KUWAIT 3RD FLOW MEASUREMENT TECHNOLOGY CONFERENCE

19 - 21 NOVEMBER 2017

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THE IMPORTANCE OF DYNAMIC TESTING

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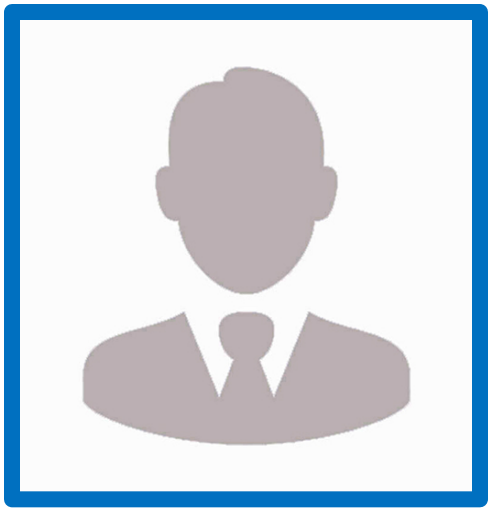

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KUWAIT FLOW MEASUREMENT TECHNOLOGY CONFERENCE 2017

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DISCUSSION TOPICS

- Dynamic testing theory
- Liquid ultrasonic meter fundamentals
- Reynolds number and velocity profile
- Dynamic testing process
- Multi-path USM test results
- Summary and conclusions

DYNAMIC TESTING

Dynamic testing

- is a simulation over the **Reynolds Number range** as the meter will encounter in the field application. It provides a test range for ultrasonic and helical turbine meters based on the concept of dynamic similitude.

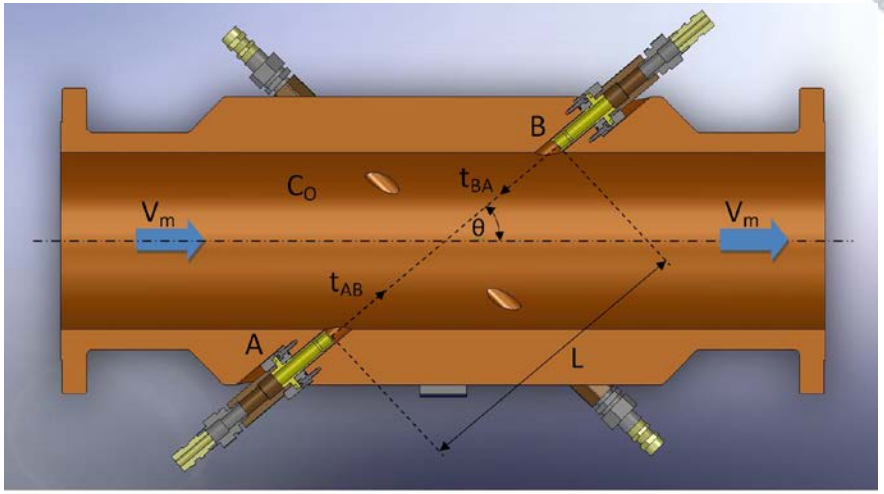
The method

- Performance at a given Reynolds Number is similar with **various combinations of flow rate and viscosity**.
- Flow meter performance on a test system can be validated on a higher or lower viscosity and/or flow rate than the field operating conditions.

LIQUID ULTRASONIC METERS

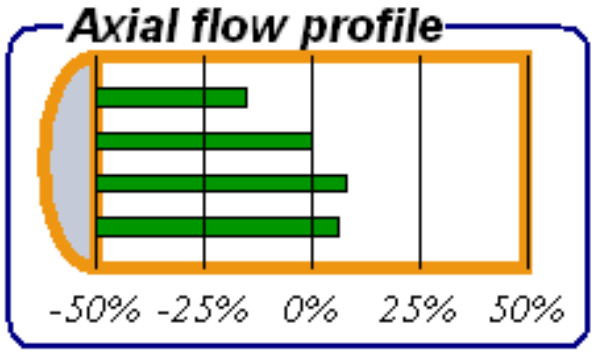
Theory:

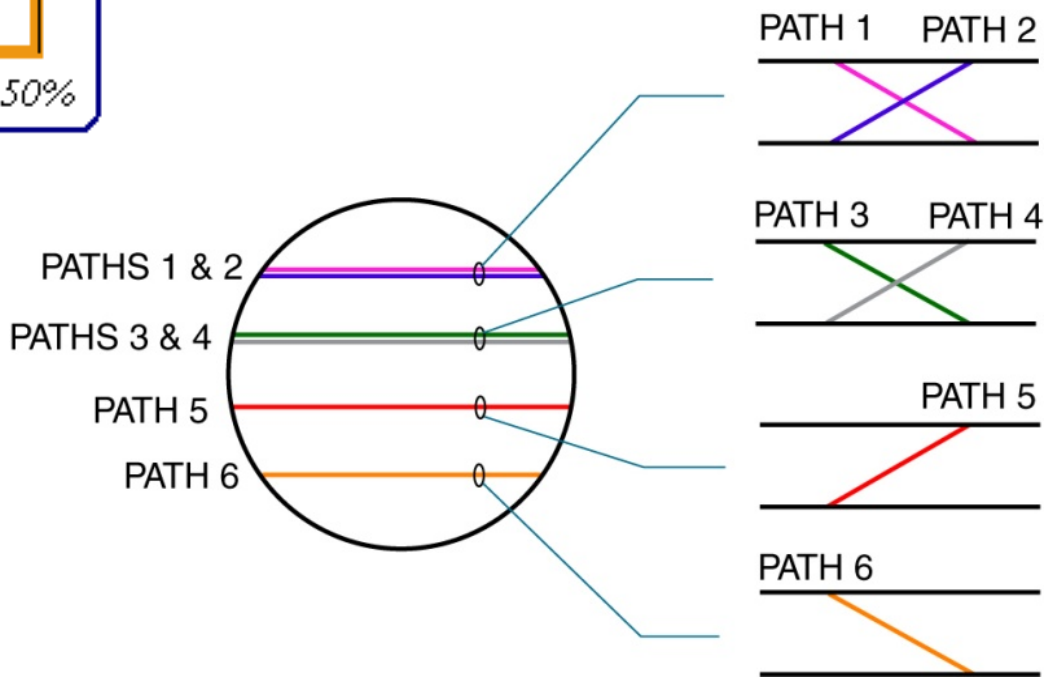
- Inferred volume throughput = Fluid velocity x Area



