KUWAIT FLOW MEASUREMENT TECHNOLOGY CONFERENCE 2017

Comparison of Four Gas Measurement Technologies Orifice/Turbine/Coriolis & Ultrasonic

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Over 30 years experience spanning all aspects of measurement in the hydrocarbon supply chain including the design, testing, consulting & auditing of Measurement Systems.

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PREVIOUS STUDY

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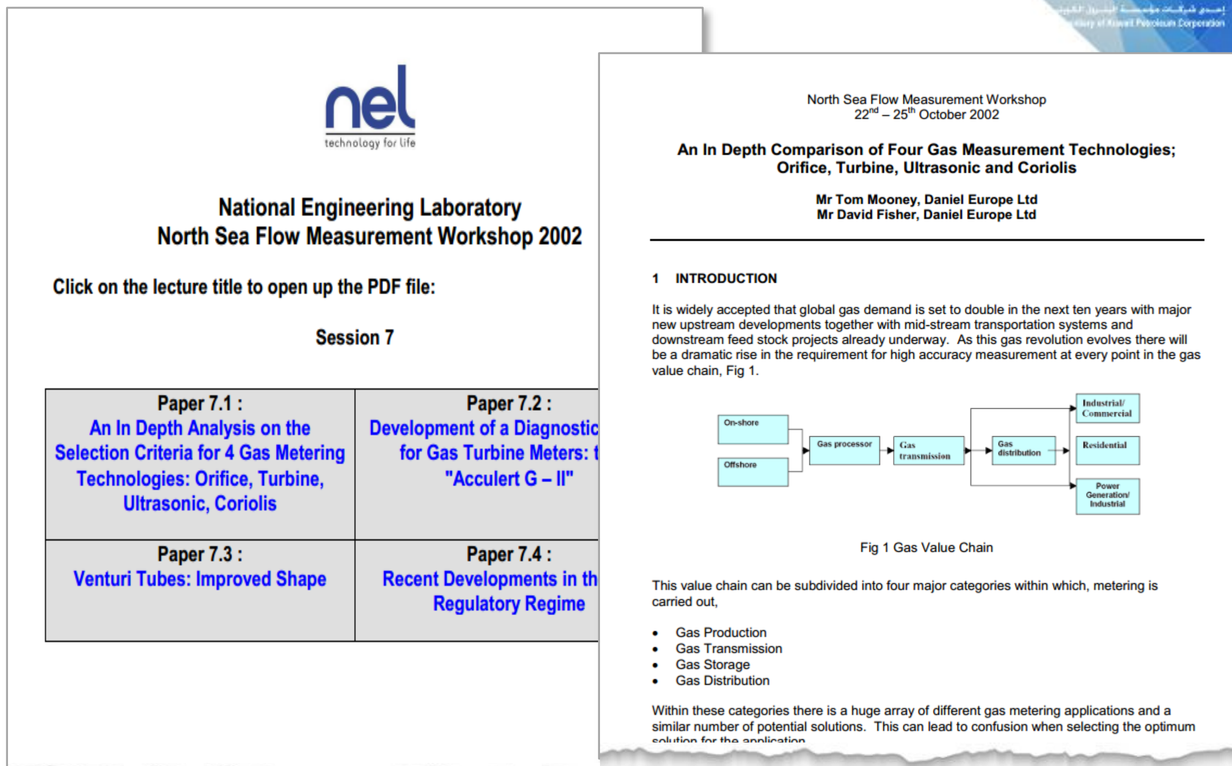
Industry Paper already Presented 2002 NSFMW :-
co author David Fisher

In 15 years the same technologies have advanced, furthermore the Industry Standards have changed.


nel
technology for life

National Engineering Laboratory
North Sea Flow Measurement Workshop 2002

Click on the lecture title to open up the PDF file:

Session 7

Paper 7.1 : An In Depth Analysis on the Selection Criteria for 4 Gas Metering Technologies: Orifice, Turbine, Ultrasonic, Coriolis	Paper 7.2 : Development of a Diagnostic for Gas Turbine Meters: t "Acculert G – II"
Paper 7.3 : Venturi Tubes: Improved Shape	Paper 7.4 : Recent Developments in th Regulatory Regime

North Sea Flow Measurement Workshop
22nd – 25th October 2002

An In Depth Comparison of Four Gas Measurement Technologies; Orifice, Turbine, Ultrasonic and Coriolis

Mr Tom Mooney, Daniel Europe Ltd
Mr David Fisher, Daniel Europe Ltd

1 INTRODUCTION

It is widely accepted that global gas demand is set to double in the next ten years with major new upstream developments together with mid-stream transportation systems and downstream feed stock projects already underway. As this gas revolution evolves there will be a dramatic rise in the requirement for high accuracy measurement at every point in the gas value chain, Fig 1.

Fig 1 Gas Value Chain

This value chain can be subdivided into four major categories within which, metering is carried out,

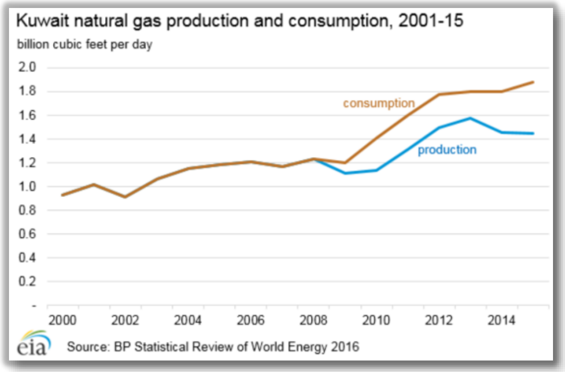
- Gas Production
- Gas Transmission
- Gas Storage
- Gas Distribution

Within these categories there is a huge array of different gas metering applications and a similar number of potential solutions. This can lead to confusion when selecting the optimum solution for the application

Today's Take-on these Technology Comparisons & Add Liquefaction in the Supply Chain Applications

KUWAIT'S GAS LANDSCAPE

Today Kuwait is increasingly relying on imports of natural gas to meet domestic demand.

