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19 - 21 NOVEMBER 2017

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A Subsidiary of Kuwait Petroleum Corporation

Metrological Support for LNG and LBG as Transport Fuel (**LNGIII**)

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INTRODUCTION

This work is part of the **EMPIR** (European Metrology Programme for Innovation and Research) project.

It follows on from the successful European Metrology Research Programme (**EMRP**) executed between 2010-2017.

EMPIR has been developed as an integrated part of Horizon 2020, the EU Framework Programme for Research and Innovation.

[Horizon 2020 is the biggest EU Research and Innovation programme ever with nearly €80 billion of funding available over 7 years (2014 to 2020). It promises more breakthroughs, discoveries and world-firsts by taking great ideas from the lab to the market]

INTRODUCTION

The EMPIR calls launched between 2014 and 2020

Have a total allocated budget of €600M, with €300M from the participating states and up to €300M from the European Commission using Article 185 of the European Treaty

EMPIR calls will focus on priority areas to address the EU's Grand Challenges in Health, Energy, Environment and Industry, and to progress fundamental measurement science.

Since the first EMRP call in 2010, LNG flow measurement and its traceability has been identified by EU NMI’s as a challenge and priority area to address.

LNG- BACKGROUND

LNG currently traded in the form of Energy transferred and requires measurement of volume, density and GCV.

Following the procedures of the GIIGNL and ISO 10976-2012.

The volume is measured by tank gauging methods (up to 1% error = €900M per year in 2015, EU only)

Flow meters have many advantages over tank gauging for LNG custody transfer measurements (accuracy, capital cost...).

However, calibration facilities and procedures need to be developed before flow meters are widely accepted.

This is a very challenging task for the pipe size and flowrates required in custody transfer applications.

This is the main motivation for EMRP/EMPIR LNG projects.

LNG Metrology- Development Stages by Sector

LNG Metrology

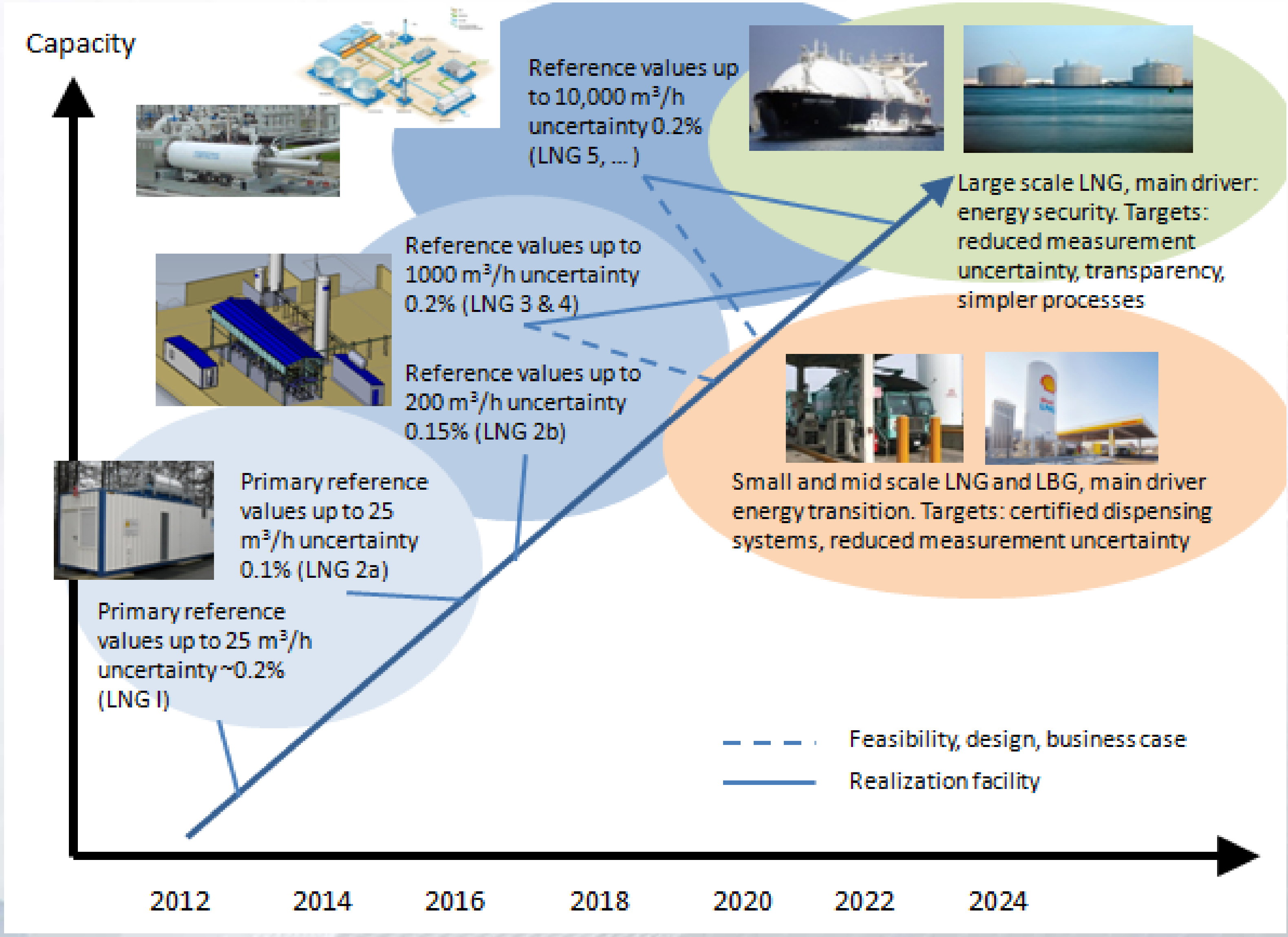
Transportation	**Bunkering**	**Custody Transfer**
As fuel for truck and bus long distance transport...	As fuel for refuelling and bunkering	Custody transfer (Ship loading/unloading)
LNG1, LNG2 and LNG3	LNG4	LNG5 +??
Small Scale Facility	**Mid Scale Facility**	**Large Scale Facility**
Up to 200 m³/hr	**400- 1000 m³/hr**	**Up to 10,000 m³/hr**
2010 - 2020	**2020-2023**	**2023 +**