The fluid velocity Vm is proportional to the difference in time between an ultrasonic signal traveling with the flow (t_{AB}) and against the flow (t_{BA}).

NON-REFRACTING CORDAL PATHS





$$Q_{total} = A * \sum_{i=1}^{6} w_i v_i$$

REYNOLDS NUMBER

$$\mathrm{Re} = \frac{\rho v D_\mathrm{H}}{\mu} = \frac{v D_\mathrm{H}}{\nu} = \frac{Q D_\mathrm{H}}{\nu A}$$

- A dimensionless parameter that defines the measurement or dynamic operating range. This is used as a means of comparing flow meter applications between field and test conditions.
- Quantitatively it is the **ratio of the inertia forces** (diameter x velocity x density) **to the viscous forces** (a fluids resistance to flow).
- In terms of flow rate, meters size (inches) and viscosity (cSt) it can be expressed as:

Re No = (CF x flow rate) / (meter size x cSt)

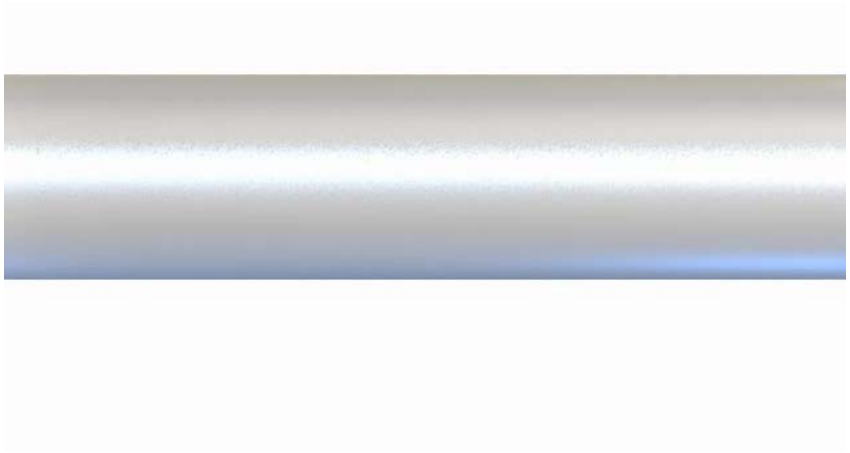
Where Conversion Factor:

CF = 2214 for flow rate in bph and,

CF = 13927 for flow rate in m3/h

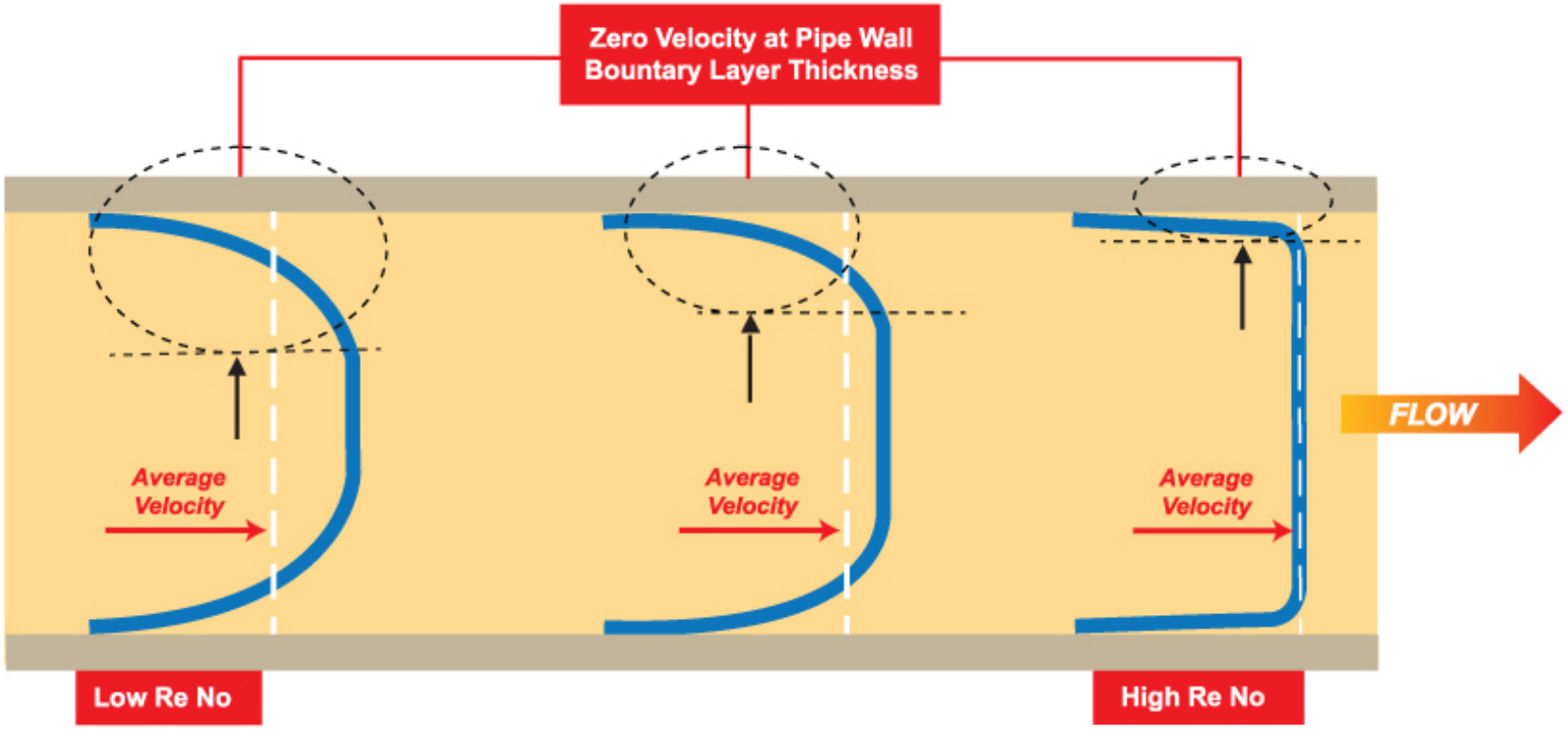
REYNOLDS NUMBER

Flow Profile vs. Reynolds Number

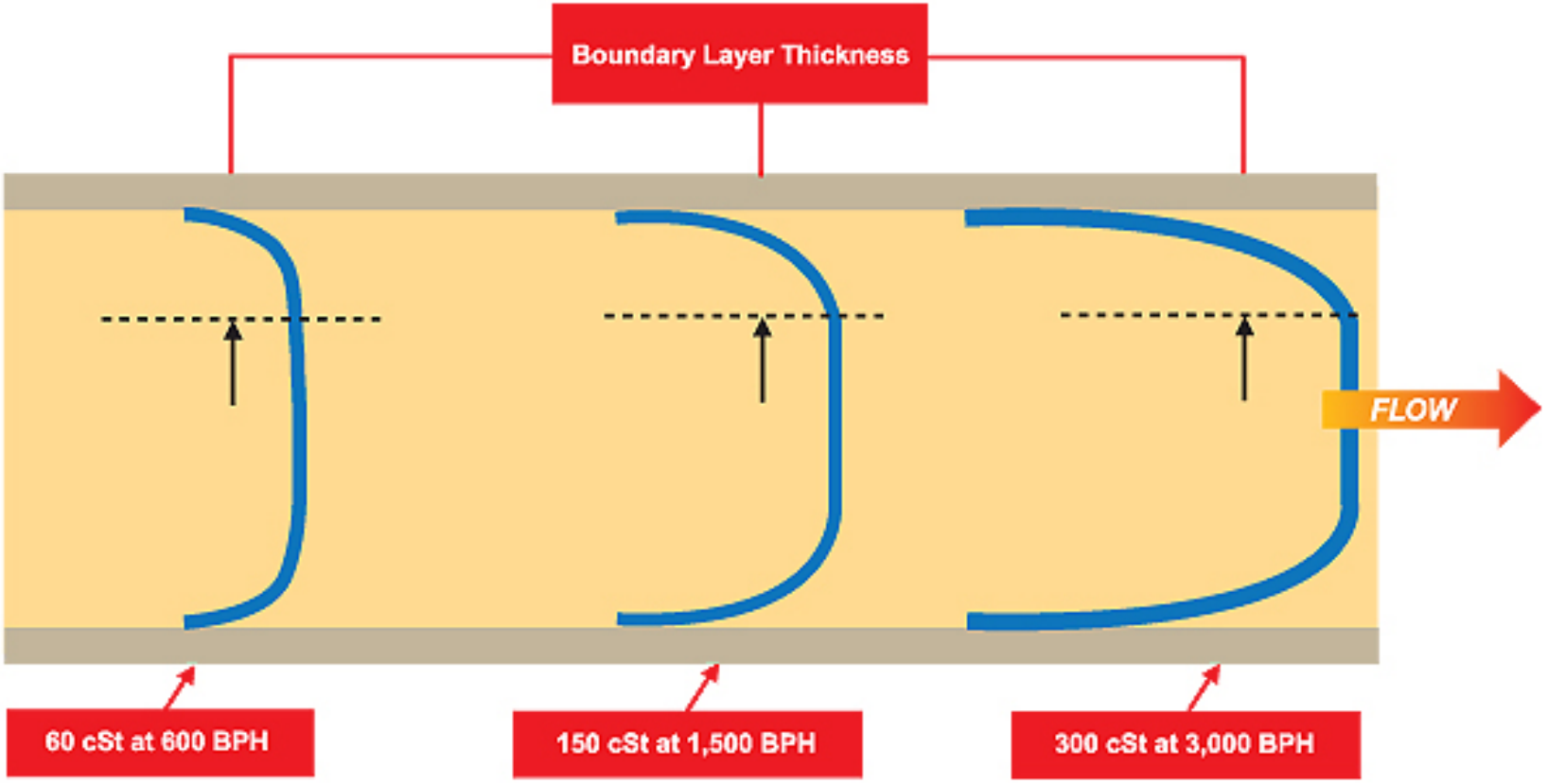


- **Laminar flow** – High viscosity and / or low flow rate, under 2,000 Reynolds number
- **Turbulent flow** – Low viscosity and / or higher flow rates, which is typically developed at Reynolds Numbers greater than 6,000 to 8,000
- **Transitional flow** – Fluctuates between flow regimes and can be difficult to measure

