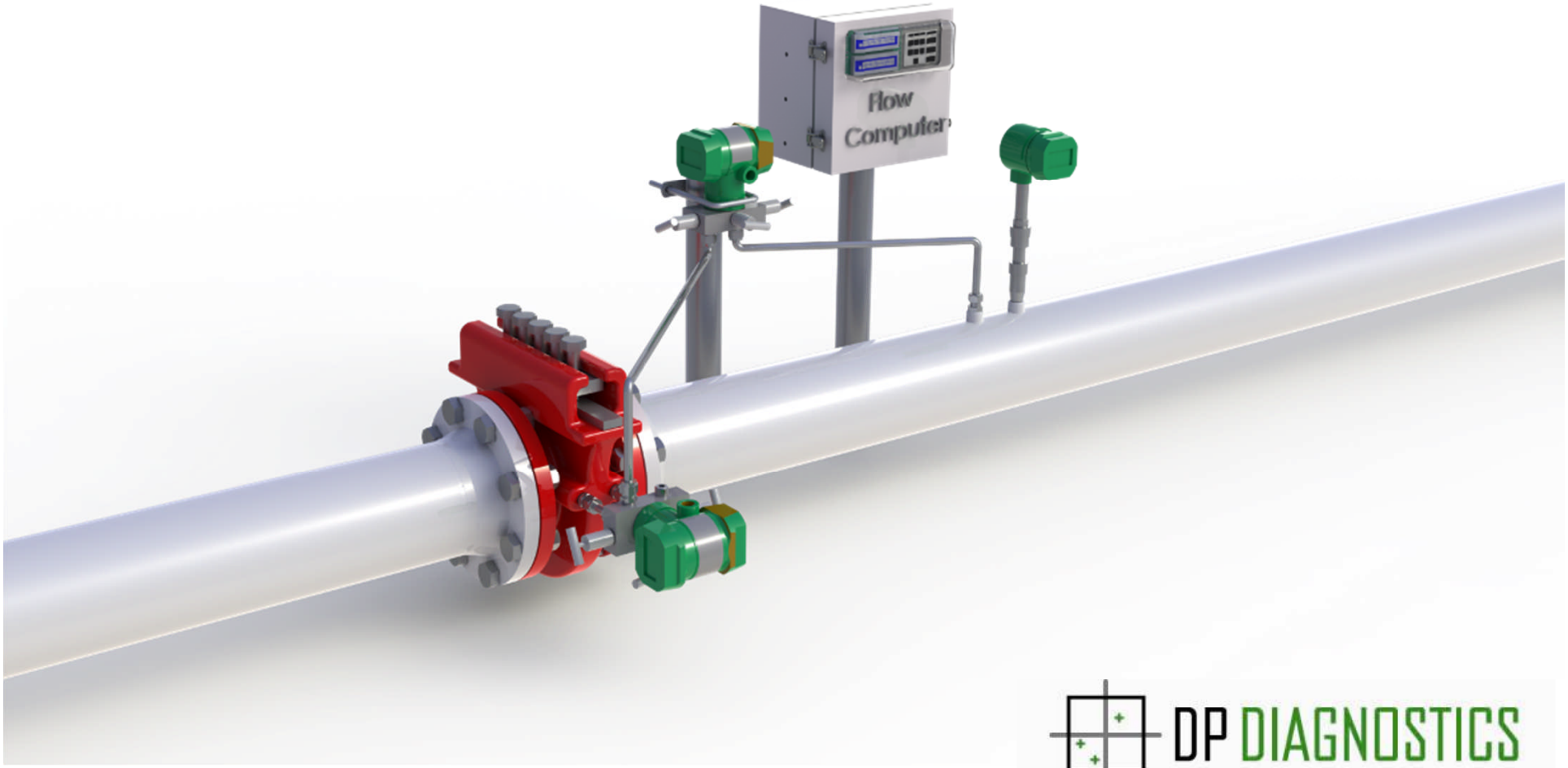
Orifice Meter Diagnostics – Theory, Laboratory Tests, Operator Interface & Field Results

by

Kim Lewis
DP Diagnostics

DP DIAGNOSTICS

MONITOR, VERIFY, AND TRUST YOUR DP METER



DP DIAGNOSTICS

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Introduction

- Orifice meters are as popular as they are simple, generally inexpensive & reliable, however…

  there is a long held axiom throughout industry that orifice meters have no internal diagnostics.

- A flow meter diagnostic system is desirable for several reasons:

  – guarantees meter performance therefore reducing exposure to measurement error,

Introduction (cont.)

- allows ***condition based maintenance*** (CBM) instead of routine scheduled maintenance (RSM):
  - avoiding unnecessary risky routine scheduled maintenance on HP systems!

    … if it ain't broke don't try and fix it,

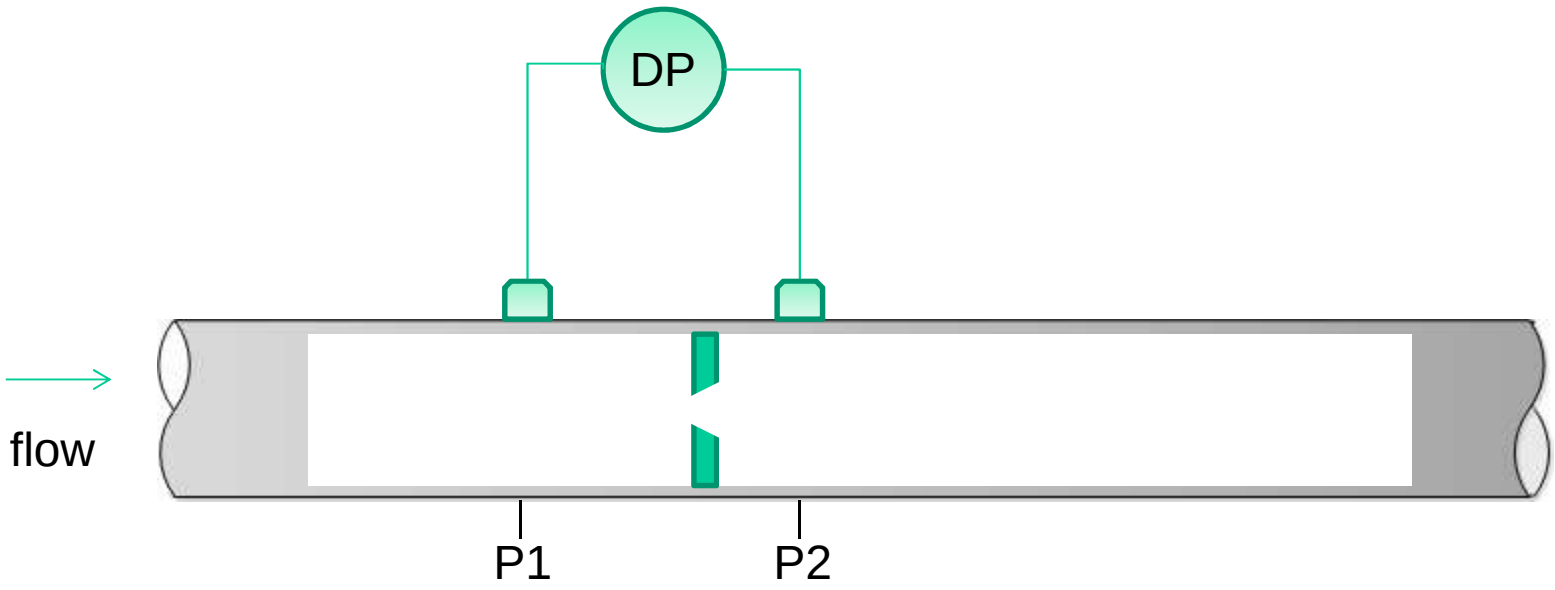
    - there is always the risk of loss of containment.

- CBM makes technicians in the field ***hugely*** more productive & efficient. They go to a meter with a problem every time, instead of blindly searching for problems!

Introduction (cont.)

- CBM decreases the **Safety Factor** for Technicians
  - Less Time Behind the Windshield
  - Reduces the Exposure to Hazardous Conditions
    - Unnecessary to Break Containment during the Inspection of the meter
    - Reduced Exposure to H2S Hazards

Traditional DP Orifice Meter



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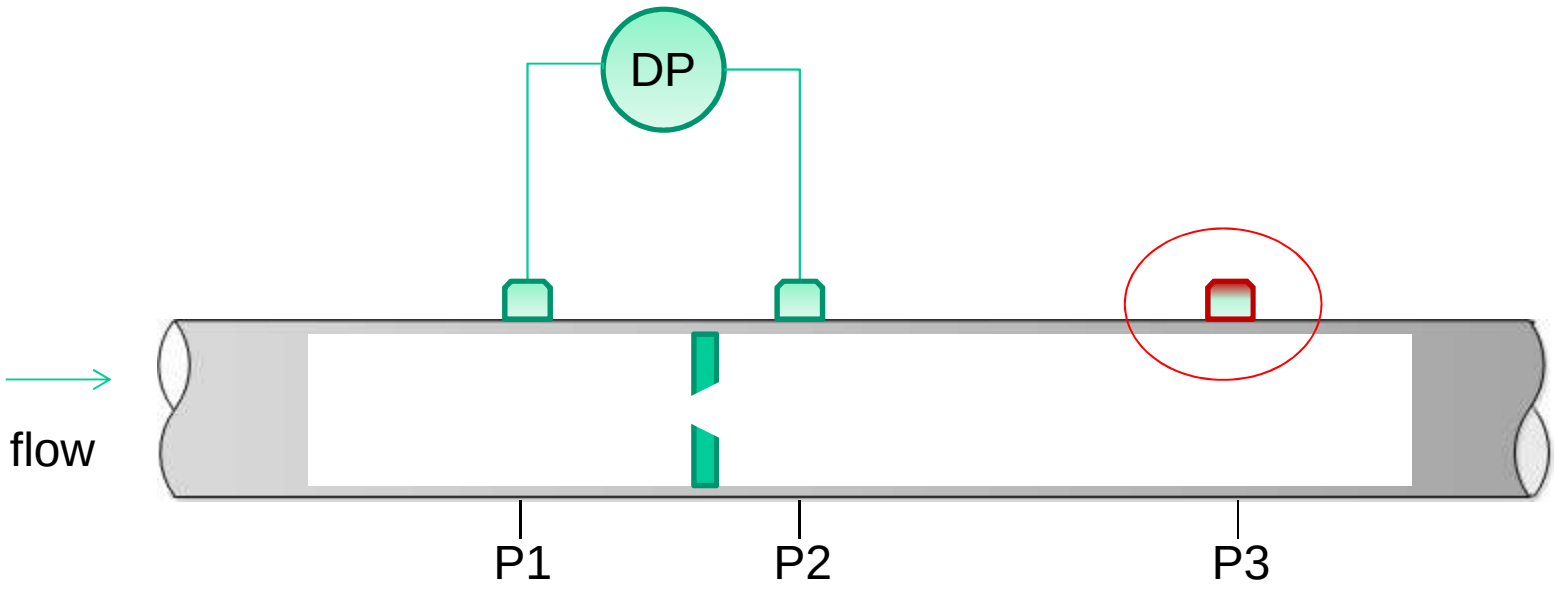
Add a downstream tapping



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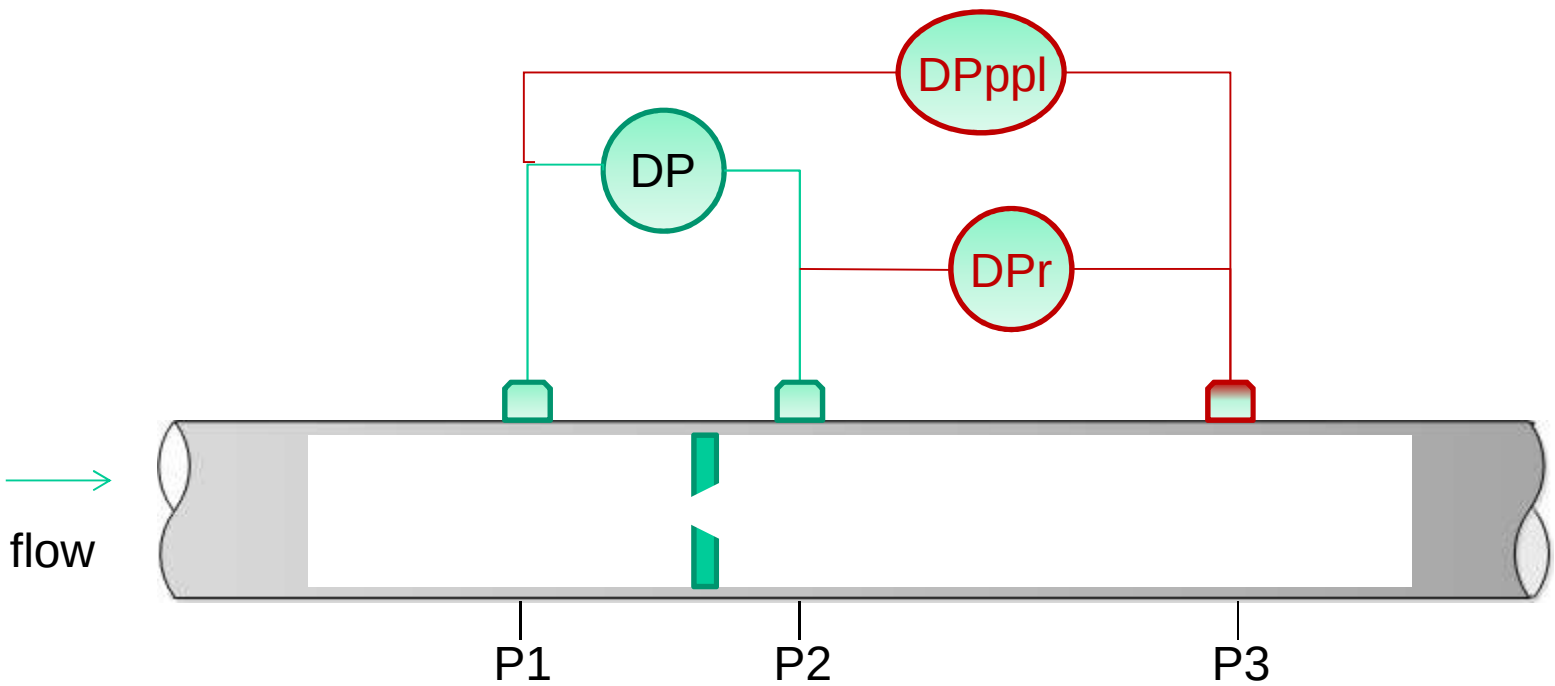
Two Extra DP Transmitters



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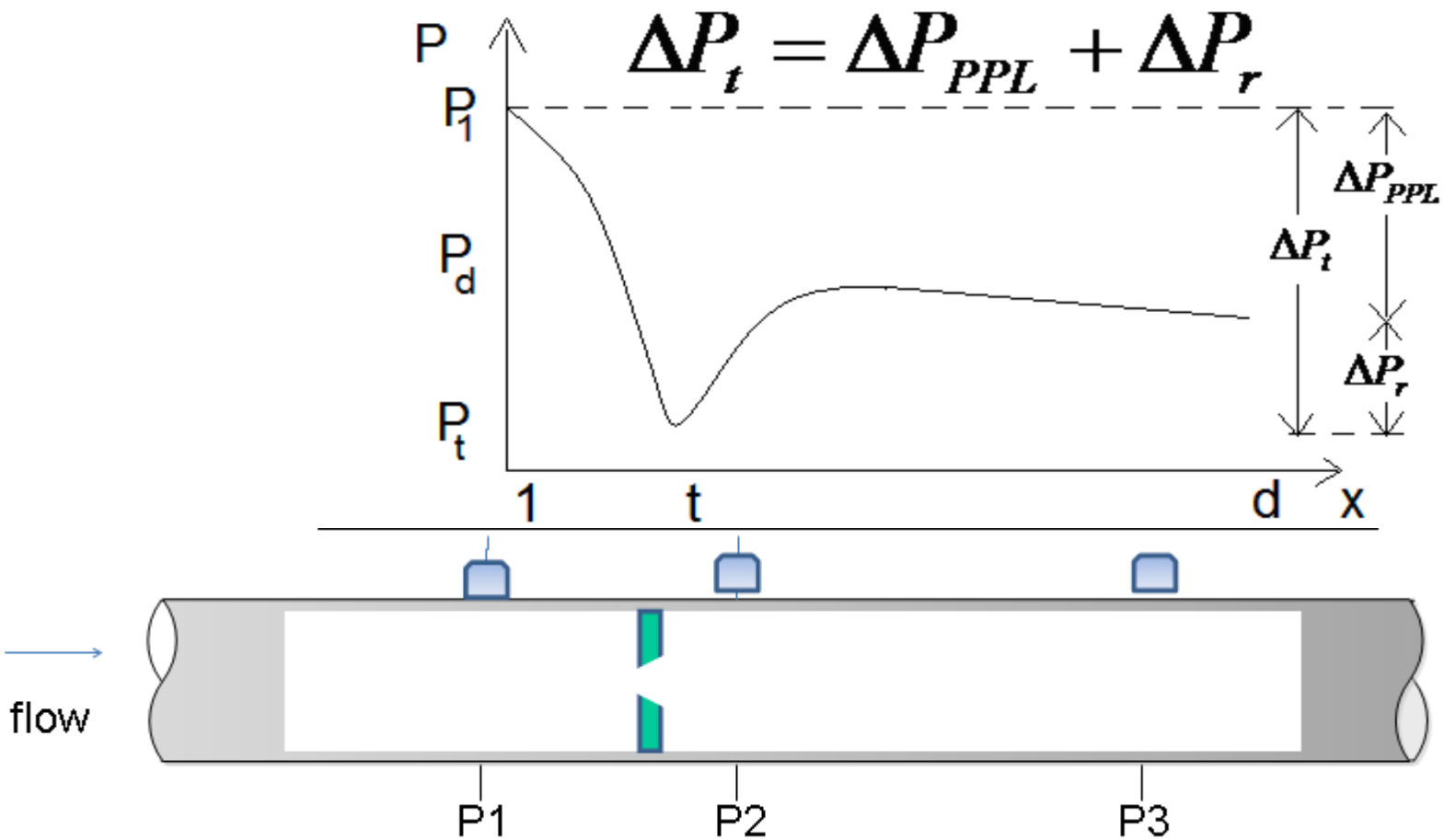
DPt = DPr + DPppl



