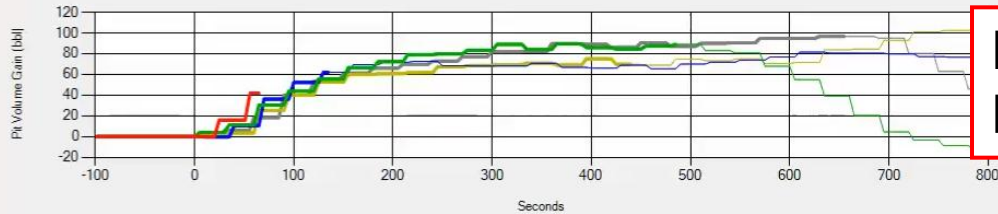
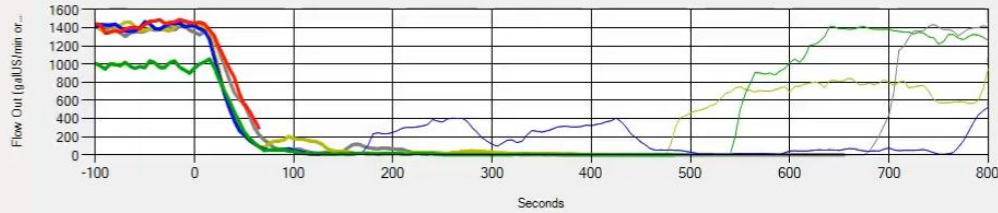
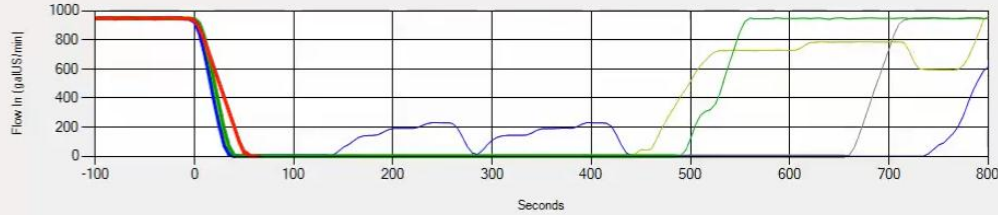
Usability  
Testing

Compatibility  
Testing

# EXAMPLE Connection Event Display Evolution

Demonstration: 9/29/2013 07:48:23 : Meas Hole/Bit Depth = 11334 / 11330 : On Bottom at pumps off

Event Data



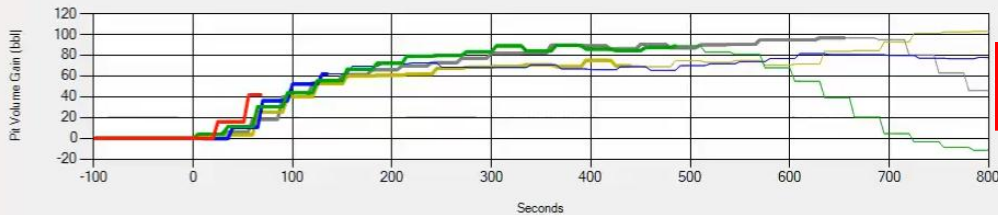
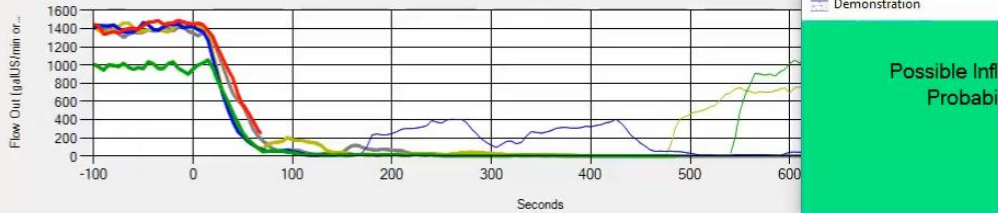
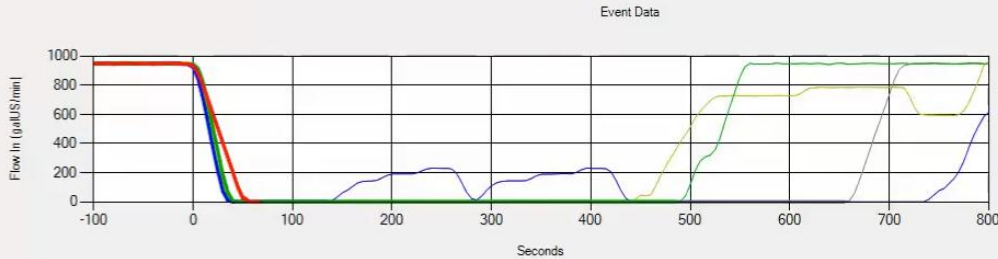
Event Information

