

Developments in Saturated (“Wet”) Steam Flow Measurement

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MONITOR, VERIFY, AND TRUST YOUR DP METER



Azbil North America, Inc.

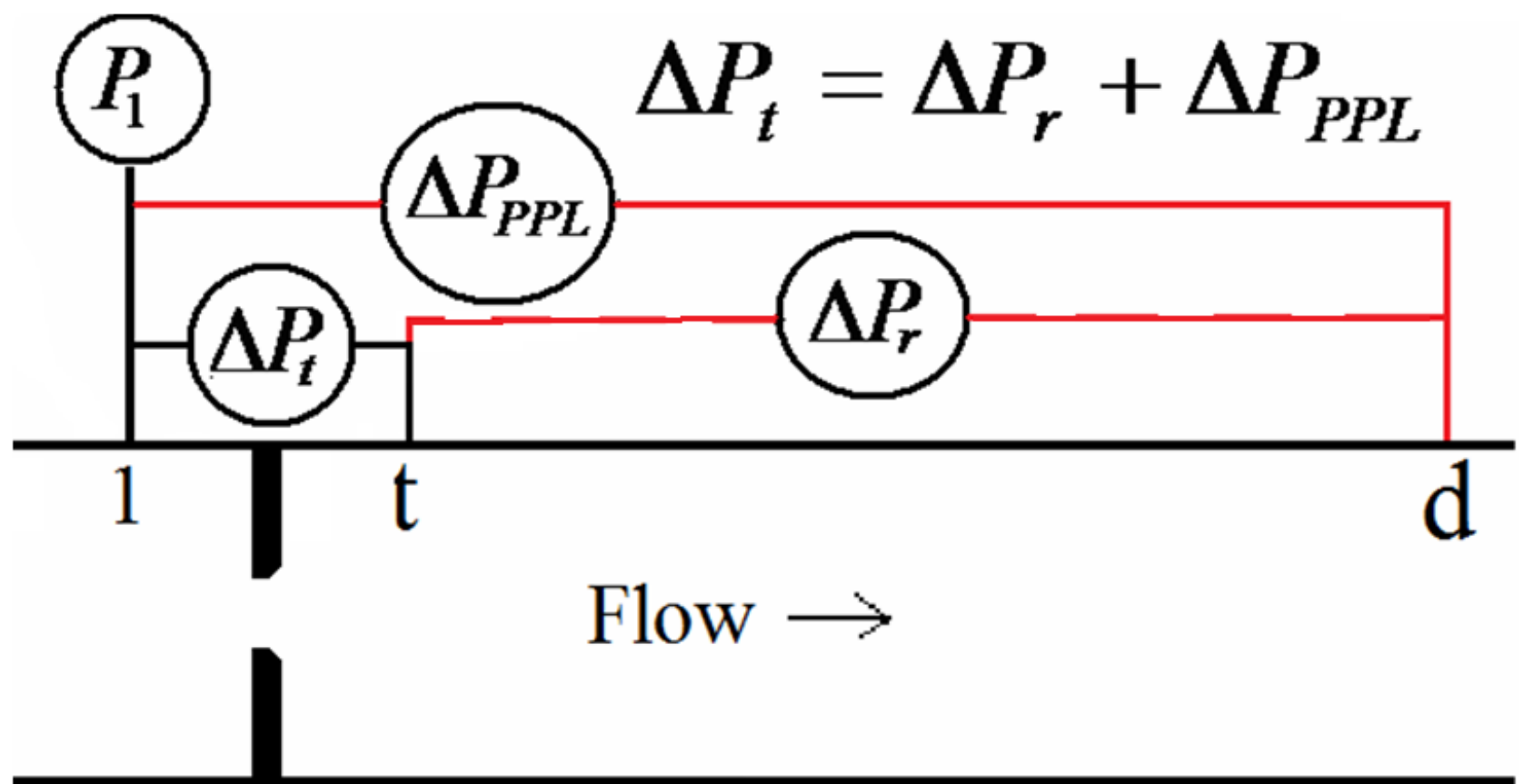
Introduction

- Saturated steam flow is common, but a challenge to meter when quality $x < 100\%$.
- Saturated steam metering at $x < 100\%$ is analogous to the metering of 'wet natural gas' flows.
- Most saturated steam flows and wet natural gas flows are metered with standard gas meters.
- **All** gas meters are adversely affected by liquids (e.g. water) present with the gas (e.g. steam).
- This presentation looks at two wet natural gas meter techniques applied to saturated steam flows.

1. DP Meter Verification System

- DP meters, such as orifice meters, are traditional popular meters for gas / dry steam metering.
- DPD has developed a DP meter verification system.