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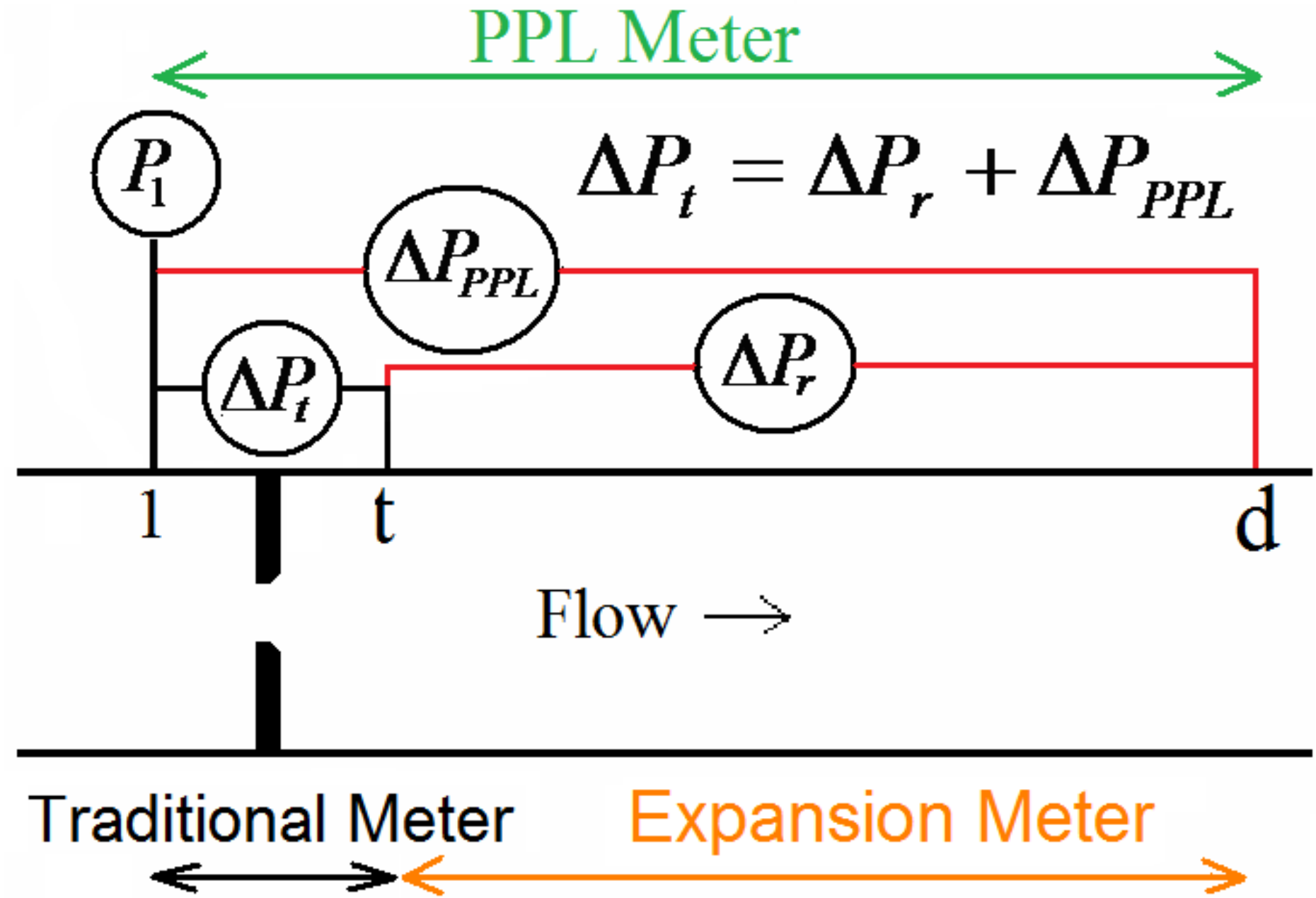
The DP Diagnostics method:

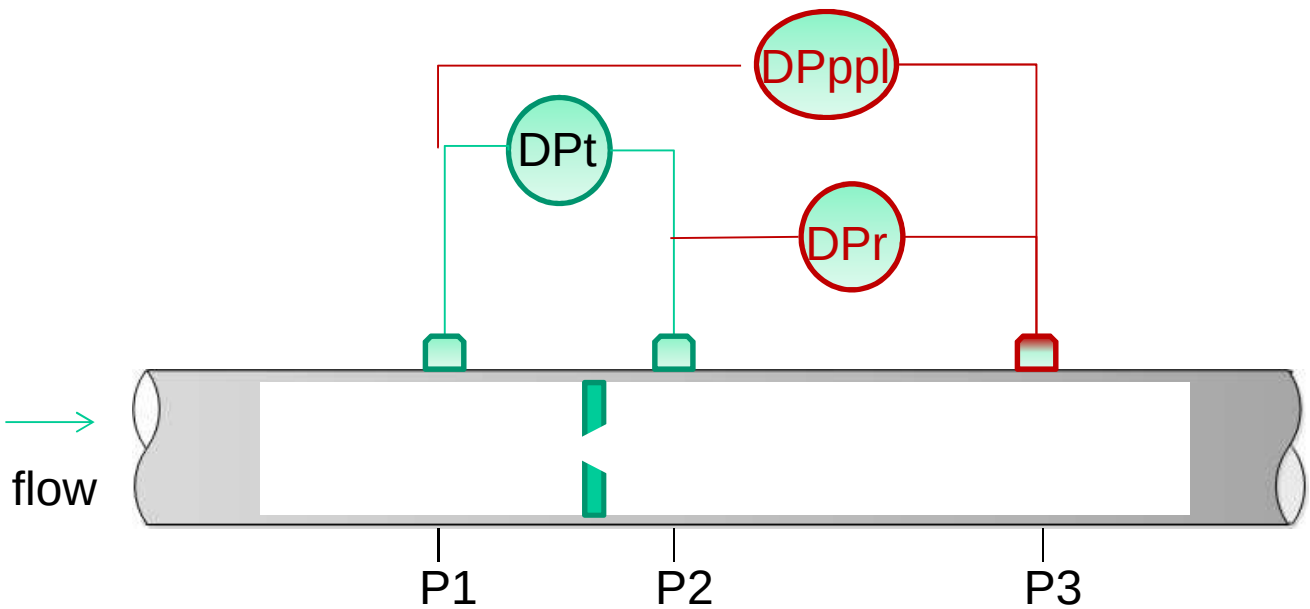


Three Flowrate Predictions

$$m_t = k \sqrt{DP_t}$$

$$m_r = k_r \sqrt{DP_r}$$

$$m_{ppl} = k_{ppl} \sqrt{DP_{ppl}}$$



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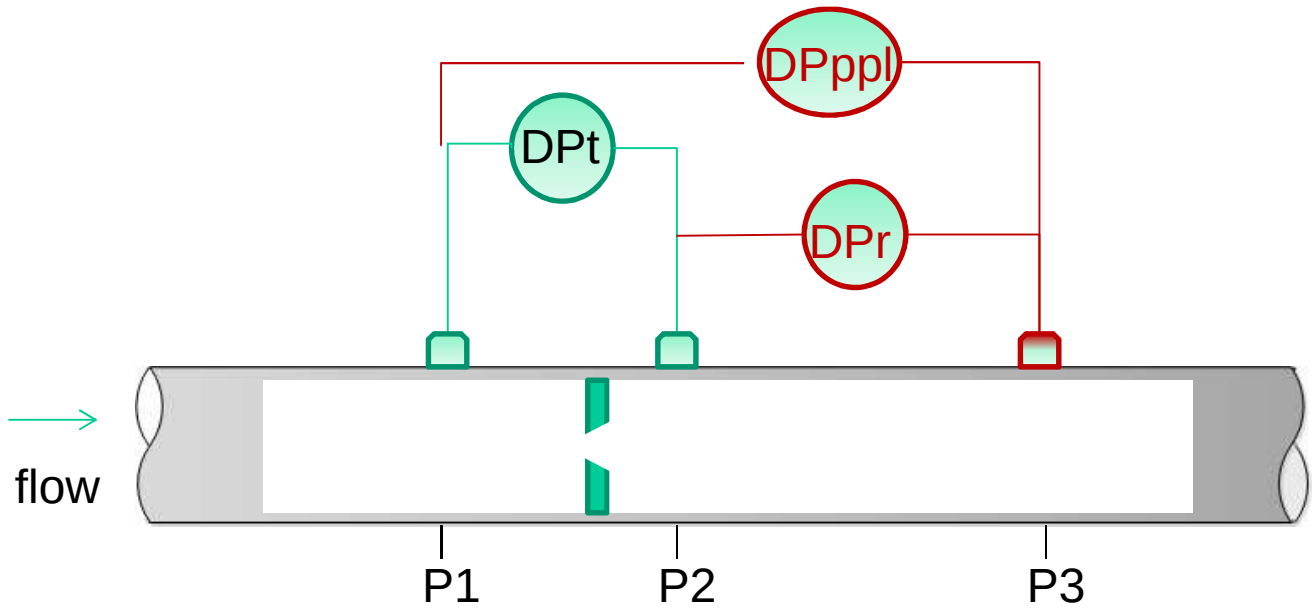
Three DP Pairings plus DP Ratios

$DP_{ppl} / DP_t = PLR$

$DP_r / DP_t = PRR$

$DP_r / DP_{ppl} = RPR$



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3 DP's produces 3 DP pairs & 3 DP ratios:

$$\frac{\Delta P_{PPL}}{\Delta P_t}, \quad \frac{\Delta P_r}{\Delta P_t}, \quad \frac{\Delta P_r}{\Delta P_{PPL}}$$

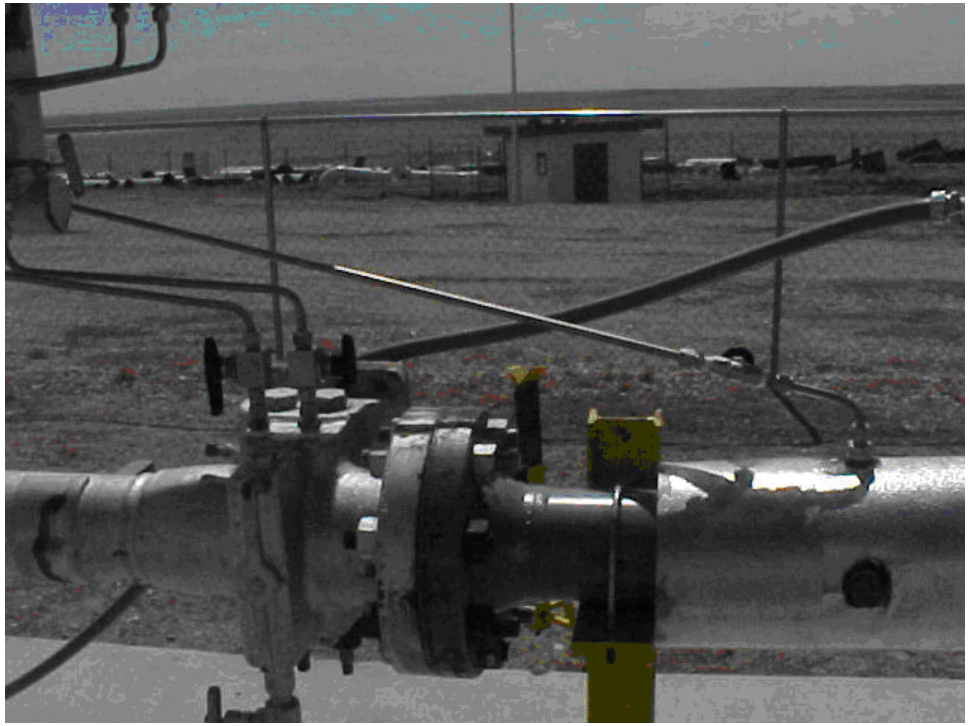
i.e. "PLR" "PRR" "RPR"

- ***DP ratios are set characteristics of the meter***. Hence, we can compare each "read" value to the expected value.

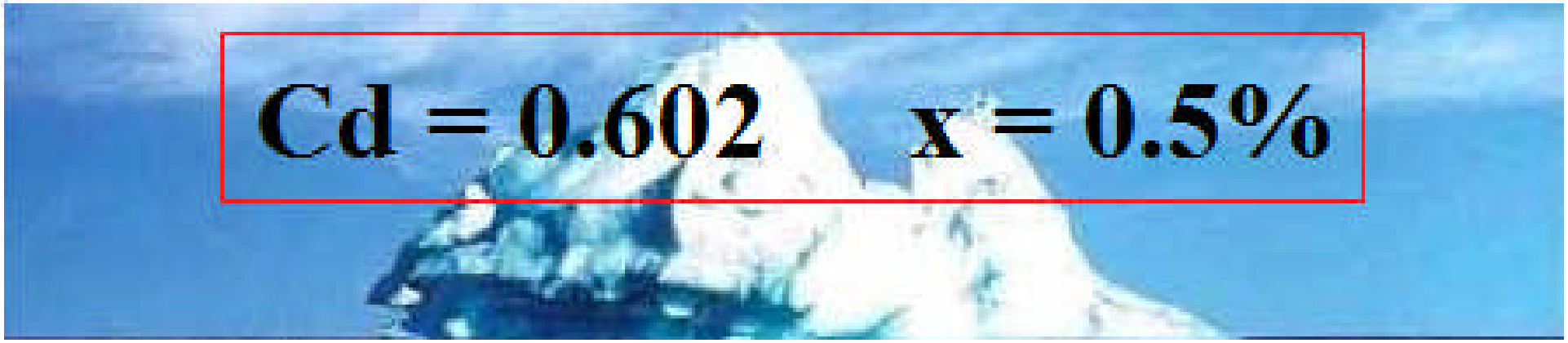
- All orifice meter diagnostic characteristics are derivable from the standards.

4”, 0.5 beta ratio orifice plate data

- CEESI Double Chamber with Daniel Plate, Natural Gas, 112 pts



- 2008: Daniel Paddle Plates, Air, 44 pts
- 2009: Yokogawa Paddle Plates, Air, 124 pts



DP DIAGNOSTICS

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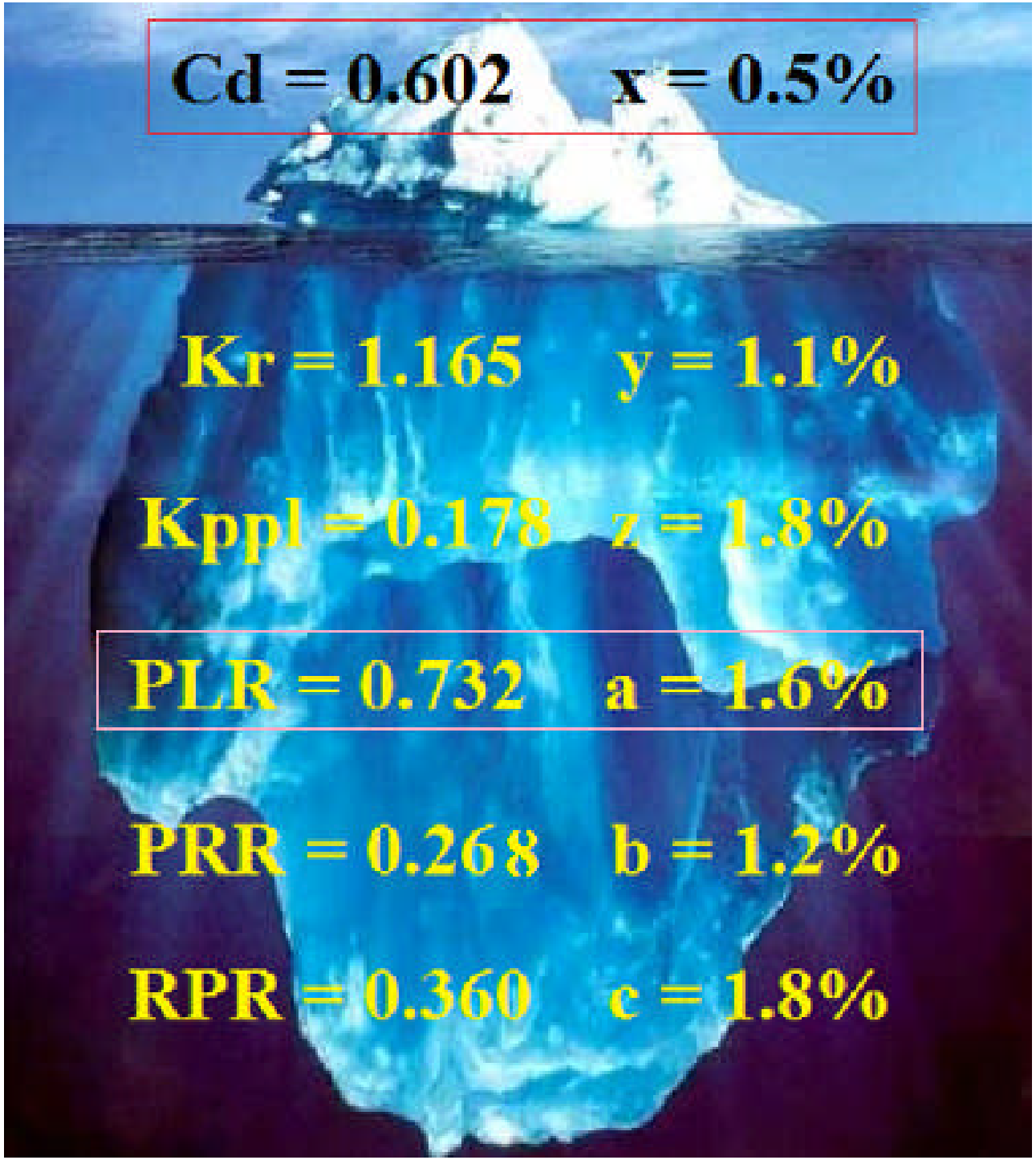
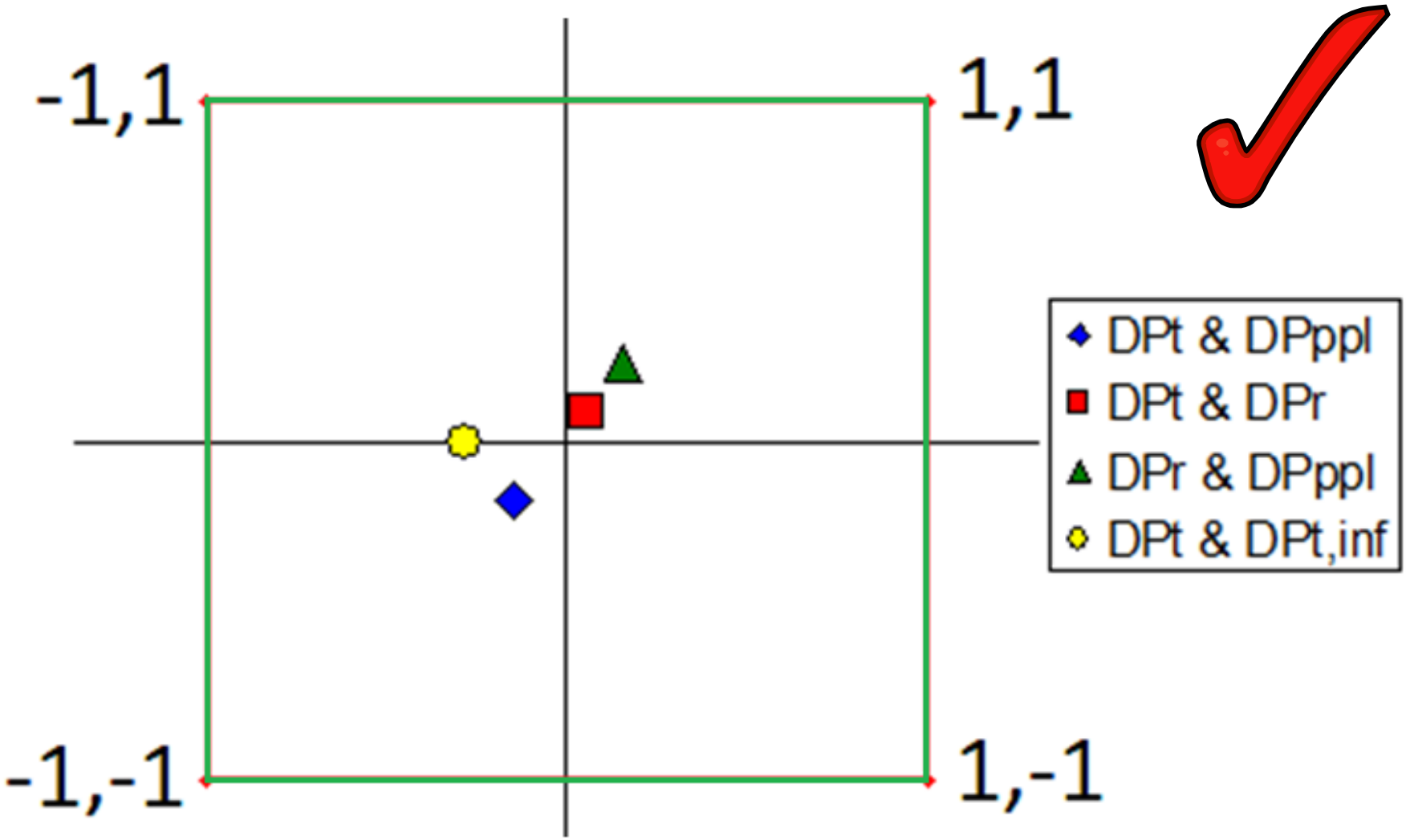

