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الراعـي الرسمـي

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Flow Meters with Heavy Oil / Low Reynolds Number Flow

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DP DIAGNOSTICS

MONITOR, VERIFY, AND TRUST YOUR DP METER

MEASUREMATION

Introduction

- Heavy oil (API < 20^0) is a challenging flow to meter.
- Meters are sensitive to Reynolds number (Re).
- But to know Re you need to know the viscosity.
- Heavy oil fluid properties are not always known.

Reynolds Number

$$\mathrm{Re} = \frac{inerta\ force}{viscous\ forces} = \left(\frac{4}{\pi}\right)\left(\frac{1}{D}\right)\left(\frac{\dot{m}}{\mu}\right)$$

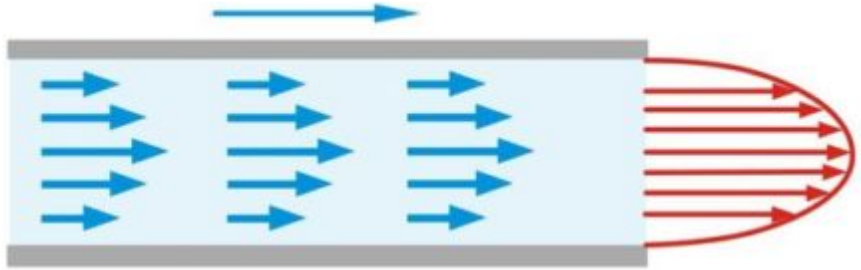
for a given diameter

mass flow to viscosity ratio

- For a given pipe diameter the *Reynolds Number* is set by the ratio of the mass flow & viscosity.

Reynolds No. Dictates the Flow Turbulence

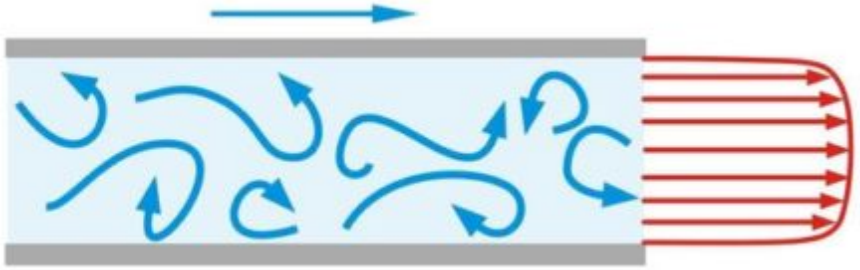
Re / turbulence dictates velocity profile...



laminar

Re < 2000 ??

Transition 2000 < Re < 4000 ??



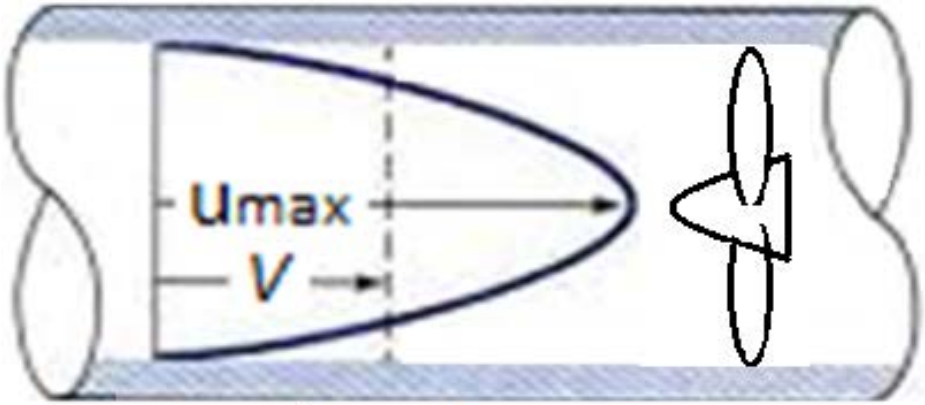
Turbulent

Re > 4000 ??

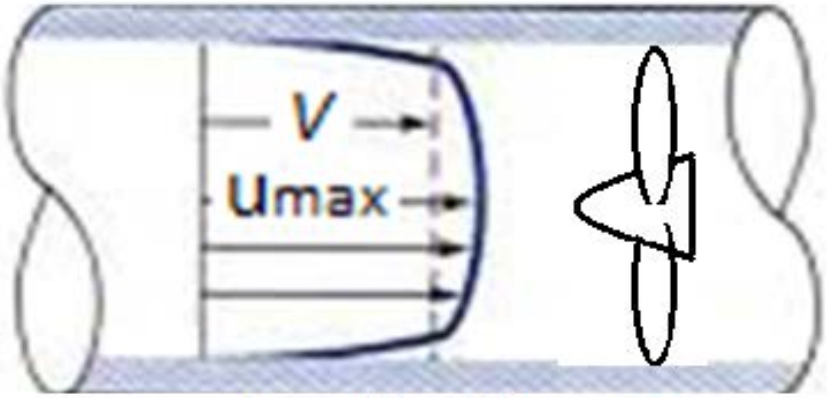
Re transition ranges are very approx, and are case dependent!

Why Does Velocity Profile Matter?

- Velocity profile dictates what the meter mechanism / sensors ‘see’ and therefore report.