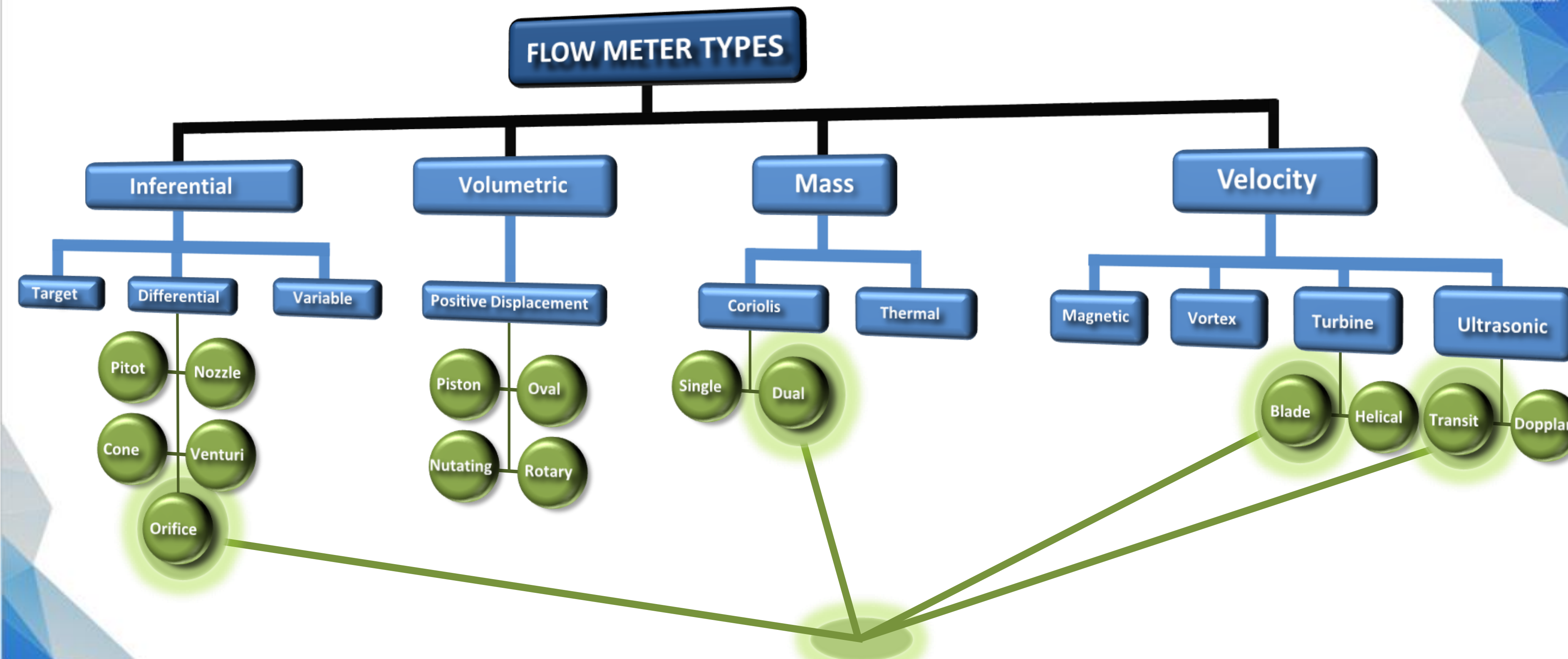


~ **63 trillion cubic feet** (Tcf) of proven natural gas reserves.

According to the Oil & Gas Journal, as of January 2016

KPC Drive to Increase NG production to 3 billion cubic feet per day by 2030

MEASUREMENT DEVICES



The Technologies that Industry Applies for High Accuracy Transfers in the Gas Supply Chain

DEVICES COMPARISONS

	Accuracy Level	DP (Orifice, Cone, Venturi)	Turbine Meter (Radial Vane)	Coriolis	Ultrasonic Meter (Multipath Transit Time)
Fiscal/Custody Transfer	HIGH	Y	Y	P For Mass Flows	Y
Process Control	MODERATE	Y	PN	Y	PN
Mass Balance/Process	HIGH	Y	PN	P	P (only large sizes)
Utilities	MODERATE/LOW	Y	Y	Y	N
Safety/Environment		Y	Y	Y P for Mass Flows	Y
Fluids		Liquids, Gas & Steam	Liquids, & Gas	Liquids, Gas & Slurries	Liquid & Gas
Pressure Loss		HIGH	MEDIUM	HIGH/MEDIUM	LOW
TwoPhase Flow		N	N	Y	N
Vibration		per IEC61298-3	Avoid	per IEC68.2.6	Immune
Pulsation		Y Dampening Inst Req.	Avoid	Limit	PN Sampling Frequency Increased
On-Line Meter Verification		Y Performance Only	Y Performance Only	Y Meter Verification	Y Meter Verification
Viscosity Effects		Increased Viscosity can Limit Low End Qmin	Increased Viscosity can Limit Low End Qmin	None	Liquids: < 100,000 Re
Line Sizes		2" to 96"	1/2" to 18"	1/10" to 12"	4" to 42"
Uncertainty or Linearity		Application Dependant, possible +/-0.75% or Rate	Liquids: +/-0.15 to 0.5% Gases: +/-1.0%	Liquids: +/-0.1% of Rate Gases: +/-0.35% of Rate	+/-0.1% Linear
Turndown		Application Dependant, possible 8:1 stacking DP	10:1 (Low Flow Limitations)	20:1 for CT, 50:1 Liquid, 100:1 Gas	40:1 Liquid, 100:1 Gas
Process Temp max/min (F)		-200 to +1200	-50 to +500	* -58 to +662	* -50 to +302
Process Press max/min (psig)		upto 3640 psig	upto ANSI Class 2500#	Size Dependant	upto ANSI Class 2500#

* For Coriolis and Ultrasonic Meter in a Cryogenic Application, the meters can be special designed for this case.