Cd = 0.602 x = 0.5%
Kr = 1.165 y = 1.1%
Kppl = 0.178 z = 1.8%
PLR = 0.732 a = 1.6%
PRR = 0.268 b = 1.2%
RPR = 0.360 c = 1.8%

Sample Actual Baseline Result, in a NDB:

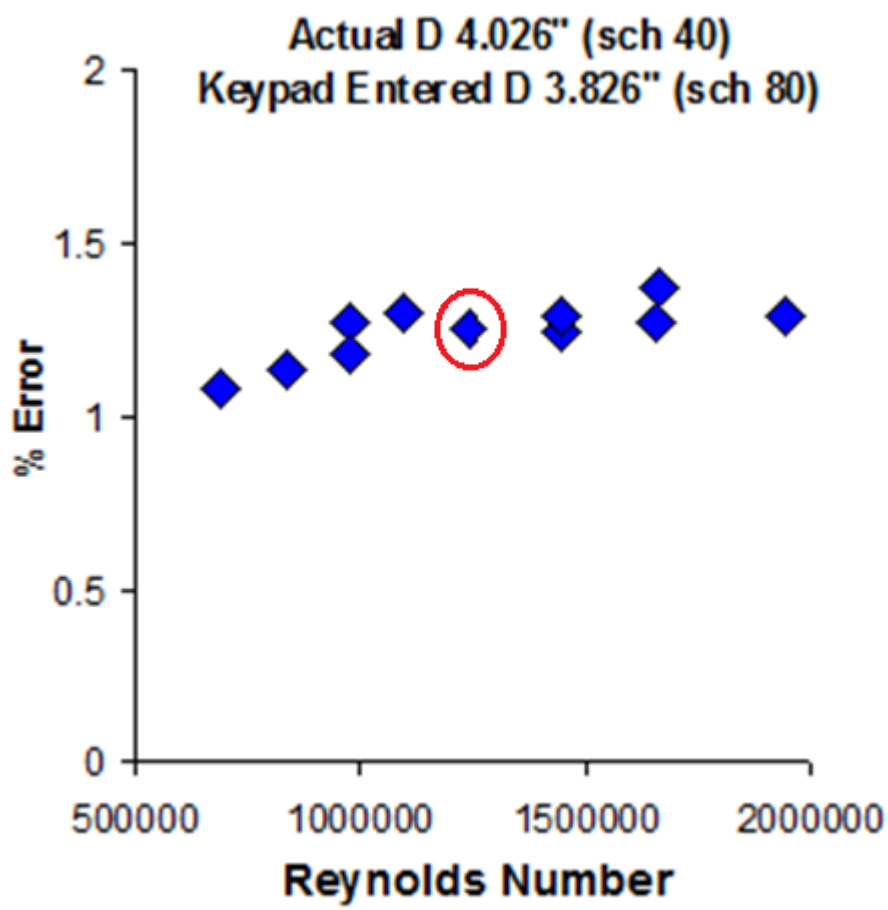


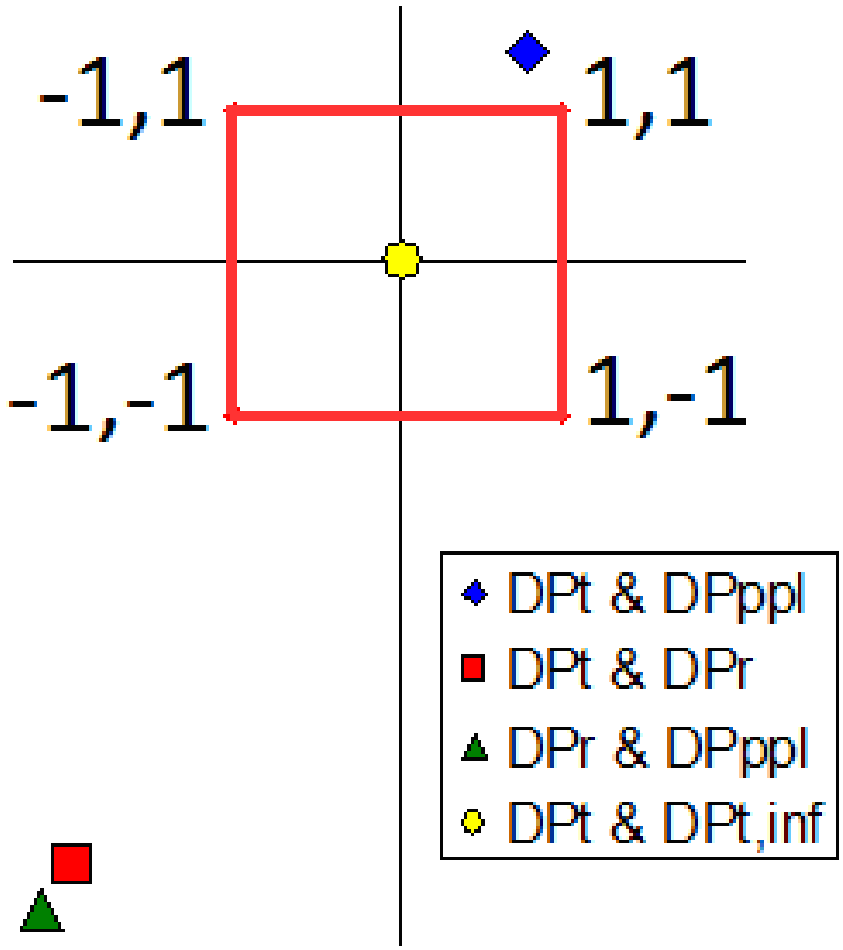
Orifice Meter Malfunction Examples

- 4”, 0.5 β paddle plate orifice meters with air flow were given various malfunctions at CEESI.
- Each example shows the scale of the induced bias & the corresponding diagnostic response.
- To put the induced bias in industrial context the monetary value of such a bias for a mid-range natural gas flow through such a meter is also given.

1 MMSCF is approx $3,500 /day

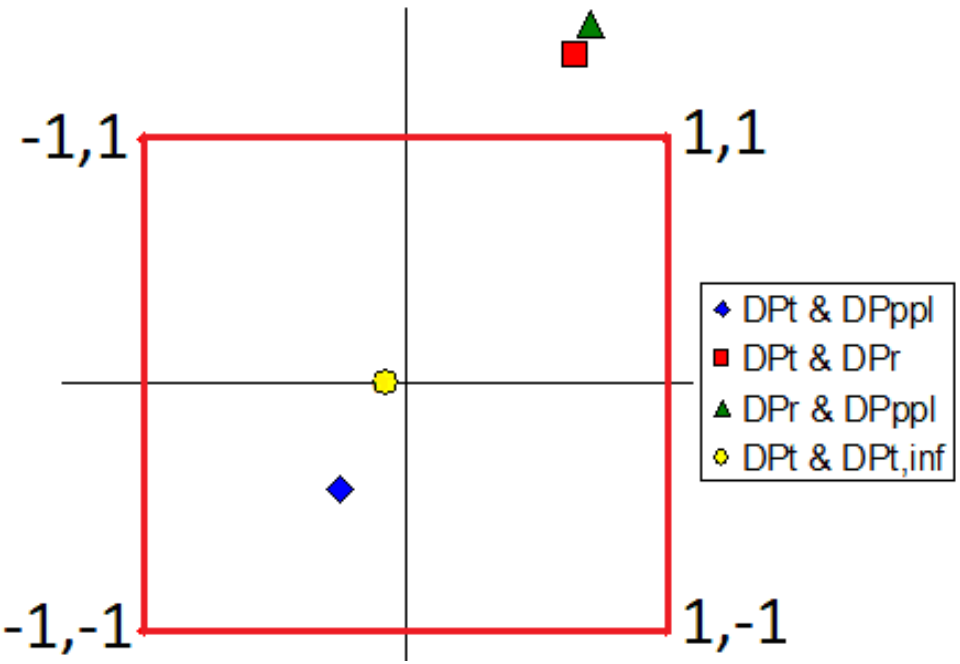
4”, 0.5 β Orifice Meter with Error in Inlet Diameter Keypad Entry

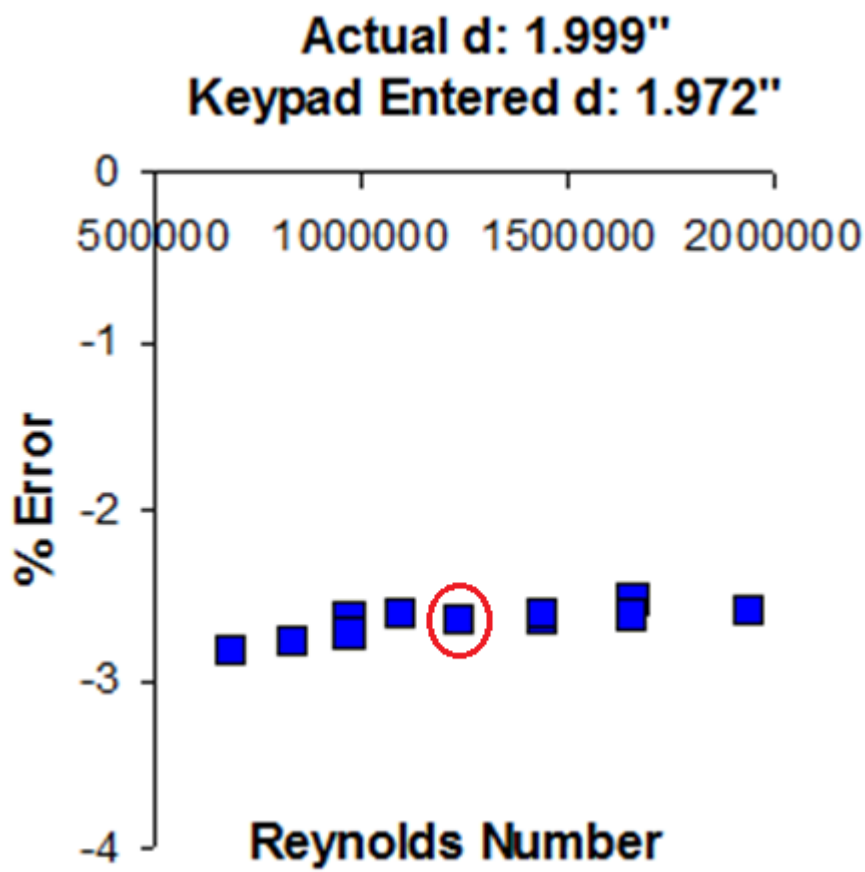




+1.2% bias > +$13.3K / quarter

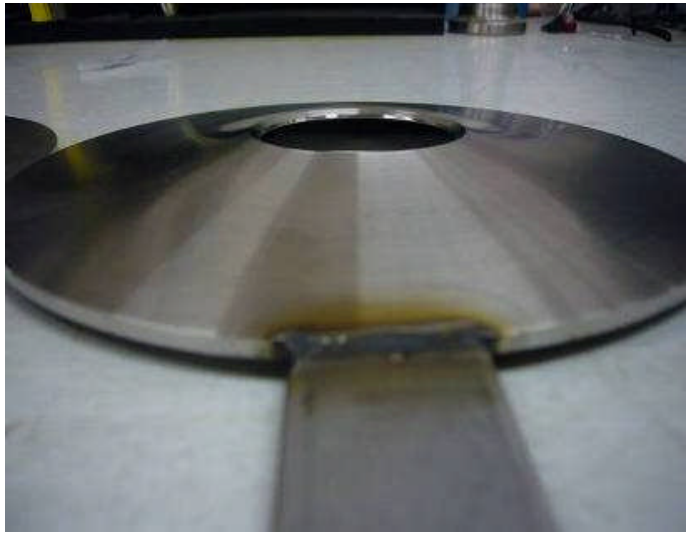
4”, 0.5 β Orifice Meter with Error in Orifice Diameter Keypad Entry

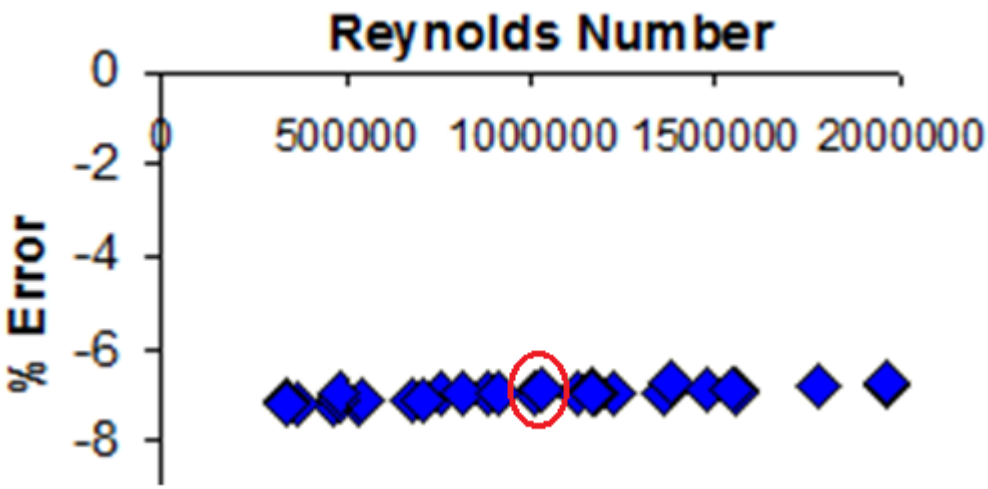


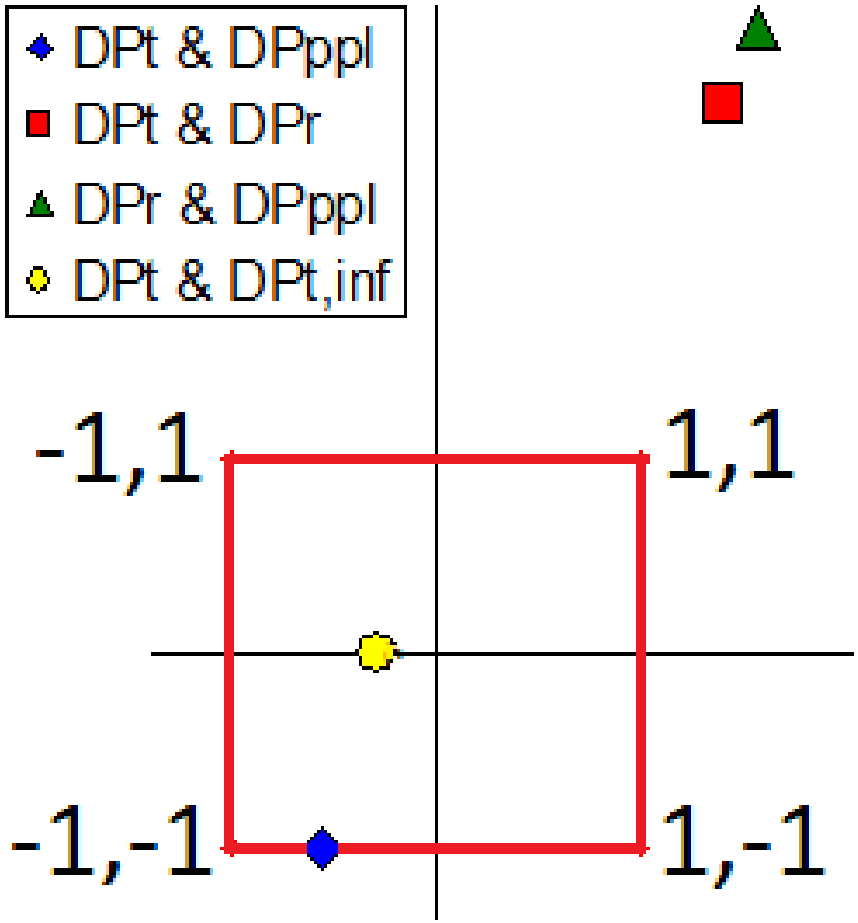


-2.6% bias > -$28.5K / quarter

4”, 0.5 β Orifice Meter Buckled Plate

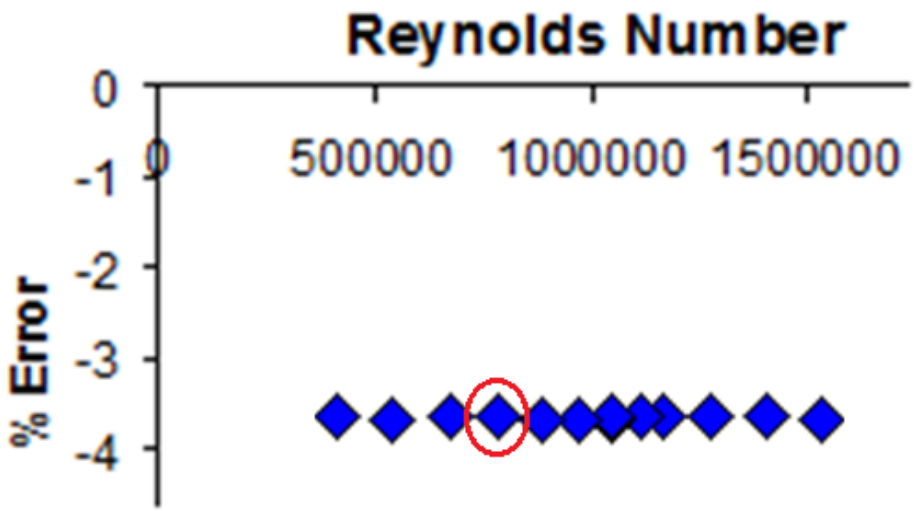


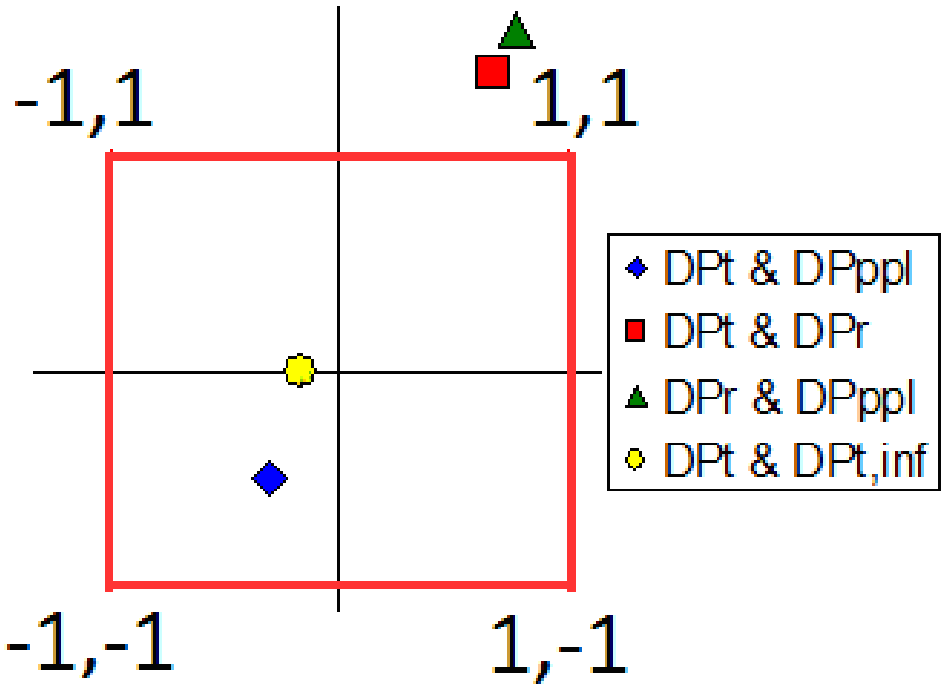




-7% bias > -$78K / quarter

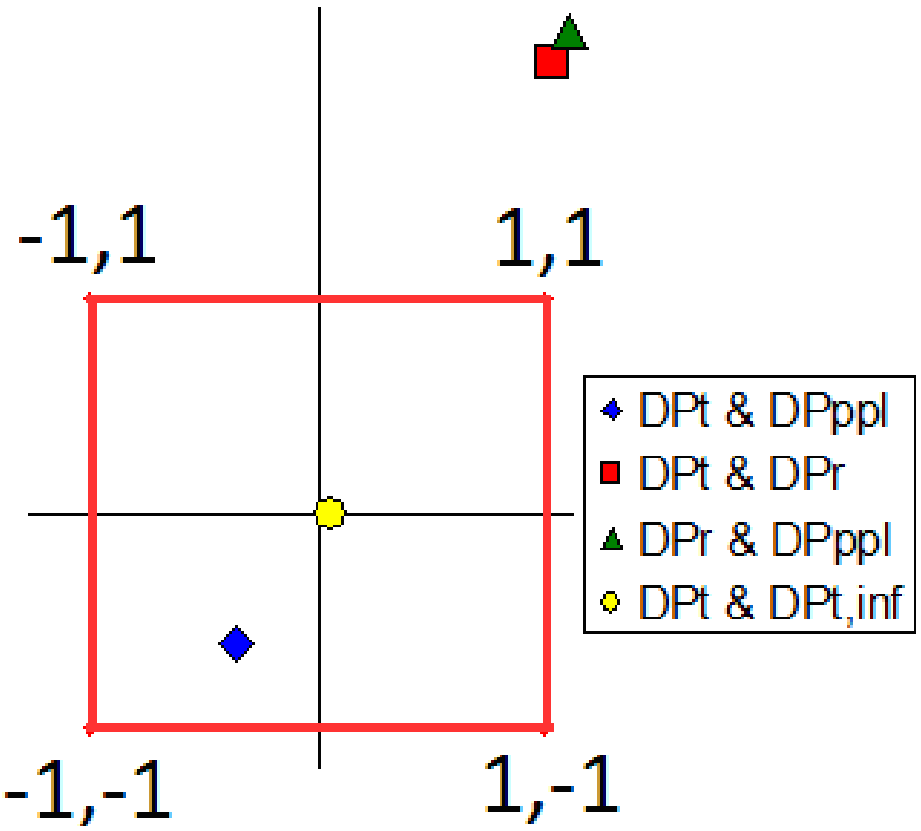
4”, 0.5 β Orifice Meter Contaminated Plate