laminar

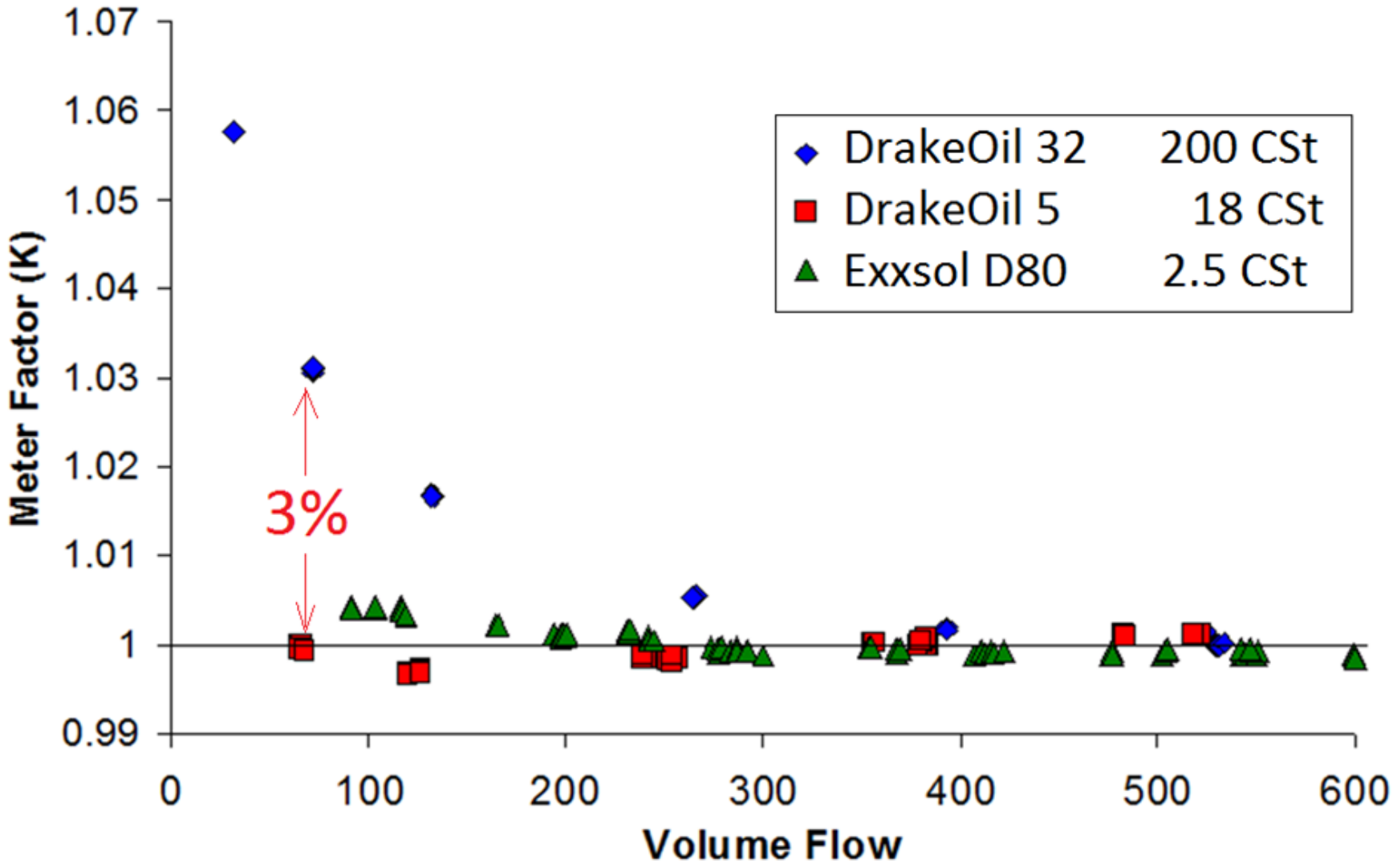


turbulent

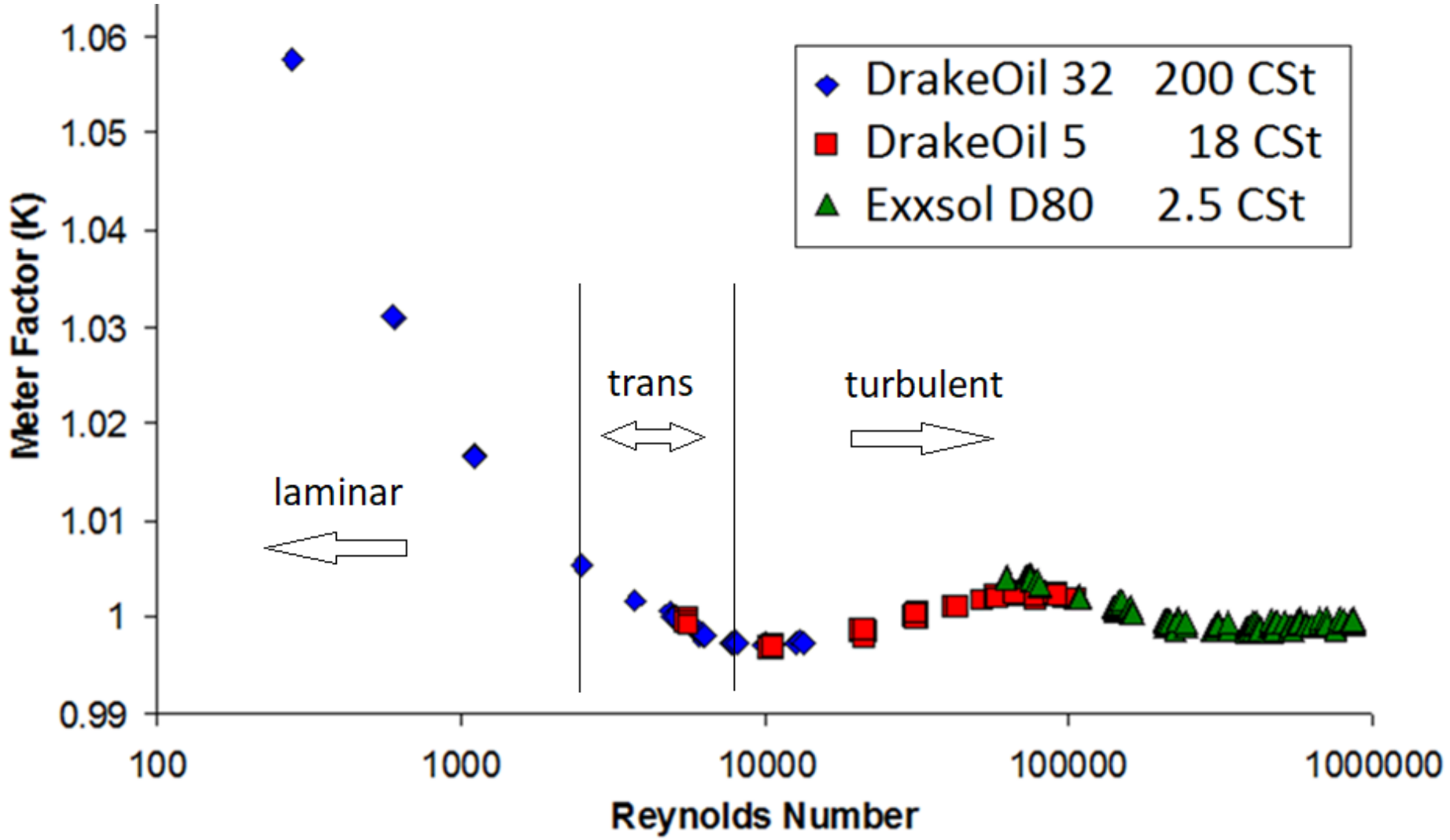
- Hence, *Re*, influences turbulence levels, influences velocity profile, influences meter performance.
  - i.e. Reynolds number influences meter factor!