BOUNDARY LAYER

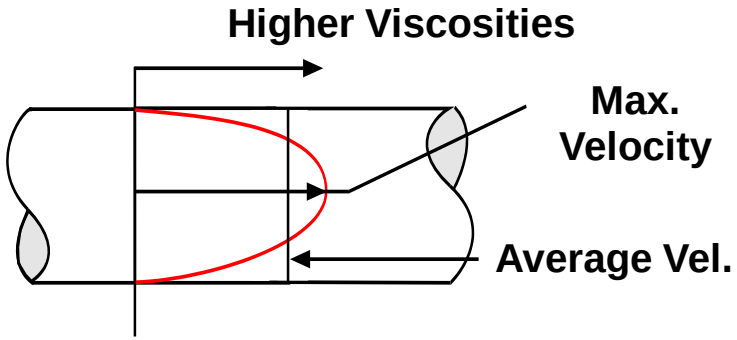


REYNOLDS NUMBER AND FLOW PROFILE

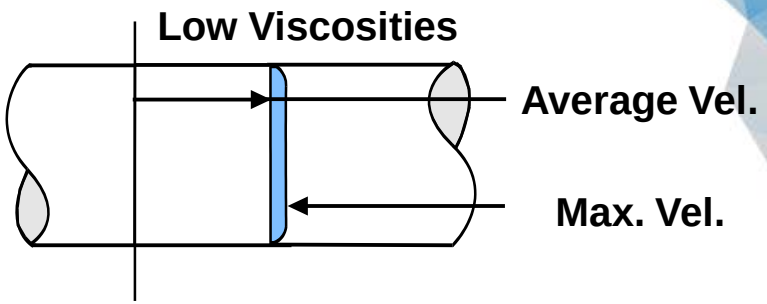


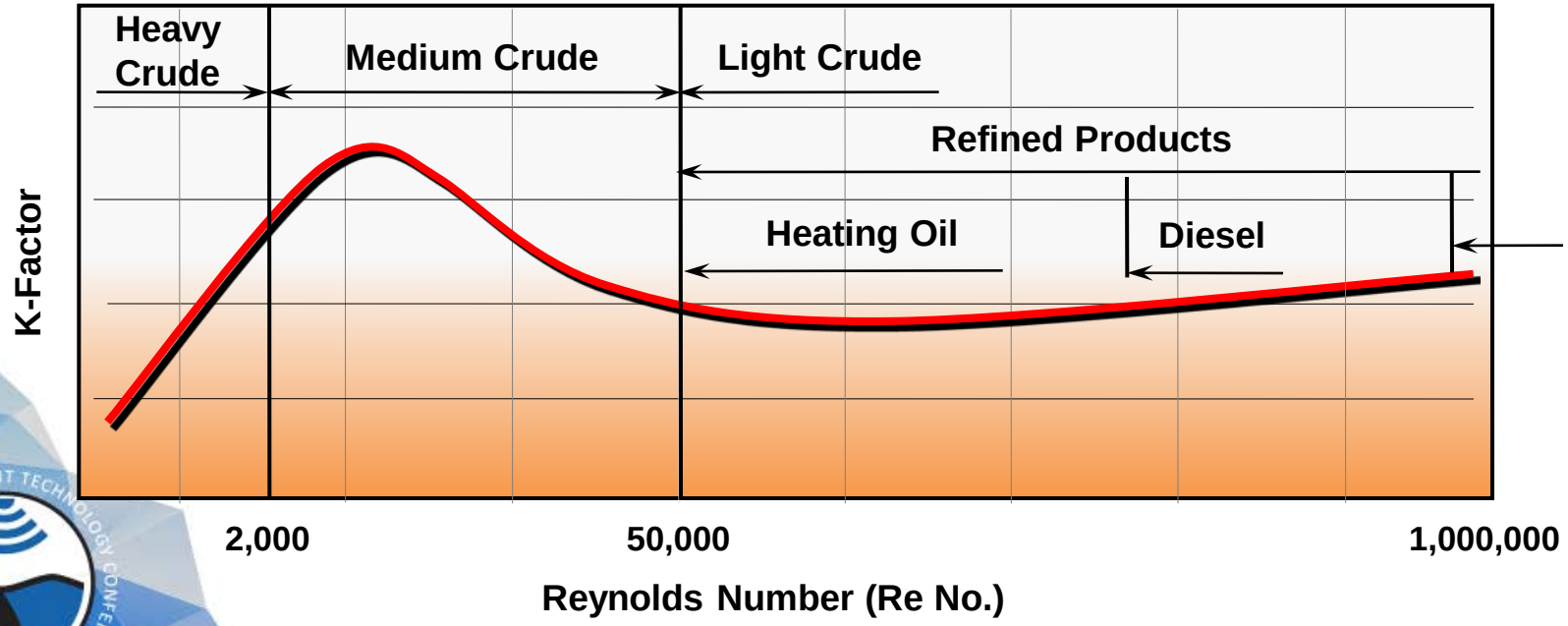
PETROLEUM PRODUCTS

Laminar Flow
(Re < 2,000)



Turbulent or “Plug” Flow
(Re > 6,000)