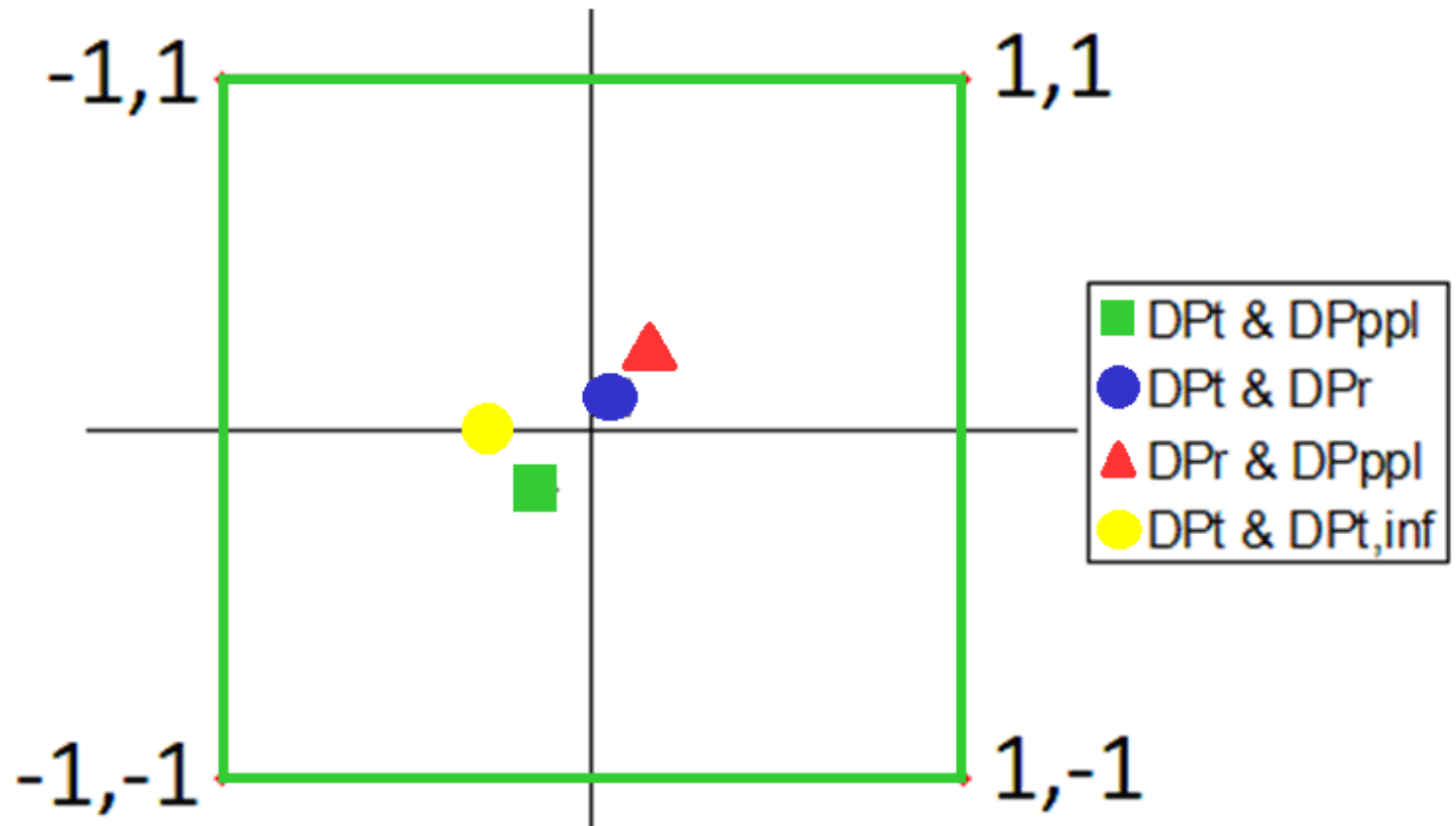
1 DP summation

3 flow meters to compare

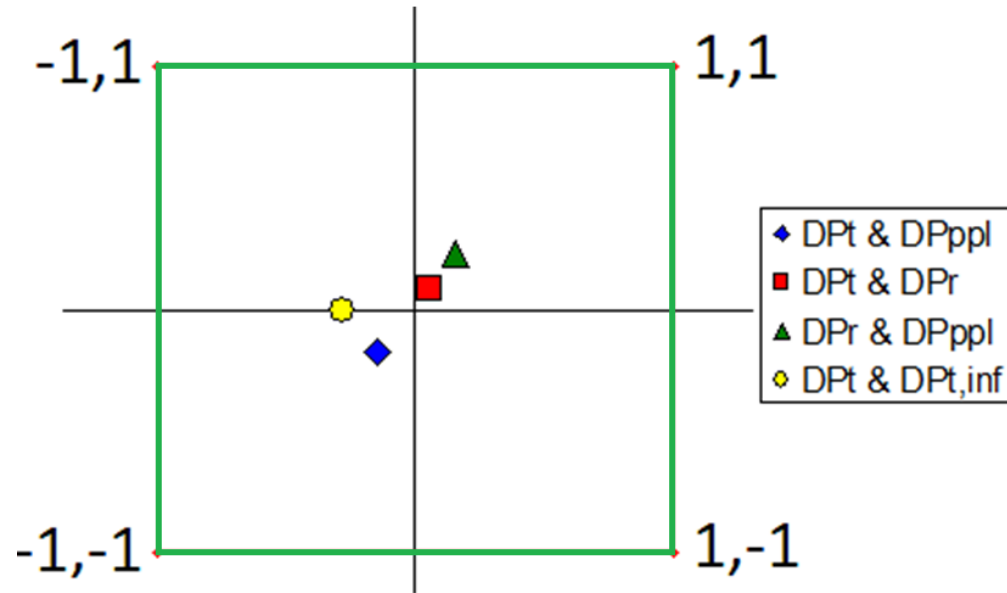
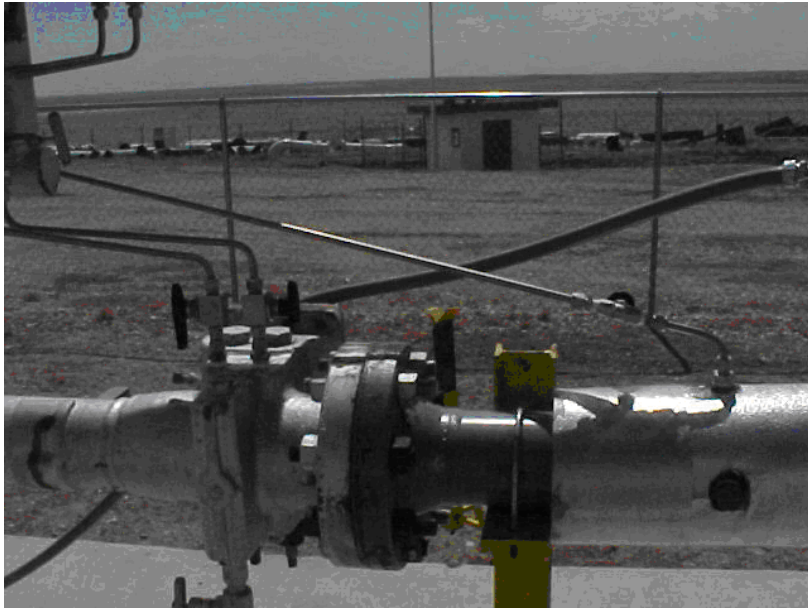
3 DP ratios to check

System Interface

- 7 Checks, 7 Co-ordinates



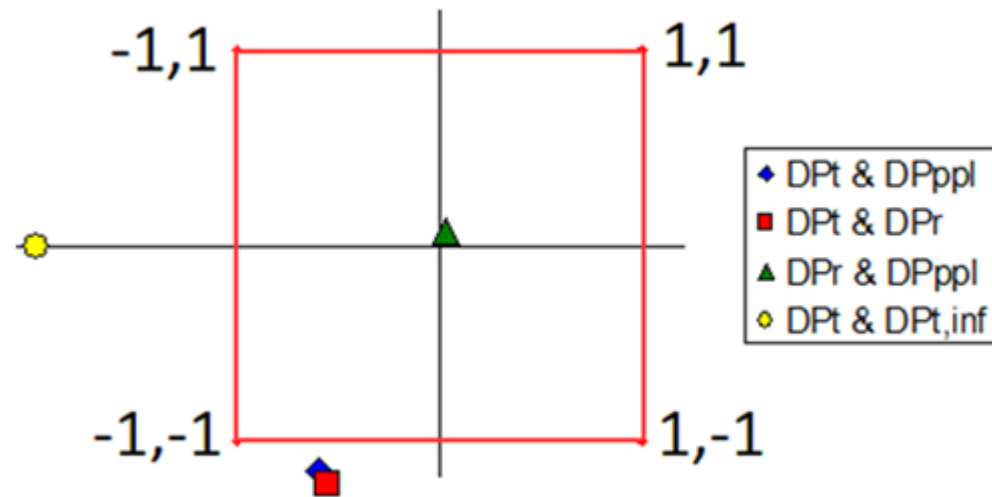
Normal Dry Gas / Steam Operation



- The majority of DP meters operate in dry gas and have no problems...
- This is such an example, actual data from a 4" orifice meter operating with dry gas at CEESI.

