KUWAIT 3RD FLOW MEASUREMENT TECHNOLOGY CONFERENCE

19 - 21 NOVEMBER 2017

HILTON KUWAIT RESORT , AL DORRA BALLROOM

OFFICIAL SPONSOR

إحـــدى شركـــات مؤسســـة البتـــرول الـكـويتيـة
A Subsidiary of Kuwait Petroleum Corporation

KROHNE SOLUTIONS FOR LNG APPLICATIONS

HERMAN HOFSTEDE

Business Development Manager

KROHNE Oil & Gas

WHAT IS LNG ?
LIQUIFIED NATURAL GAS

Natural Gas that has been converted to liquid form by cryogenic temperatures, for ease and safety of non-pressurized storage or transport

LNG occupies about 1/600 the space of methane in its gaseous form it can be exported in purpose-built tanker ships

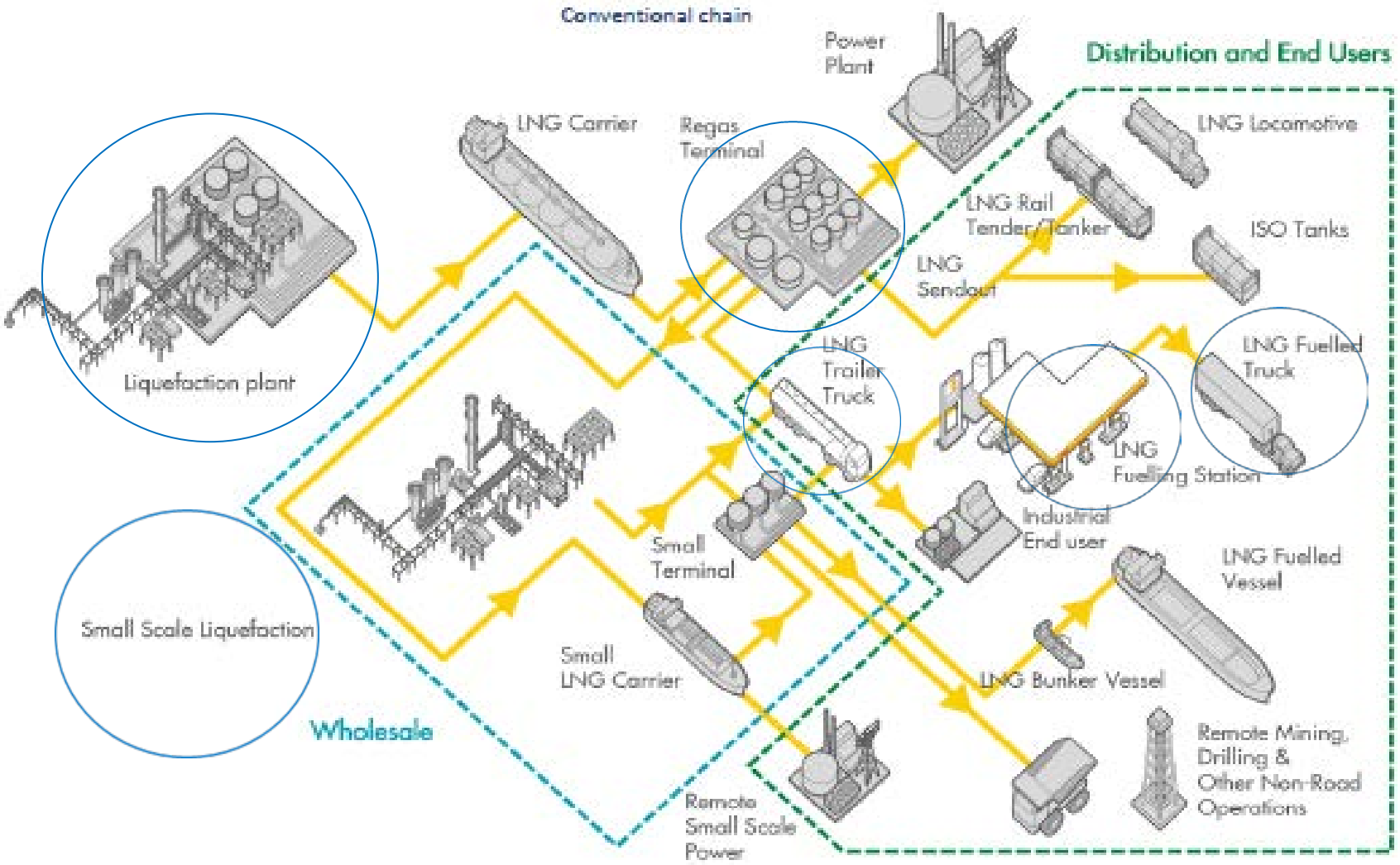
Composition: **Methane 87 – 98 %**
Ethane 1.5 – 9.5 %
Propane 0.4 – 2.5 %

IMPACT OF PERFORMANCE IMPROVEMENT FOR LNG VLCC CARRIERS.