LNG1- 2010 – 2013 **Completed**
LNG2- 2014 – 2017 **Completed**
LNG3- 2017 – 2020 Current

LNG4, LNG5……………..are Future projects

Focus of this presentation

Development of LNG Flow Measurement Traceability



LNGIII- Objectives (June 2017 – May 20202)

Enable the large scale roll-out of LNG and LBG as a transport fuel

Achieved through the continued development of transparent and traceable metrological infrastructure for flow and composition measurement systems.

LNGIII forms an essential step towards measurement traceability for large scale LNG custody transfer applications.

The project will also develop and validate smart sensors for measurement of MN and MS to ensure optimal LNG engine performance.

The outcomes of the project will be implemented in relevant written standards to enable and promote the use of LNG and LBG as a transport fuel.

Why LNG for Transportation?

To address EU Clean Fuel Strategy, LNG &LBG are proposed as alternative fuel to Diesel.

LNG as fuel meets the new limits for sulphur content in marine fuels.

Also meets NOX emissions limits for marine engines

Engines running on LNG produce far less noise than diesel-operated engines.

LNG3- Project Partners
Total budget (€2.3M)

VSL Dutch Metrology Institute

nel flow measurement services

Justervesenet

VTT

NPL National Physical Laboratory

PTB

CESAME exadébit SA

CMI

INRIM ISTITUTO NAZIONALE DI RICERCA METROLOGICA

Coventry University

Technische Universität Braunschweig

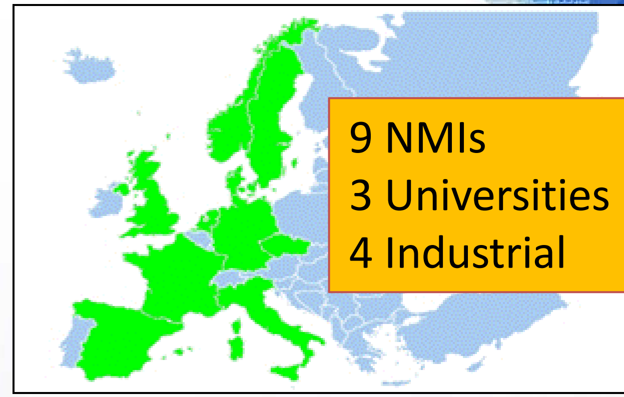
reganosa

THERMODYNAMIK

TNO

gasNatural fenosa

Mestrelab Research



Advisory Board

- Producers
- Shippers
- Import terminals
- Energy Companies
- Instrument manufacturers