4", 0.5 β Orifice Plate Meter with a Drifting DP Transmitter – Lab Data

Flow Rate is 2.28 kg/s, actual DP 362 "WC
DPt drifts 2%, DPt read 369"WC, Flow Error +1%



Orifice Meter Dry Gas Field Data Example

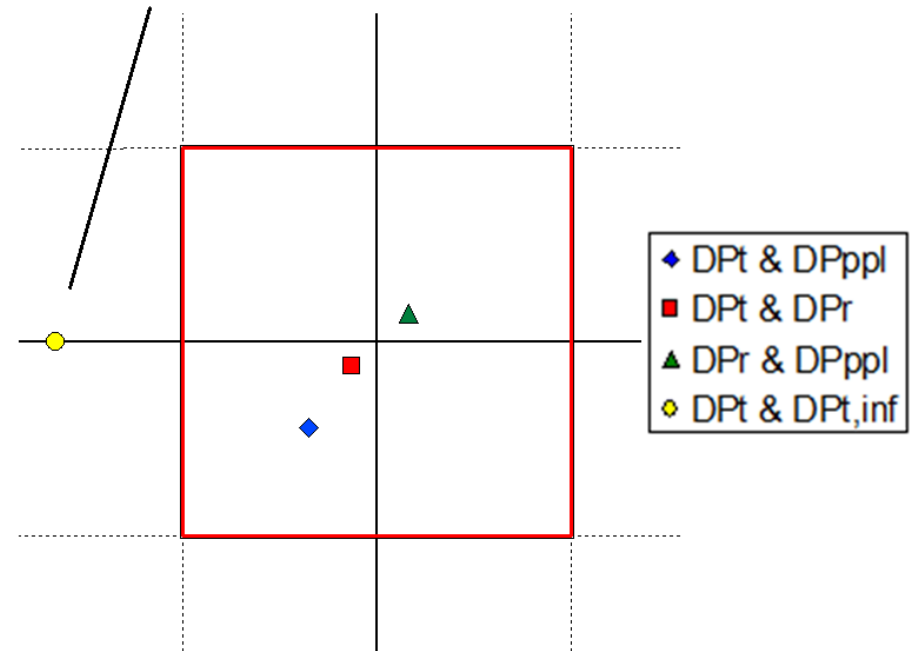
Drifted Traditional DP transmitter

DP
transmitter
enclosure

orifice
fitting

downstream pressure tap

DP reading problem



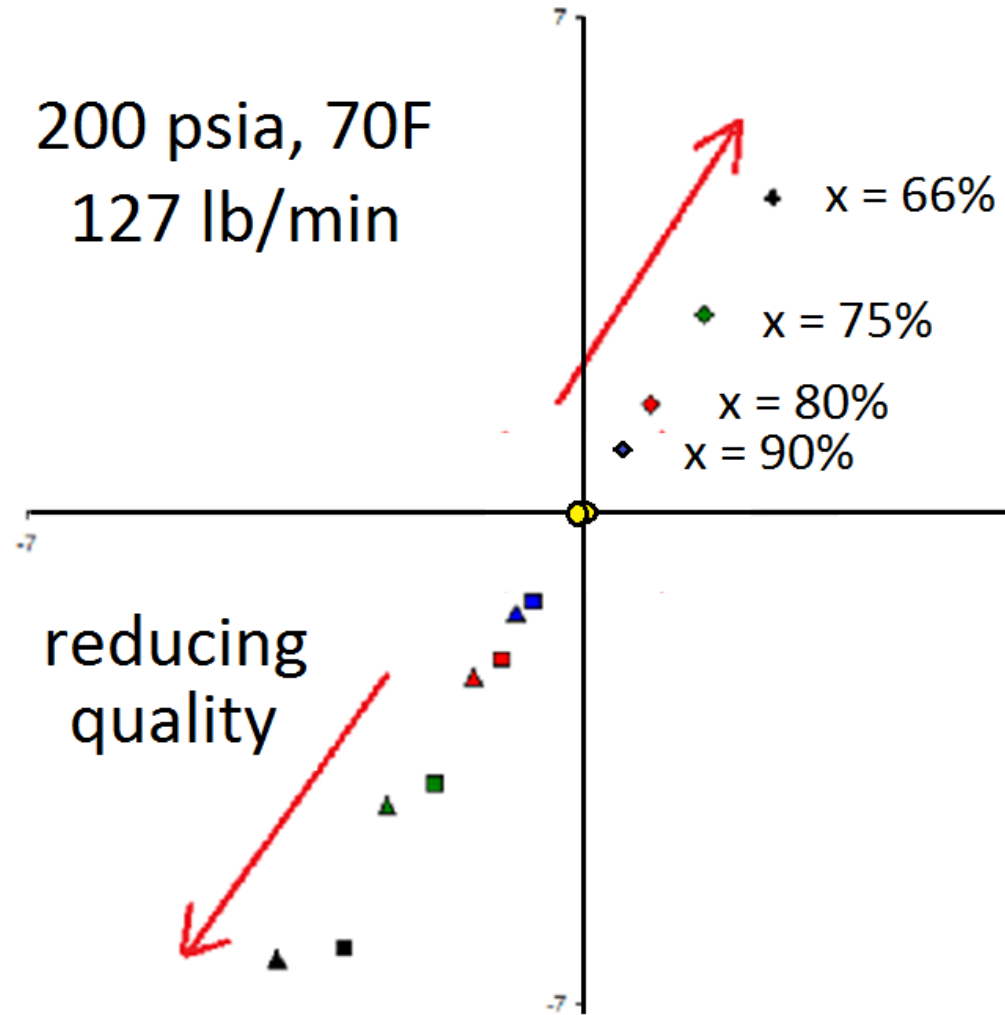
- Traditional DP transmitter found to require re-calibration