LNG Carrier Capacity = 250.000 m3 (equivalent to 150.000.000 m3 natural gas)
150.000.000 m3 natural gas is equivalent to 5.400.000 MMBTU
Value of one ship is US $ 18.900.000,=(based on 3.5 US $/MMBTU)

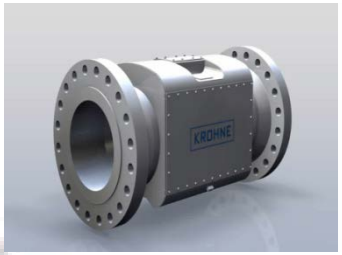
Performance improvement of 0.5 % results in US $ 94.500,= / carrier

KROHNE HAS EXPERIENCE ON ALL ASPECTS OF THE LNG VALUE CHAIN



LNG MEASUREMENT IN GOOD HANDS WITH THE GLOBAL TECHNOLOGY LEADER KROHNE

- Ultrasonic and Coriolis flow measurement technologies for Custody transfer applications:
  - Feed Gas metering systems
  - LNG metering systems
  - Boil Off Gas metering systems
  - Loading and off loading metering systems for: ships, rail cars and trucks
- Process instrumentation for liquefaction and regasification applications
- Flow computer and supervisory software
- Loading quality release system



ALTOSONC 5 for liquid

ALTOSONC V12 for gas

Optimass for liquid

Summit 8800 Flow computer

Level, Temperature & pressure

WHAT ARE THE CHALLENGES AND REQUIREMENTS FOR THE MEASUREMENT OF LNG

- Cryogenic temperatures
- Calibration and traceability
- Low or no maintenance
- Excellent long term stability (reproducibility)
- Diagnostic features to assure “healthy” measurements
- Minimum pressure loss to avoid flashing (full bore design)
- No moving parts
- Software to calculate from volume or mass to **Energy**
- Quality measurement to determine the LNG composition
- Improved performance compared to level measurement

QUANTITY AND QUALITY MEASUREMENTS REQUIRED

Quantity issue:

Quantity of the LNG will change during sea passage due to:

- carrier utilises LNG
- due to boil off and evaporisation, volume will change

Quality issues:

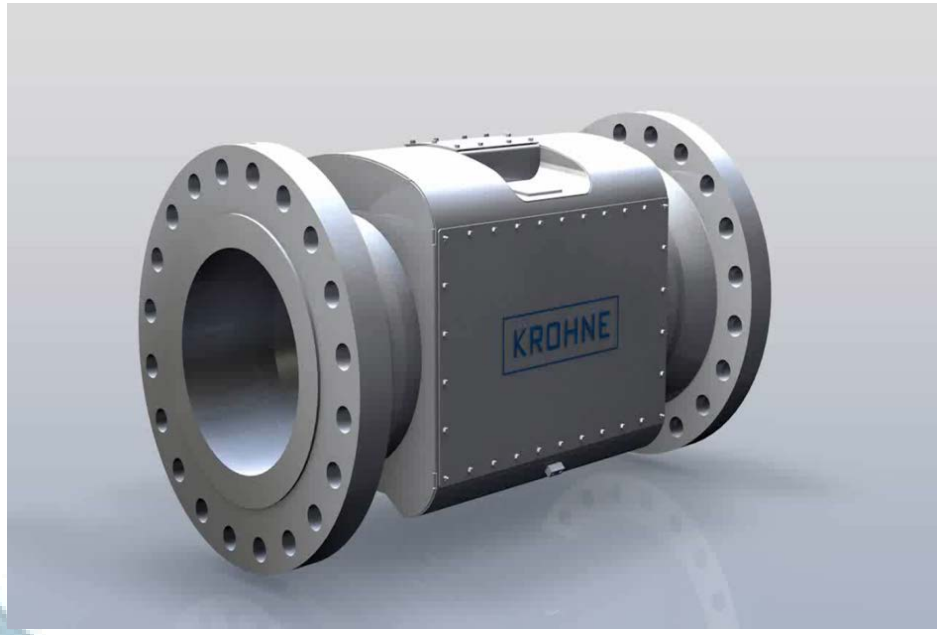
Composition of LNG will change during sea passage (aeging) due to evaporation of Methane resulting in:

- change of commercial value of the LNG

Therefore it is mandatory that during the off loading operation of a LNG carrier quantity and quality is measured !!