Possible sensor errors detected  
Pit volume slope prior to pumps-off has excessive positive  
Range: -99 - -1

**Excessive Pit Vol. Slope  
Before Pumps Off.**

# EXAMPLE Connection Event Display Evolution

Demonstration: 9/29/2013 07:48:26 : Meas Hole/Bit Depth = 11334 / 11330 : On Bottom at pumps off



- Event 24 [2013-09-28 17:33:25]: 11037
- Event 25 [2013-09-28 21:04:55]: 11156
- Event 26 [2013-09-29 03:54:00]: 11150
- Event 27 [2013-09-29 04:14:35]: 11182
- Event 28 [2013-09-29 07:47:20]: 11314

Demonstration

Possible Influx Detected  
Probability: Low

OK

Possible Influx Detected  
Probability: Low

Possible sensor errors detected

Pit volume gain prior to pumps-off has excessive positive change: -99 - -1

Possible influx issues detected

- 67 Probability = Low

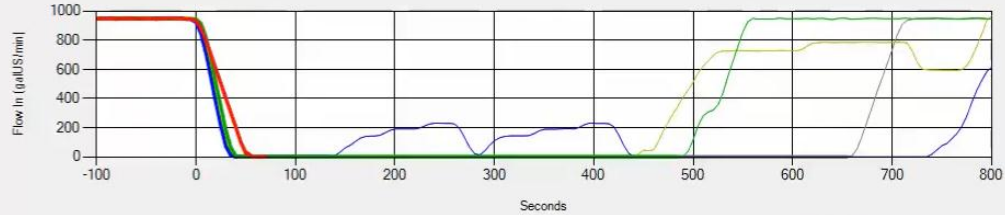
Pit volume gain excessive

**Excessive Pit Vol. Gain**

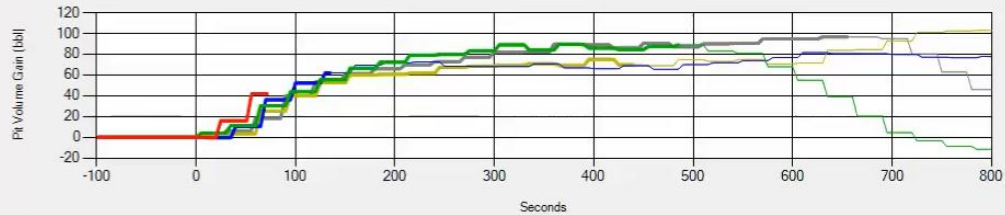
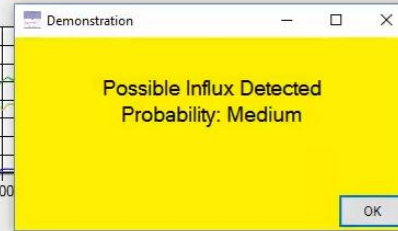
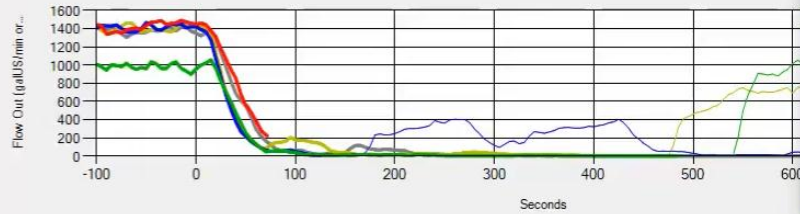
# EXAMPLE Connection Event Display Evolution