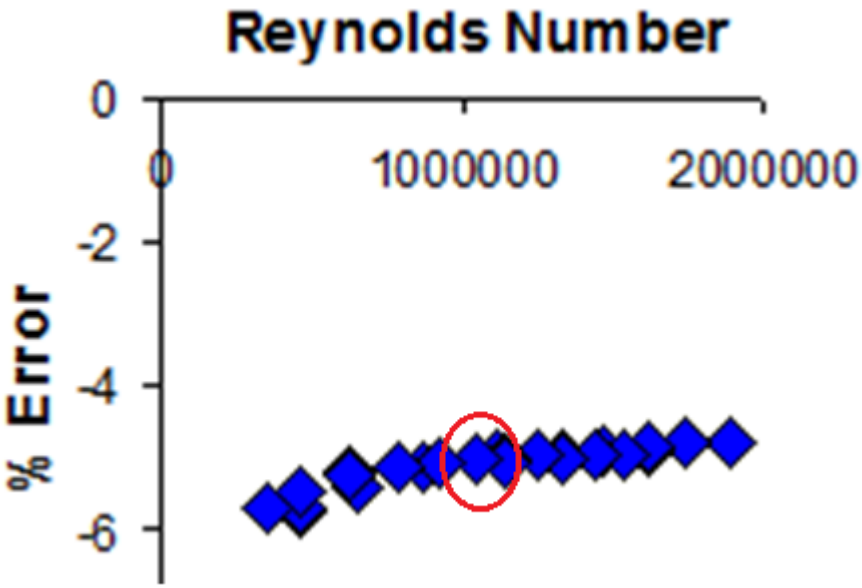




-3.5% bias > -$39K / quarter

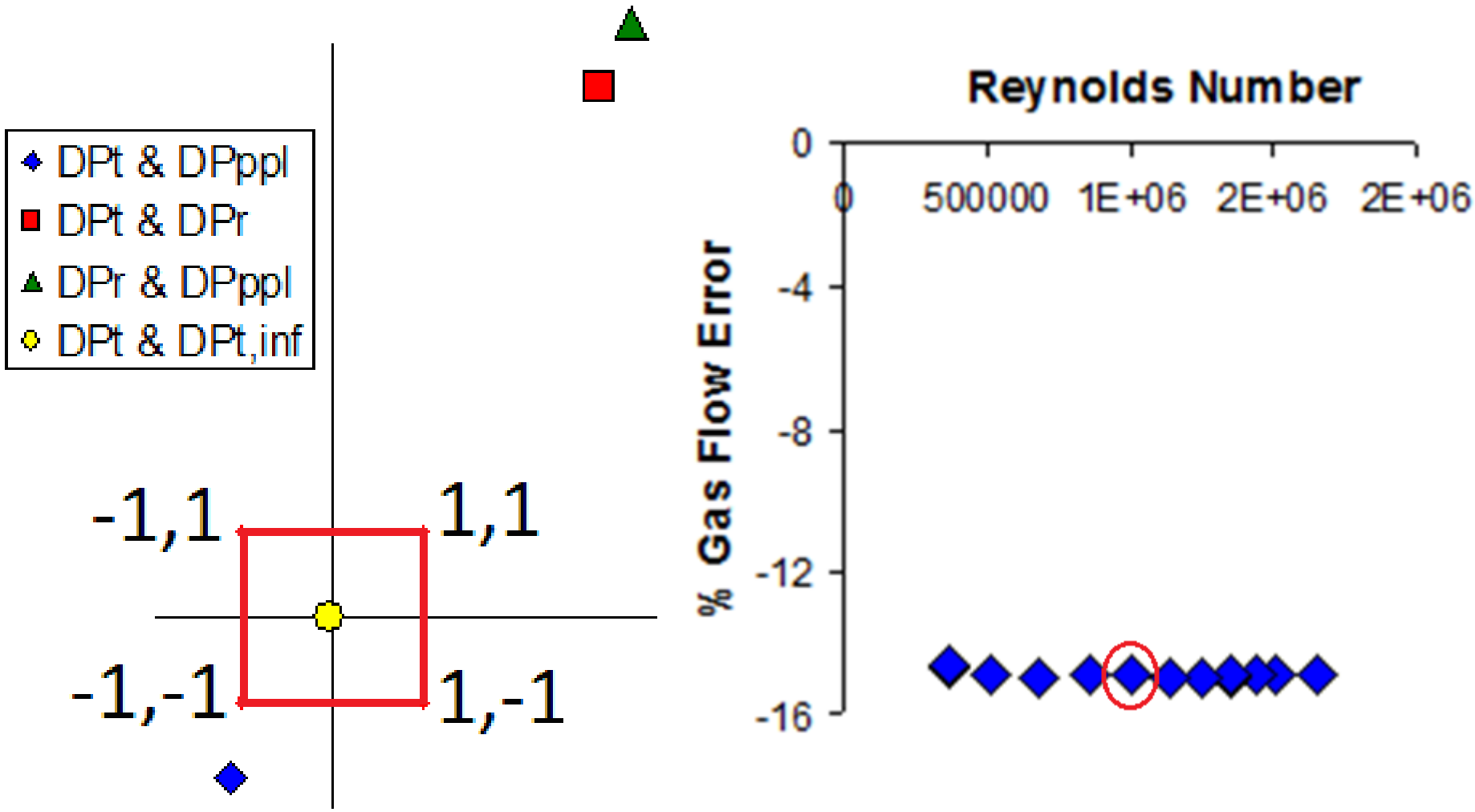
4”, 0.5 β Orifice Meter Worn Edge Plate





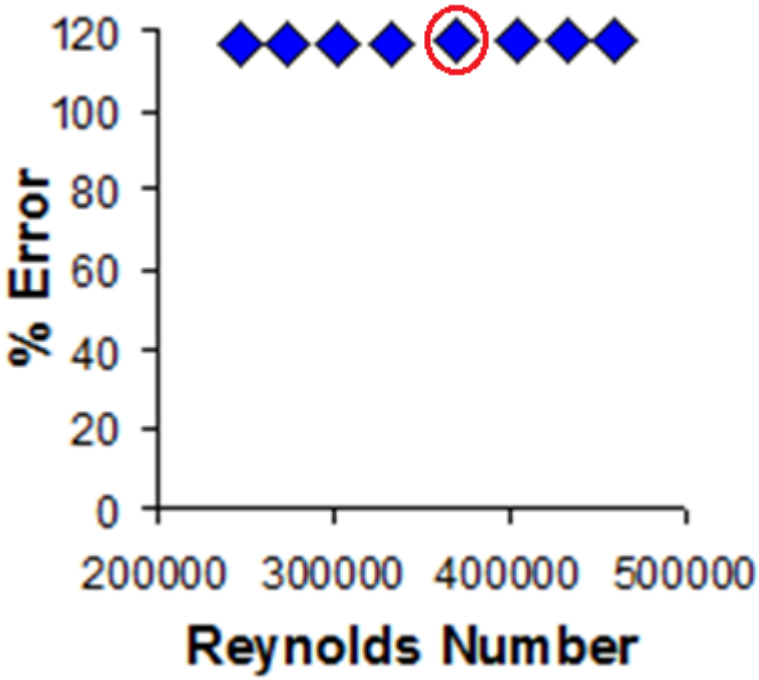
-5% > -$55K /quarter

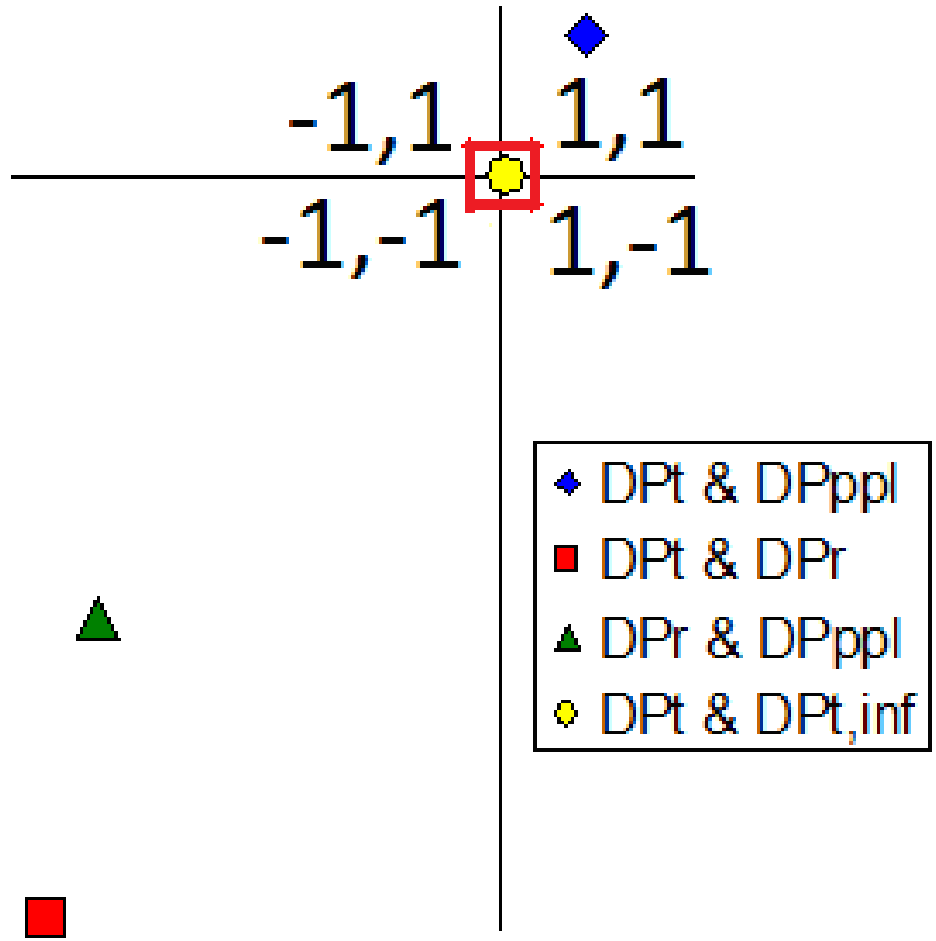
4”, 0.5 β Orifice Meter Backwards Plate



-15% > -$167K / quarter

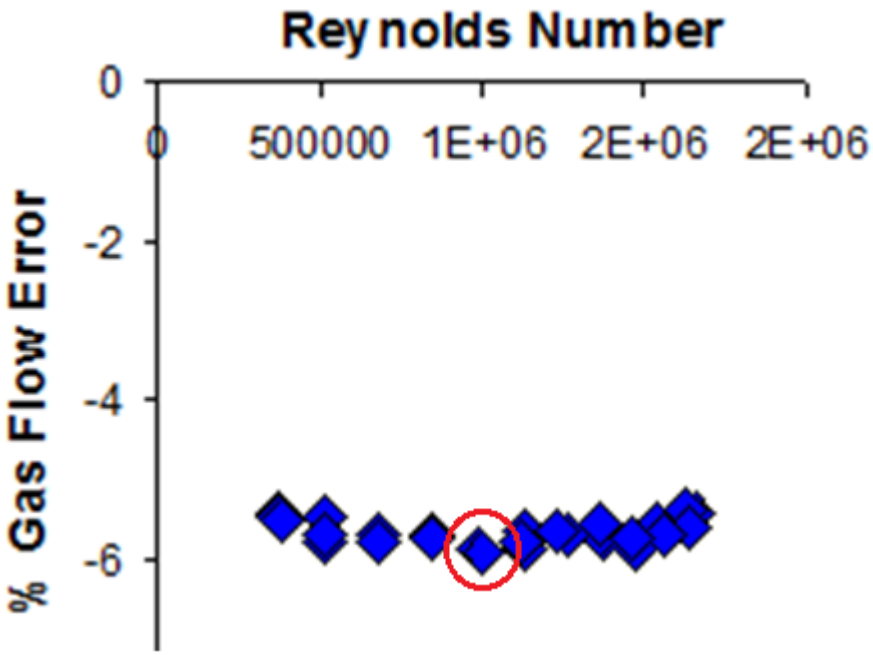
4”, 0.4 β Orifice Meter with Trapped Debris

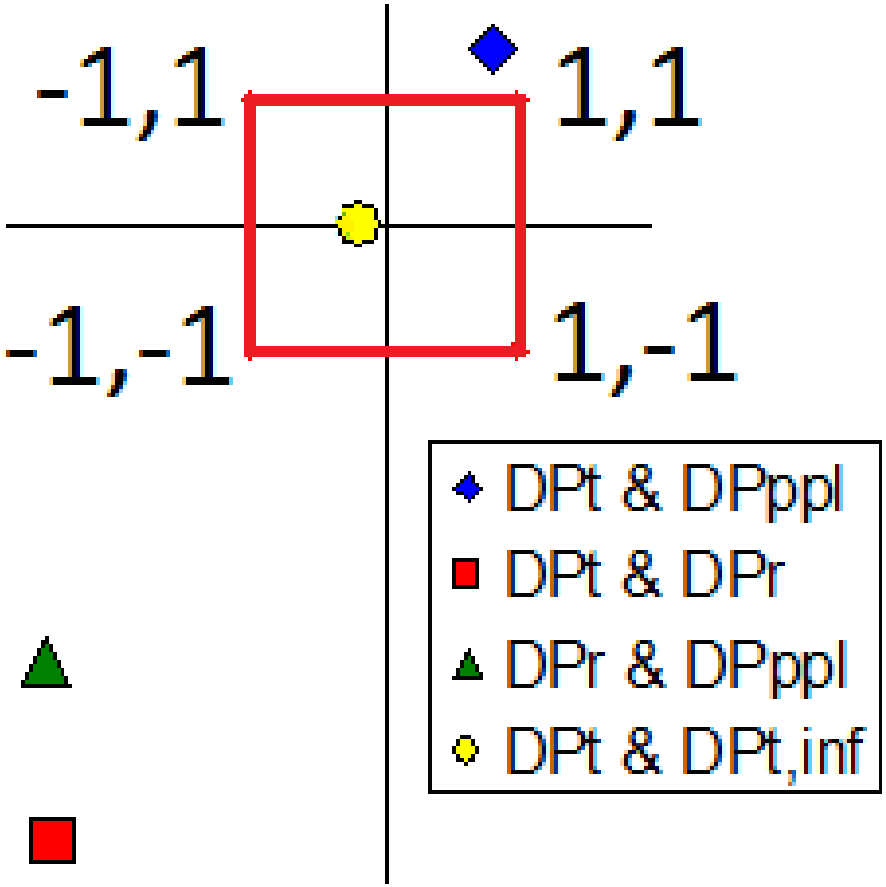




+118% > +$1.3e6 / quarter

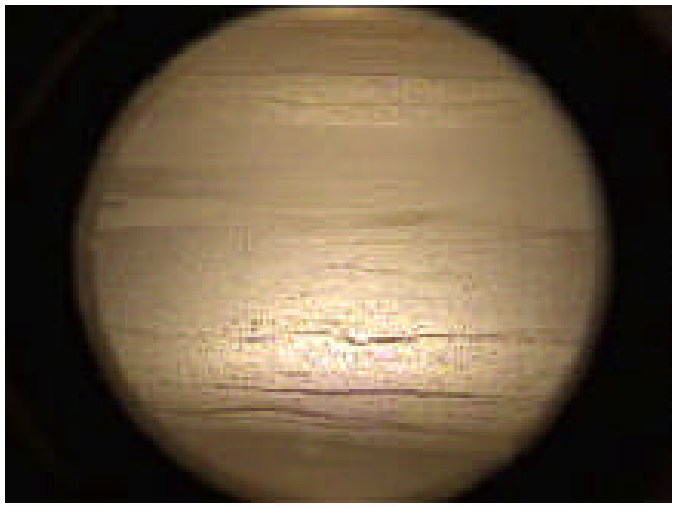
Disturbed Flow 4”, 0.5 β Orifice Meter – HMOP at 2D upstream

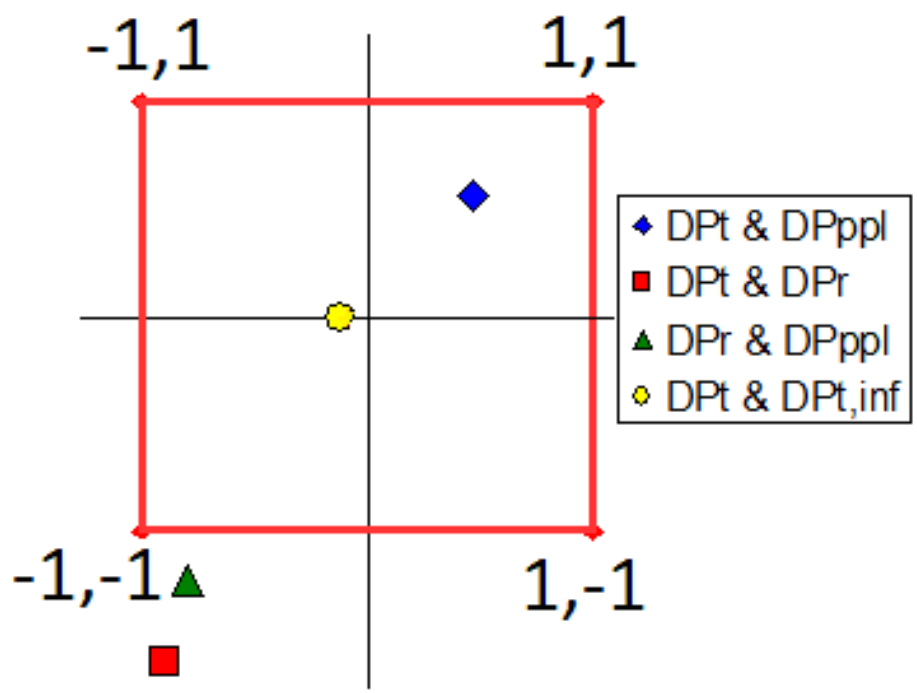




-5.8% > -$64K / quarter

4”, 0.62 β Orifice Meter with Wet Natural Gas Flow (13.7 MMSCFD)