ULTRASONIC LIQUID FLOWMETER ALTOSONIC 5

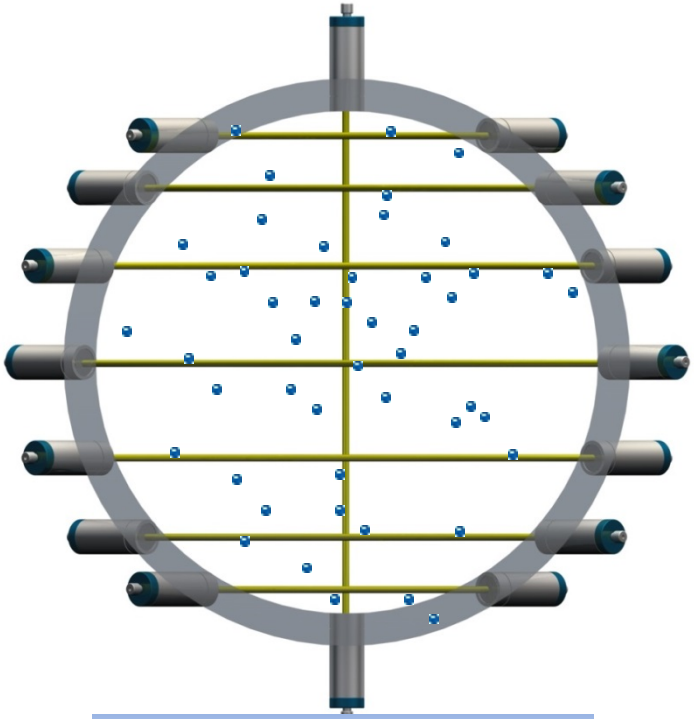
FOR LNG LIQUEFACTION PLANTS AND IMPORT TERMINALS



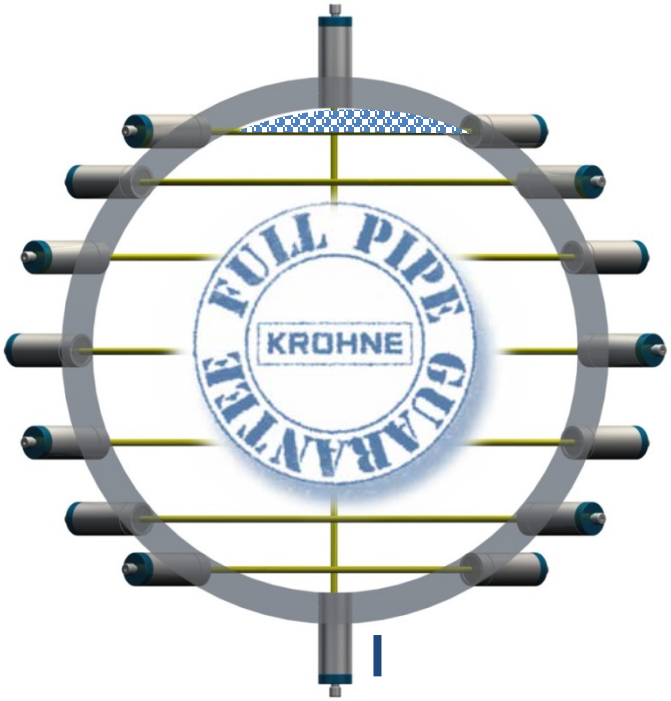
- OIML class 0.3 certified
- Full bore design
- Sizes from 4 to 48 inch
- No moving parts, no pressure loss
- Integrated full pipe detection
- Extensive diagnostic features
- Field LNG accuracy < 0.23 %
- Factory accuracy 0.10 %
- Uncertainty 0.027 %
- Turn down ratio : 0.2 to 15 m/s
- Certified temperature range -200 °C to +250 °C

Flow sensor

How to detect gas/vapour?