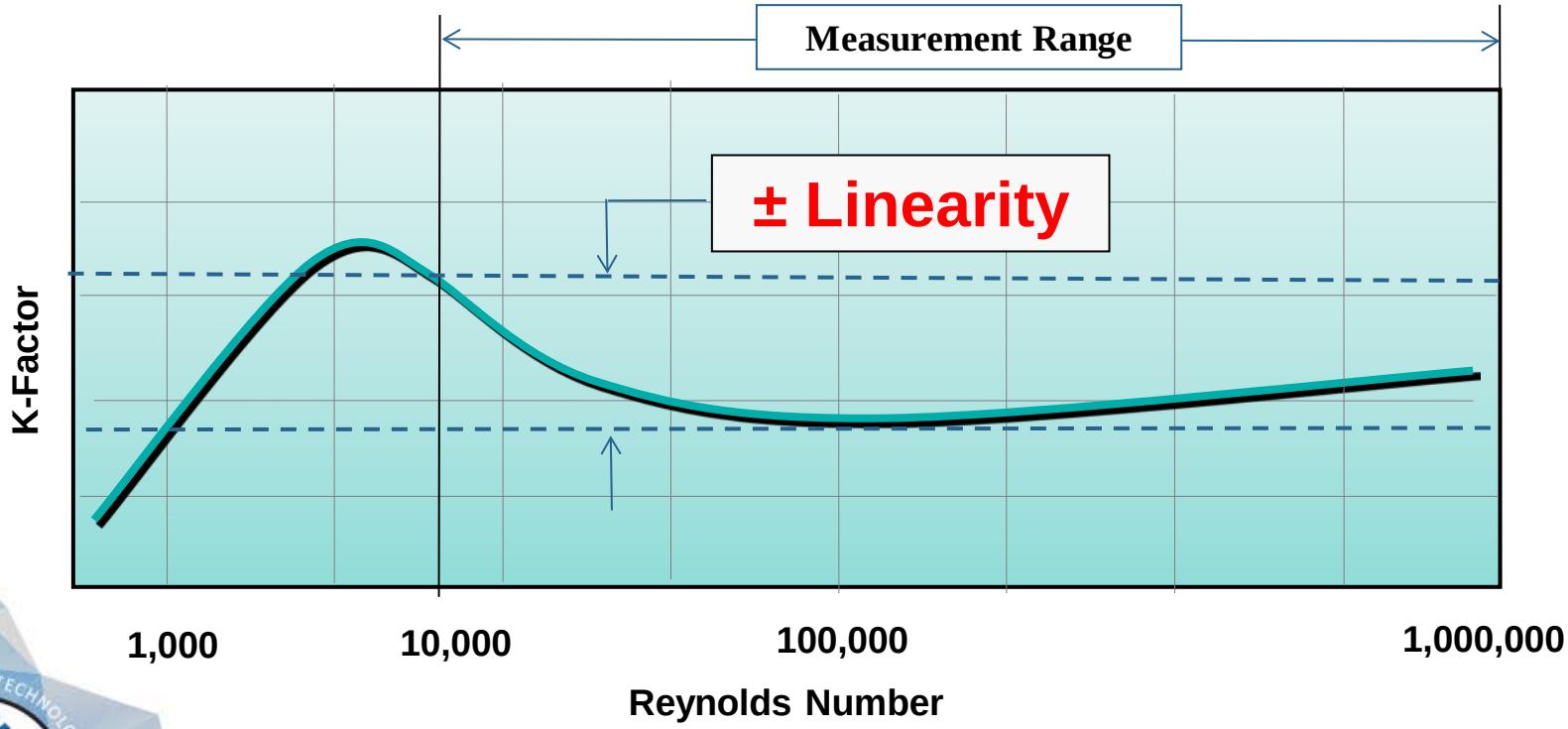




DYNAMIC FACTORY TESTING

Measurement range for a specific meter size is quantitatively expressed as:

Re No Range = (CF x Flow Range) / (Meter Size x Viscosity Range)



DYNAMIC TEST EXAMPLE

Meter (Inches)	Flow Range			Viscosity (cSt)	Reynolds Number Range	
6	bph	1,500	4,500	800	690	2,080
	m^3/h	240	720			
12	bph	6,330	19,000	1,000	1,170	3,510
	m^3/h	1,010	3,020			
20	bph	14,000	42,000	1,000	1,550	4,650
	m^3/h	2,230	6,680			