8” Helical Blade Turbine Meter at CEESI Oil Facility

8” Helical Blade Turbine Meter



8” Helical Blade Turbine Meter



Blinded 4” Coriolis Meter Data

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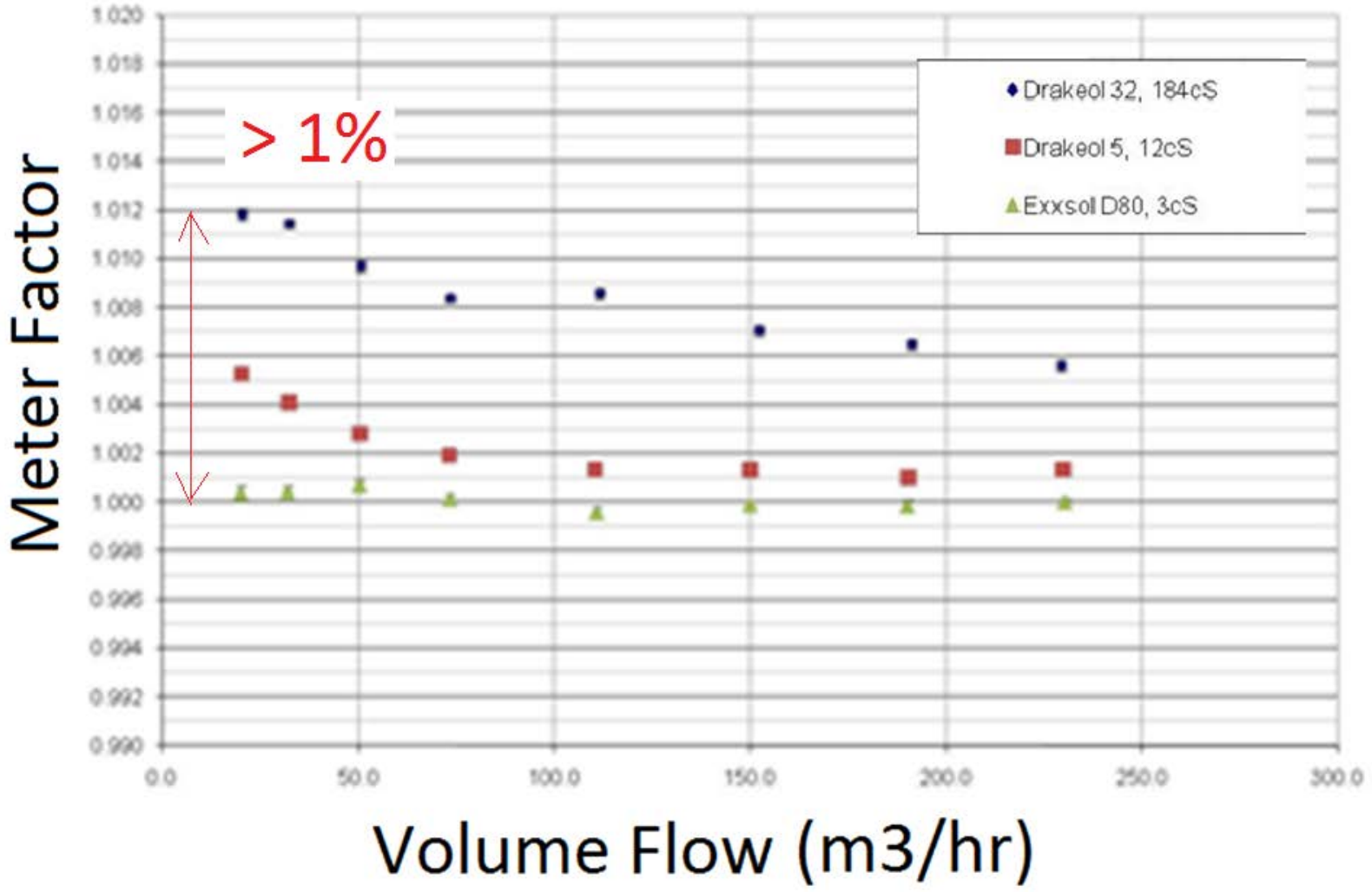
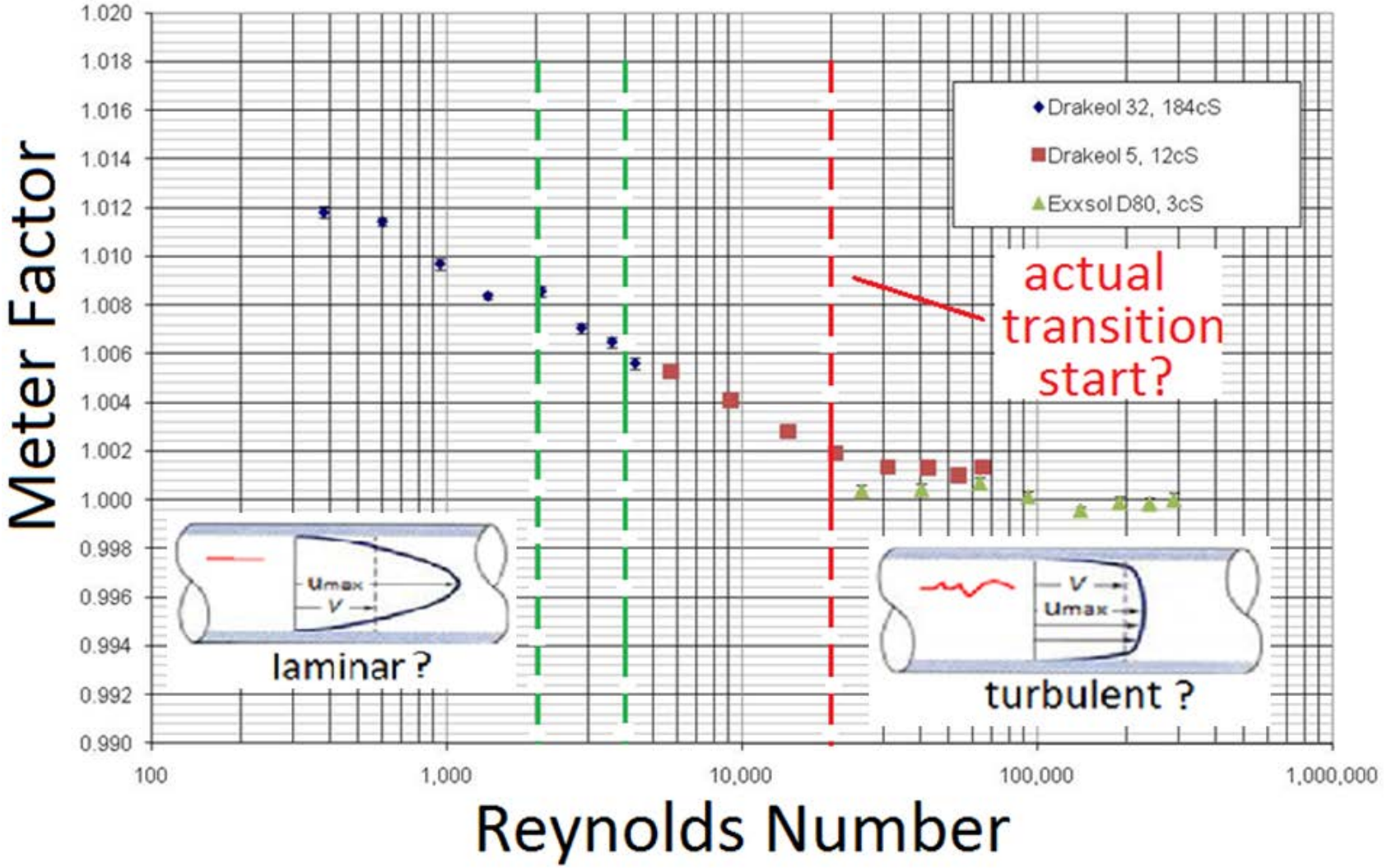
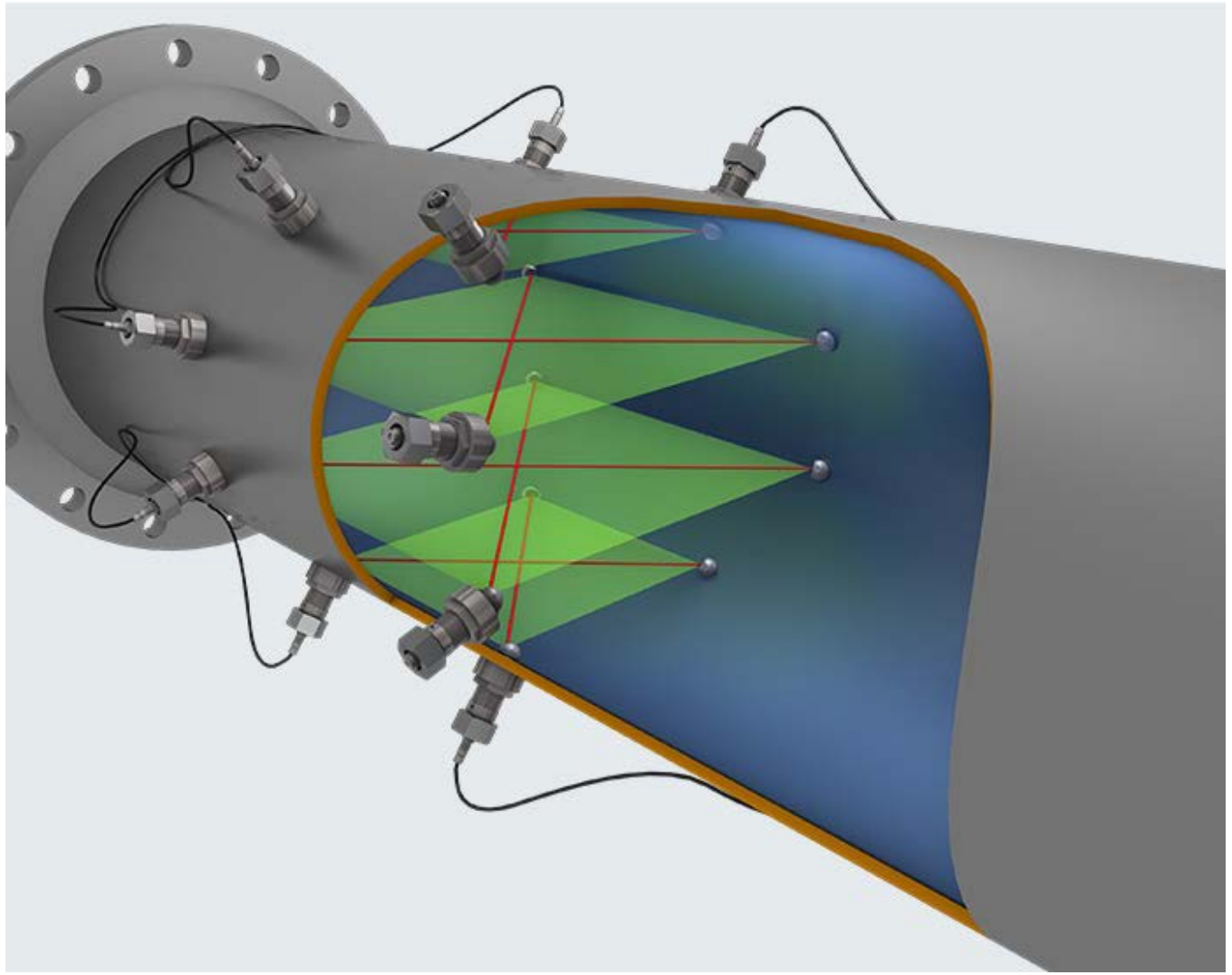