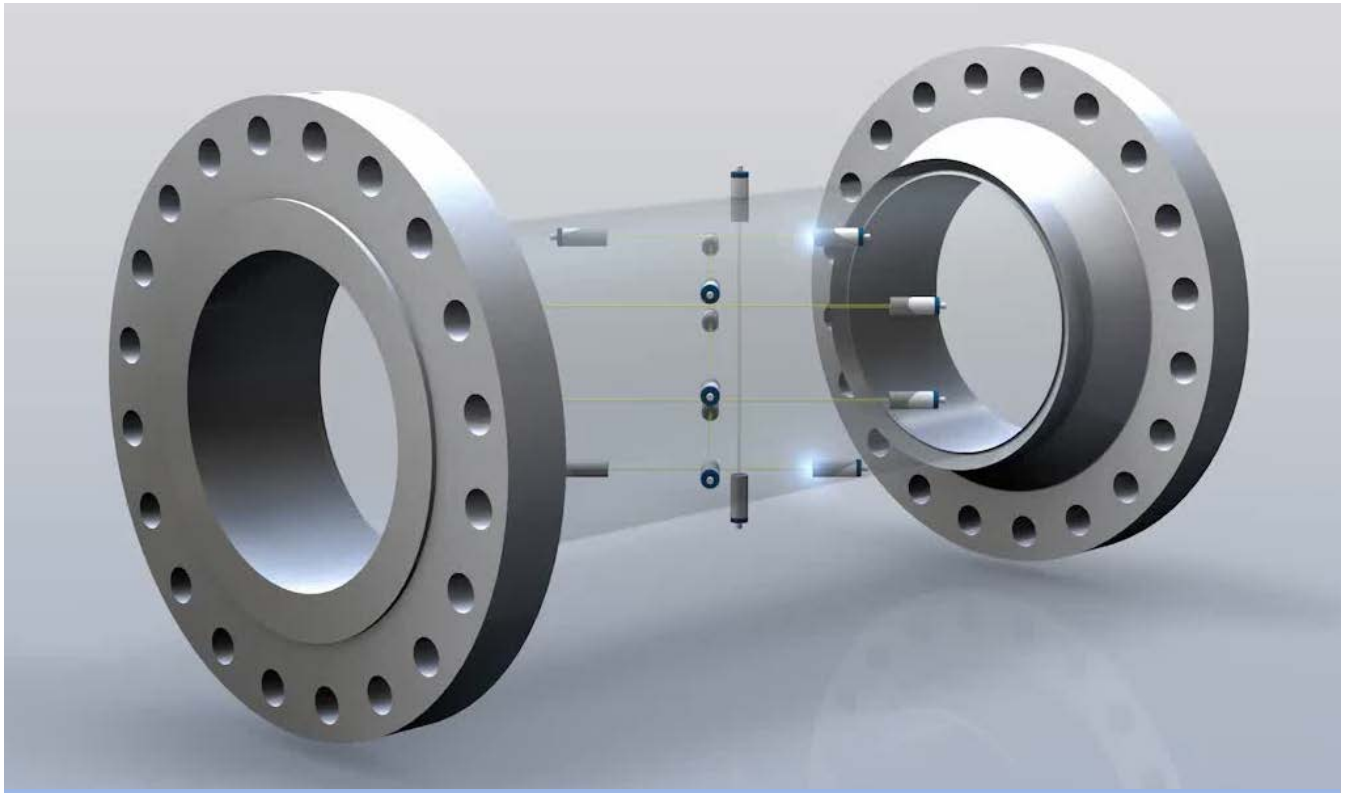
by signal to noise ratio



by the diagnostic path

Flow sensor

Enhanced 8 path design

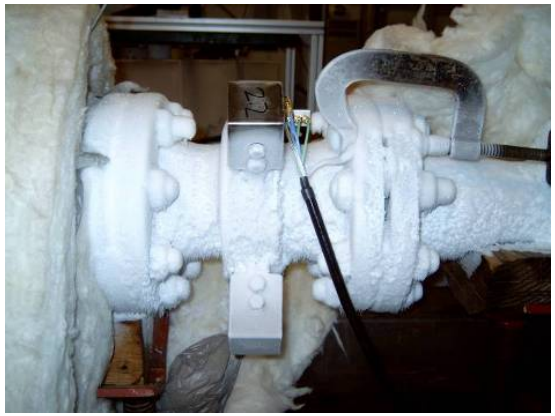


ALTOSONIC 5 path configuration

ALTOSONIC V ON LIQUEFIED NITROGEN AT NIST

Flowmeter tested on sensitivity to:

- Pressure
- Temperature
- Flow rate
- Thermal cycling
- Witnessed by NMi



CONCLUSIONS AFTER THE NITROGEN AND IN-HOUSE KROHNE CALIBRATIONS

Results of KROHNE Research estimated uncertainty considering following parameters:

- Special designed cryogenic transducers
- Temperature / thermal expansion
- No mechanical impact of signal processing e
- Reynolds extrapolation
- Calculated thermal expansion of the meter b
- Dedicated signal processing software for sign
- Additional uncertainty calculation due to the

NMi confirmed estimated Volume uncertainty:

0.26 to 0.33 % (document C-SP-WV-0178)

Succesfully applied at LNG facilities worldwide

Our reference
C-SP-06-WV-0178

Subject
Estimated uncertainty Ultrasonic LNG Volume Measurement

Dear Mr. Hogendoorn,

With reference to the meeting mentioned above, please allow me to inform you that we have carried out a preliminary study on the estimated measurement uncertainty in Volume Measurement by your Altosonic V Ultrasonic flowmeter on LNG.
This preliminary study was based on:

- the test results presented by you
- scientific data provided by NIST
- our experience with the Altosonic V on other media

Please note that in the absence of traceable, volumetric LNG standards, this is the best we could provide on such short notice. We strongly recommend to follow-up on this preliminary study, for instance with accuracy tests on Liquified Nitrogen (-196 °C) in order to obtain more confidence in the Altosonic V for LNG applications.
Also note that broad international acceptance in the field of legal metrology requires all tests to be performed or witnessed by an independent third party such as ourselves, rather than relying on a manufacturer's own test results. Therefore some of the research tests you already performed, as well as all future tests will need to be repeated / performed by, or in the presence of such a party.

With the above in mind, I would like to refer you to pages 2 and 3 of this letter, which summarised show that we expect the uncertainty in Volumetric measurement of LNG by the Altosonic V to be within a range of 0.26 to 0.33% of measured value.

I trust this informs you satisfactorily on this matter.

With kind regards,
NMi Certin B.V.

Wim Volmer B.Sc.
Senior Product Manager, Liquid Measurement

CONCLUSIONS AFTER THE NITROGEN AND IN-HOUSE KROHNE CALIBRATIONS

Declaration by NMi on estimated uncertainty considering following parameters:

- Temperature / thermal expansion
- Reynolds extrapolation

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ULTRASONIC GAS FLOWMETER ALTOSONIC V12

FOR FEED GAS AND RE-GASSIFICATION PLANTS

- OIML R137 class 0.5 certified
- Full bore design
- Sizes from 4 to 36 inch
- No moving parts, no pressure loss
- Extensive diagnostic features
- Accuracy 0.10 %
- Repeatability 0.05 %
- Excellent reproducibility (long term stability)
- Turn down ratio : 0.5 to 35 m/s
- Certified temperature range -40 ^{o}C to +100 ^{o}C