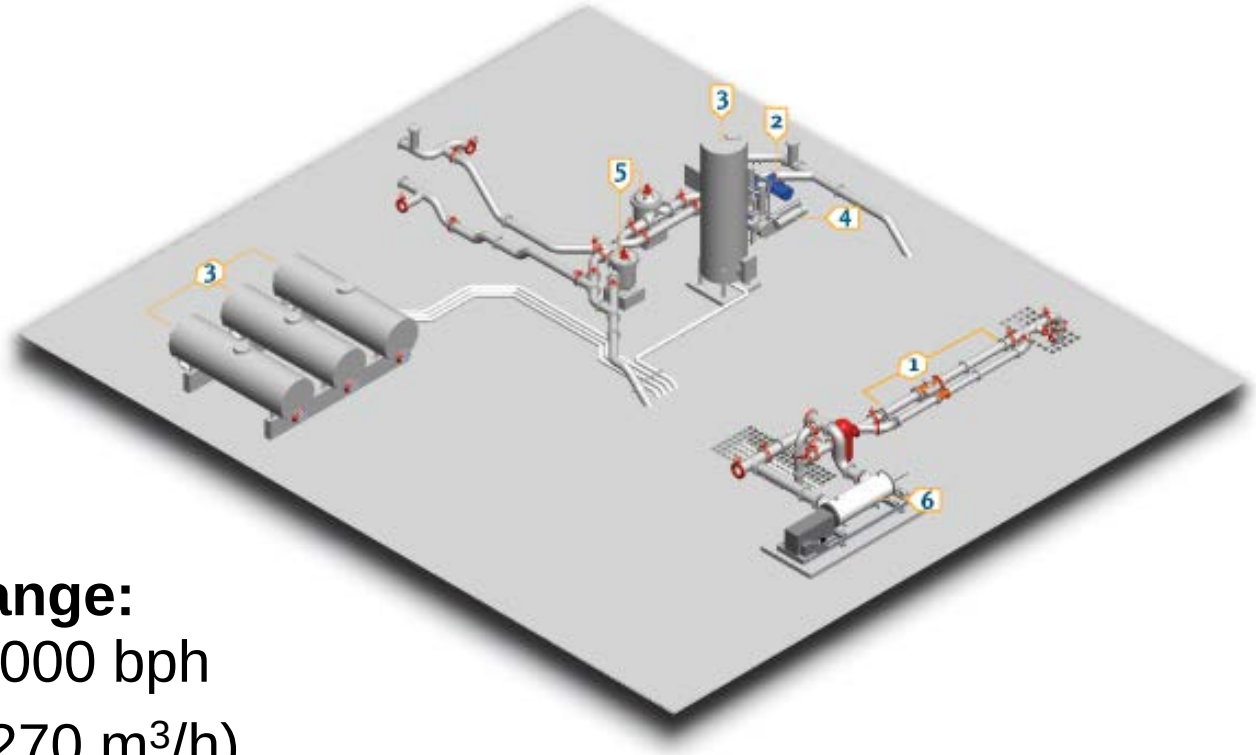
Field Conditions with actual flow rates and fluid viscosities ranging from 800 to 1,000 cSt produce a certain Reynolds Numbers Range

Meter (Inches)	Flow Range			Viscosity (cSt)	Reynolds Number Range	
6	bph	560	1,690	300	690	2,080
	m^3/h	90	270			
12	bph	1,900	5,710	300	1,170	3,510
	m^3/h	300	910			
20	bph	4,200	12,600	300	1,550	4,650
	m^3/h	670	2,000			

Dynamic testing at the factory simulates the same Reynolds Numbers Range the meters will see in the field by varying flow rates in combination with the available test fluid (300 cSt in the example)

MULTI-VISCOSITY (MV) TEST SYSTEM

1. Test Run
2. Pumps/Drives
3. Tanks
4. Chiller
5. Master PD Meter Provers
6. Master Prover



Flow Range:
200 to 8000 bph

(30 to 1270 m^3/h)

Viscosity: 2 - 250 cSt

DYNAMIC TEST EXAMPLE

Multiple Test Systems

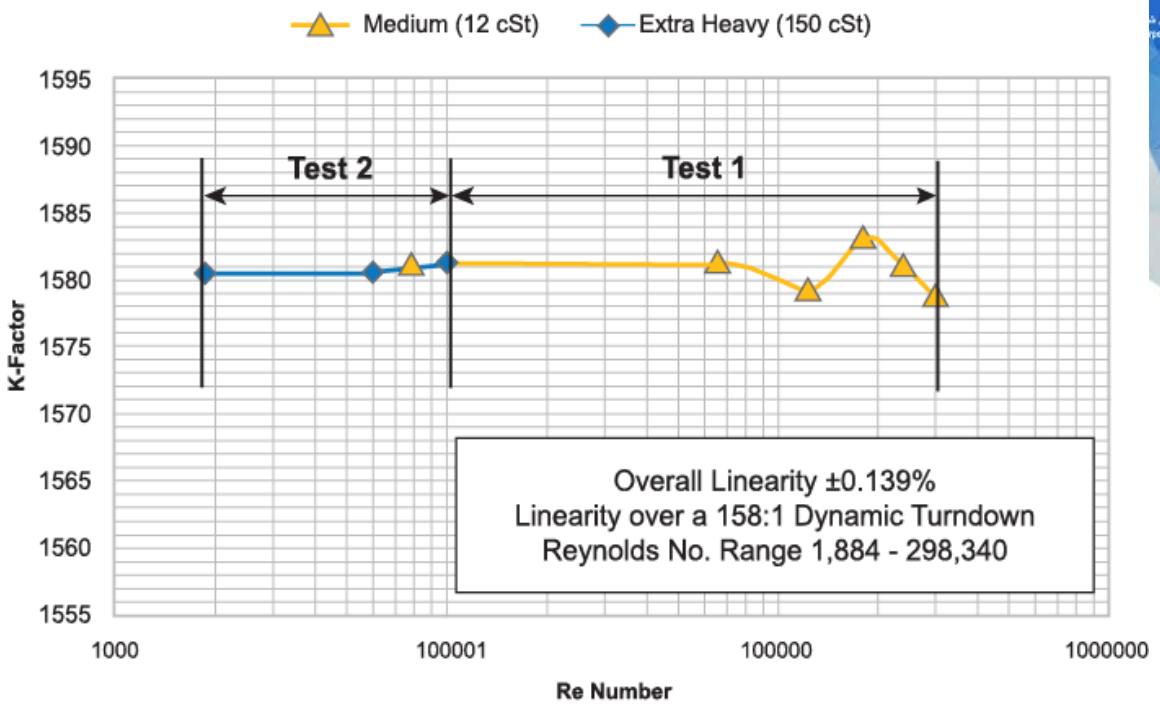
Field Operating Conditions

Flow Range
Actual: 636 to 1,113 m³/h
(4,000 to 7,000 bph)