Monitoring Wet Gas /Saturated Steam Quality

4", 0.68 β Orifice Meter



200 psia, 70F
127 lb/min

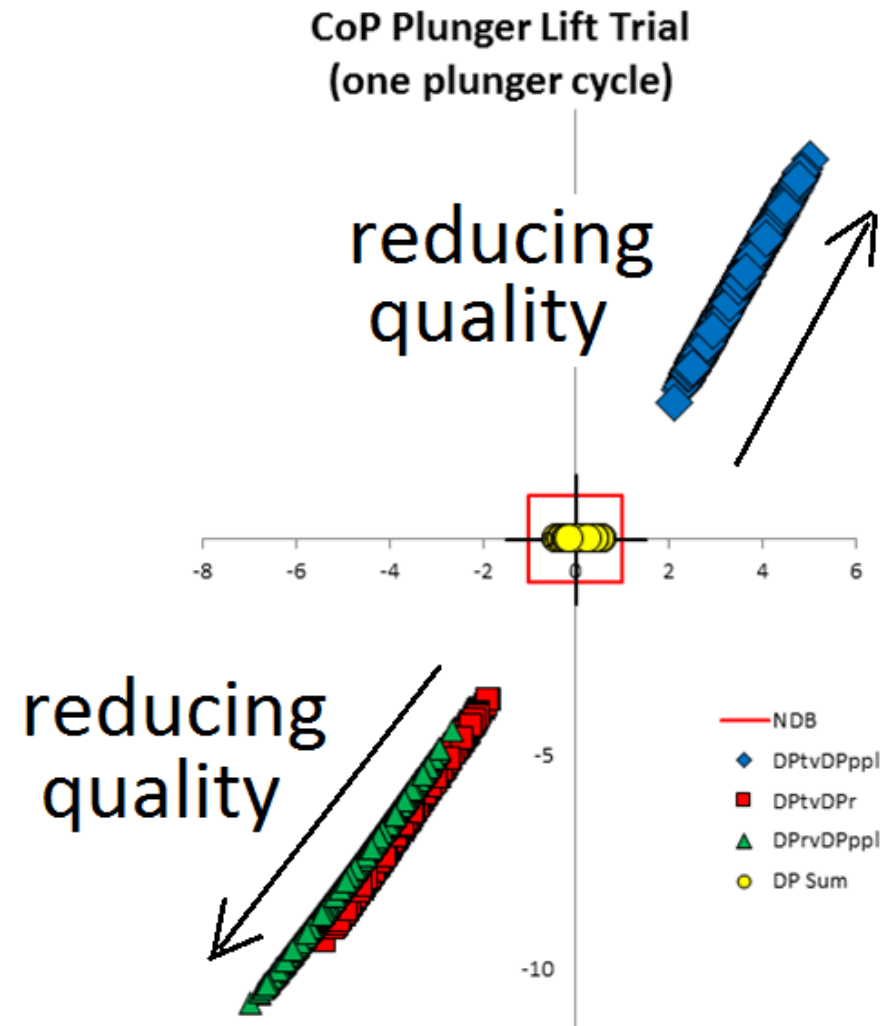


Orifice Meter Field Data Example

Varying Wet Gas / Steam Quality

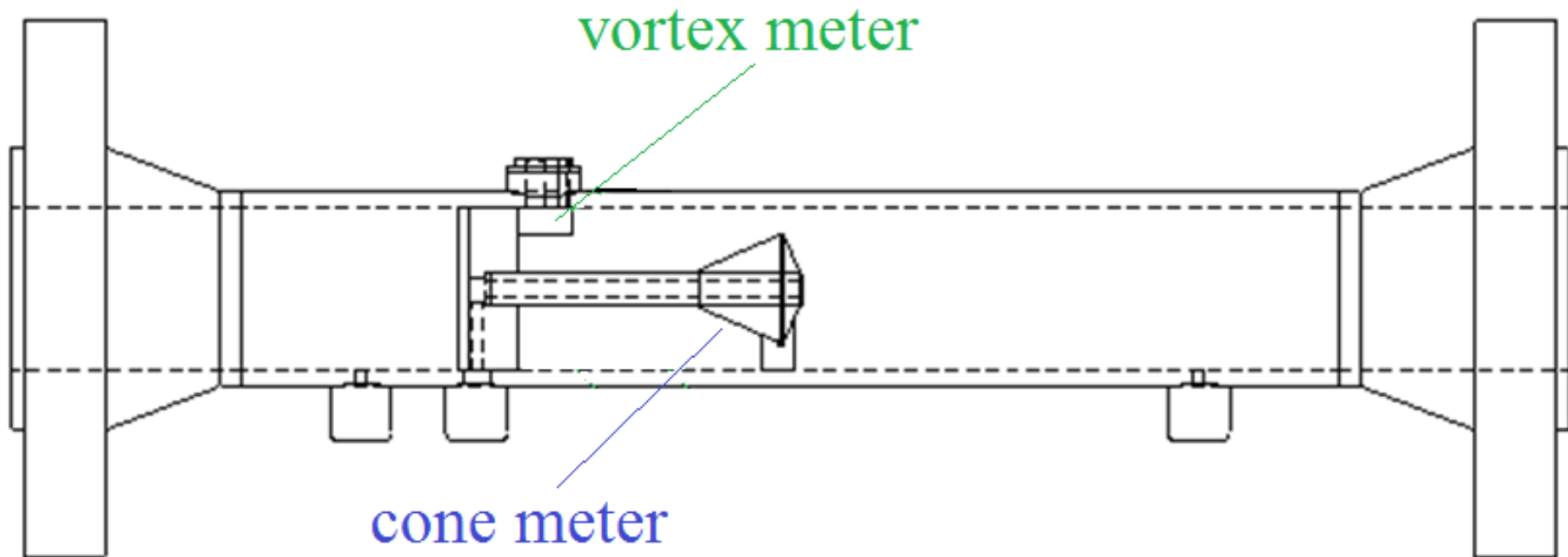


- Field trial of a 4" orifice meter with varying saturated gas qualities.



2. Novel ('Boden') Mass Meter Design

- The cone DP meter operates normally.
- The vortex meter operates normally.
- Combining the two meters produces a mass meter / densitometer.