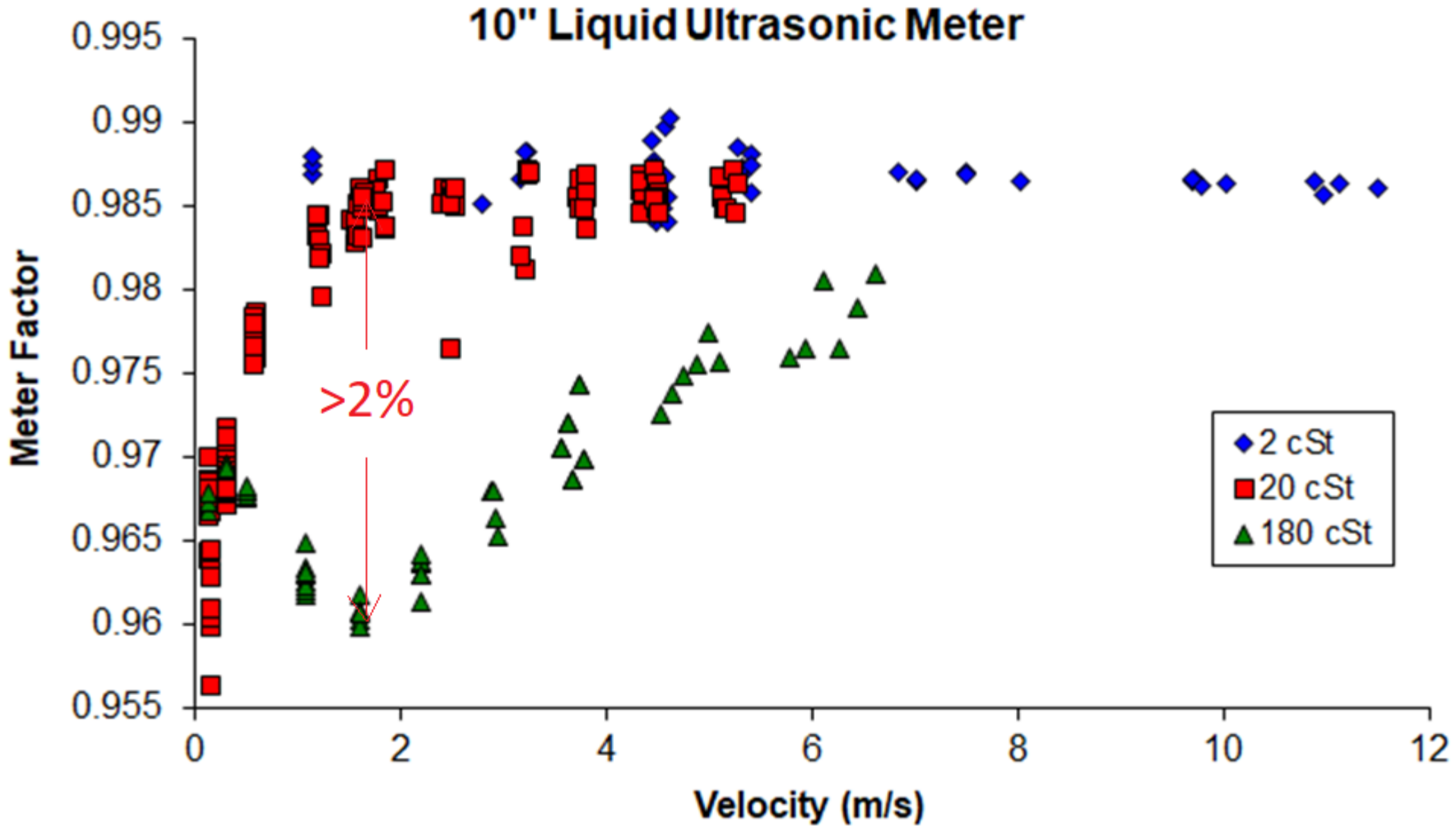
Blinded 4” Coriolis Meter Data



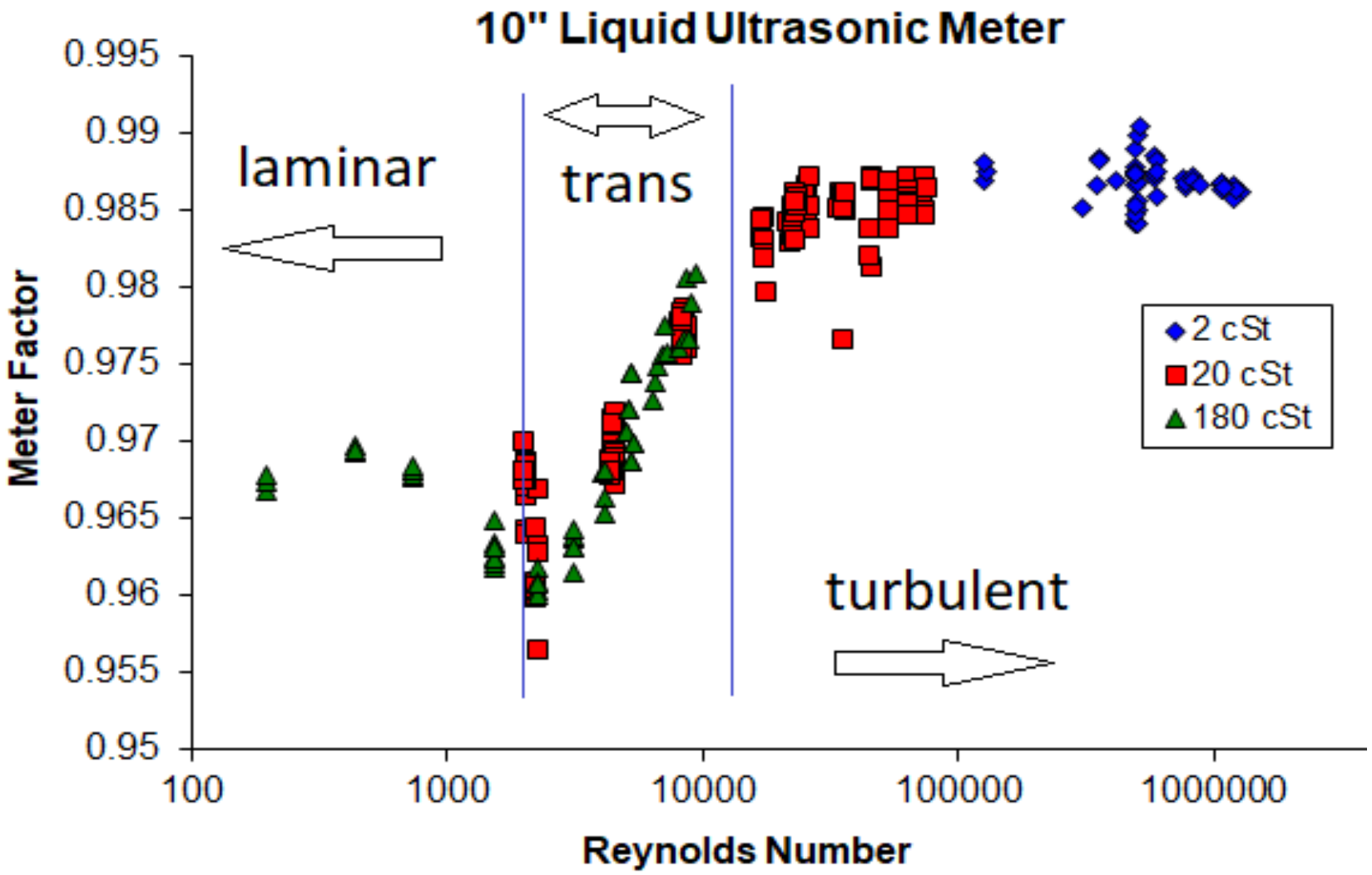
Blinded 10” Ultrasonic Meter Data



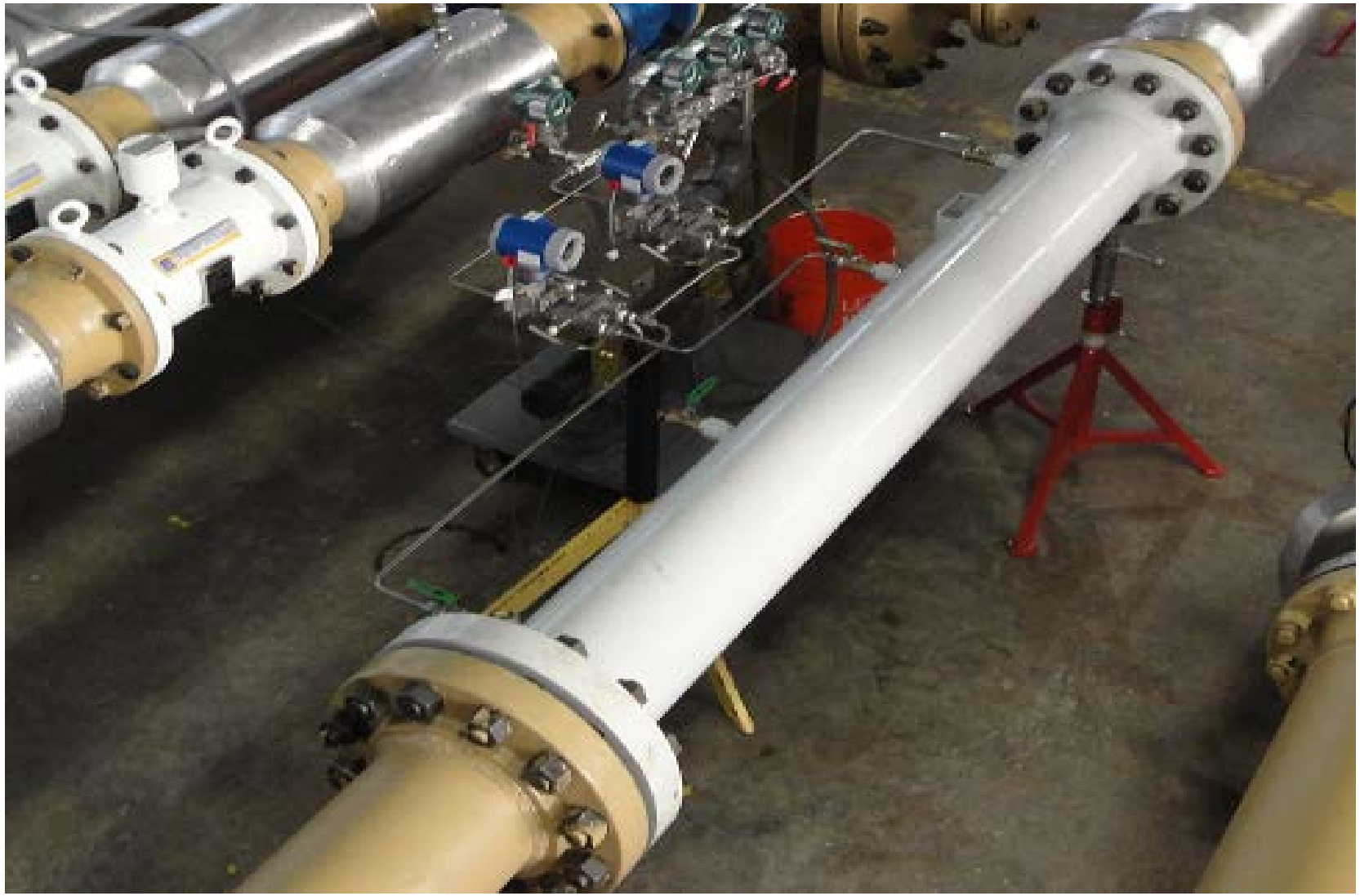