- Cameron – Caldon Ultrasonics
- Cameron – Jiskoot
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- Emerson Process Management – Daniel Measurement..
- Emerson Process Management – Micro Motion
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- Grain LNG Importation Terminal
- Honeywell Enraf
- Kongsberg Maritime AS
- Krohne Altometer
- Krohne Ltd.
- Petronas
- Rasgas company Ltd.
- Scientific Instruments
- Shell Global Solutions International BV
- Tokyo Gas Co. Ltd.
- Valtronics

LNG3- Work Packages

WP1: Reduced uncertainty for dynamic flow measurements. (NEL)

WP2: Traceable small scale liquefier and density measurements. (VSL)

WP3: Smart sensor development and testing for measurement of MN and MS. (TNO)

WP4: Smart sensor validation and engine testing (PTB)

WP5: Creating Impact (JV)

WP6: Management (VSL)

WP1: Reduced uncertainty for dynamic flow measurements (Coriolis & US meters)

Objectives and targets:-

Fully understand influence of following parameters on meter accuracy (under ambient and cryogenic conditions):

- Upstream disturbances
- Presence of 2nd phase
- Coriolis meter inclinations
- Meter insulation under cryogenic conditions
- Coriolis meter response time, thermal stability & YM vs Temp.

- Recommend meter installation setups to reduce measurement uncertainty to 0.5%.
- Feasibility of using a cryogenic piston prover to reduce flow measurement uncertainty.
- Validation of cryogenic mass flow meters using a cryogenic LDV standard.
- Feasibility study for a mid-scale LNG calibration facility (up to 1000 m^3/hr).

WP2: Traceable small scale liquefier and density measurements

Objectives:-

- Development and validation of a small scale liquefier for natural gas and similar mixtures. It will be used to validate LNG and LBG sampling and composition measurement systems (GC and Raman Spectroscopy)

- Develop and test cost effective sensors for in-line LNG density measurement (Coriolis and US sensors). Validate against reference measurement from primary densitometer developed in LNG1 and LNG2.

- Development of traceable methods for performing measurements of particulates present in LNG and LBG. This is need to be known in order to decide of e.g. LNG engine service interval and type of filters used at fuelling stations.

WP3: Smart sensor development and testing for measurement of MN and MS

Objectives:-

- Develop cost effective and reliable sensors for measurement of Methane number (MN). [*MN is the measure of resistance of fuel gases to engine knock (known as detonation) and therefore an important factor for determining LNG engine performance*].

- Develop cost effective and reliable sensors for measurement of Methane Slip (MS). [*MS is unburned methane emissions released from the LNG engine due to incomplete combustion. The global warming potential of* ***methane*** *is a 25 times higher than that of* CO_2.]

- Define and agree an acceptable criteria for measurement accuracy from each sensor based on international standardisation, legislation and available data

- The sensors will be developed to the level ready for deployment in the engine tests in WP4.

WP4: Smart sensor validation and engine testing

Objectives:-

- Develop a chemical kinetic model which can accurately predict the combustion and ignition behaviour of LNG with different MNs within the range 70-100. This will be ultimately used by end users to support the design phase of engines and engine control in vehicles.

- Conduct truck and stationary gas engine tests of standardised LNG mixtures over a wide range of gas compositions in order to obtain the Methane Number. Data will be used for development of MN algorithm.

- Validate the MN and MS sensors developed in WP3 in an environment that is typical for current and future heavy-duty gas engines.

WP5: Creating Impact

Knowledge transfer

- Conference presentations
- Peer-reviewed papers
- Feedback to Standards bodies (ISO, OIML, TC Flow and GIIGNL)
- Development of new standard for dynamic flow measurements under ISO-TC28 WG20
- Input to ISO/TR22302 on Methane Number calculations
- Implement results from LNGI, LNGII and LNGIII to GIIGNL CT handbook
- Best practice guides

Training and Workshops

- Workshop and training course at NEL (Month 18)
- Workshop and training course at RUB (Month 36)

WP1 Progress-

(Reduced uncertainty for dynamic flow measurements)

Work is progressing to achieve the first objective of:

Fully understand influence of following parameters on meter accuracy:

- Upstream disturbances
- Presence of 2nd phase
- Coriolis meter inclinations
- Meter insulation under cryogenic conditions
- Coriolis meter response time, thermal stability & YM vs Temp

Testing will be carried out under ambient and cryogenic conditions:

- Testing with water at NEL
- Testing with LNG at VSL

Experimental setup:

- Design of metering skids for testing above (Completed)
- Fabrication of metering skids (Under way)

Flow meters and sensors under test

2” Ultrasonic flowmeter (USM)

2” Coriolis flow meter

2” Clamp-on ECT device

Density sensor for the 2” USM

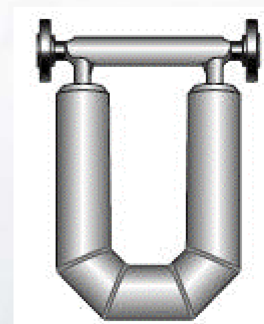
4” Ultrasonic meter- 1

4” Ultrasonic meter- 2

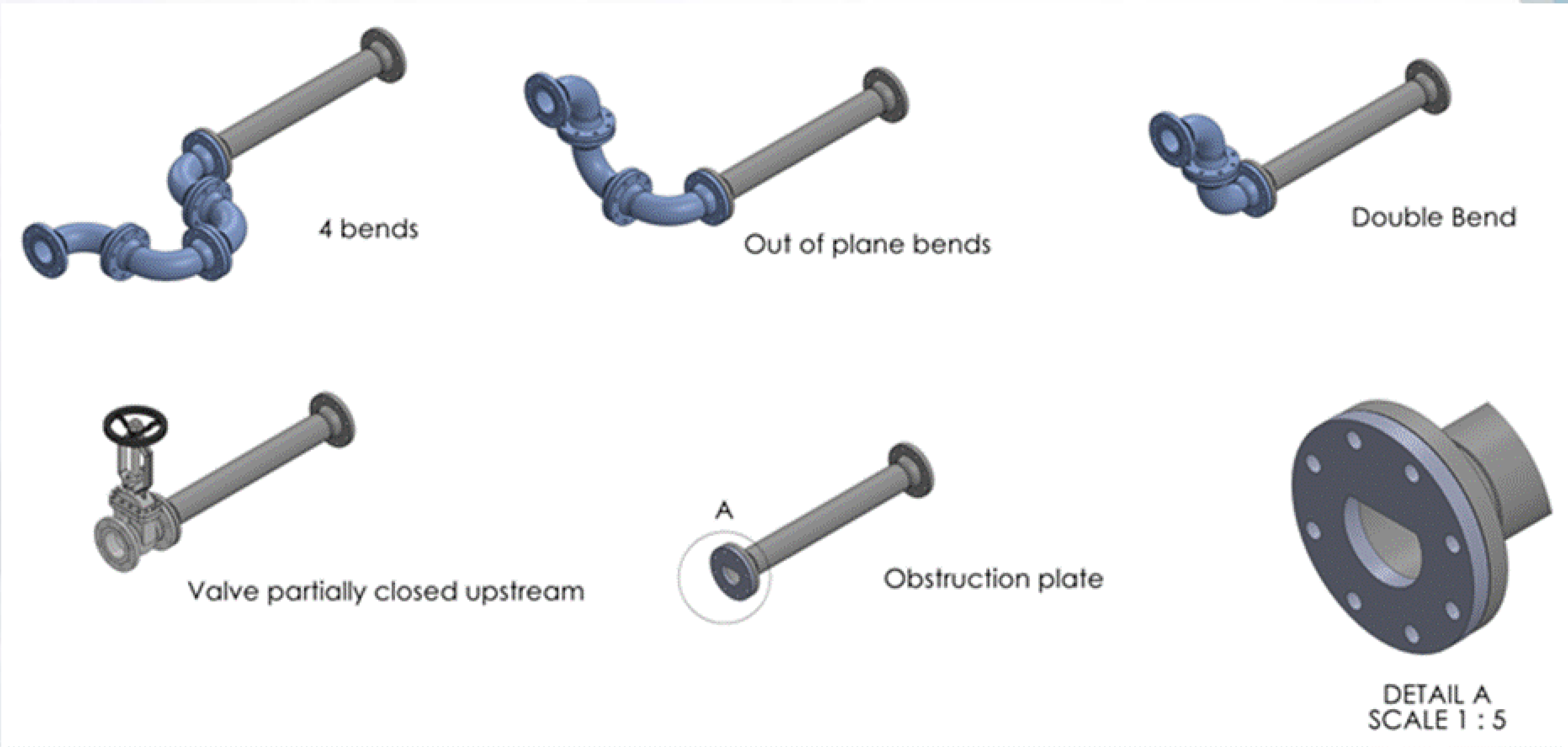
4” Coriolis flow meter

4” Clamp-on ECT device

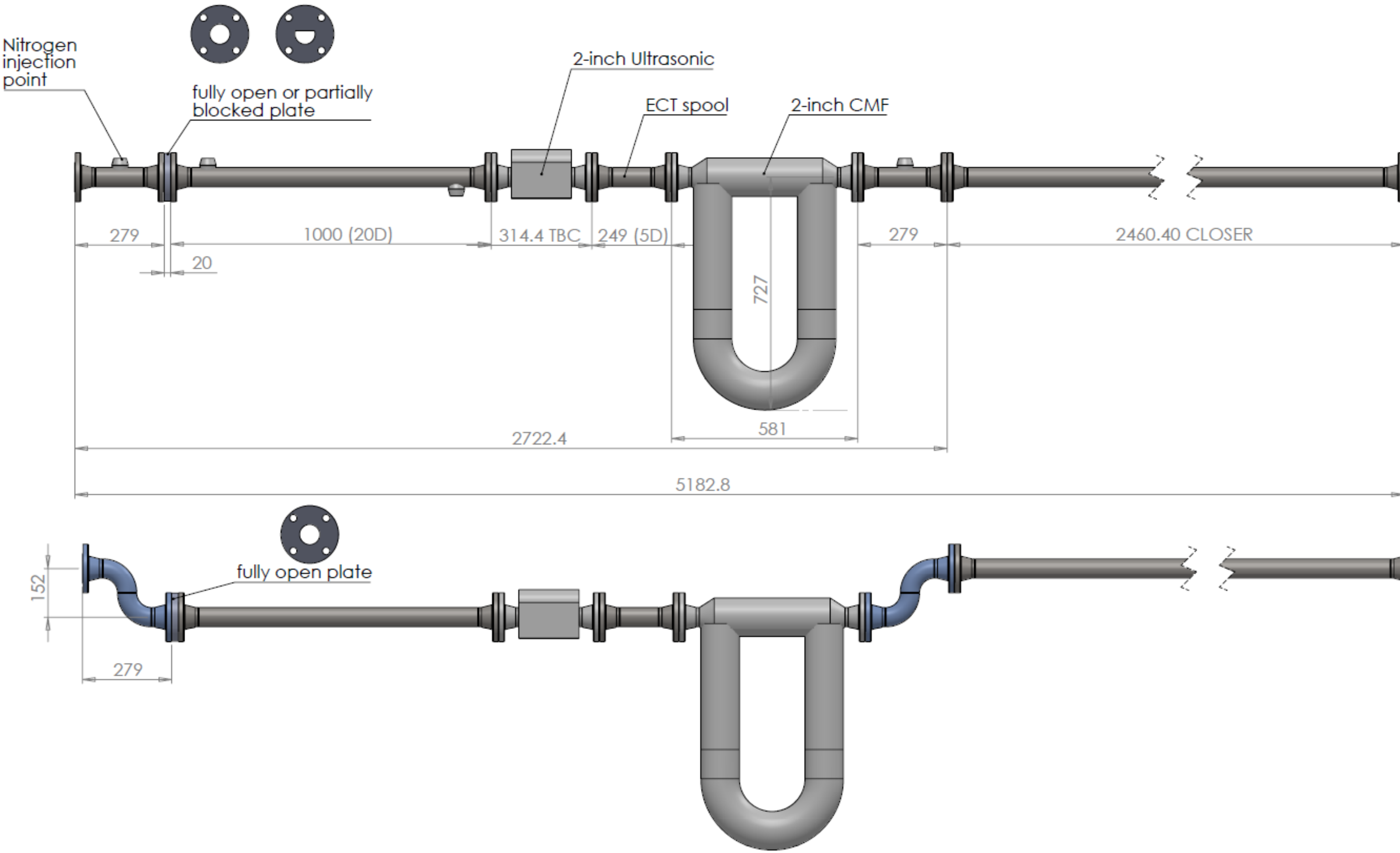
Density sensor for the 4” USM



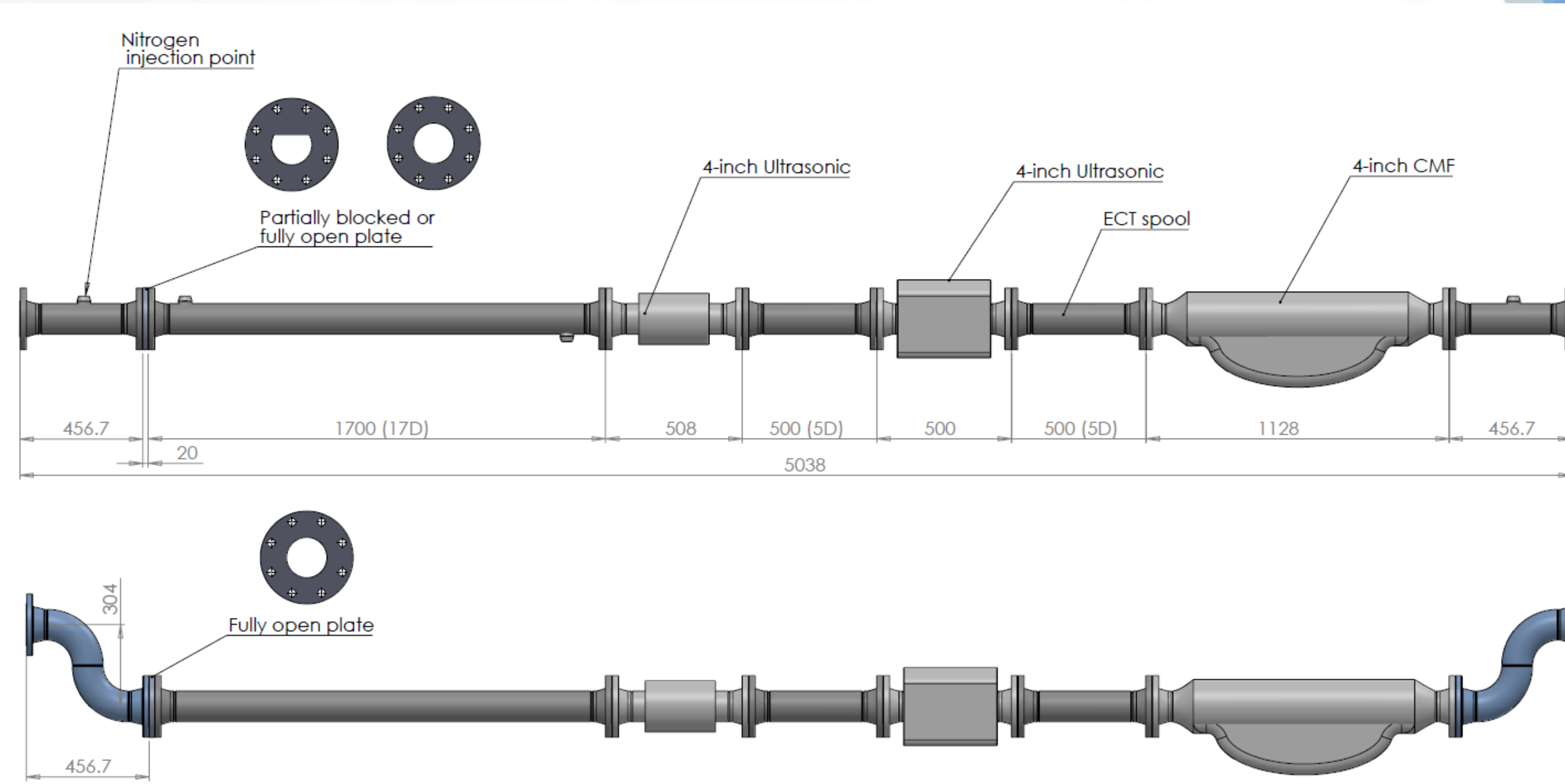
Proposed flow disturbances



2” Metering Setup



4” Metering Setup



NEL Water Flow Measurement Facility (UKAS accredited meter calibrations)

NEL's Water Flow Measurement Facility

Facility Specification and operating conditions:-

Flowrate 0.05 l/s to 400 l/s (approx. 0.2 m^3/hr to 1400 m^3/hr).

Line pressure 0 to 5 bar (72 psi) up to 400 l/s.

Line pressure 0 to 10 bar (145 psi) up to 200 l/s.

Line temperature 10 to 40^{o}C (controlled to < 1^{o}C).

Line sizes 0.5-inch to 10-inch.

Horizontal line length 25m.

Vertical line height 5m.