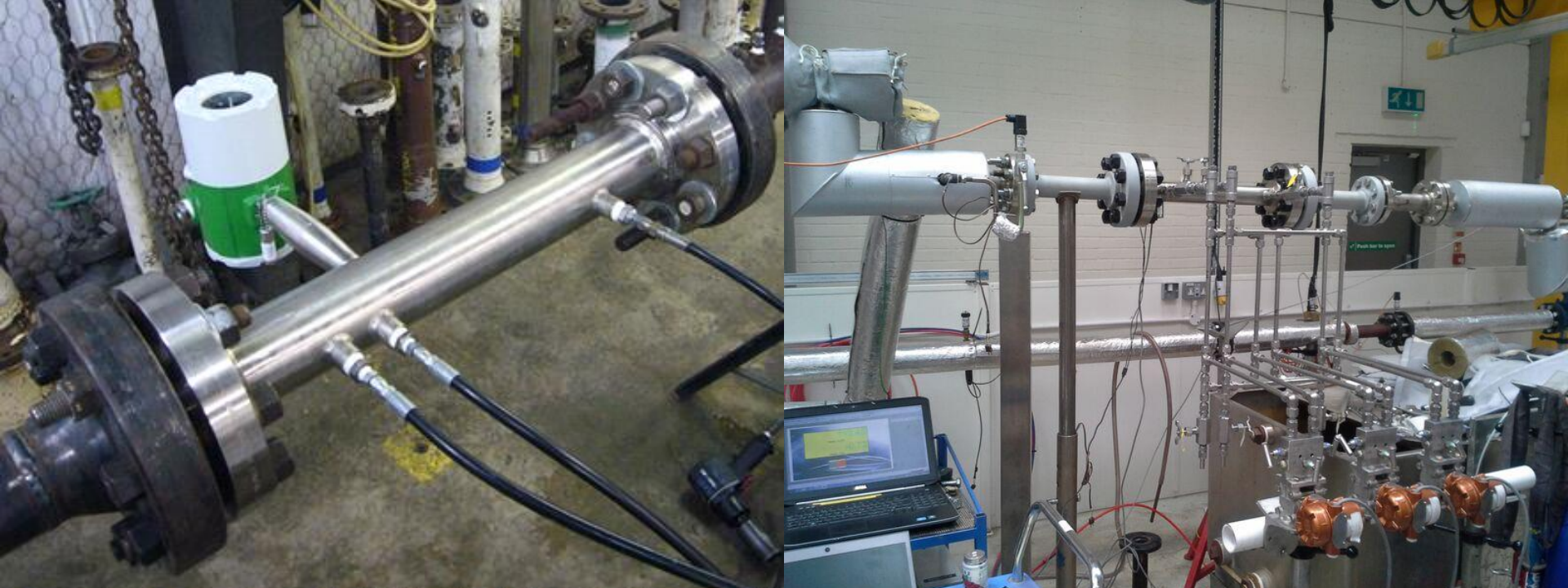
Basic Theory:

- A vortex meter predicts gas volume flow ' Q_v ', but needs density to predict mass flow rate ' Q_m '.
- A cone meter needs density to predict volume & / or mass flow rate. Therefore:

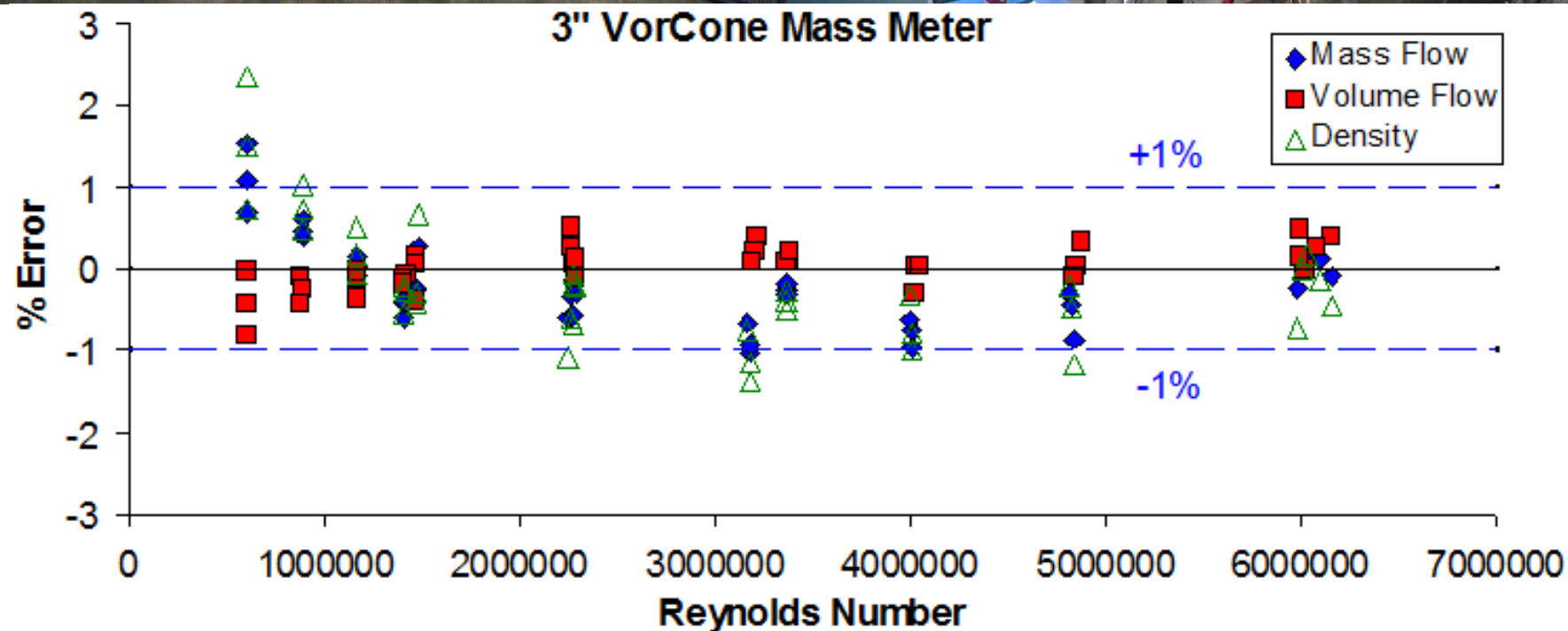
$$Q_v = f(\rho, \Delta P) \quad \rho = f_1(Q_v, \Delta P)$$