Demonstration: 9/29/2013 07:48:30 : Meas Hole/Bit Depth = 11334 / 11330 : On Bottom at pumps off

Event Data



Event 24	[2013-09-28 17:33:25]: 11037
Event 25	[2013-09-28 21:04:55]: 11156
Event 26	[2013-09-29 03:54:00]: 11150
Event 27	[2013-09-29 04:14:35]: 11182
Event 28	[2013-09-29 07:47:20]: 11314



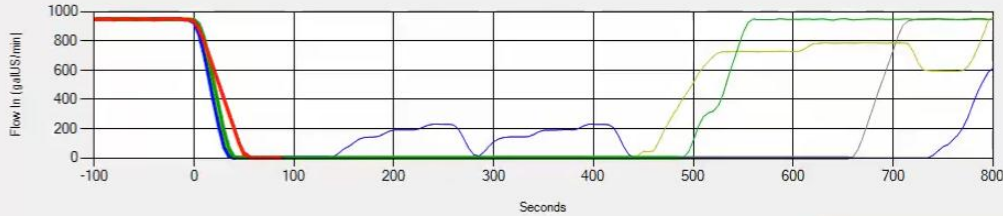
Possible Influx Detected  
Probability: Medium

Possible sensor errors detected  
Pit volume slope prior to pumps-off has excessive positive  
Range: -99 -1  
Possible influx issues detected  
-- 67:Probability = Low  
Pit volume gain excessive  
-- 71:Probability = Medium  
Pit volume gain excessive

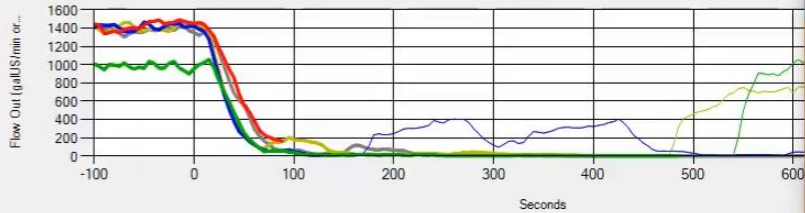
# EXAMPLE Connection Event Display Evolution

Demonstration: 9/29/2013 07:48:46 : Meas Hole/Bit Depth = 11334 / 11330 : On Bottom at pumps off

Event Data

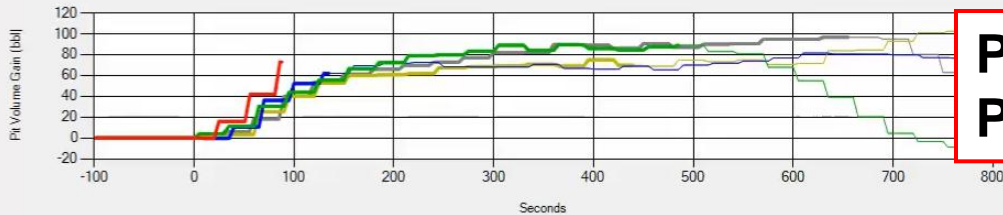


- Event 24 [2013-09-28 17:33:25]: 11037
- Event 25 [2013-09-28 21:04:55]: 11156
- Event 26 [2013-09-29 03:54:00]: 11150
- Event 27 [2013-09-29 04:14:35]: 11182
- Event 28 [2013-09-29 07:47:20]: 11314



Possible Influx Detected  
Probability: High  
Estimated influx volume (bbl) = 22.0

OK



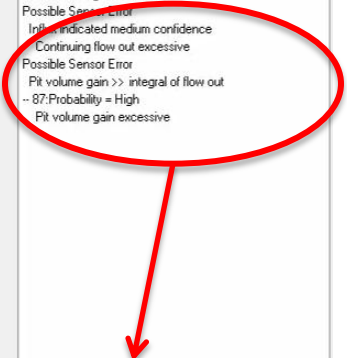
Possible Influx Detected  
Probability: High

Possible sensor errors detected  
Pit volume slope prior to pumps-off has excessive posit.  
Range: -99 - -1