Viscosity Range
5 to 350 cSt

Reynolds Number Range
2,153 to 263,796

Calibration Test Data



Size (Inches)	Test Systems		Flow (m³/h)		Viscosity (cSt)	Reynolds Number	
			min	max	Nominal	min	max
12	Test 2	MV	238	1,272	150	1,884	10,049
	Test 1	HF	79	3,020	12	7,851	298,340
Total Range			1,900	19,000		1,884	298,340

12-INCH MULTI-PATH USM DYNAMIC TEST

	Application Data	Dynamic Test Range
Meter Size	12	12
Meter Type	Multi-Path Ultrasonic	Multi-Path Ultrasonic
Flange Class	ASME Class 600	ASME Class 600
Meter Schedule (ID)	SCH XS (ID 11.750 inches)	SCH XS ID (11.750 inches)
Minimum Flow Rate	636 m^3/h [4,000 bph]	79 m^3/h [500 bph]
Maximum Flow Rate	1,113 m^3/h [7,000 bph]	3,021 m^3/h [19,000 bph]
Viscosity Range	5 –350 cSt	12 – 150 cSt
Reynolds Number Range	2,153 to 263,796	1,884 to 298,340

DYNAMIC SIMILITUDE TEST 1

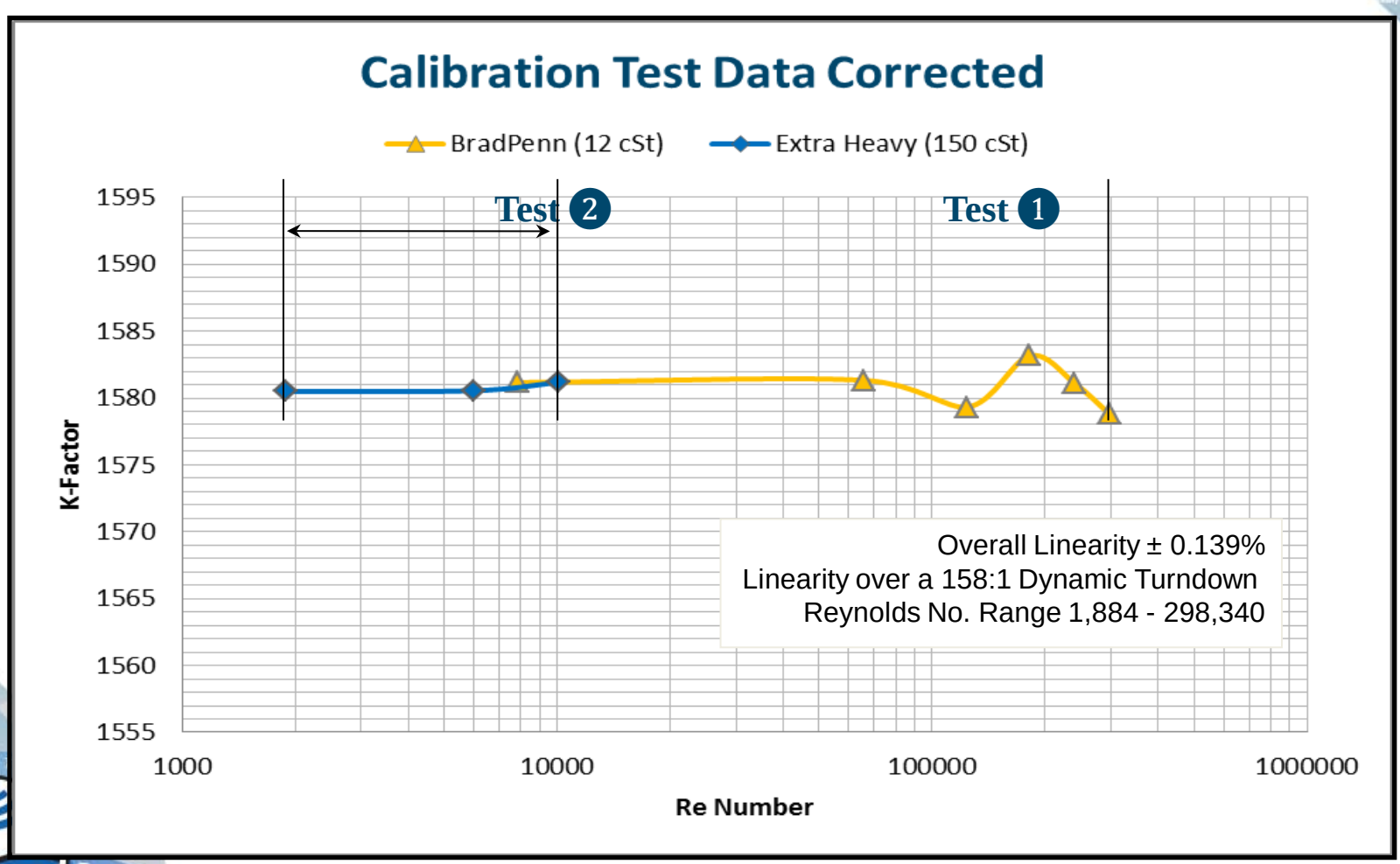
Test 1						
Test System	High Flow (HF) Test Stand					
PD Meter Master Prove	9.7 m^3 [61 bbl] Prove Volume					
Test Fluid	Medium Fluid					
Temperature	~32.2°C [90°F]					
Viscosity	12 cSt					
Nominal Flow Rates (BPH)	500	4,200	7,900	11,600	15,300	19,000
Nominal Flow Rates (M^3/HR)	79	668	1,256	1,844	2,433	3,020
Reynolds Number Test Range	7,851	65,949	124,047	182,145	240,243	298,340
Percentage of Max	2.6%	22%	42%	61%	80%	100%