P = 42.6 Bar

Gas Flow = 3.3 kg/s

Liquid Flow = 0.4 kg/s

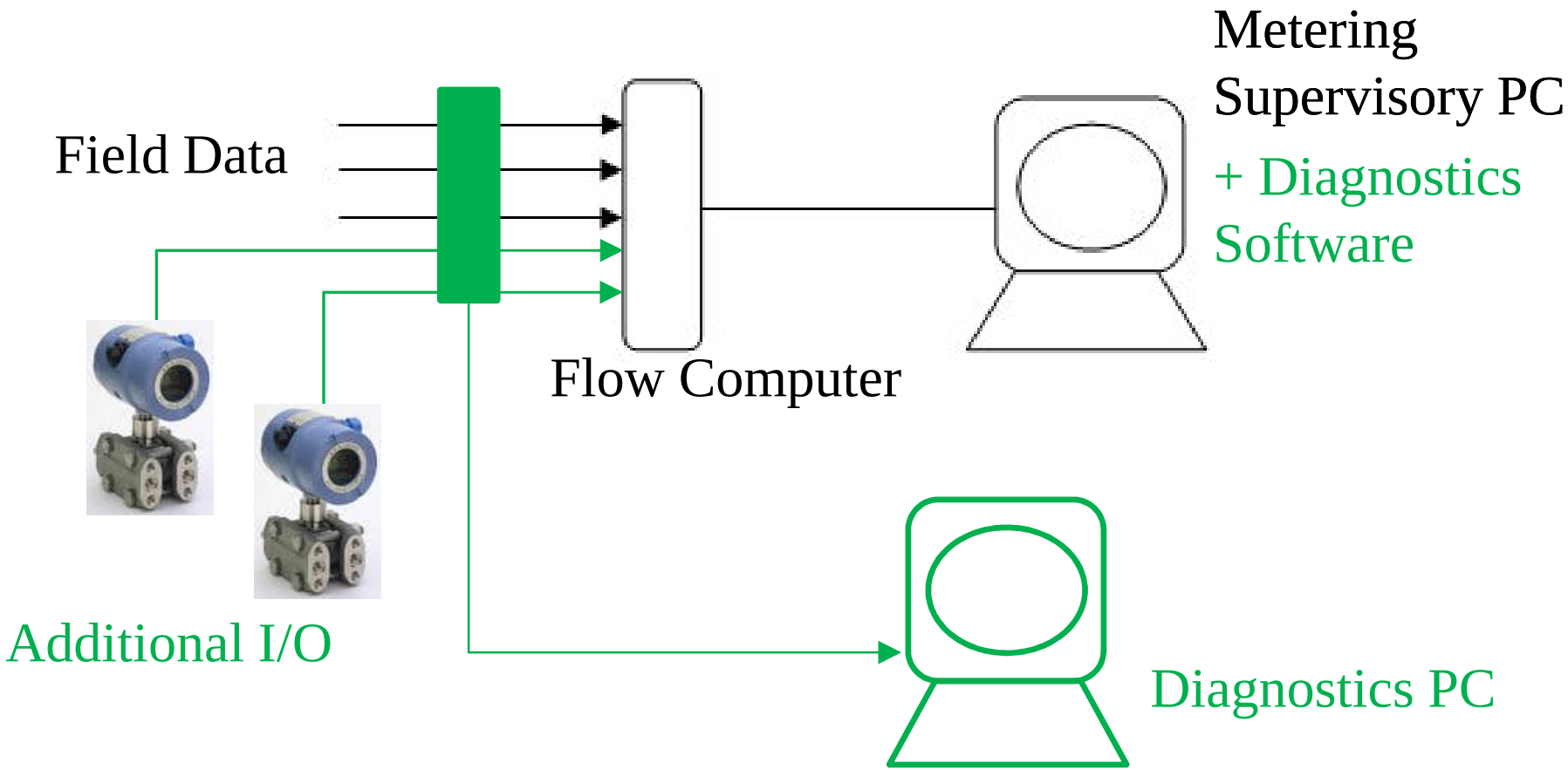
GVF = 98.9%

Meter over-reads gas flow rate by +4%

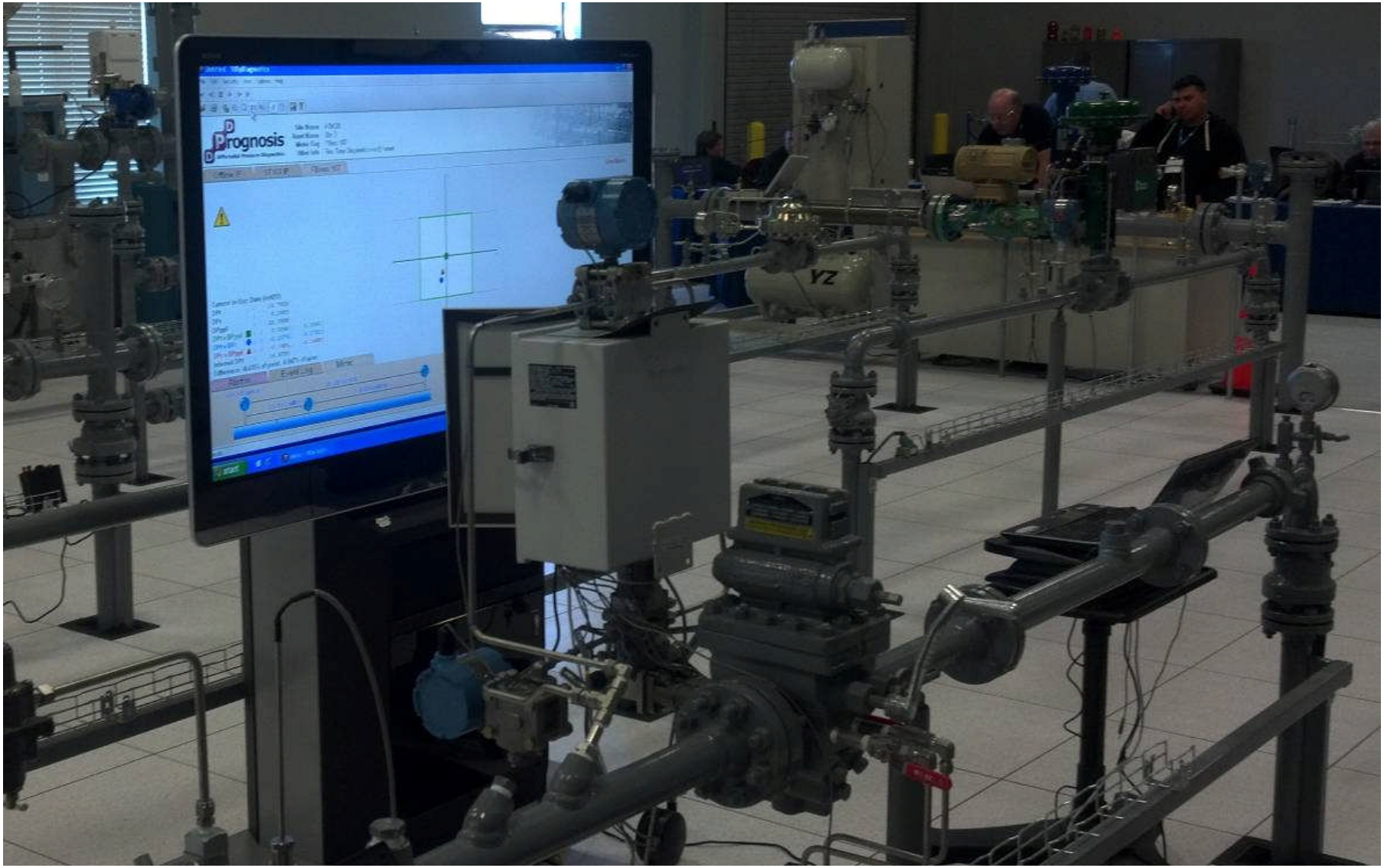
+4% > +$172K / quarter

Applying the DP Meter Diagnostics

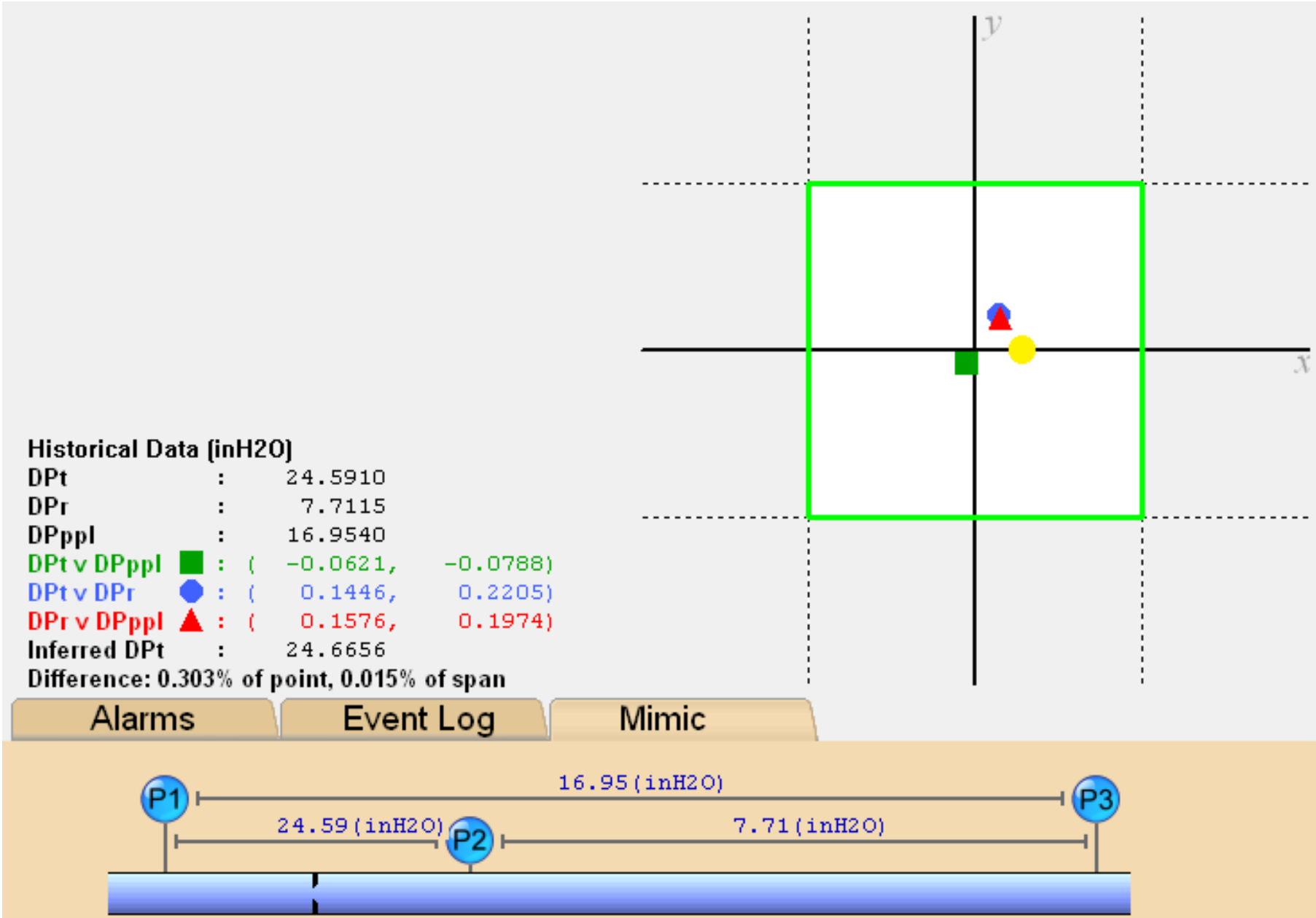
Swinton Technology has developed the DPD concept into a product called “Prognosis”.



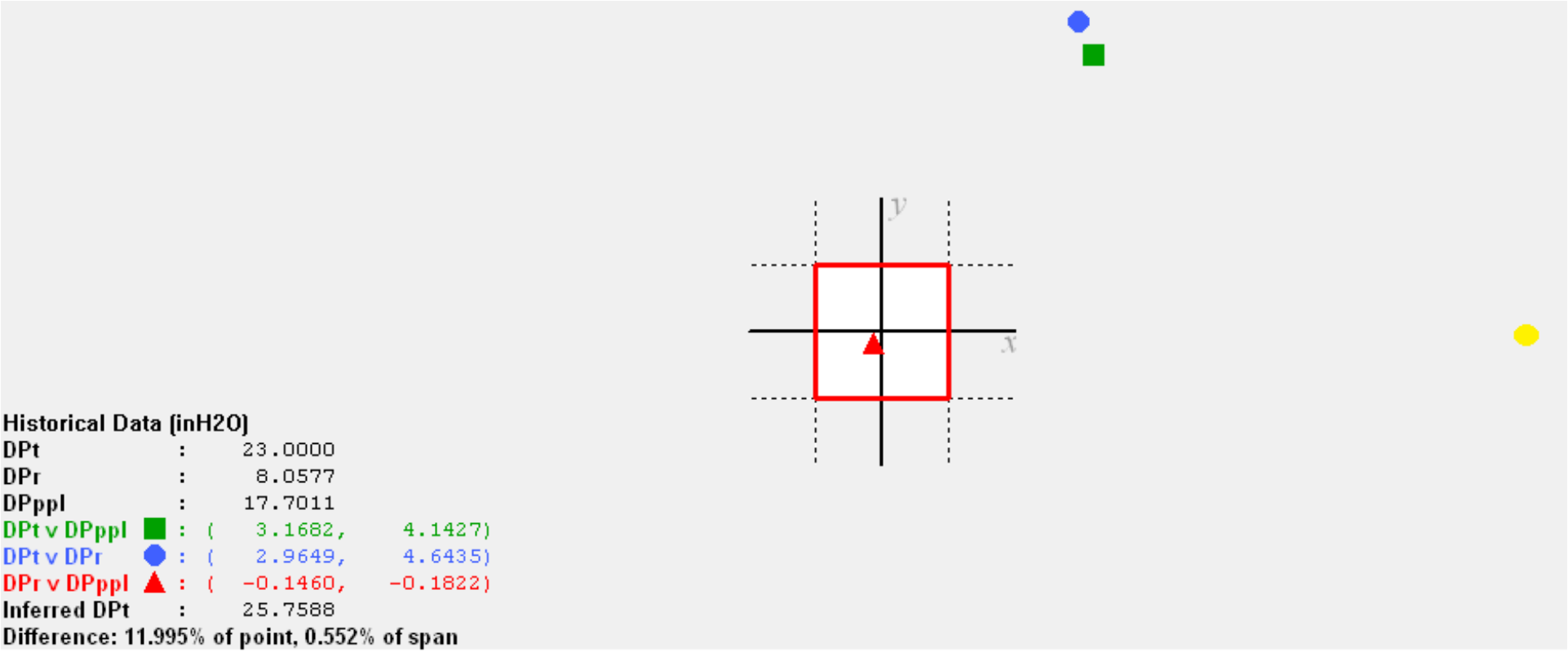
ATMOS Training Facility with Orifice Meter & Diagnostic System (Prognosis)



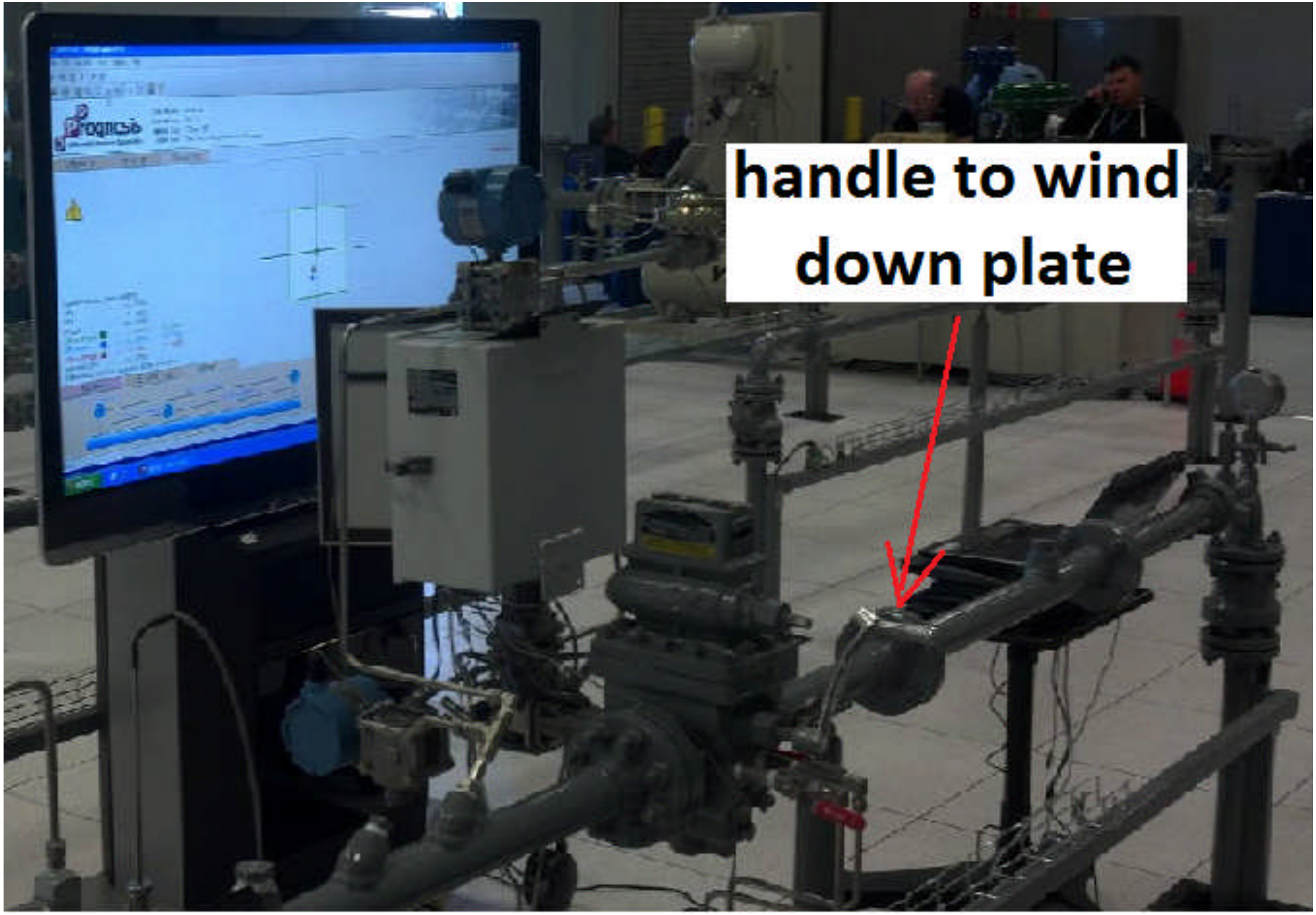
2”, 0.54 β Orifice Meter, 147 psig, 410 MSCFD



An Over-Ranged (‘Saturated’) DP Transmitter 147.5 psig, 412 MSCFD, Actual DPt 25.8 “WC, Read Value 23.0”WC, Induced Error -5.6%