Possible influx issues detected  
-- 67:Probability = Low  
Pit volume gain excessive  
-- 71:Probability = Medium  
Pit volume gain excessive

Possible Sensor Error  
Int. indicated medium confidence  
Continuing flow out excessive

Possible Sensor Error  
Pit volume gain >> integral of flow out  
-- 87:Probability = High  
Pit volume gain excessive

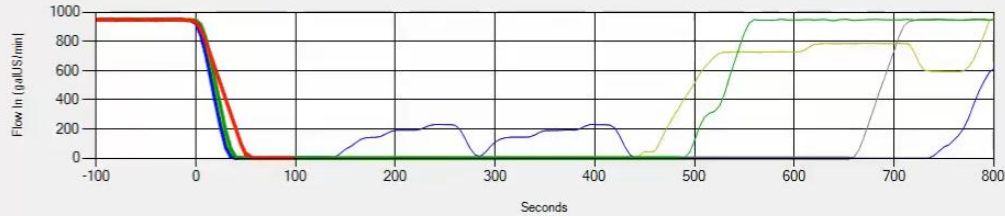


Possible Sensor Error?  
Pit Vol. Gain >  $\Sigma$ Flow Out

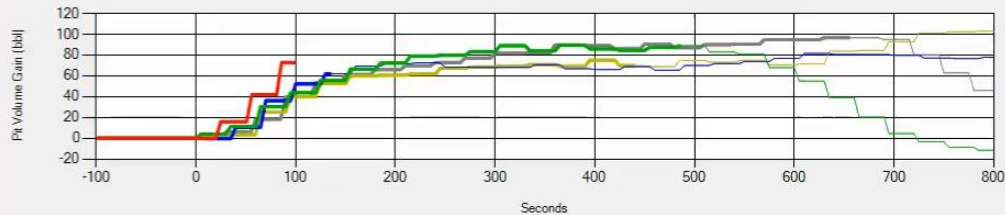
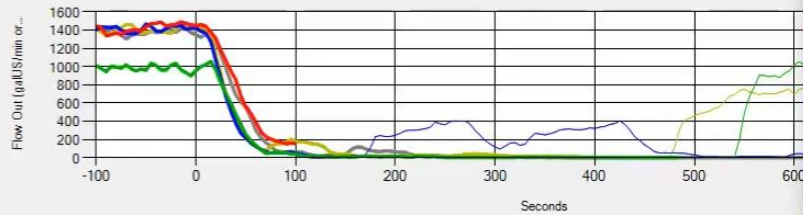
# EXAMPLE Connection Event Display Evolution

Demonstration: 9/29/2013 07:48:57 : Meas Hole/Bit Depth = 11334 / 11330 : On Bottom at pumps off

Event Data



Event 24	[2013-09-28 17:33:25]: 11037
Event 25	[2013-09-28 21:04:55]: 11156
Event 26	[2013-09-29 03:54:00]: 11150
Event 27	[2013-09-29 04:14:35]: 11182
Event 28	[2013-09-29 07:47:20]: 11314