DYNAMIC SIMILITUDE TEST 2

Test ❷				
Test System	Multi-Viscosity (MV) Test Stand			
PD Meter Master Prove	9.7 m^3 [61 bbl] Prove Volume			
Test Fluid	Extra Heavy Fluid			
Temperature	~35°C [95°F]			
Viscosity	150 cSt			
Nominal Flow Rates (BPH)	1,500	4,750	8,000	
Nominal Flow Rates (M^3/HR)	238	755	1,272	
Reynolds Number Test Range	1,884	5,967	10,049	
Percentage of Max	0.63%	2%	3.3%	

TEST RESULTS

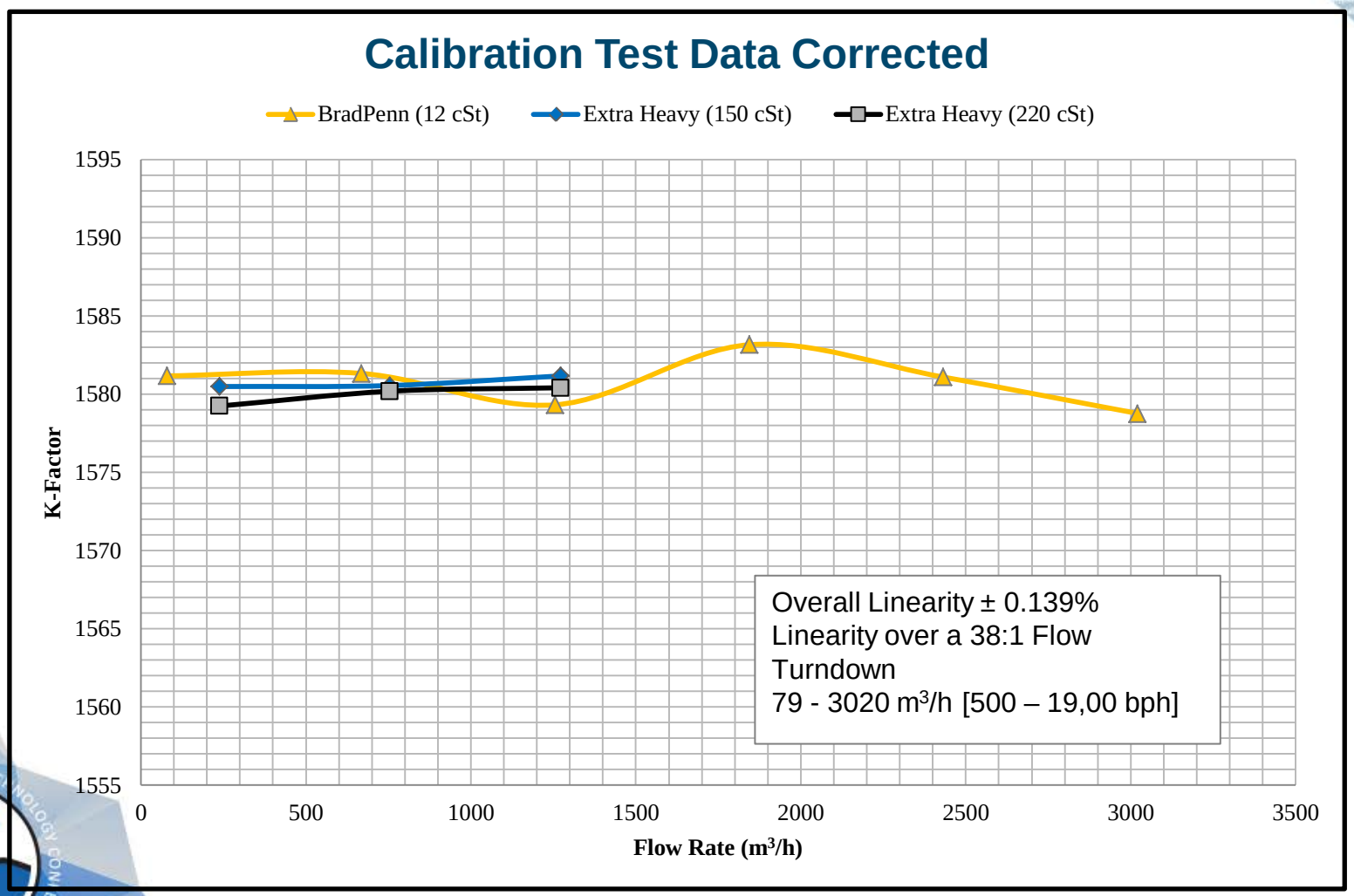
Testing Over an Application Range
(Re# Range 1,884 to 298,340)



TEST RESULTS

Testing Over an Application Range

(Re# Range 1,884 to 298,340)



SUMMARY AND CONCLUSION

- Dynamic factory testing is a important step in the application of high accuracy ultrasonic meters
- The primary focus of a Dynamic factory test is to validate the application operating range vs. the linear measurement range of the meter
- Dynamic Similitude using Reynolds number is a sound method of testing when application conditions cannot be achieved
- Multiple test systems can be used and simplified by maintaining a common calibration reference. ISO 17025 accreditation assures quality testing methods and traceability.
- Correction algorithms are critical for linearity, particularly at low Reynolds Numbers (<10,000). Test plans and validation are essential.

Thanks for Attention