CORIOLIS FLOWMETER OPTIMASS 6400

FOR SMALL SCALE LNG APPLICATIONS

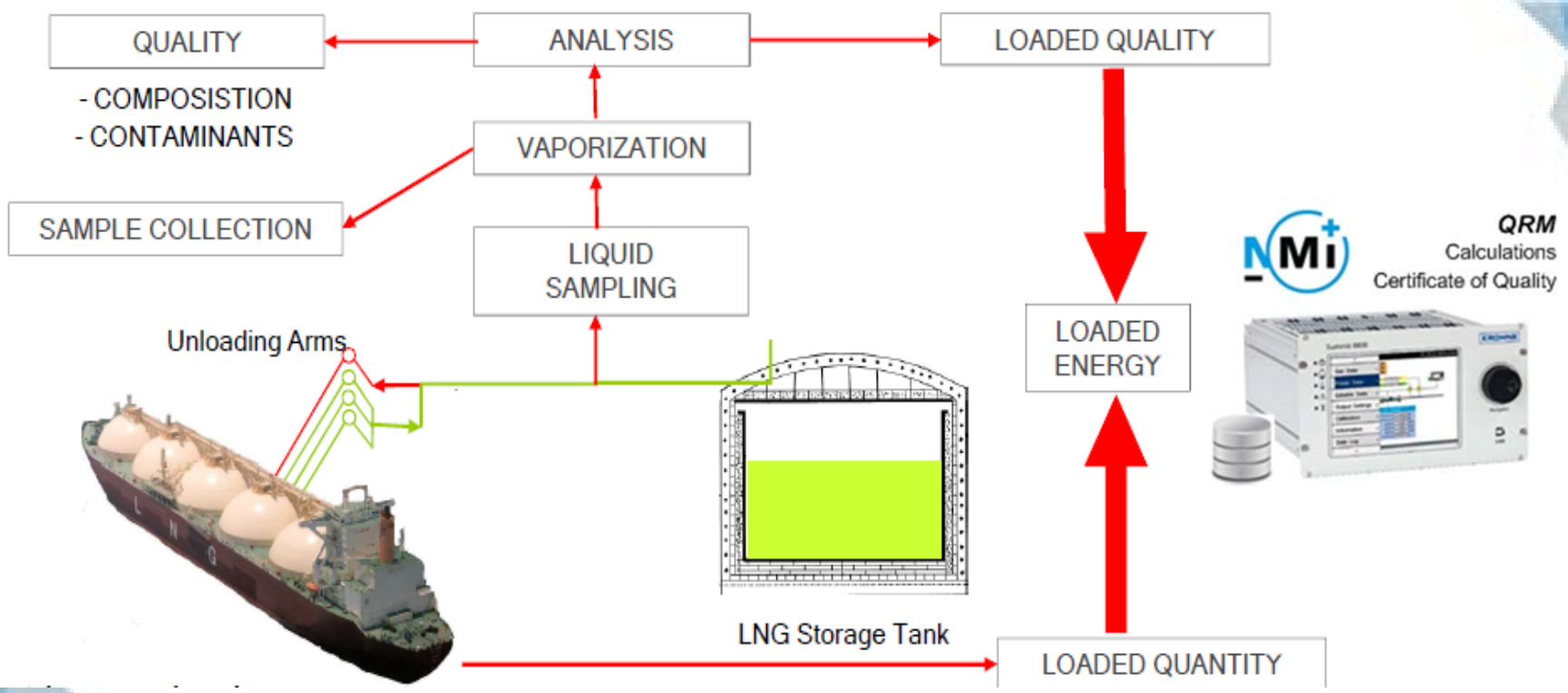
- Cryogenic & high temperature applications
  -200°C / -328°F to +400°C /752°F
- Pressure capability up to 200 bar (2900 psi)
- Gas & liquid custody transfer approvals
  OIML R117 & R137 (Nov 2013)
- Available from size 08 to 200 mm in 3 materials
- MFC 400 next generation converter
- With Entrained Gas Management (EGM)

FREQUENTLY USED METHOLOGY FOR LNG SAMPLING AND QUALITY DETERMINATION

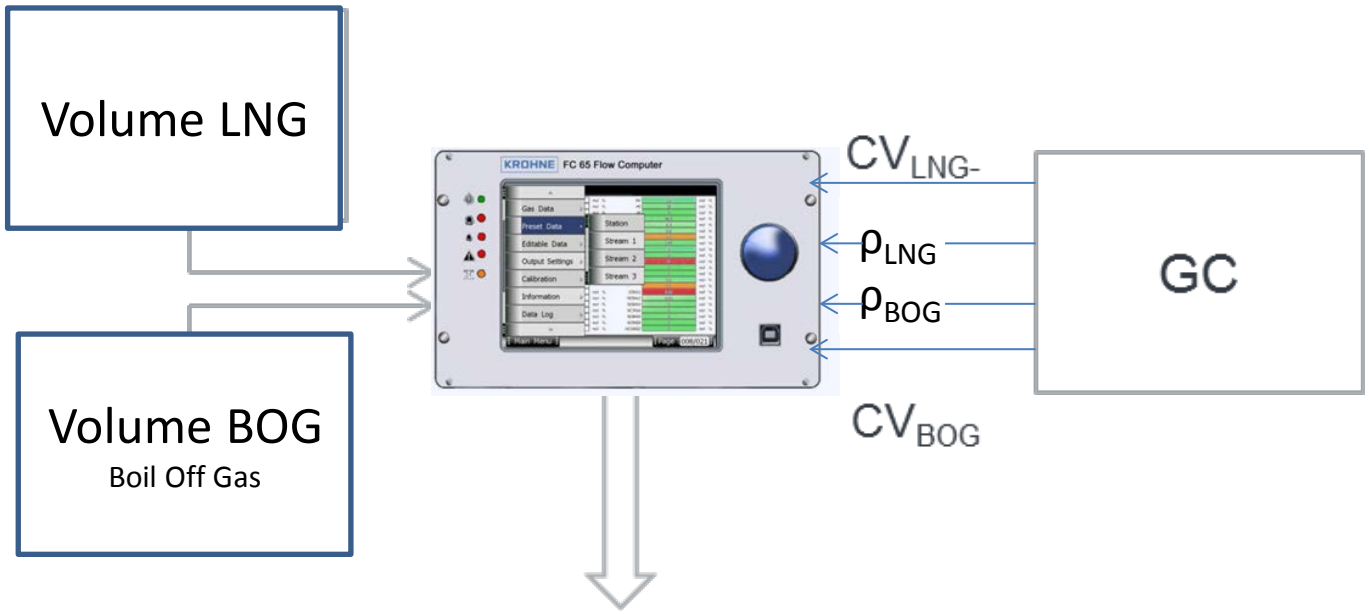
- LNG composition based on “spot” sample
- Possibility of human errors
- Calculations not validated or certifed by an independent body such as NMi
- Quality data is not traceable neither auditable
- Disputable Certificate of Quality
- No dynamic validation of data during LNG loading operation