- Therefore:

$$Q_m = \rho * Q_v$$

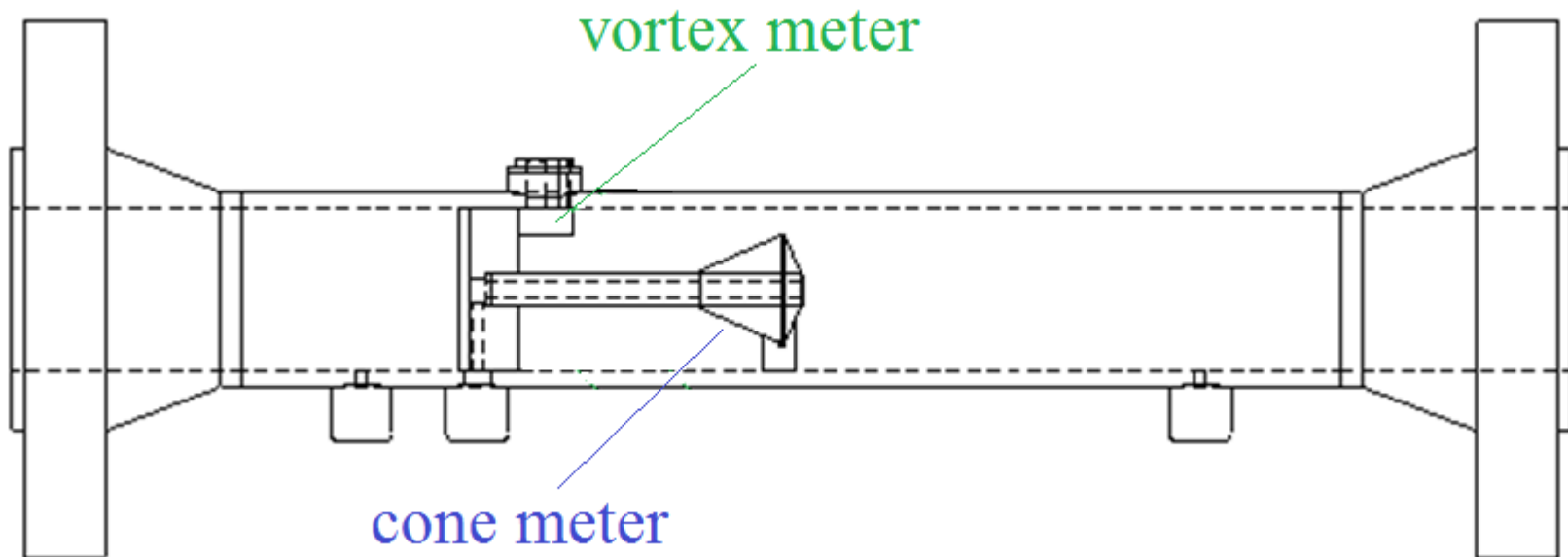


3" VorCone Mass Meter



New Mass Meter with Saturated Steam

- Assume meter mixes 2-phase flow well.
- Vortex meter predicts mixture volume.
- Vortex / cone meter predicts homogenous density.
- As P & T measured, liquid & gas density from steam tables....



from vortex meter

$$\rho_{\text{hom}} = f(Q_{\text{hom}}, \Delta P_{\text{hom}})$$

from steam tables

from
combined meter

found

$$x = \frac{\rho_g (\rho_l - \rho_{\text{hom}})}{\rho_{\text{hom}} (\rho_l - \rho_g)}$$