Blinded 10” Ultrasonic Meter Data



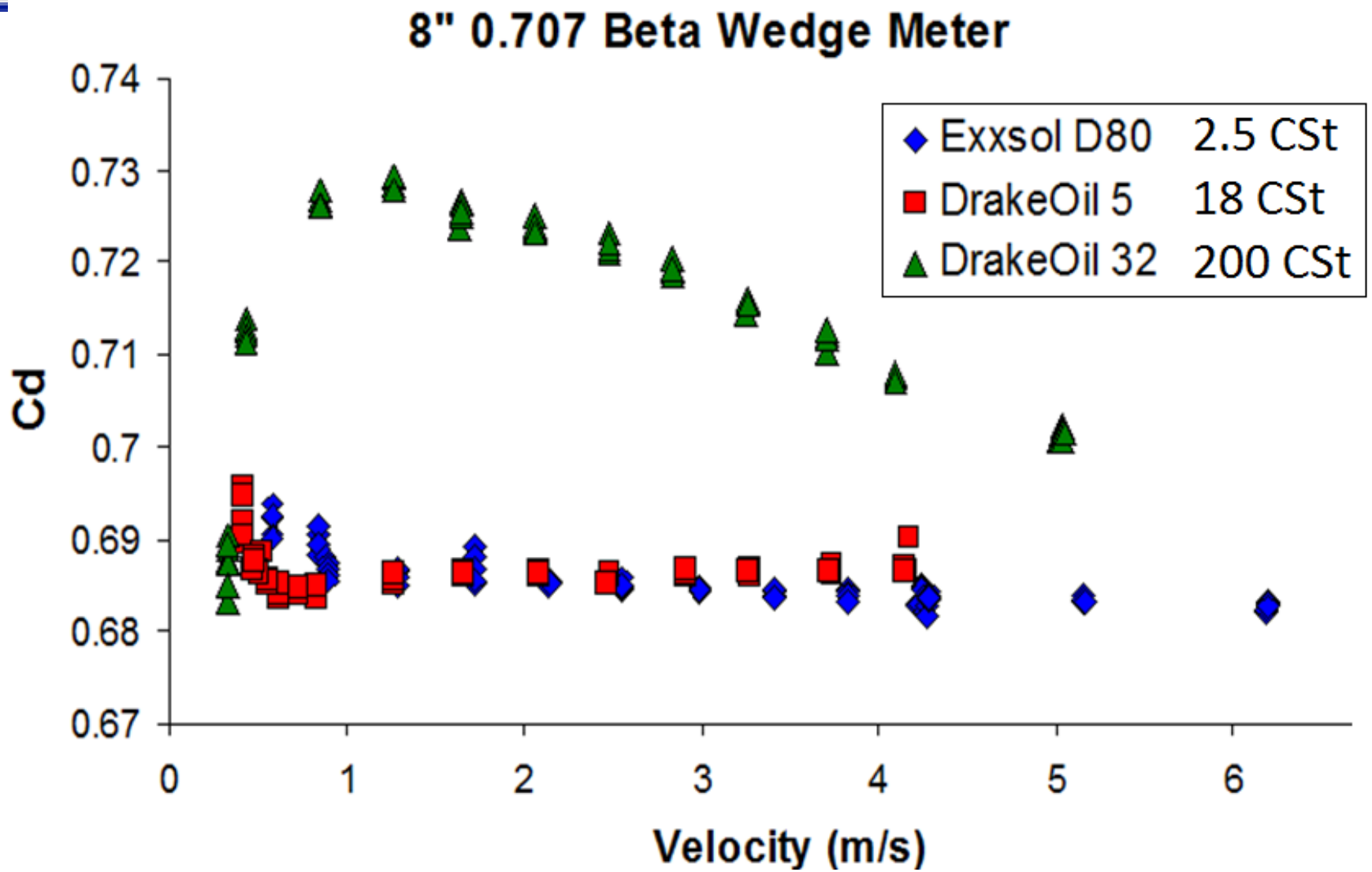
Blinded 10” Ultrasonic Meter Data



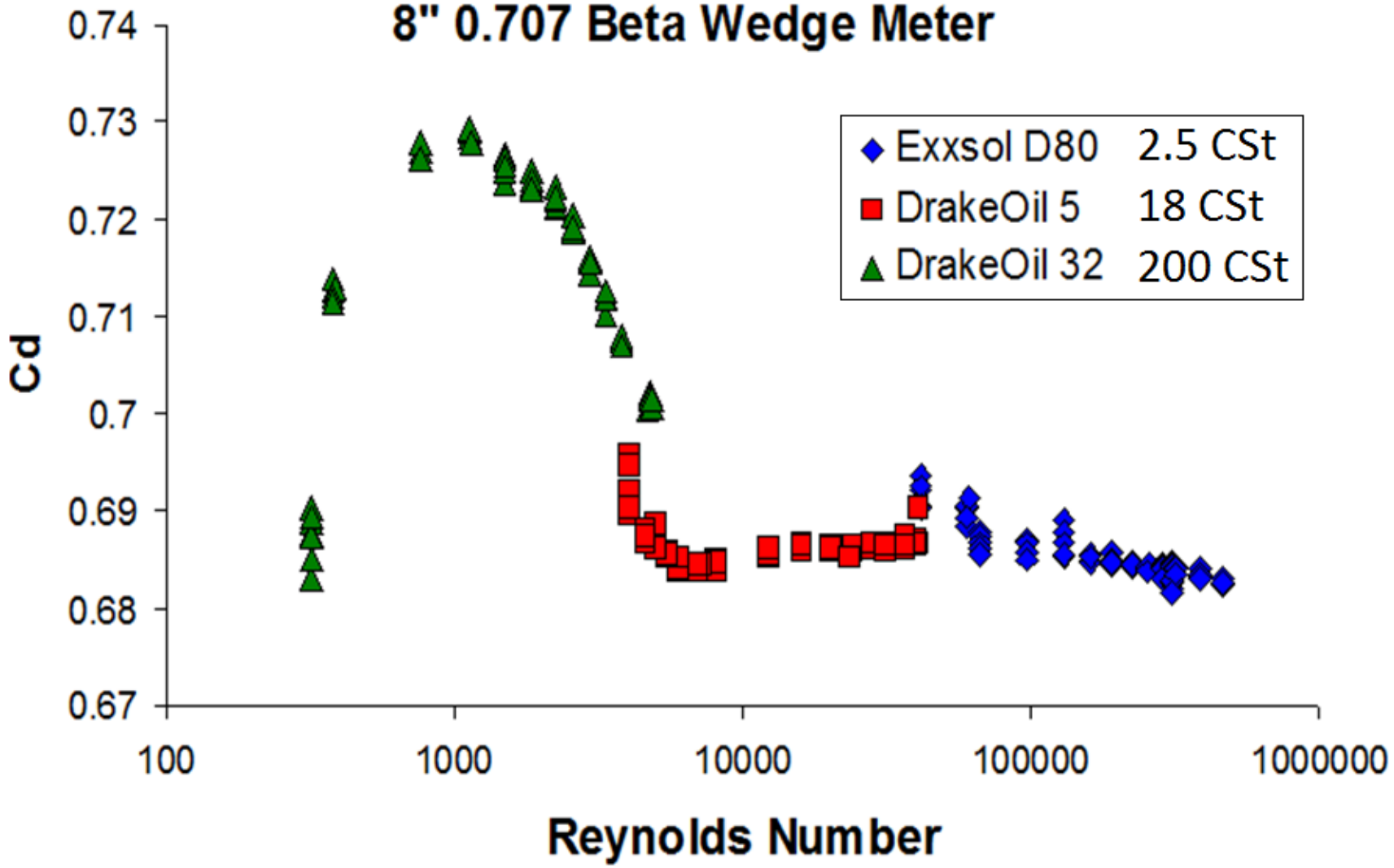