P = Preferred
Y = Suitable

Suitable with Caviat

N = Not Suitable
PN = Possible/Not Recommended

WHY IOC's SELECT CERTAIN TECHNOLOGIES

DP Orifice

Established Standards
Simple & Robust
Physical Inspection

Mechanical Meters

Excellent short term Repeatability
Direct Pulse Output
Good Transient Response

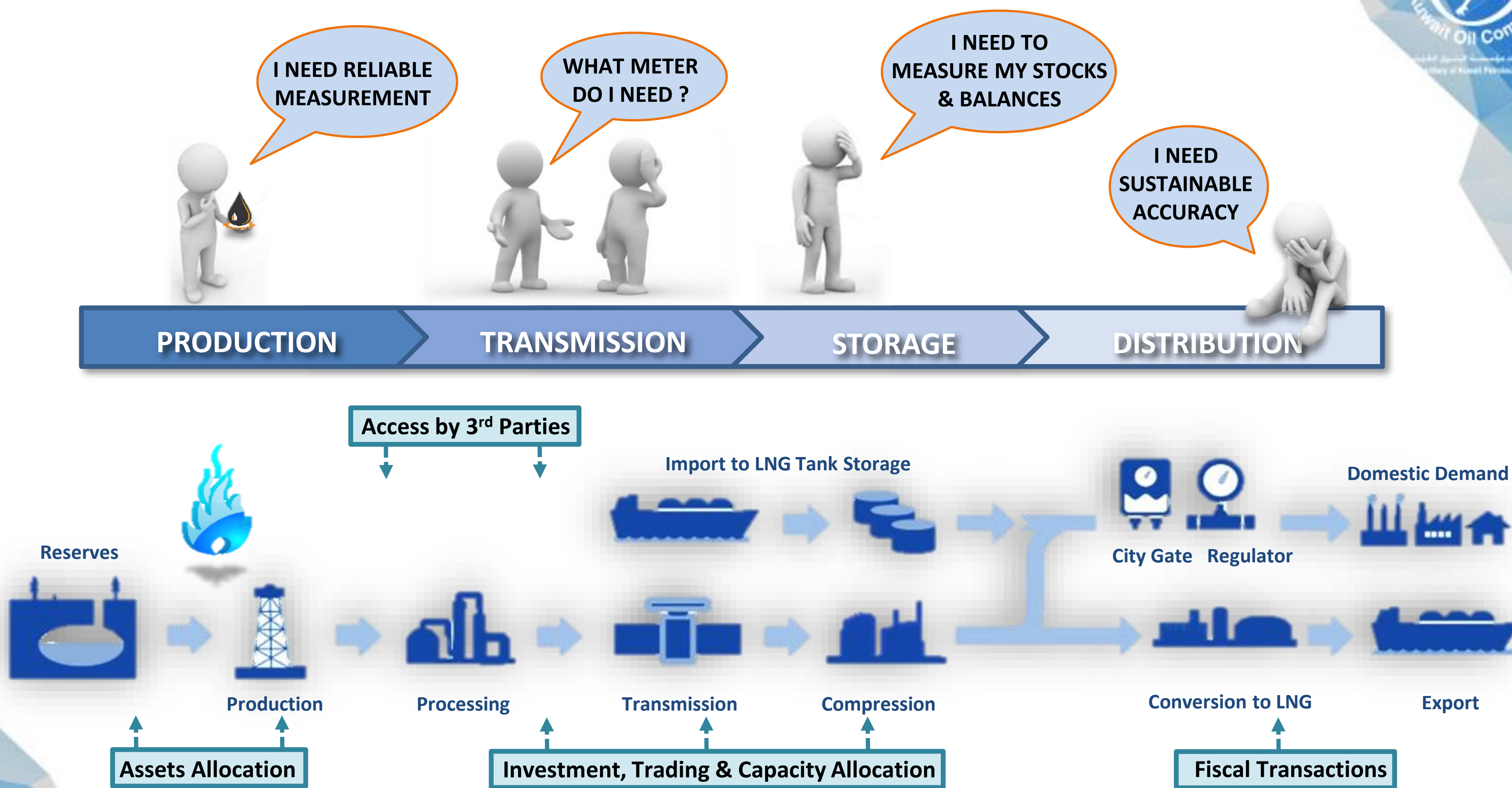
Coriolis Meters

Direct Mass Flow
Multi Variable Device
Multiple Applications

Ultrasonic Meters

Non Intrusive
Large Turn Down Ratio
Large Diagnostics Range

GAS SUPPLY CHAIN



TYPICAL NATURAL GAS SUPPLY CHAIN

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PRODUCTION - SEPARATOR

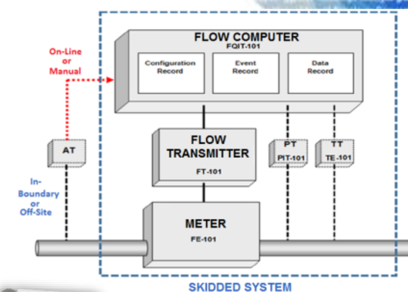
PRODUCTION

COMPARING THE FOUR TECHNOLOGIES IN A PRODUCTION APPLICATION

ALLOCATION PRODUCTION SEPARATOR

ASSOCIATED GAS LEG – Qmax 3-35 MMSCFD

Metering Requirements Dictate a System Approach



ORIFICE

Application Challenges –
- Achieving Flow Turndown
- Operating at Low DP
- Installation Footprint

Typical Performance –
Single Phase <+/-1.0% of Rate