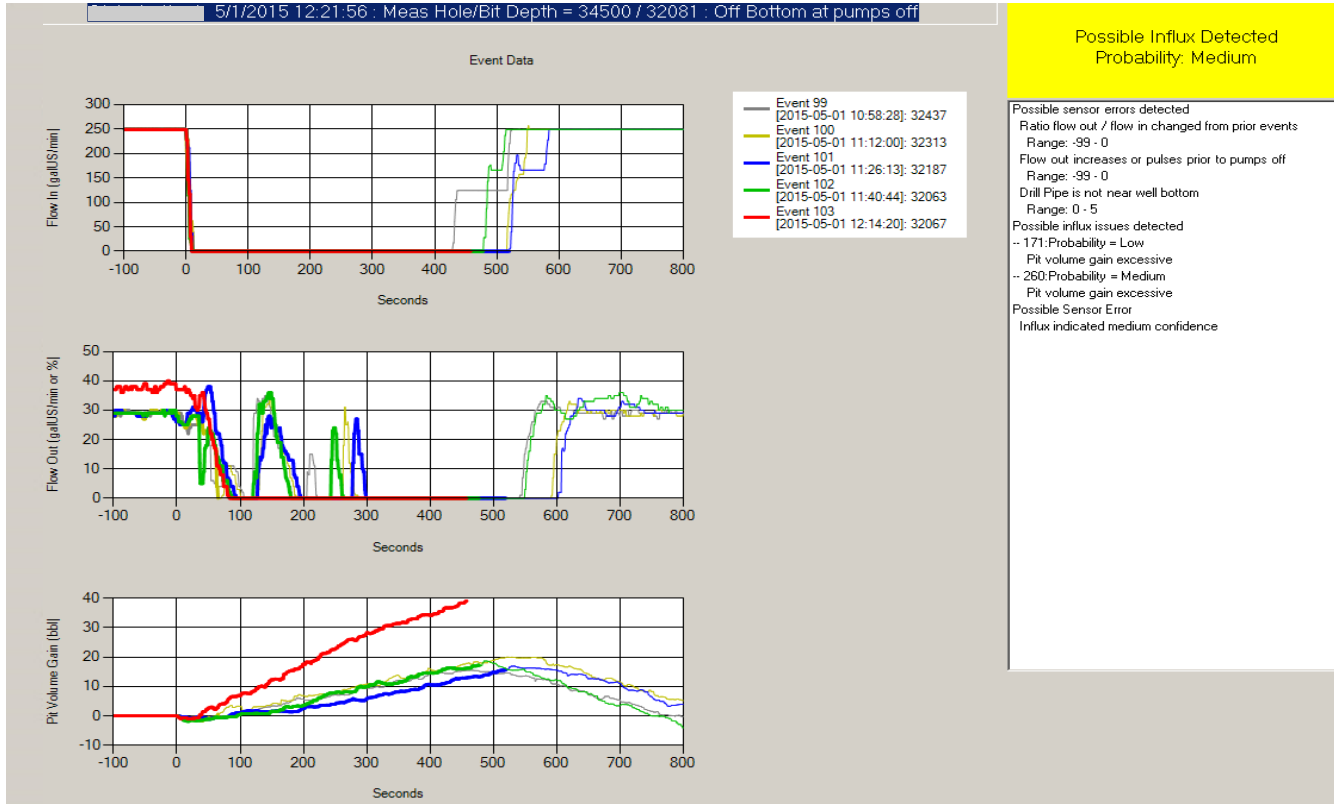
**Possible Influx Detected**  
**Probability: Confirmed**  
 Estimated influx volume (bbf) = 22.0

OK

**Possible Influx Detected  
Probability: Confirmed**

Possible sensor errors detected  
 Pit volume slope prior to pumps-off has excessive positive  
 Range: -99 - -1  
 Possible influx issues detected  
 - 67:Probability = Low  
 Pit volume gain excessive  
 - 71:Probability = Medium  
 Pit volume gain excessive  
 Possible Sensor Error  
 Influx indicated medium confidence  
 Continuing flow out excessive  
 Possible Sensor Error  
 Pit volume gain >> integral of flow out  
 - 87:Probability = High  
 Pit volume gain excessive  
 Possible Sensor Error  
 Influx indicated high confidence  
 - 98:Probability = Confirmed  
 Pit volume gain excessive