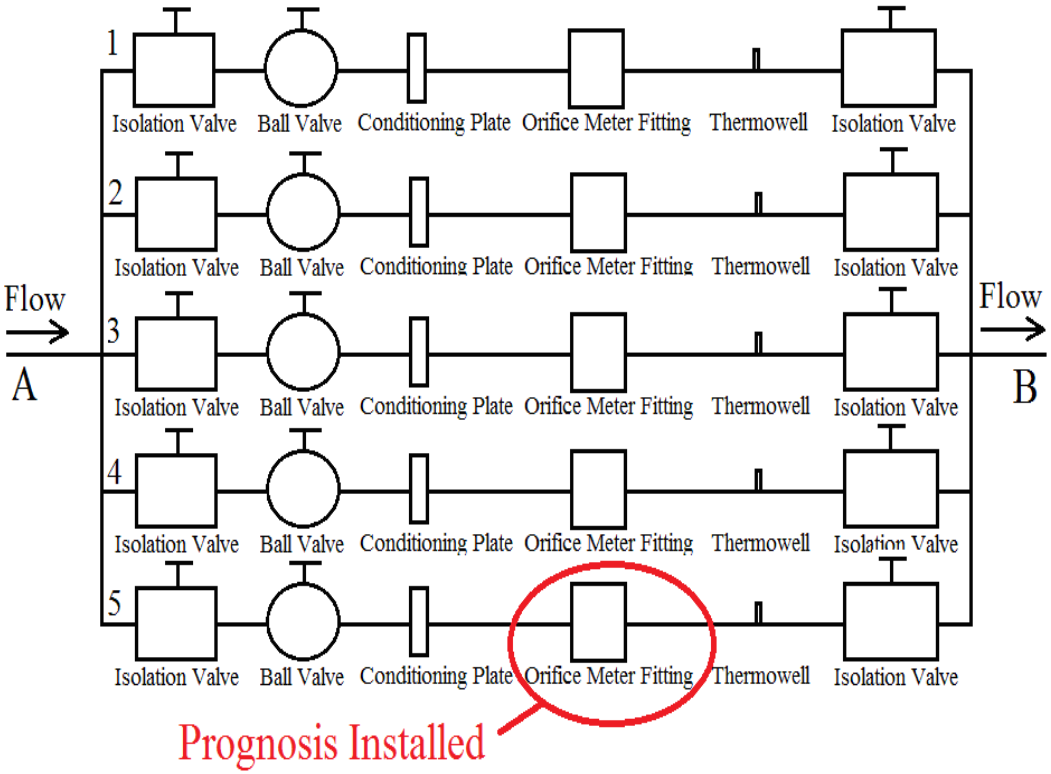


Unseated Orifice Plate in Carrier



Unseated Orifice Plate in Carrier
417.5psig, 471 MSCFD, Induced Error -15%

BP CATS, May 2010

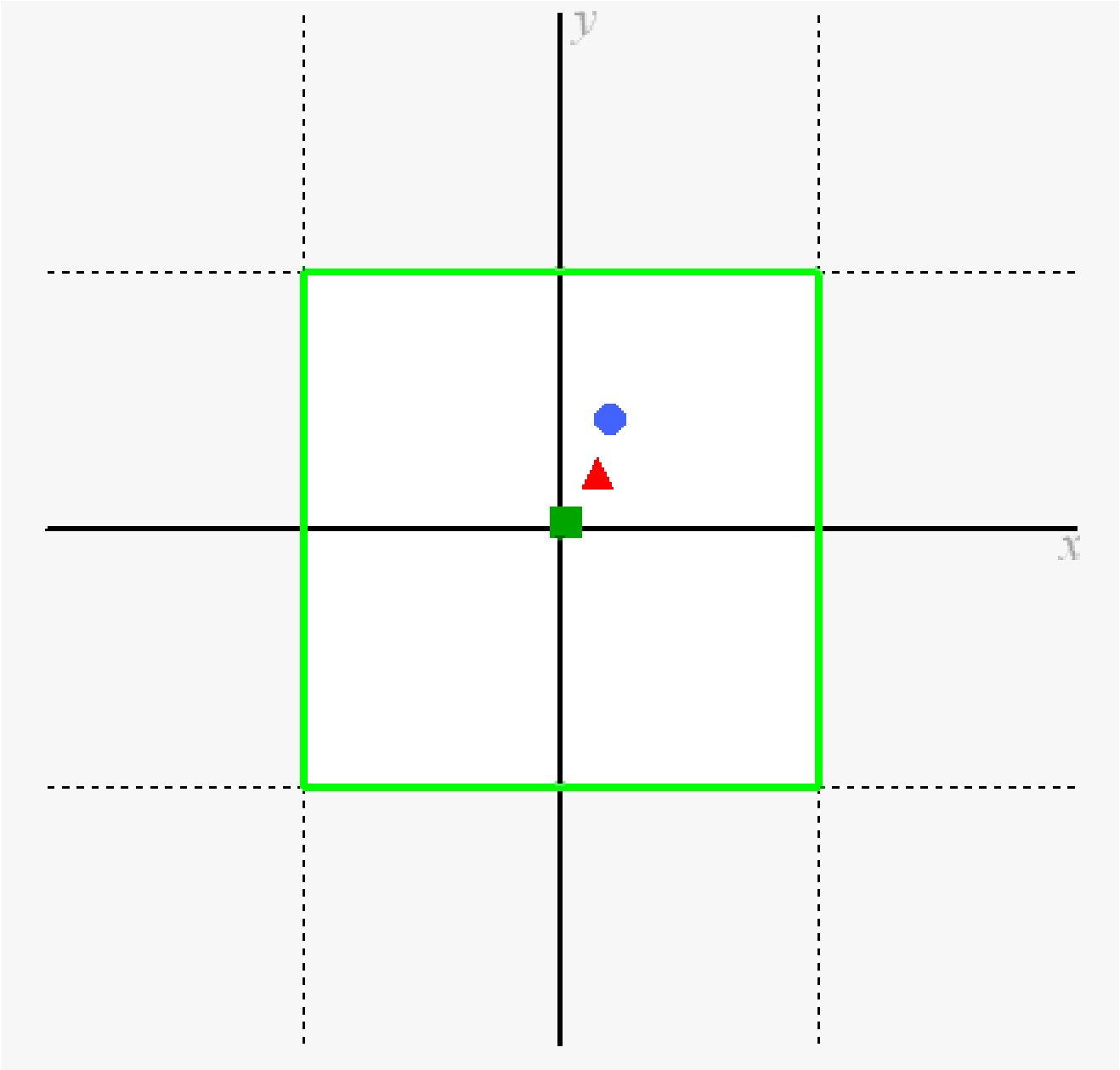


Pipe ID 13.738”

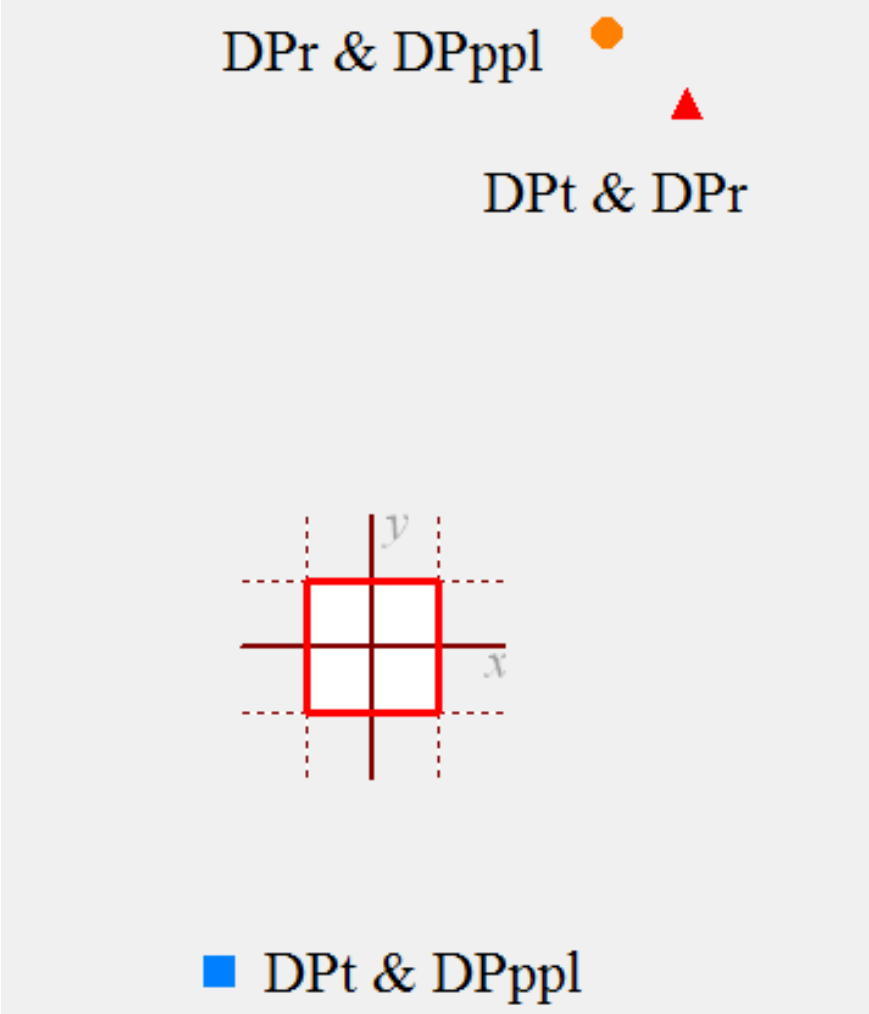
d=8.195” (0.596 beta)

201.5 MMSCFD ≈ $705K/day

Baseline Results at BP CATS (as found)



BP CATS Reversed Orifice Plate (-15% flow rate prediction error)



-15% > -$105K/day

or > -$9.5 million / quarter

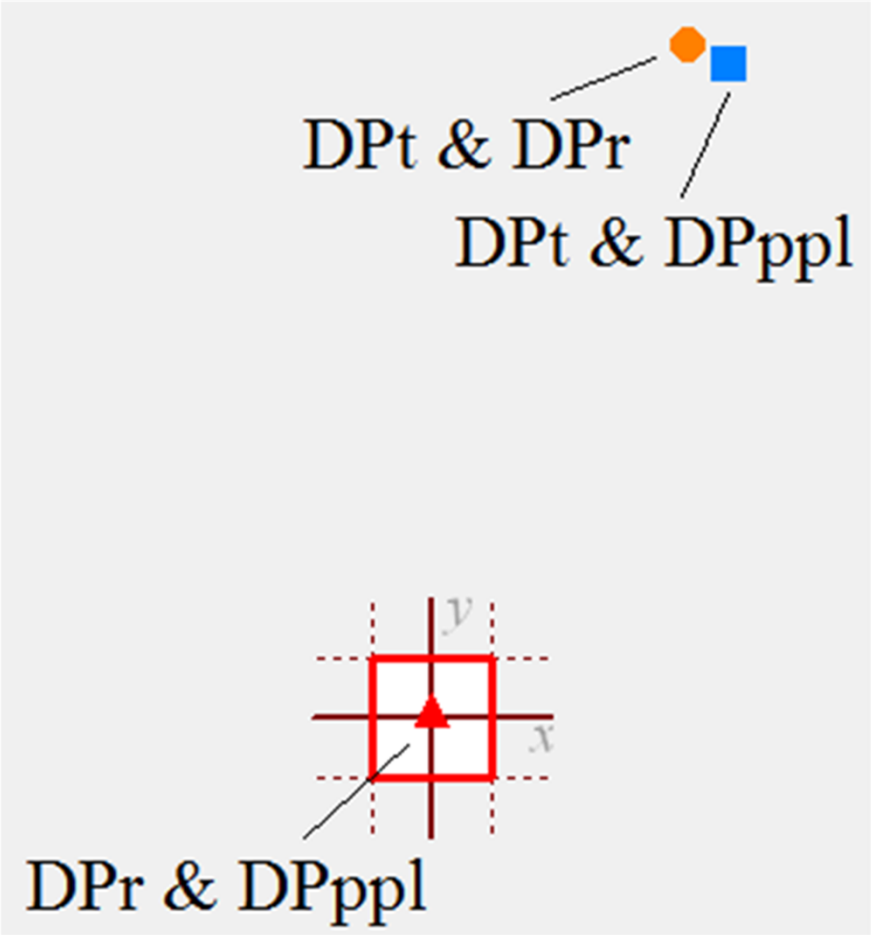
BP CATS - Saturated DP Transmitter (-6.2% flow rate prediction error)

- Tradition DP transmitter
  Spanned 15.0kPa / 60”WC

- DPt = 17.5kPa / 70”WC
  a -7.4% flowrate error

- Also with 3 DP transmitters:

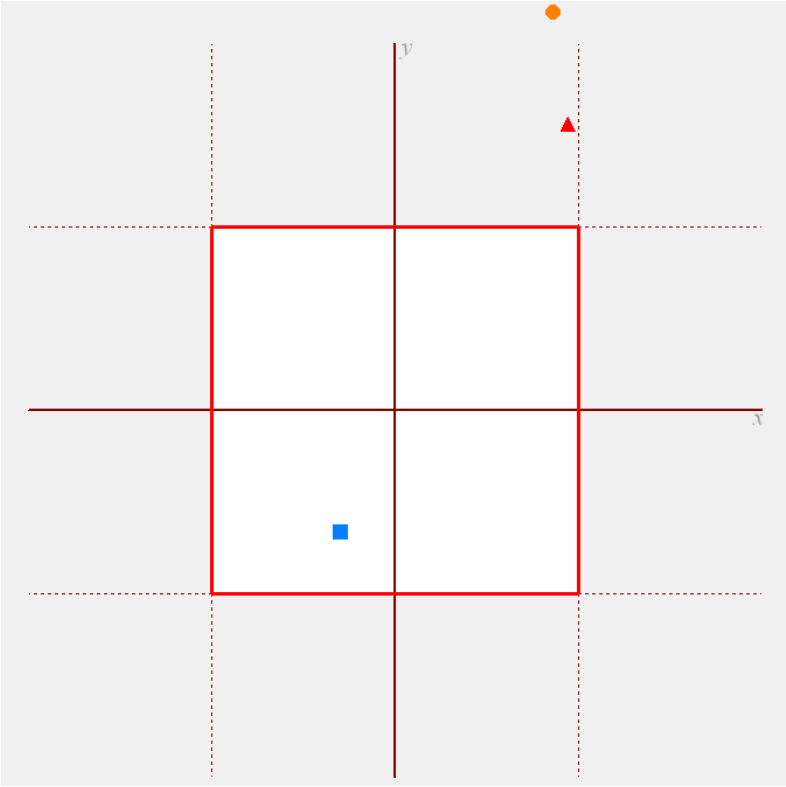
$$15.0kPa \neq (6.2 + 11.3)kPa$$



-7.4% > -$4.6 million / quarter

BP CATS - Worn Orifice Edge

- Plate deliberately worn, -2% error induced



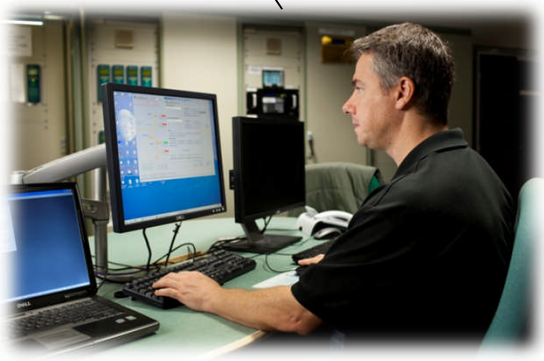
-2% > -$1.25 million / quarter

BP's & CoP's Observed Benefits

Less Safety Risk & less logistics

Improved Efficiency & Reduced Carbon Footprint

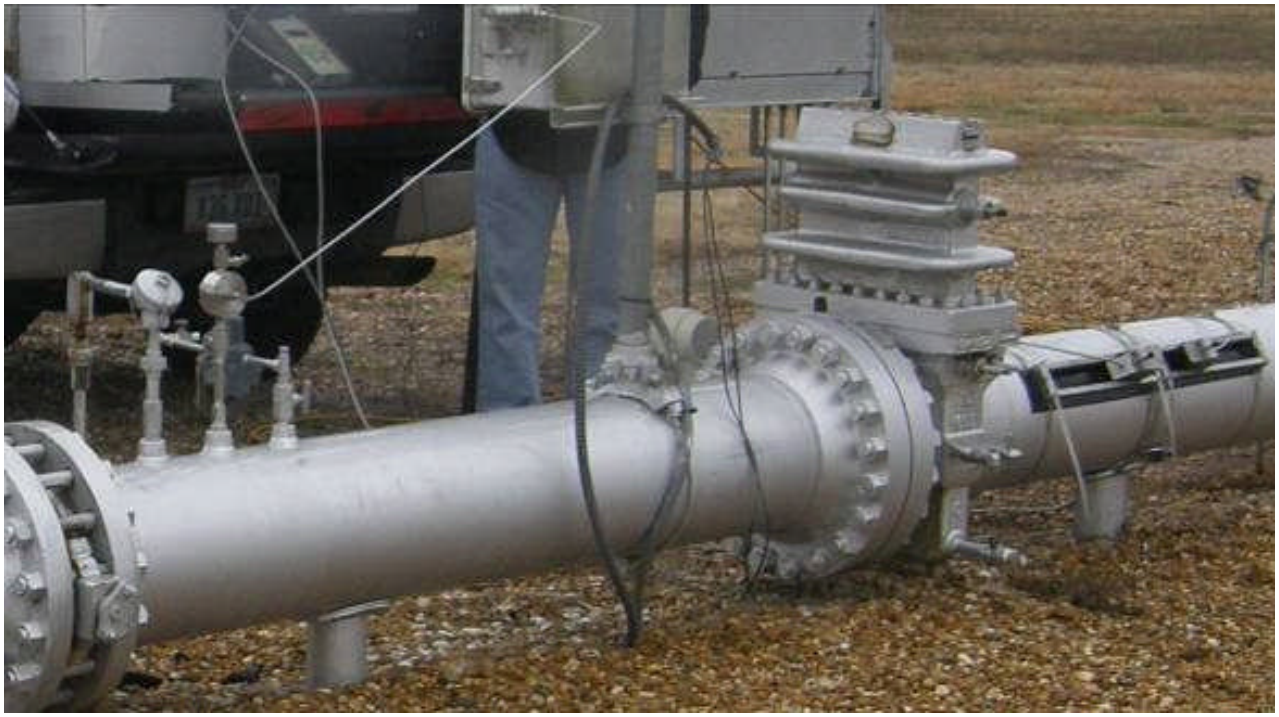
Assurance of Compliance and Accuracy

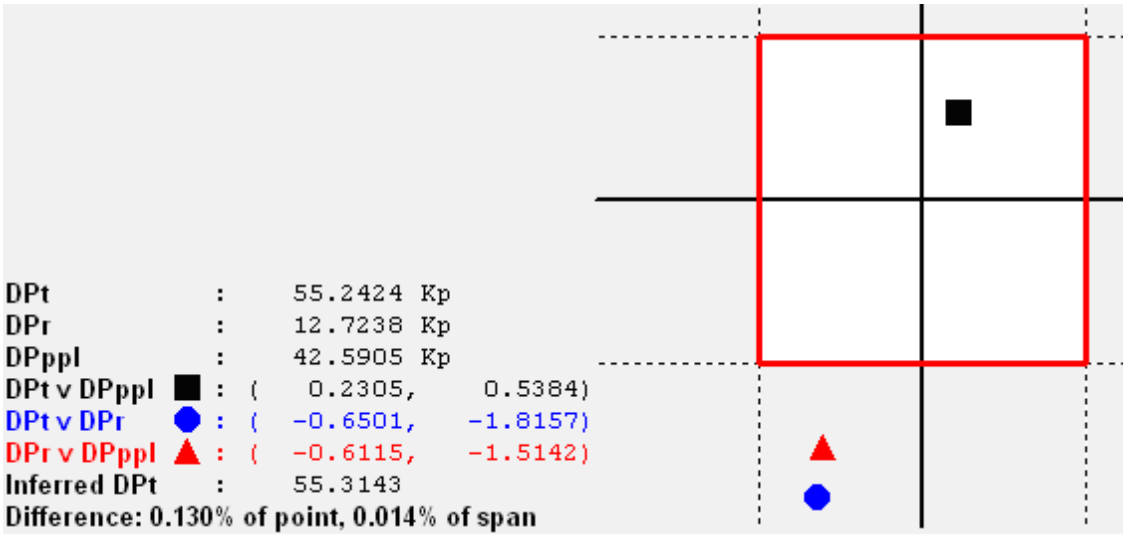


Less Routine Inspections in Remote Operation

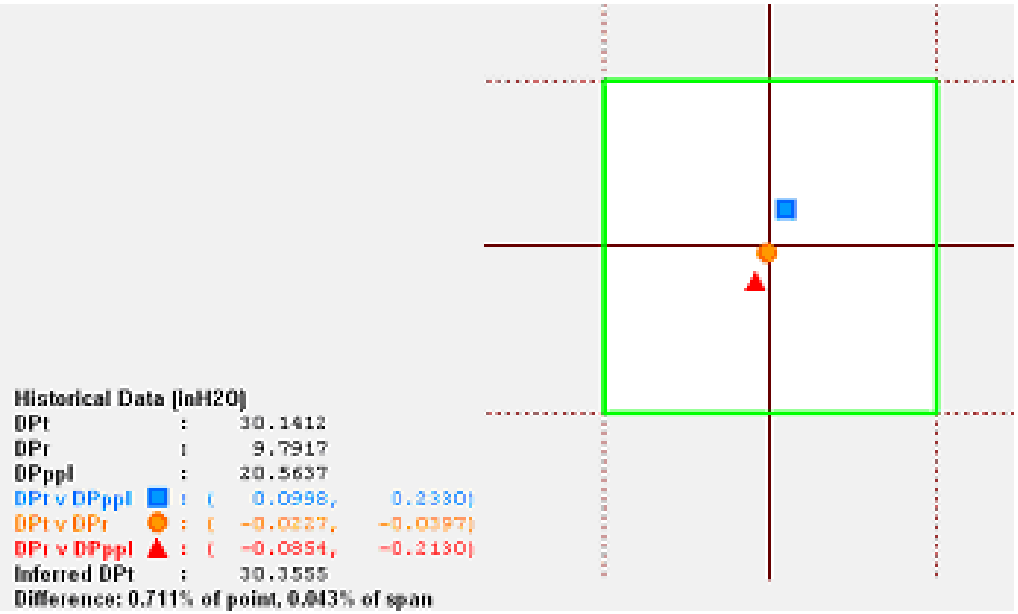
Efficient Audits

Orifice Meter Audit 1 – Wet Gas Flow Found

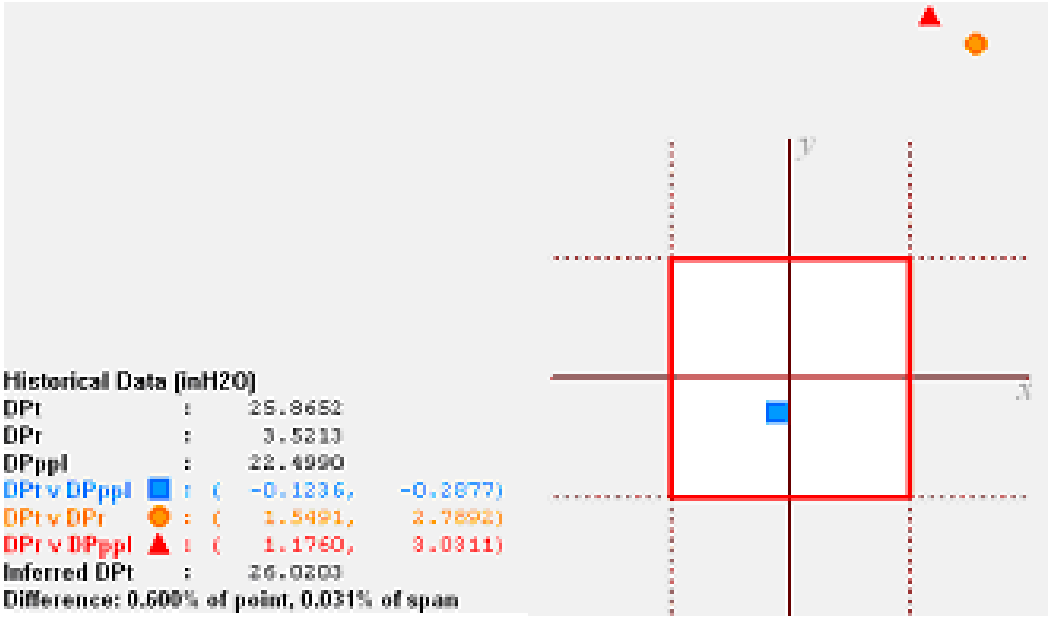




Orifice Meter Audit 2 – Serviceable Meter

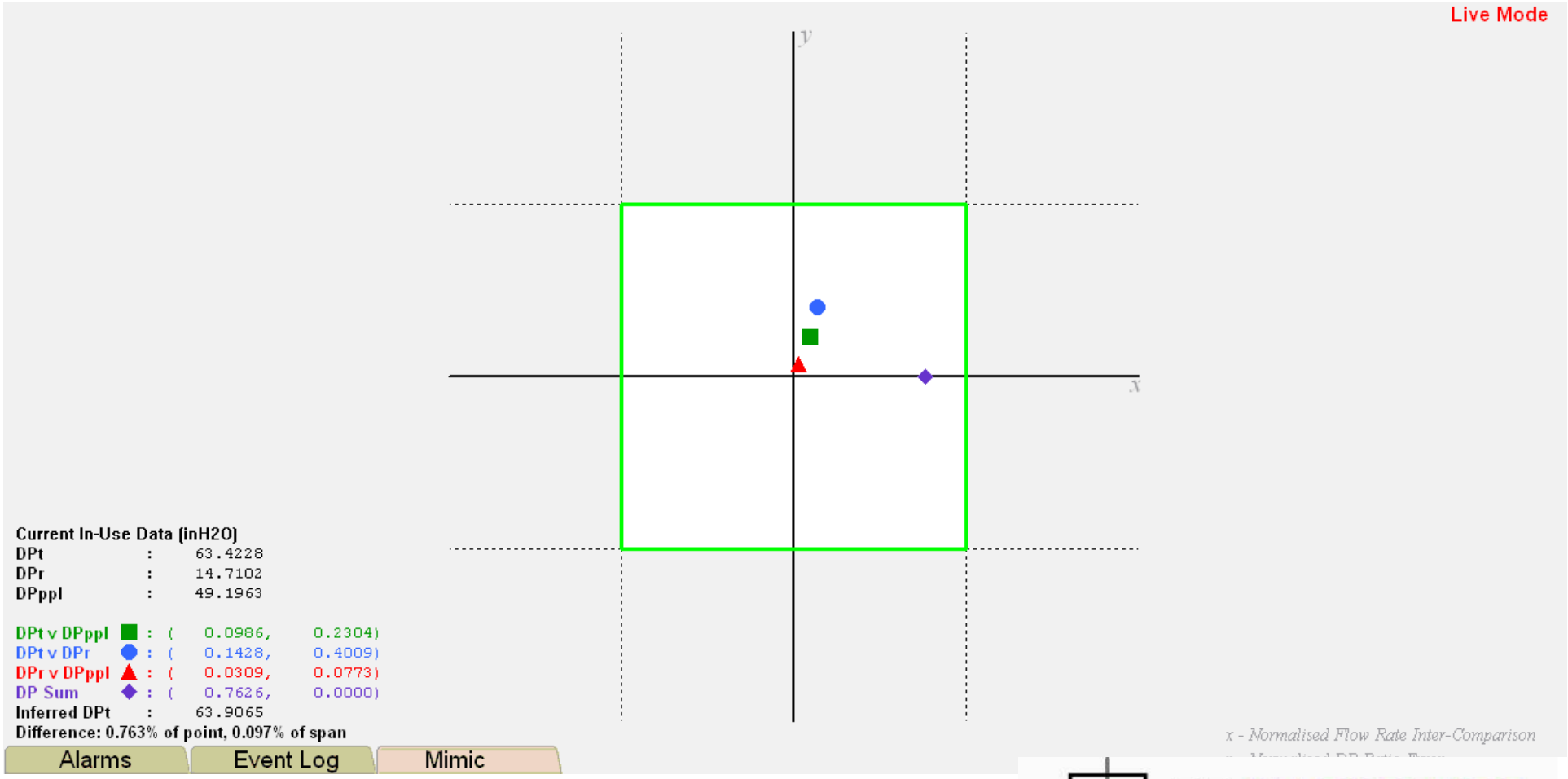


Orifice Meter Audit 3 –Contamination Found



CoP Franklyn Gas Station 10” Orifice Meter

Correct Meter Operation



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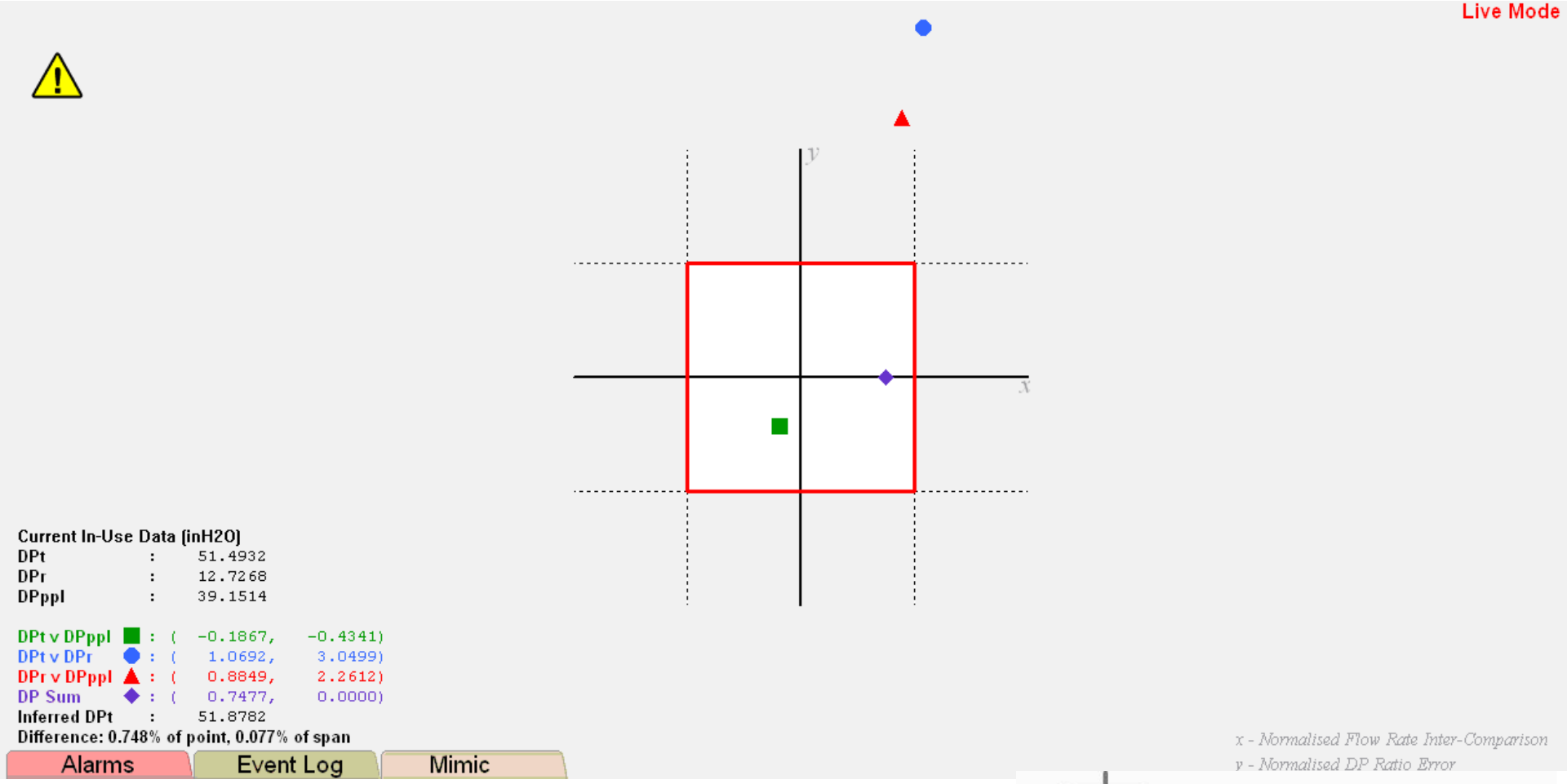
Backwards Plate



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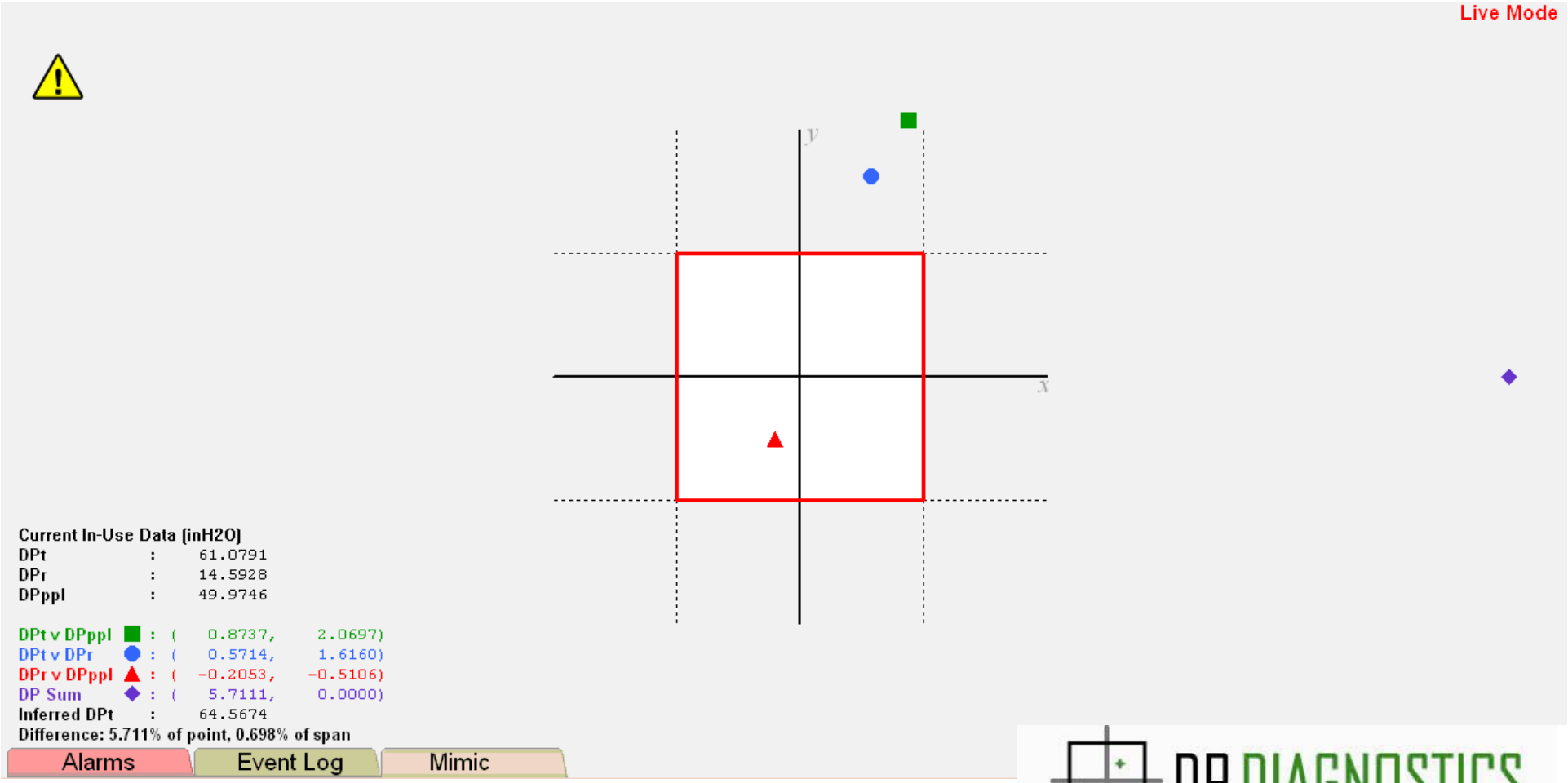
MONITOR, VERIFY, AND TRUST YOUR DP METER

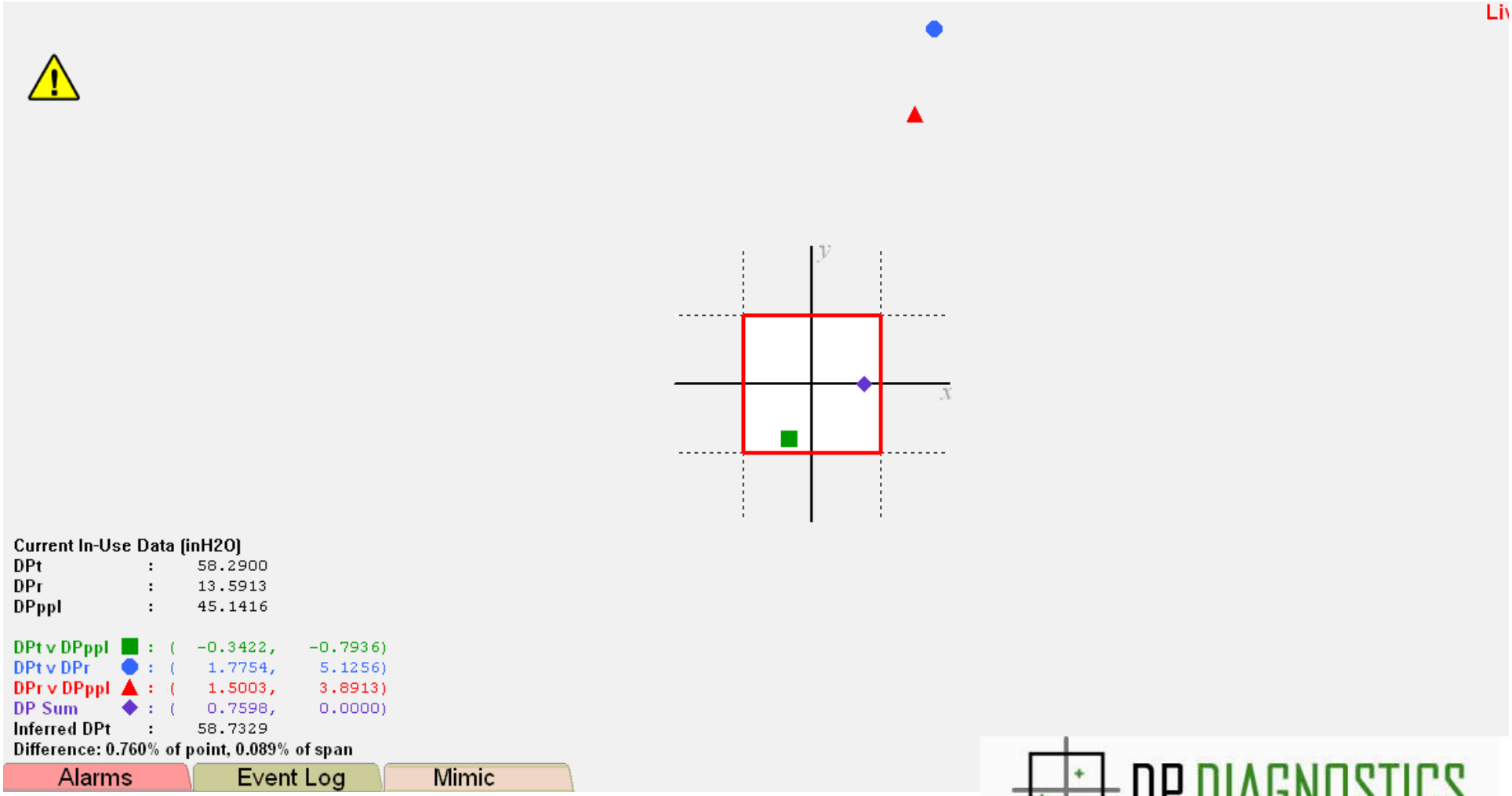
Faulty DPt Reading – Leaking 5 Way Manifold Valve