TURBINE

Application Challenges –
- Filtration Required
- Flow Profile Sensitive
- High LVF Damage Meter

Typical Performance –
Single Phase +/- 0.5% linear

CORIOLIS

Application Challenges –
- Effects of Wet Gas

Typical Performance –
Single Phase +/- 0.35% of Rate

ULTRASONIC

Application Challenges –
- Effects of Liquid Carry-Over
- Limitation on Small Sizes

Typical Performance –
Single Phase < +/- 0.15% linear

CAPEX – Taking account of Instrument and Skid Fabrication costs

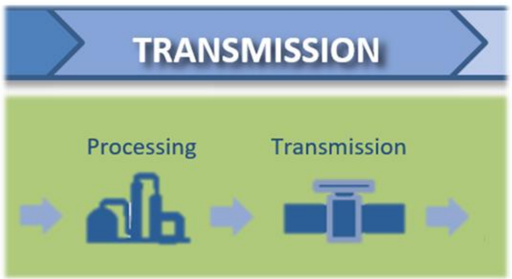
Orifice	Turbine	Coriolis	Ultrasonic
Skid Footprint	Additional Accessories	No Installation Effect	Upstream Pipework

OPEX – Taking account of 5 year Maintenance Requirements and Re-Calibration Frequencies

Orifice	Turbine	Coriolis	Ultrasonic
Manual Intervention	Frequent Blade Checks	Can Re-Calibration on Water	Periodic Re-Calibration

In all cases same process data, high methane compositions are being evaluated with calorific values in the upper range limit > 800 kJoule/mol