# EXAMPLE INTERVENTION #1



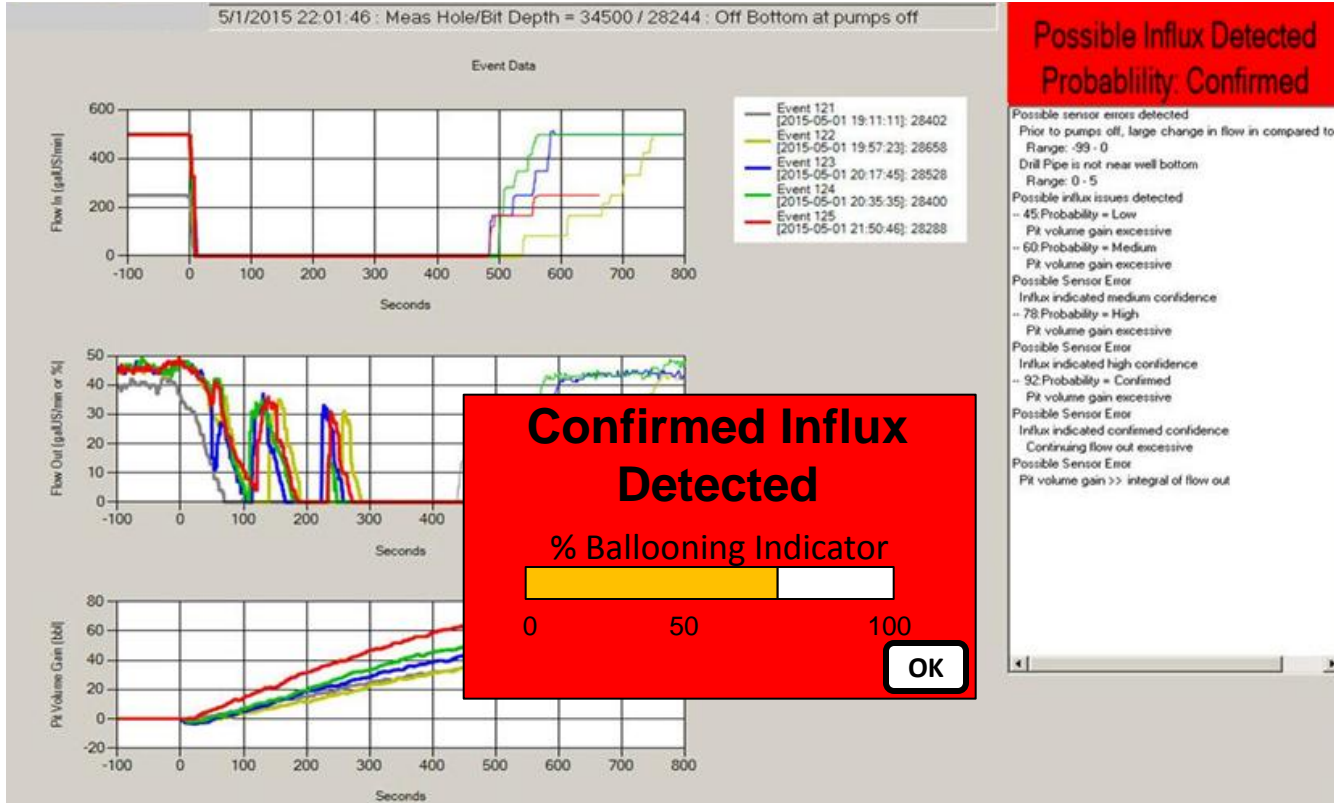
Operation:  
Pumping out of  
the hole.

Action:  
**RTOC Engineer  
Notified the Rig.**

No indication of  
flow during  
remainder of trip  
out.



# EXAMPLE INTERVENTION #2



**Operation:**  
Reaming tight spot.

**Action:**  
**RTOC Engineer**  
**Notified the Rig.**

Flow checked well (no flow).

**Ballooning?**



# CONCLUSIONS

1. By using advanced machine learning and optimal trend detection processing IDAPS achieved:
  - Probability of detection (PD) of 1.0 (no kicks missed)
  - False alarm rate (FAR) of 1/195 connections
  - Confirmed kick alarm in as little as 84 seconds
2. Overlay plots of recent pumps-off event flow and pit volume data are being used by the operators RTOC engineers to validate anomalous connection signatures identified by IDAPS.
3. IDAPS possible influx alerts and confirmed influx alarms are now taken seriously by the operators rig teams.
4. New Formation Breathing/Ballooning Discriminator now being tested.

# THANK YOU

## QUESTIONS & COMMENTS

**Paper Reference For More Information: IADC/SPE-178821**

*Next Generation Kick Detection during Connections: Influx Detection at Pumps Stop (IDAPS) Software*  
**Brian Tarr, Doug Ladendorf & Diego Sanchez Shell International E&P Inc., Martin Milner CoVar Applied Technologies Inc.**