from

combined meter

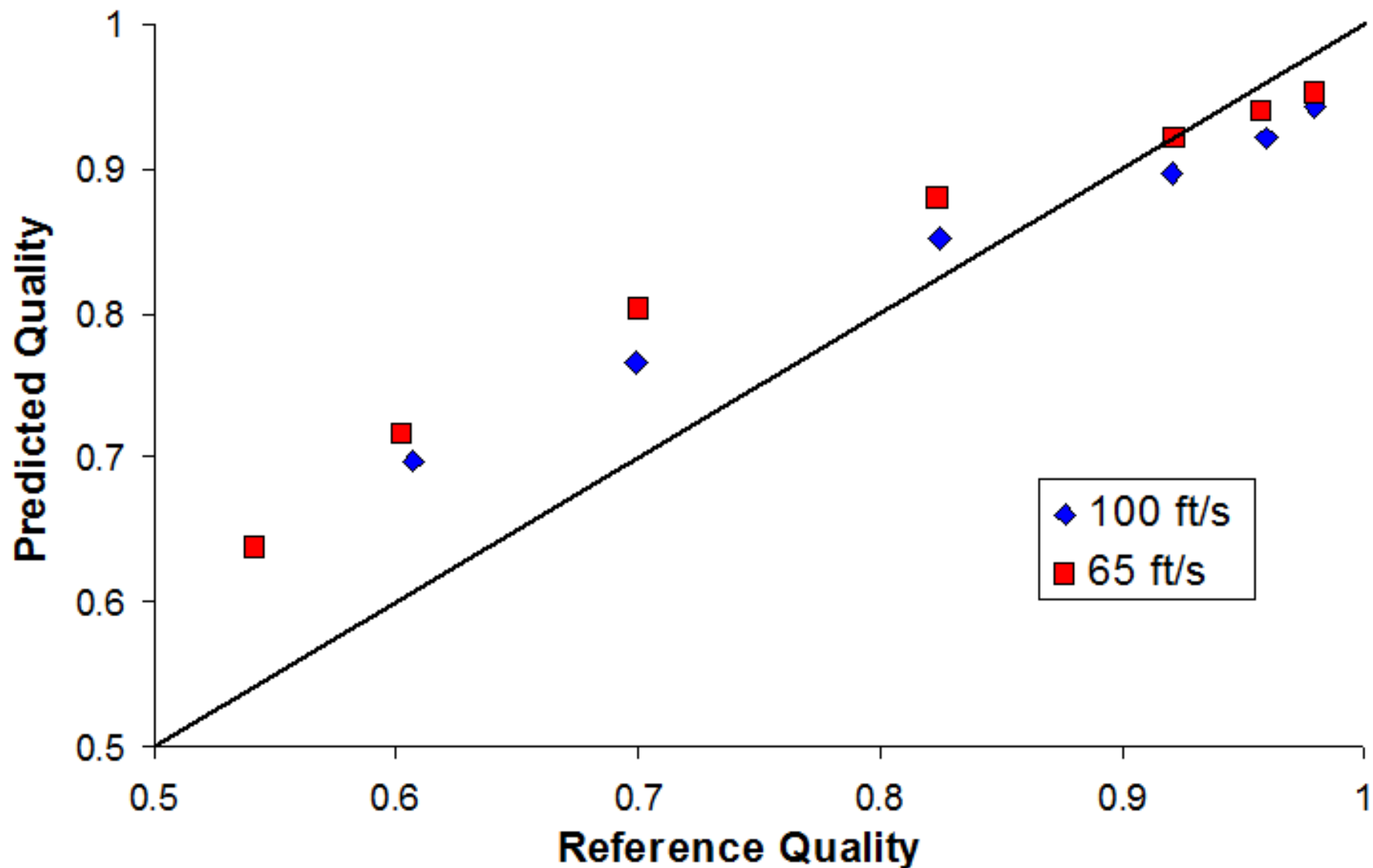
from steam tables

3" VorCone Meter Wet Gas Tests at CEESI



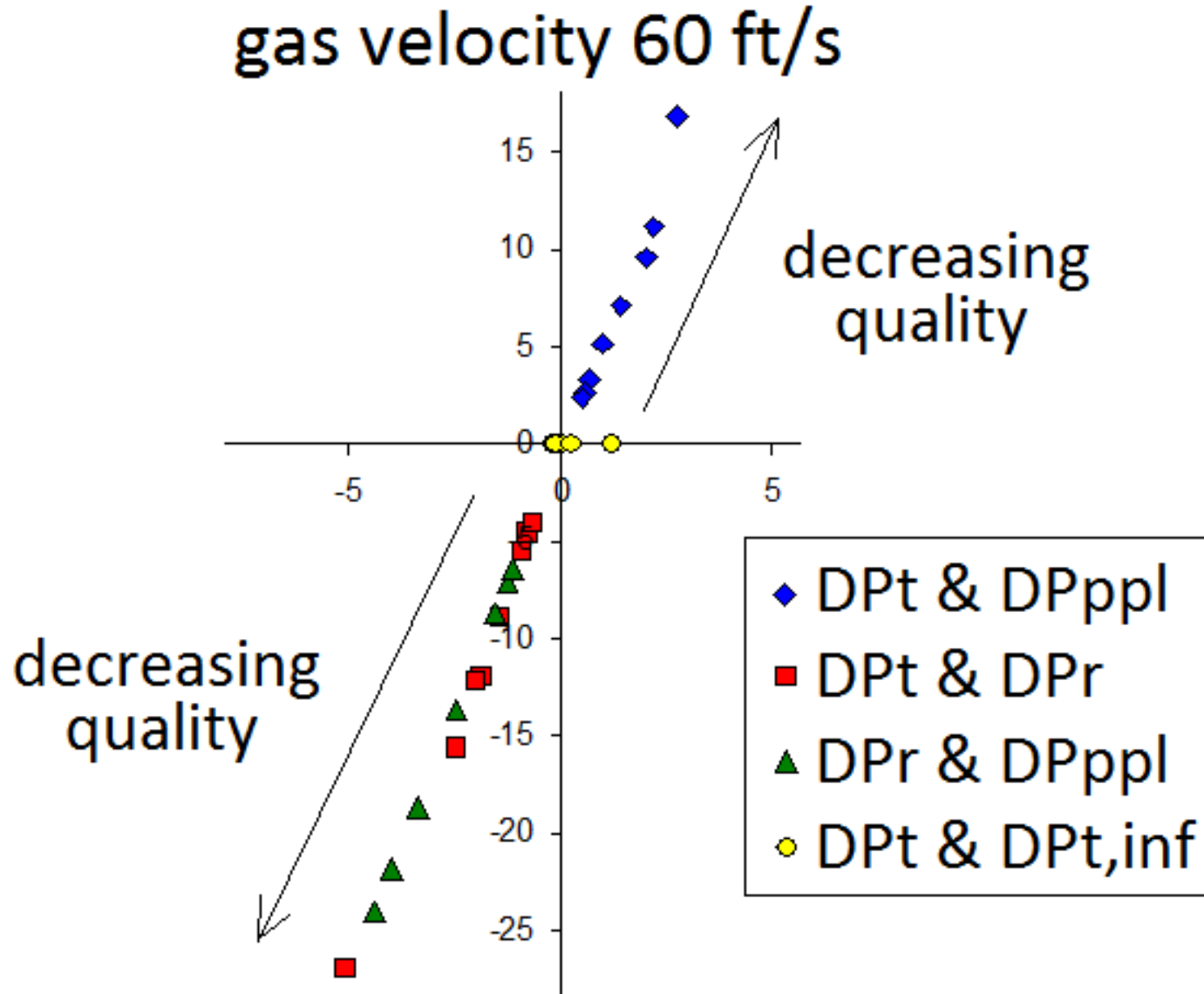
- **Caveat:** data set is for gas flow at > 50 ft/s, to promote well mixed gas / liquid flow.
 - such velocities can be induced in applications (if required) by reduced bore meters.

Lab Results - Quality Measurement By Theory of Cross-Referencing Vortex & DP Meter Outputs