With above considerations the risk of using disputable methods to calculate LNG energy is present

LNG DYNAMIC QUALITY CERTIFICATION SYSTEM



CUSTODY TRANSFER LNG ENERGY MEASUREMENT



Net Energy = $(vol_{LNG} \times dens_{LNG}) \times CV_{LNG}$- $(vol_{BOG} \times dens_{BOG}) \times CV_{BOG}$

WHAT IS INCLUDED IN THE KROHNE LNG DYNAMIC QUALITY CERTIFICATION SYSTEM ?

- Automated generation of Certificate of Quality
- Dynamic validation of measurement data, during the entire on- or off loading operation
- Representative measurement and sample collection during on- or off loading
- Automated validations for all instrumentation related to LNG loading
- Validated and certified Calculations by an independent body (NMi)
- Dynamic justification of measurement data by using outlier checks
- Monitoring of all critical parameters and alarms for audit purposes

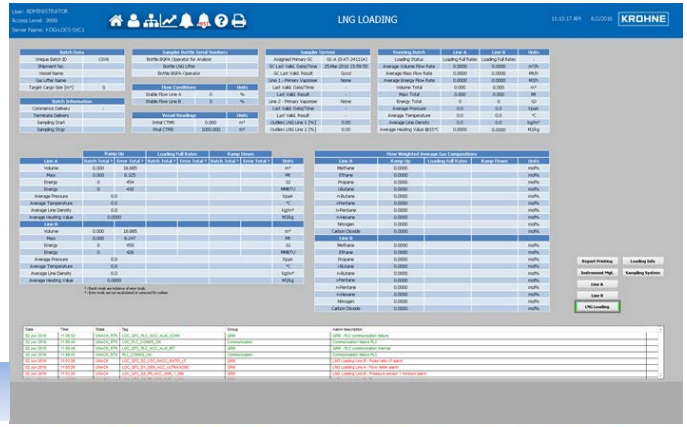
Succesfully installed and commissioned at major LNG liquefaction plants in Australia

REPORTING IN THE QUALITY CERTIFICATION SYSTEM

- Automatic generation of reports
  No human involvement required
- Information and data displayed on the reports can NOT be influenced
  Integrity of the presented figures is guaranteed
- Reporting is real time and generated immediate after completion of cargo
  No need to wait for laboratory analysis reports

Content of Reports:

- General loading information
- Time and validation results of the On-line GC
- Final loaded values of: composition, volume and calculated energy



HMI Main loading page

Certificate of Quality

Wheatstone LOCS
LNG Loading Lines

Batch ID:	20160722210735_Test_V41.1_Part1	Print Date:	22-Jul-2016 21:42:33
Shipment No:	123	Commence Delivery:	22-Jul-2016 21:24:21
Vessel Name:	horizon	Terminate Delivery:	22-Jul-2016 21:41:39
Gas Lifter Name:	1123	Sampling Start:	22-Jul-2016 21:25:15
Target Cargo Size:	0	Sampling Stop:	22-Jul-2016 21:41:10
LOCS System:	KOG-LOCS-SVC1 / KOG-LOCS-QRM1	Sampling Pause Time:	0 [s] (Loading Line 1)

	Loading Full Rates		
LNG Line A	Batch Total [1]	Error Total [2]	
Volume	265.5744	265.5744	m3
Mass	116.228	116.225	Mt
Average VFR	1000.0		m3/hr
FWA Pressure	1015.33		kPa
FWA Temperature	-160.00		degC
FWA Line Density	437.65		kg/m3
FWA Heating	54.47308		MJ/kg
LNG Line B			
Volume	265.5747	265.5747	m3
Mass	116.226	116.223	Mt
Average VFR	1000.0		m3/hr
FWA Pressure	1015.33		kPa
FWA Temperature	-160.00		degC
FWA Line Density	437.64		kg/m3
FWA Heating	54.47350		MJ/kg