Reference System

Primary gravimetric standard 12t, 1.5t, 300kg, weighbridges (to 200 l/s), uncertainty 0.10%.

Secondary Standard Reference turbine meters (to 400 l/s), 0.15%.

VSL's Mid-scale LNG Flow Measurement Facility

Flow Rate: 5 – 200 m^3/h Expandable to 400 m^3/h

Target uncertainty: 0.15 % on mass (0.2% on volume)

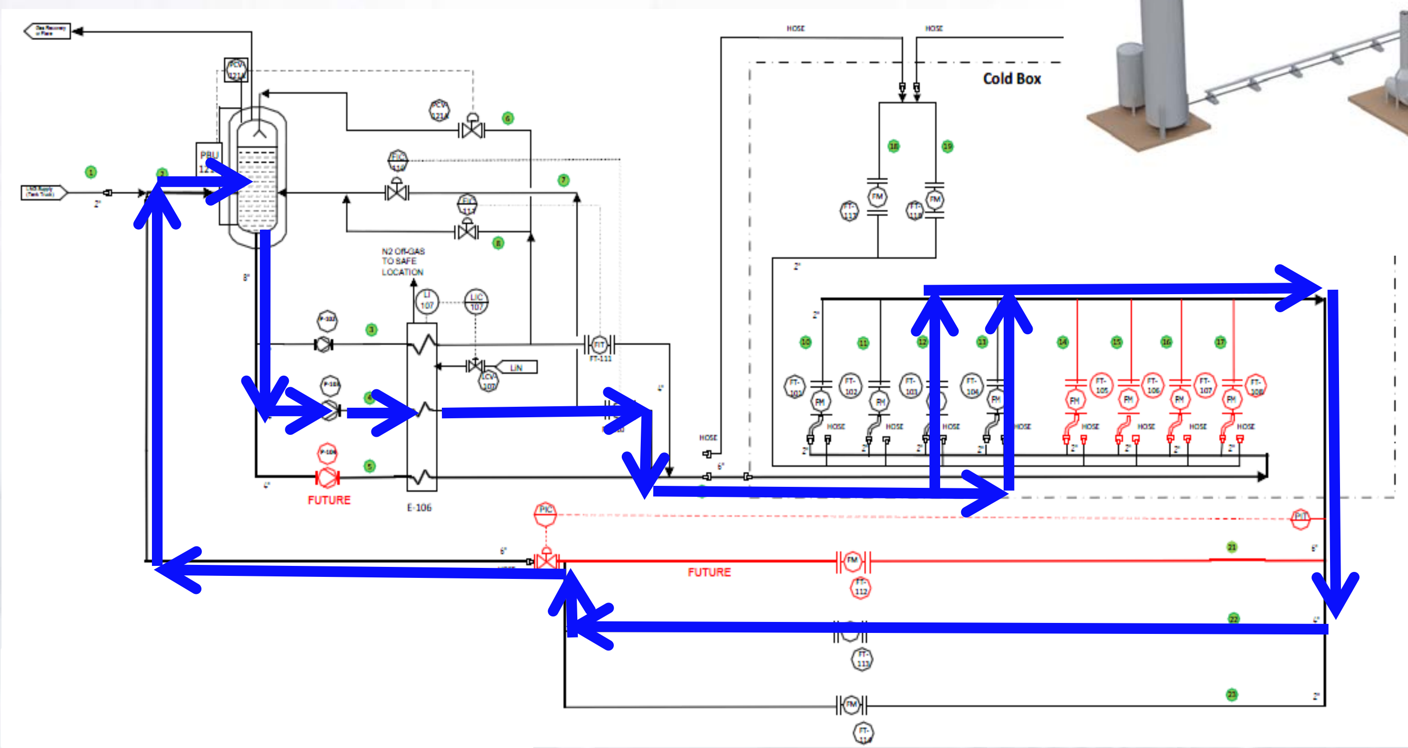
Traceable to primary standard

Line pressure: 1 – 10 bar(g)