Lab Results of DP Meter Verification System

Response to the Varying Gas / Liquid Quality



Saturated Steam Field Tests

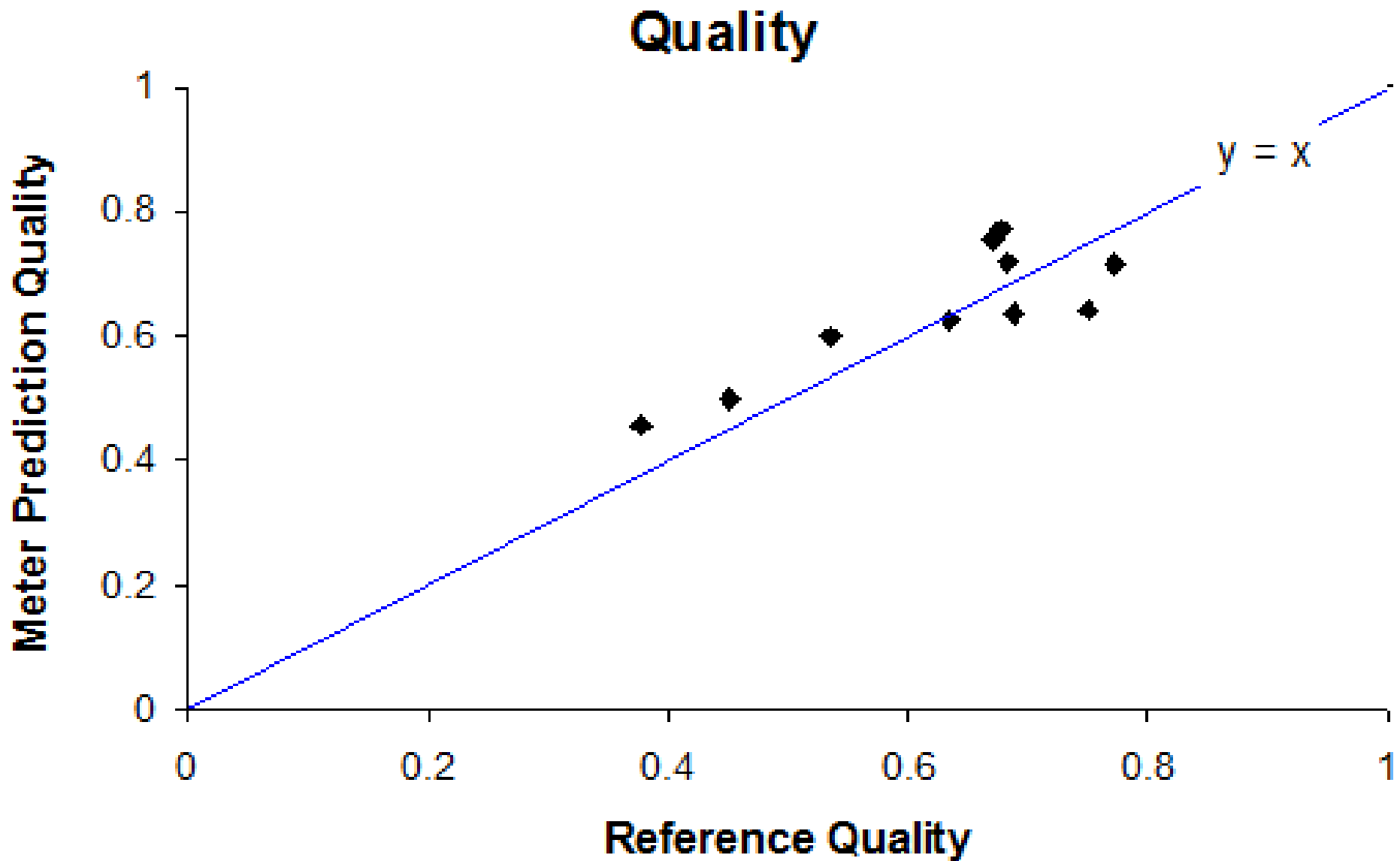


- 3" Vorcone mass meter under saturated steam field tests.

- Quality reference from portable separator system with Coriolis meters.

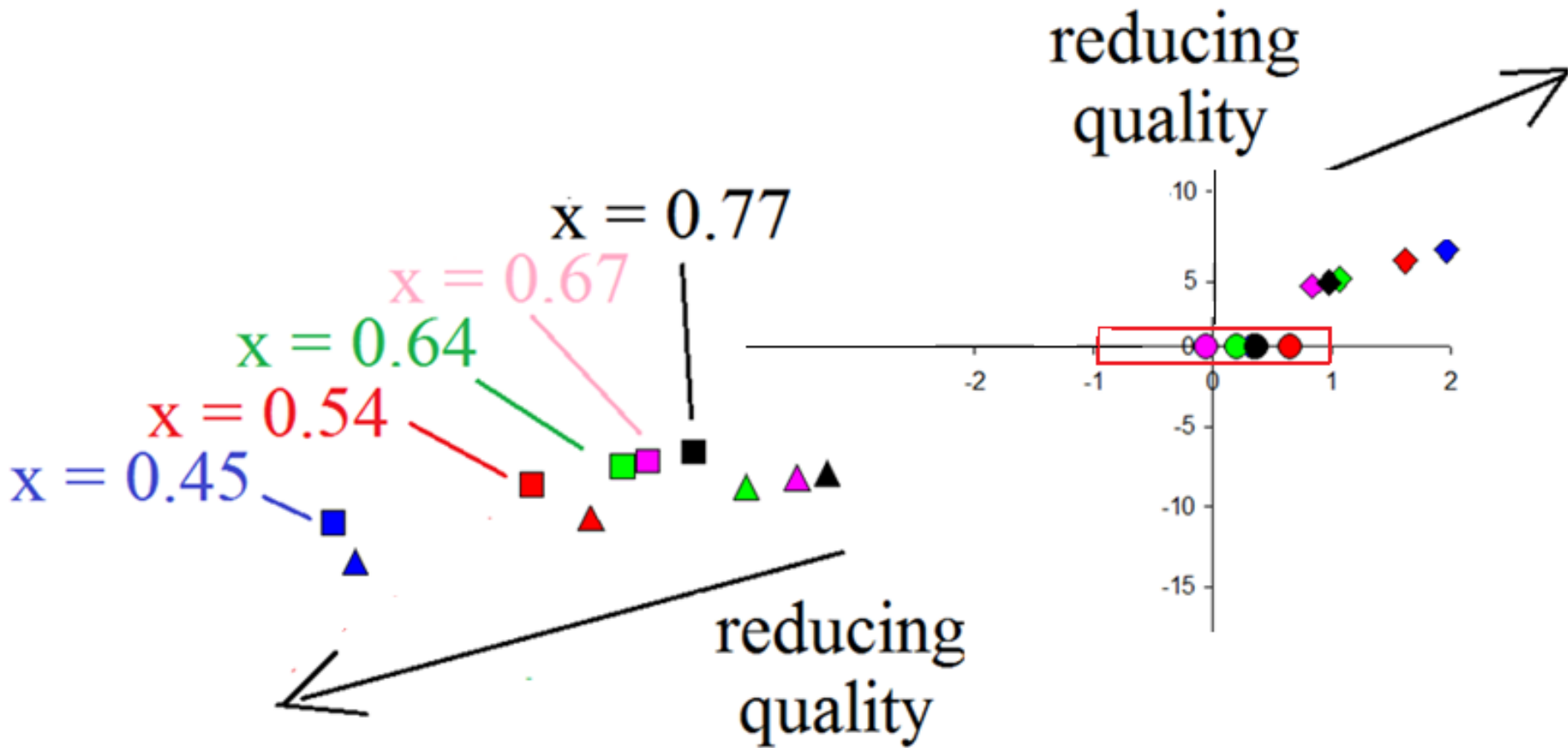


Field Results- Quality Measurement By Theory of Cross-Referencing Vortex & DP Meter Outputs



Field Results of DP Meter Verification System

Response to the Varying Steam Quality



Conclusions

- The DP meter verification system 'Prognosis' lets standard DP meters track changes in steam quality.
- The simple & robust VorCone mass flow meter can use theory alone to predict and track changes in steam quality.
- 'Prognosis' also operates on the VorCone meter & offers a 2nd & independent method of tracking steam quality.

Thank You Questions?



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