[1]: Batch totals are inclusive of error totals

[2]: Error totals are not recalculated or corrected for outliers

	Loading Full Rates	
Section Totals		
FWA Pressure	1015.33	kPa
FWA Temperature	-160.00	degC
FWA Line Density	437.64	kg/m3
FWA Heating	54.47329	MJ/kg

Section Volume Totals		
Ramp Up	30.0028	m3
Loading Full Rates	531.1492	m3
Ramp Down	16.1122	m3

Note: For manual recalculation of the loaded figures, the values in the tables above are shown with an increased amount of decimal places

Loaded Figures		
Total Volume	577.264	m3
Avg. Line Density	437.6	kg/m3
Avg. Heating	54.4733	MJ/kg
Avg. Pressure	1015.3	kPa
Avg. Temperature	-160.0	degC
Energy	13761	GJ
Energy	13042	MMBTU

Vessel CTMS Readings		
Initial volume	0.000	m3
Final volume	0.000	m3
Final - Initial	0.000	m3
Avg. Pressure	0.0	kPa
Avg. Temperature	0.0	degC
Calculated energy	0	GJ
Calculated energy	0	MMBTU

Note: Averages in the table above are derived from Loading Full Rates

Report ID: 16783660, generated on: 22/07/2016 at: 21:42, user: Engineer, computer: KOG-LOCS-SVC1, Report Generator version: 3.2.0.9633

Certificate of Quality
Wheatstone LOCS
LNG Loading Lines

KOG-LOCS-SVC1 / KOG-LOCS-QRM1 Batch ID: 20160722210735_Test_V41.1_Part1 Print Date: 22-Jul-2016 21:42:33

Assigned Primary GC:	GC-A (0-AT-24111A)
Last Validation Date/Time:	13-Jul-2016 20:03:26
Last Validation Result:	Bad
Loading Line A - Primary Vaporiser:	None
Last Validation Date/Time:	Unknown
Last Validation Result:	Undefined
Loading Line B - Primary Vaporiser:	None
Last Validation Date/Time:	Unknown
Last Validation Result:	Undefined
Loading Line A - Stable Flow:	0 %
Loading Line B - Stable Flow:	0 %
Loading Line A - GC Coverage:	3694.2 %
Loading Line B - GC Coverage:	3694.2 %

Used Gas Composition (Loading Full Rates)				
	Line A	Line B	Loaded	
C1H4	96.1279	96.1287	96.1283	mol%
C2H6	2.1449	2.1444	2.1446	mol%
C3H8	0.2956	0.2956	0.2956	mol%
IC4H10	0.1317	0.1317	0.1317	mol%
NC4H10	0.1206	0.1206	0.1206	mol%
ICSH12	0.0701	0.0701	0.0701	mol%
NCSH12	0.0507	0.0507	0.0507	mol%
C6+	0.2858	0.2857	0.2858	mol%
N2	0.7725	0.7725	0.7725	mol%
CO2	0.0000	0.0000	0.0000	mol%
Summation (Loading Full Rates)				
	Line 1	Line 2	Loaded	
C3+	0.9547	0.9545	0.9546	mol%
C4+	0.6591	0.6589	0.6590	mol%
C5+	0.4067	0.4066	0.4066	mol%

Outlier Samples		
	Line A	Line B
Valid	49	49
Rejected	3	3
Total	52	52

Loaded outlier percentage: 5.77 %

Bottle Operator for Analysis S/N:

Bottle LNG Lifter S/N:

Bottle Operator S/N:

Flow Tx Alarm:	No	FC System Alarm:	No	Prim. GC Alarm (PLC):	No
Pressure Tx Alarm:	No	Line A - Vap. Alarm (PLC):	No	Prim. GC SCS Alarm (PLC):	No
Temperature Tx Alarm:	No	Line B - Vap. Alarm (PLC):	No	Common SCS Alarm (PLC):	No
Density Tx Alarm:	No	Sampler Alarm (PLC):	No		

Name	Signature	Date
Name	Signature	Date
Name	Signature	Date
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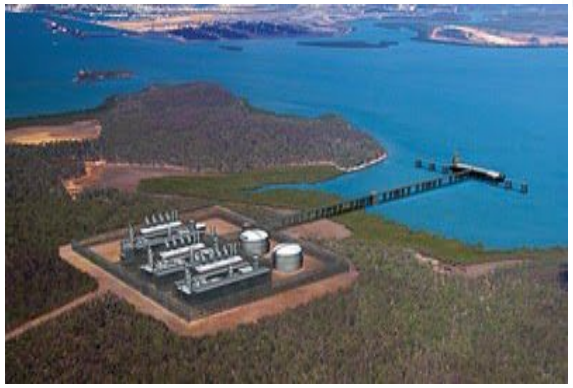
LNG FLOW METERING AT AP LNG PLANT, AUSTRALIA

End user: AP LNG (Australia Pacific LNG)

Application: Custody-transfer measurement for loading ships at LNG terminal

Medium: LNG, Natural Gas



Scope of supply:

2 x LNG metering systems
6 pcs ALTOSONIC V LNG, 10"/150 lbs

3 x Feed gas metering systems
6 pcs ALTOSONIC V12, 20", 900 lbs,
3 pcs ALTOSONIC V12, 4", 900 lbs

2 x Boil Off Gas systems

FEED GAS METERING SKID TO APLNG TERMINAL

Metering skids installed in the field to measure gas being fed in the main supply line to AP LNG terminal, based on 10” ALTOSONIC V12 ultrasonic flowmeters.