8” Wedge Meter (with Prognosis) at CEESI



Wedge Meter Data Cd Calibrated to Velocity

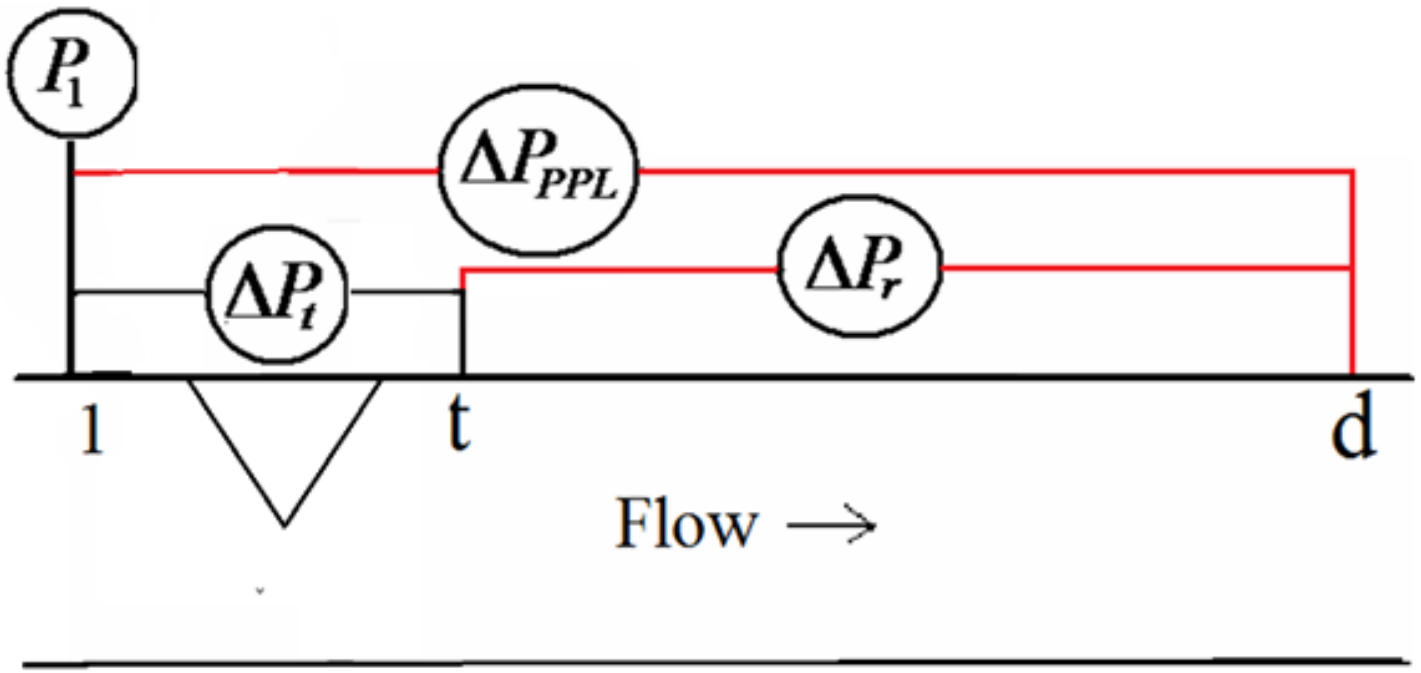


Wedge Meter Data Cd Calibrated to Re No.