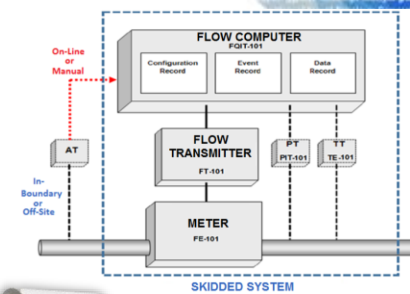
TRANSMISSION - PIPELINE



COMPARING THE FOUR TECHNOLOGIES IN A TRANSMISSION APPLICATION

GATHERING CENTRE DISCHARGE TO TRANSMISSION NETWORK – Qmax 1,500 MMSCFD

Metering Requirements Dictate a System Approach



ORIFICE

Application Challenges –
- Installation Footprint
- Multiple Streams Required

Typical Performance –
< +/- 1.0% of Rate

TURBINE

Application Challenges –
- Filtration Required
- Installation Footprint
- No Diagnostics

Typical Performance –
+/- 0.5% linear

CORIOLIS

Application Challenges –
- Large Amount of Gas being Measured

Typical Performance –
+/- 0.35% of Rate

ULTRASONIC

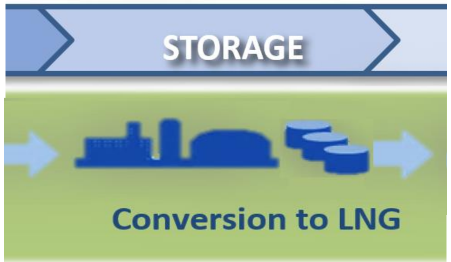
Application Challenges –
- Installation Footprint

Typical Performance –
< +/- 0.15% linear

Orifice	Turbine	Coriolis	Ultrasonic
CAPEX – Taking account of Instrument and Skid Fabrication costs			
Skid Footprint (yellow)	Additional Accessories (orange)	Many Meters Required (red)	Reduced Equipment (green)
OPEX – Taking account of 5 year Maintenance Requirements and Re-Calibration Frequencies			
Manual Intervention (yellow)	More Equipment Checks (orange)	Multiple Equipment Checks (red)	Master Metering Available (green)

In all cases same process data, high methane compositions are being evaluated with calorific values in the upper range limit > 900 kJoule/mol

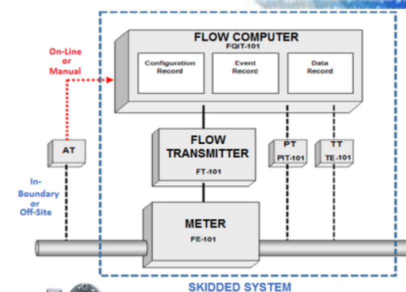
STORAGE - LNG



COMPARING THE FOUR TECHNOLOGIES IN A STORAGE APPLICATION

LIQUEFACTION TO LNG STORAGE TANKS – Per Train Qmax 800 MMSCFD

Metering Requirements Dictate a System Approach



ORIFICE

Application Challenges –
- Installation Footprint
- Operating at Low Temp

Typical Performance –
Not Suitable

TURBINE

Application Challenges –
- Cryogenic Requirement

Typical Performance –
Not Suitable

CORIOLIS

Application Challenges –
- Low Pressure & Density

Typical Performance –
Achievable +/- 0.5% of Rate

ULTRASONIC

Application Challenges –
- Installation Footprint

Typical Performance –
Proven < +/- 0.22% linear

CAPEX – Taking account of Instrument and Skid Fabrication costs

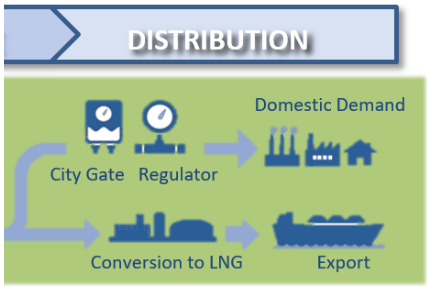
Orifice	Turbine	Coriolis	Ultrasonic
Skid Footprint (orange)	Additional Accessories (red)	Special materials (yellow)	Reduced Equipment (green)