DP DIAGNOSTICS

MONITOR, VERIFY, AND TRUST YOUR DP METER

Erroneous Orifice Diameter
4.25” entered instead of 4.5”



DP DIAGNOSTICS

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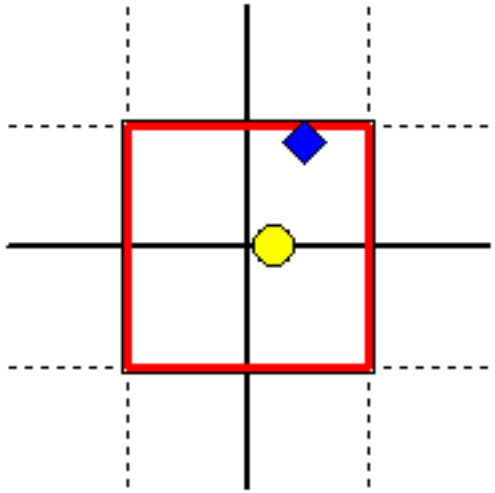
ConocoPhilips / Rosneft “Polar Lights” Field

Meter Alarm [Alarm 3]

The pattern suggests a potenial over-reading bias.
Possible issues include:

Orifice diameter entered falsely high
Pipe ID entered falsely low
Meter contamination or liquid carry-over
Meter throat obstruction
Problem with Pressure port affecting two DPs
Problem with one of the DP inputs (if one DP is inferred)



Current In-Use Data

DPt	:	4282.90 Pa
DPr	:	581.14 Pa
DPppl	:	3711.80 Pa
DPtInf	:	4292.94 Pa
DP Sum % Difference	:	0.23
◆ DPt vs DPppl	:	(0.47, 0.85)
■ DPt vs DPr	:	(-2.37, -4.96)
▲ DPr vs DPppl	:	(-2.14, -3.64)
○ DP Sum	:	(0.23, 0.00)

DP DIAGNOSTICS

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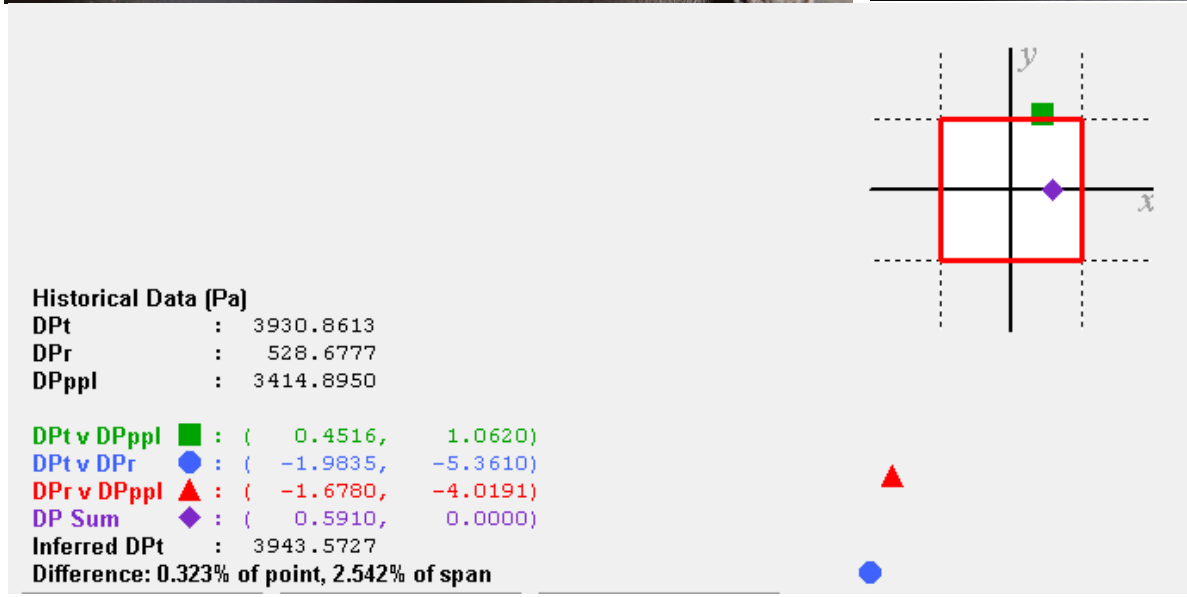
Metering Stream thought to be a Pristine Meter Run



DP DIAGNOSTICS

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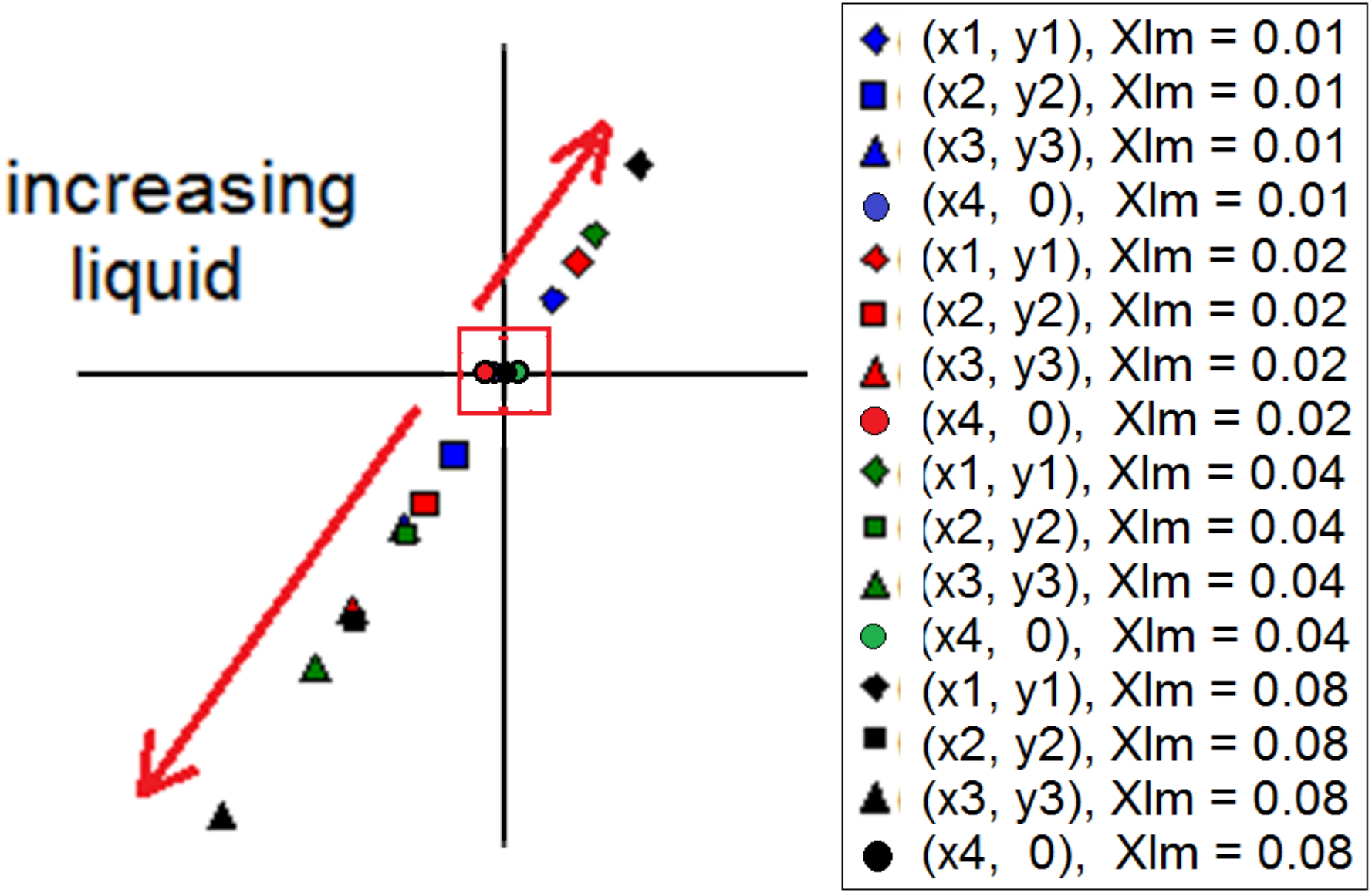
Trending Case Study - Wet Gas Flow Metering

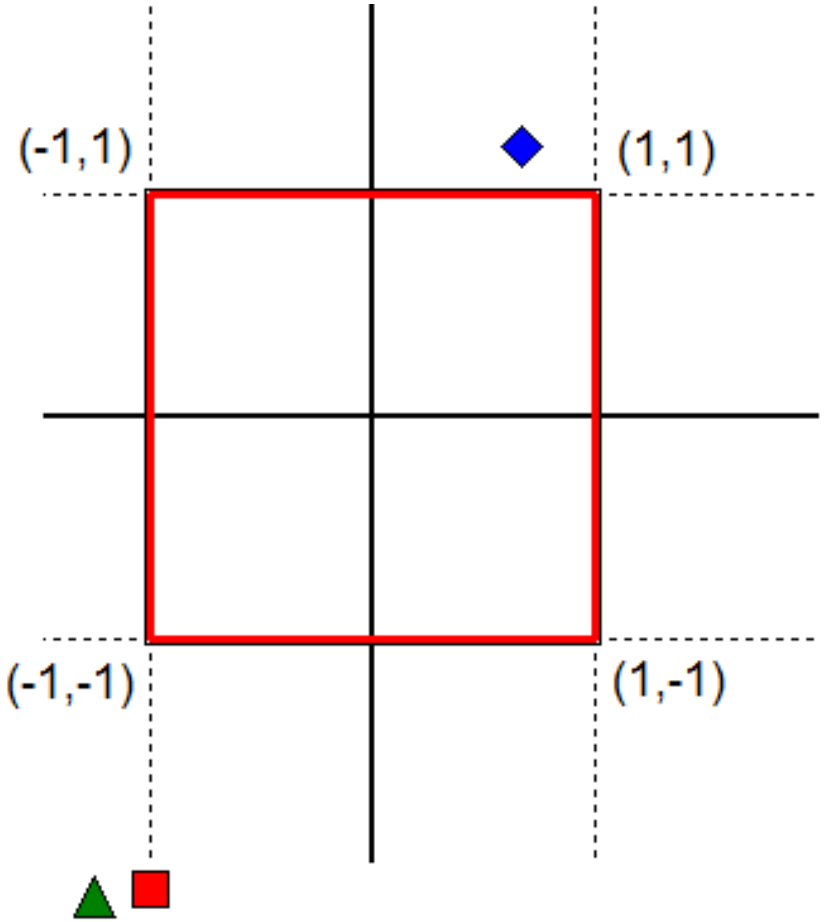
- The diagnostics show trending in meter performance, e.g. they can show a problem getting better or worse,

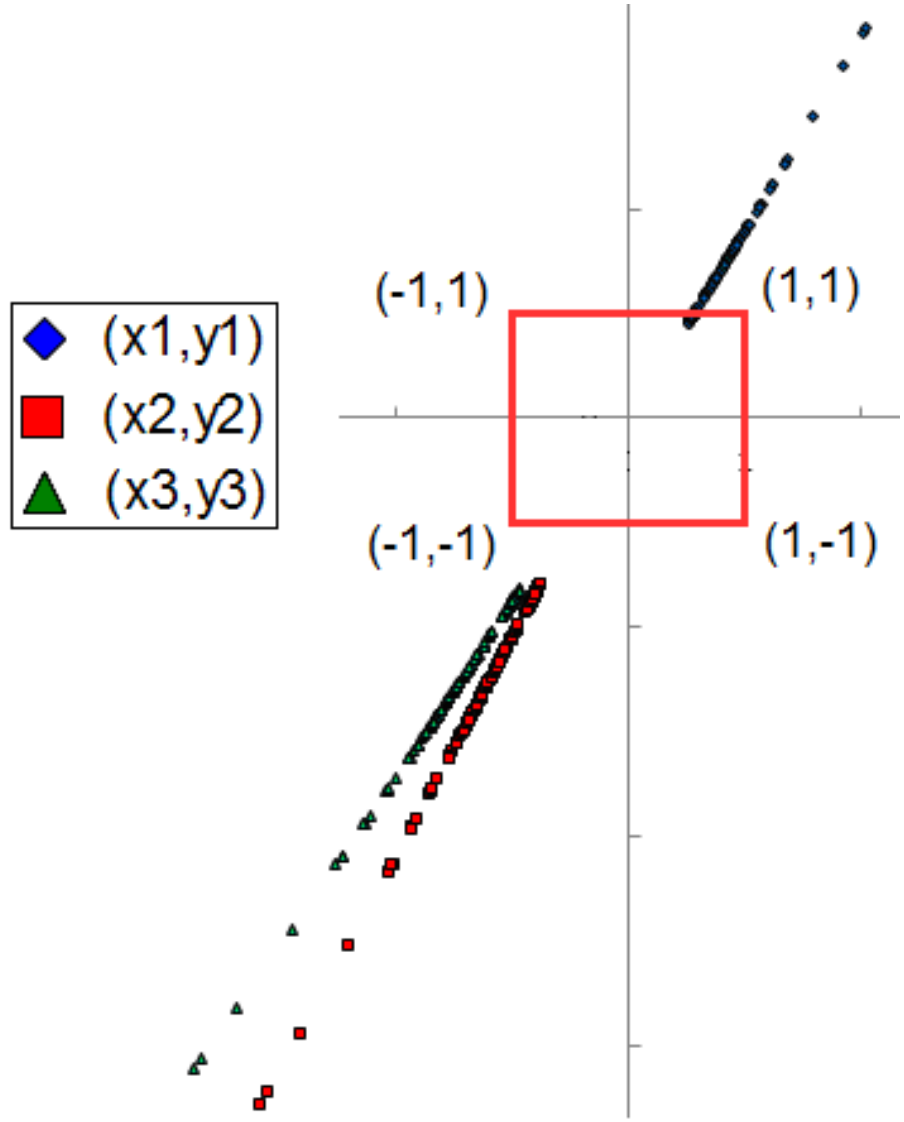
e.g. a wearing sharp edge, contamination build up, DP transmitter drift, wetness of a gas…

4”, **0.683β** Orifice Meter
72 Bar (a), 40C, 15 MMSCFD

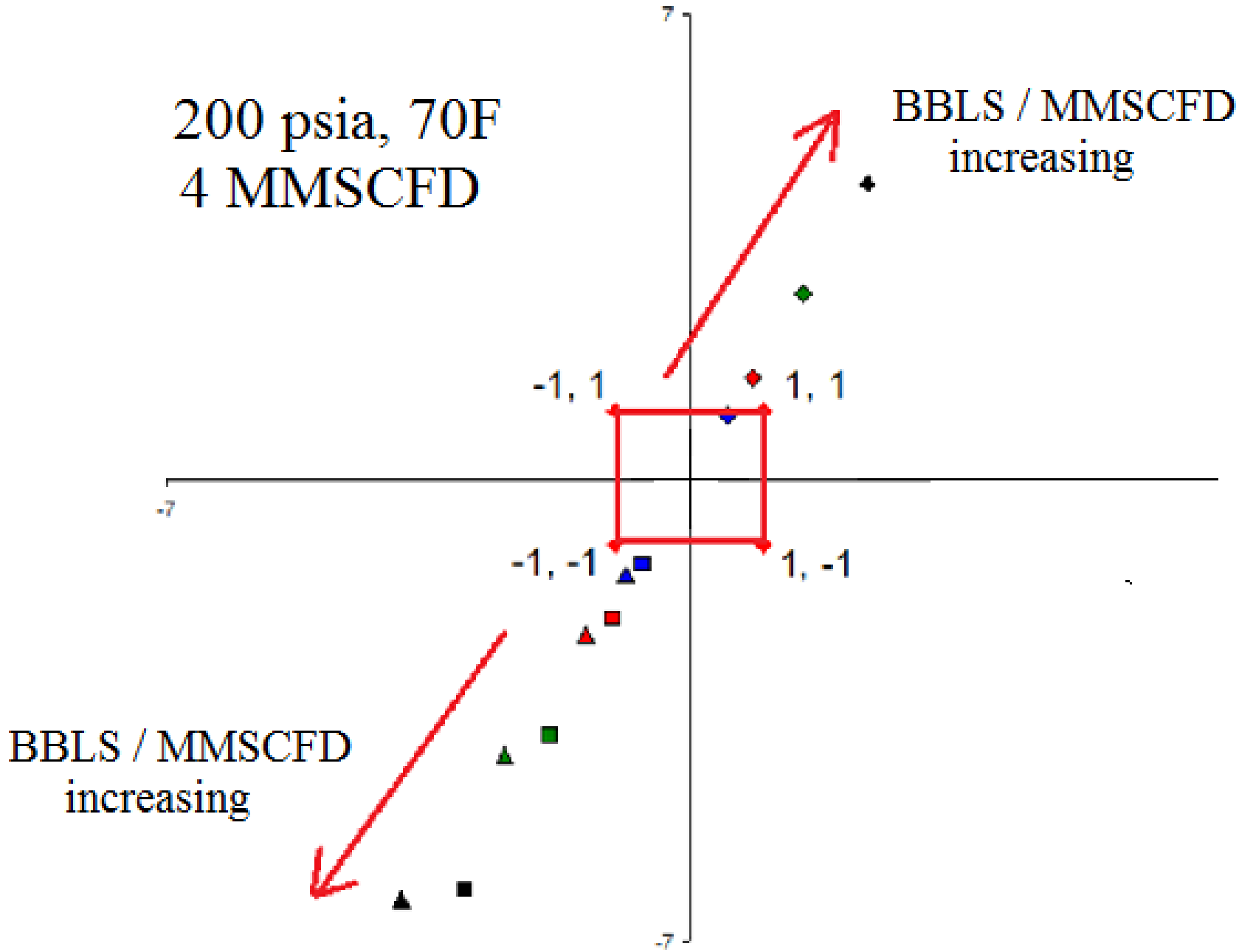


CoP Jasmine 12”, 0.636β Orifice Meter Test Separator Gas Outlet





4", 0.68 Beta Ratio Orifice Meter



Conclusions

- DP Diagnostics has developed and proven an orifice meter diagnostic tool called “Prognosis”.
- Prognosis can:
  - assure correct orifice meter operation
  - reduce exposure to mis-measurements
  - increase the productivity of field technicians
  - limit risk by limiting maintenance to orifice meters that are shown to require it only!

- Prognosis has been laboratory tested by:
  - CEESI (Colorado & Iowa)
  - NEL (UK) *confidential*
  - ATMOS (Texas)
  - CIATEQ (Mexico)
- Prognosis has been field tested at:
  - BP CATS
  - CoP TGT
  - CoP Franklyn
  - UK National Grid (Corby)

- In the 5th year on the market Prognosis is already been procured by:

  BP, ConocoPhillips, Centrica, Petronas, Yanpet (Exxon/Saudi Aramco), E.ON Ruhrgas, UK National Grid, GDF Suez, Perenco, Talisman, EnCana, Nova Chemical, Maersk + others.

- The concept is now mentioned in:
  - the UK governments DECC "Guidelines for Petroleum Measurement"
  - The Canadian regulators "Directive 17"

PROGNOSIS END USERS

Canadian Natural

encana natural gas

TALISMAN ENERGY

سابك sabic

ExxonMobil

GDF SUEZ ÊTRE UTILE AUX HOMMES

centrica

e·on Ruhrgas

ConocoPhillips

PETRONAS

nationalgrid

bp

MAERSK OIL

PERENCO

SSGC

NOVA Chemicals

Britannia

Thank You.

Questions?

DP DIAGNOSTICS

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