INLET FEED GAS METERING SYSTEM

LNG METERING SYSTEM

ALTOSONIC 5
6 x 10” 150 lbs

BOIL OF GAS METERING SYSTEM

LNG TRUCK LOADING AND DISPENSING WITH OPTIMASS 6400

LNG truck loading:

Increasing number of small scale LNG projects require LNG transport by tanker truck

Truck loading and truck unloading applications with OPTISMASS 6400

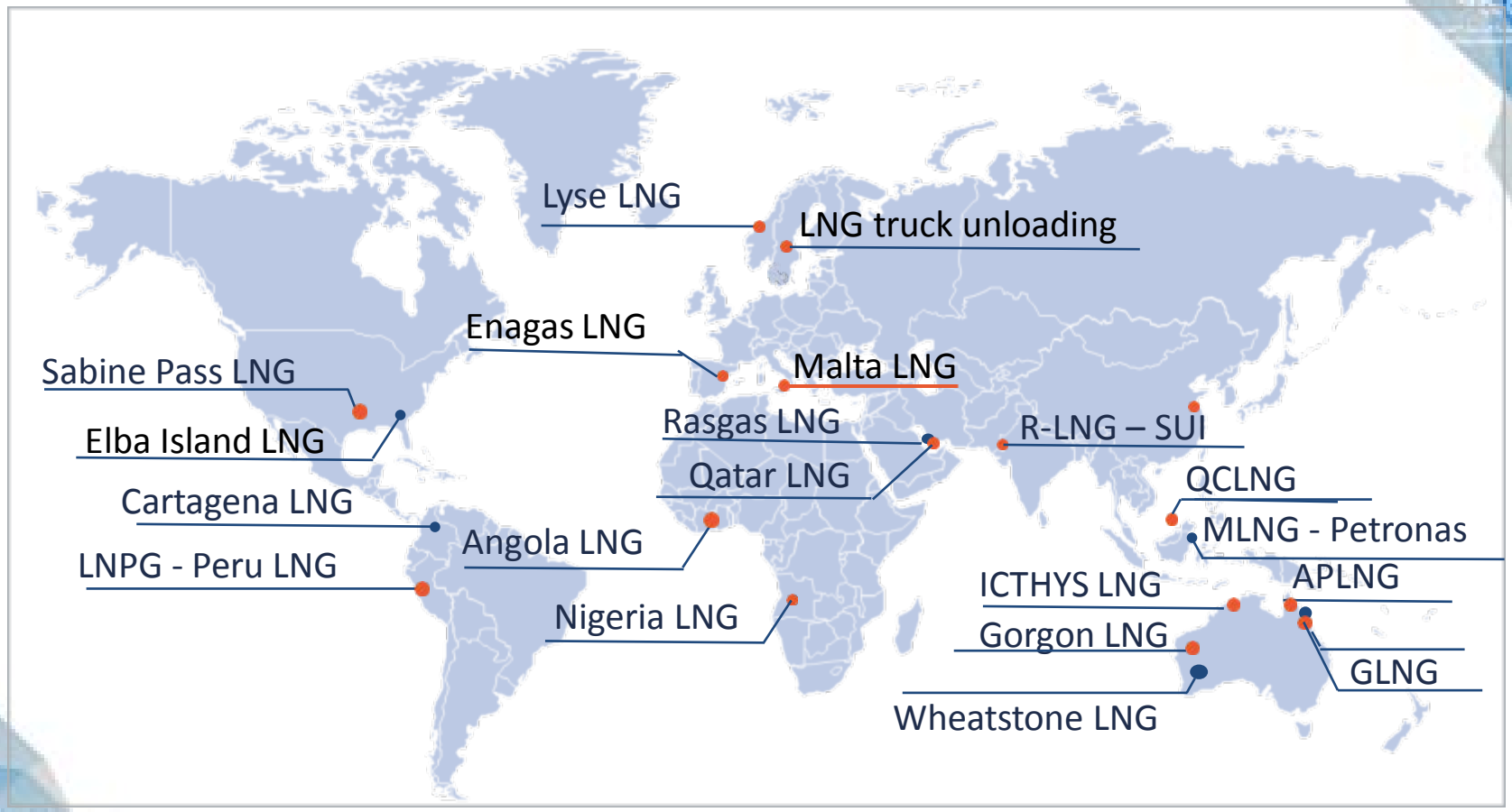
LNG dispensing:

6400 S25 for feed meter (Liquid)

6400 S15 for return meter (liquid and gas phase)

Large potential as LNG is increasing to be used to fuel trucks

LNG PROJECTS EXECUTED BY KROHNE



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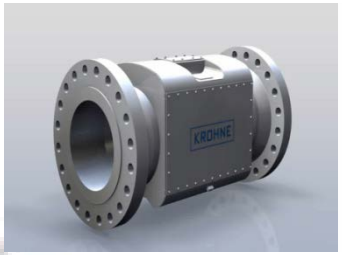

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Thanks for Attention