OPEX – Taking account of 5 year Maintenance Requirements and Re-Calibration Frequencies

Orifice	Turbine	Coriolis	Ultrasonic
Manual Intervention (red)	More Equipment Checks (orange)	Frequent HSE checks (yellow)	Calibration transfer accepted (green)

In all cases same process data, high methane compositions are being evaluated with calorific values in the upper range limit > 900 kJoule/mol

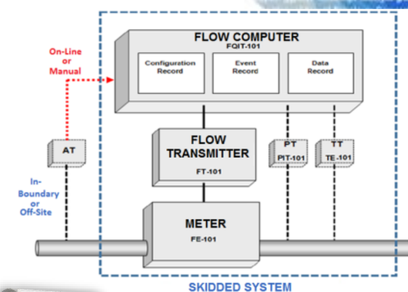
DISTRIBUTION – CITY GATE



COMPARING THE FOUR TECHNOLOGIES IN A DOMESTIC APPLICATION

CITY GATE SMALL CONSUMER – Qmax 1-10 MMSCFD

Metering Requirements Dictate a System Approach



ORIFICE

Application Challenges –
- Installation Footprint
- Achieving Flow Turndown

Typical Performance –
< +/- 1.0% of Rate

TURBINE

Application Challenges –
- Filtration Required
- Installation Footprint
- No Diagnostics

Typical Performance –
+/- 0.5% linear

CORIOLIS

Application Challenges –
- PRS

Typical Performance –
+/- 0.35% of Rate

ULTRASONIC

Application Challenges –
- Installation Footprint
- Limitation on Small Sizes
- PRS

Typical Performance –
< +/- 0.15% linear

CAPEX – Taking account of Instrument and Skid Fabrication costs			
Skid Footprint (orange)	Additional Accessories (yellow)	Ease of Installation (green)	Limited in small sizes (red)
OPEX – Taking account of 5 year Maintenance Requirements and Re-Calibration Frequencies			
Manual Intervention (red)	More Equipment Checks (orange)	Low Maintenance requirements (green)	Minimal Maintenance (yellow)

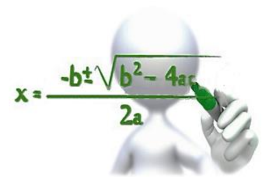
In all cases same process data, high methane compositions are being evaluated with calorific values in the upper range limit > 920 kJoule/mol

UNITS & UNCERTAINTY

PHASE Units	Volumetric Velocity Meters	Mass with Density Sampling Solution
GAS Act m3/h	Qgov	Qgov = Qm / ρf
GAS Std m3/h ●	Qsv = Qgov × ρf / ρb	Qsv = Qm / ρb
GAS kg/h	Qm = Qgov × ρf	Qm
GAS MJ/kg	Qe = Qsv × CVavg	Qe = Qsv × CVavg
GAS BTU/lb	Qe = Qm × CVavg	Qe = Qm × CVavg

Where:

Qgov = Gross Volume Flowrate
Qm = Mass Flowrate
Qsv = Standard Volume Flowrate
Qe = Energy Flowrate
Pf = Flowing Gas Density
Pb = Base Density of Gas
CVavg = Calorific Value Averaged either for Mass or Volume



NOW FOR THE MATH....

MAIN CONTRIBUTORS TO MEASUREMENT UNCERTAINTY

ORIFICE
Coefficient of Discharge brings the biggest error
TURBINE
K-Factor & Reynolds No. Effect
CORIOLIS
Mass Calibration
ULTRASONIC
Reference Standard & Installation Effect
LNG
Using the G.I.I.G.N.L Handbook as a reference, this states measurement accuracies as follows:
Volume +/- 0.21 %
Density +/- 0.27 %
Gross Calorific Value +/- 0.35 %
For static measurements, dynamic measurement needs traceable reference.