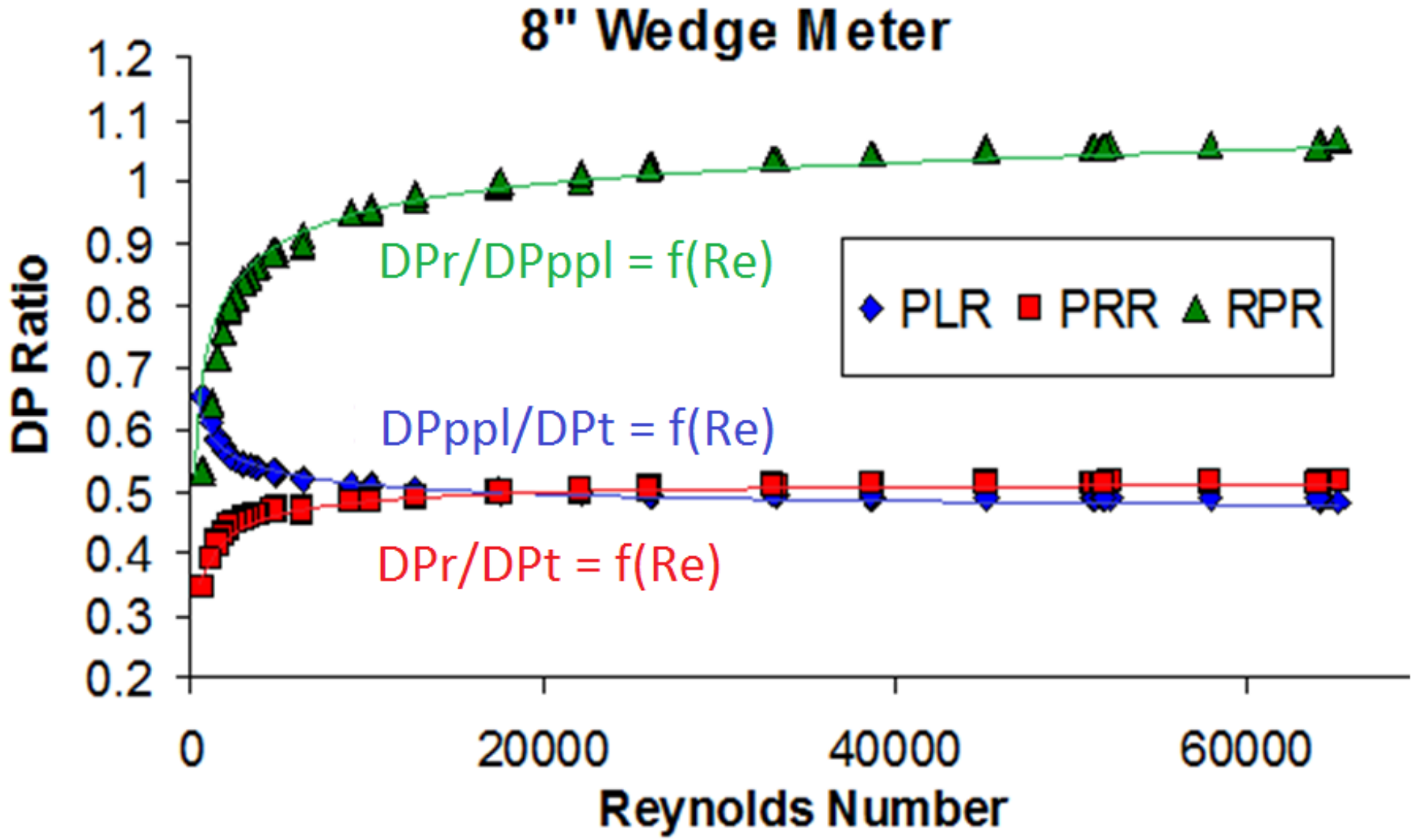


Calibration Only Half the Cure

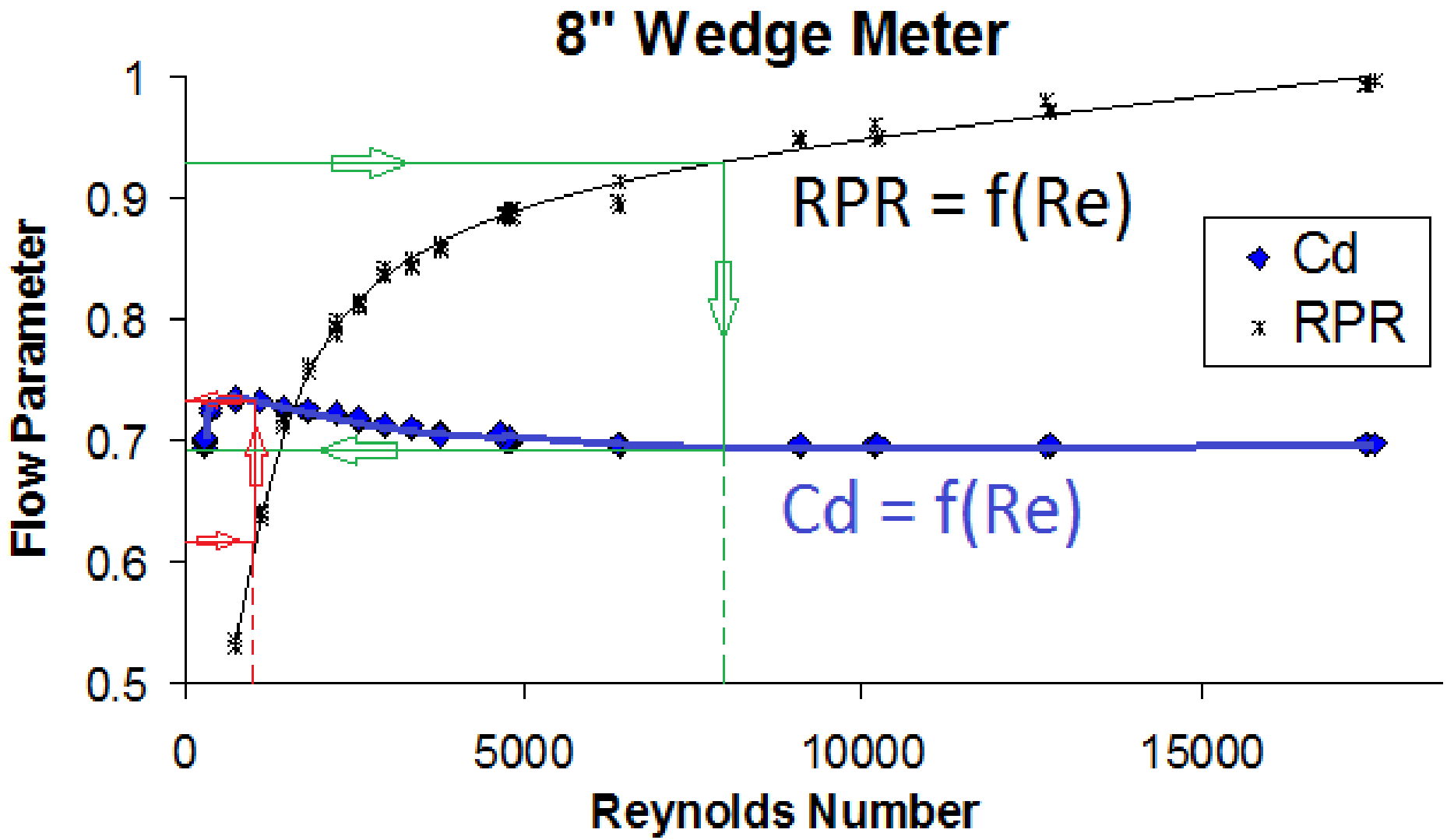
- After calibration MF or Cd = f(Re) is known, but in the field Re may not be known, or incorrectly estimated.
- The DP meter pressure profile diagnostic system ‘Prognosis’ can be applied:



DP Ratios vs Re No Calibration



Prognosis Pressure Profile Analysis



Conclusions

- Metering highly viscous oil flows is a challenge.
- Flow meter performance can vary significantly across low Reynolds number ranges.
- It is essential to calibrate a flow meter across the appropriate *Reynolds number range.*
- Calibrating across an applications velocity / volume / mass flow range (but not Re no. range) may result in incorrect flow rate predictions.

Conclusions (cont.)

- Even after calibration to the Reynolds number, in the field the viscosity (and hence Reynolds number) is often not known.
- For DP meters, ‘Prognosis’ Pressure Profile Analysis can predict the viscosity & Reynolds number.
- This Reynolds number can be an input to the DP meter or a separate meter design in series.
- Such measurement of Reynolds number allows the heavy oil flowrate to be derived without the need for continuous external viscosity measurement.

THANK YOU