- *For gas flow, std m3, the design and measured compressibility factors at standard conditions (101.325 Kpa, 15degC) are assumed to be the same compressibility factors for most gases and are close to unity at standard conditions*

THE STANDARDS

THE INTERNATIONAL GUIDELINES USED FOR GAS MEASUREMENT DEVICES

CORIOLIS

AGA Report No11 / API 14.9:2013 - Measurement of Natural Gas by Coriolis Meters

ASME MFC-11-2006 - Measurement of Fluid by Means of Coriolis Mass Flowmeter

ISO 10790:2015, Measurement of fluid flow in closed conduits -- Guidance to the selection, installation and use of Coriolis meters

ORIFICE

AGA Report No3 / API 14.3:2016 - Orifice metering of natural gas.

ISO 5167:2016- Orifice plates, nozzles and venturi tubes inserted in circular cross-section conduits running full)

TURBINE

AGA Report No7:2006 - Measurement of gas by turbine meters

ISO 9951:1993 - Measurement of Gas Flow in closed conduits: Turbine Meters

ULTRASONIC

AGA Report No9:2017 - Measurement of Gas by Multipath Ultrasonic Meters

AGA Report No10:2003 – Speed of sound in Natural Gas and other related Hydrocarbons

ISO 17089-1:2010 - Measurement of fluid flow in closed conduits - Ultrasonic meters for gas

GENERAL

AGA Report No6:2013 - Field Proving of Gas Meters Using Transfer Methods

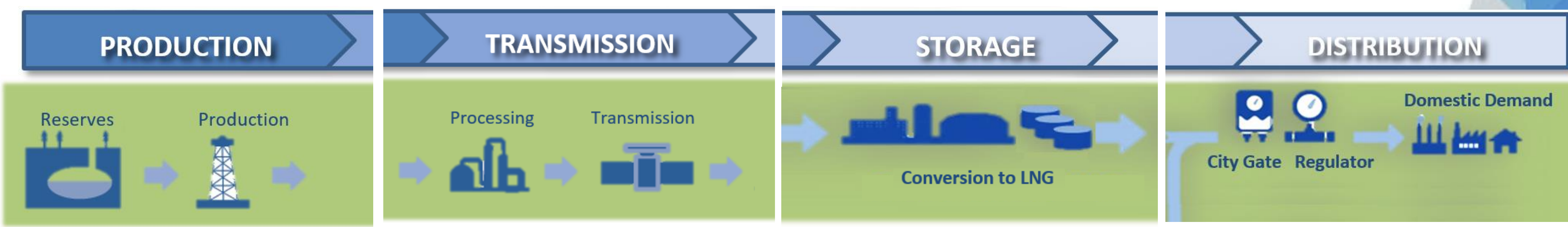
OMIL R137:2014 – International Recommendations Gas Meters

API Chapter 14:2016 - Natural Gas Fluids Measurement

GIIGNL's 2017 - 5TH Edition LNG Custody Transfer Handbook

CONCLUSION

IN SUMMARY



PRODUCTION METERING

it is shown that **Coriolis** meters offer the best CAPEX and OPEX costs as well as providing the best immunity to process upsets in terms of for functionality and accuracy. However in stable conditions **DP** meters can provide the best economical solution.

PIPELINE METERING

In the transmission pipeline applications, it is shown that **Ultrasonic** meters provide the most economic option both in terms of CAPEX and OPEX. Due to very large volumes the technology copes best.

LNG STORAGE

When storing refrigerated product stock taking becomes crucial and knowing, with degrees of accuracy your inputs and outputs. Both **Coriolis** and **Ultrasonic** technologies are well adapted for this application.

CITY GATE METERING

For the distribution example with small consumers, the **Coriolis** meter proves to be the optimum solution. However large to medium consumers the **Ultrasonic** meters can provide the best economic solution.

Thanks for Attention

Back at 12.50pm