Temperature: -123 °C to -175 °C

Closed loop/ no boil-off

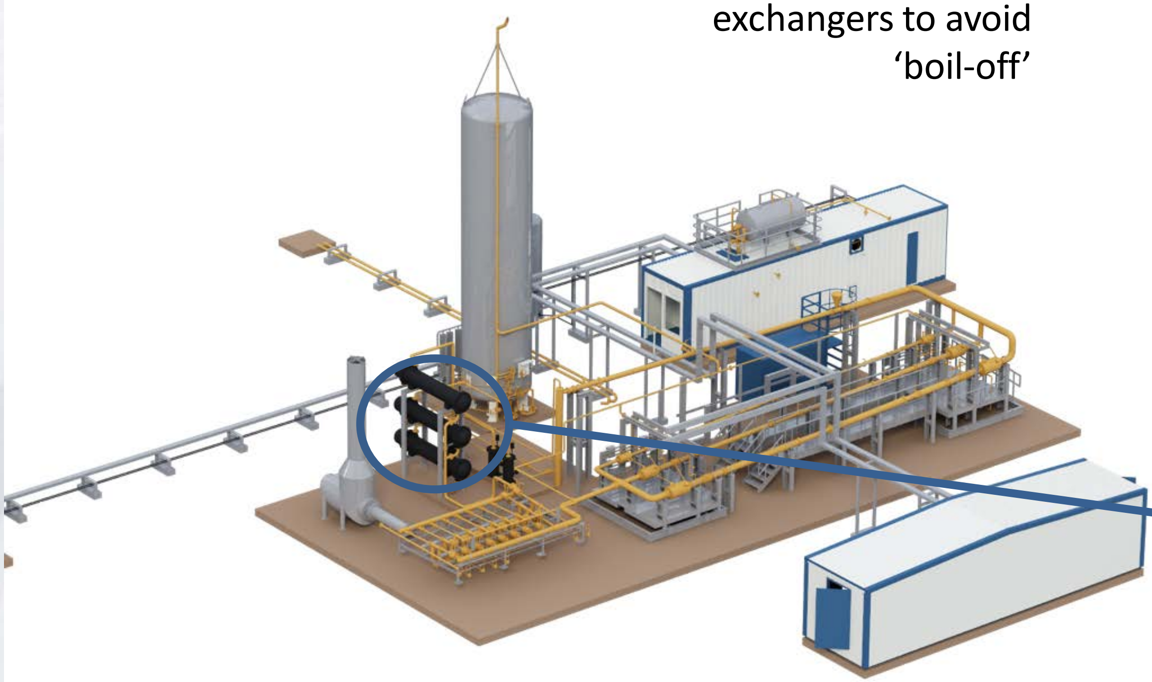
Process Flow Diagram



World metrology day 2017 conference
Singapore, May 2017

Heat Exchangers

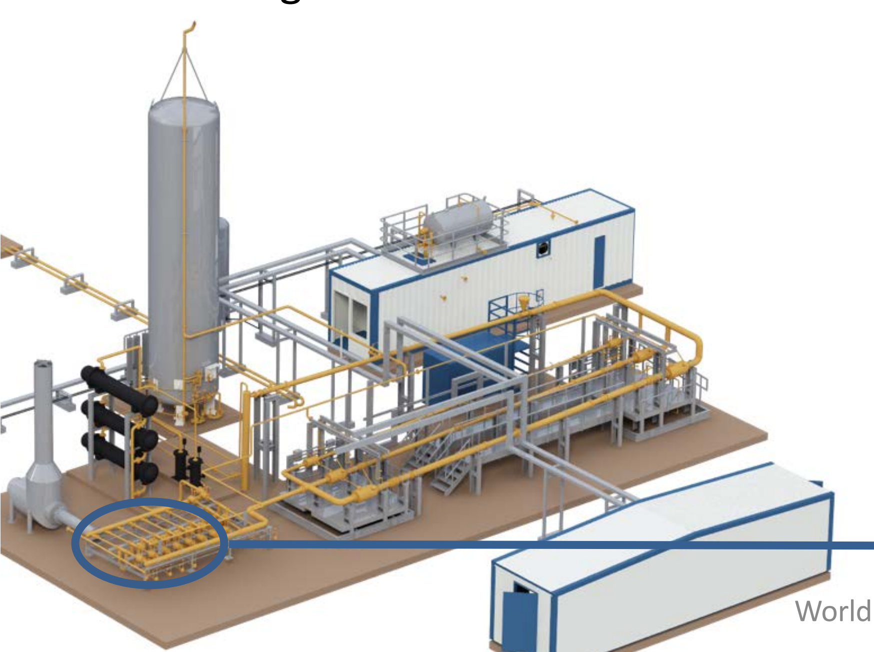
LIN/ LNG heat exchangers to avoid 'boil-off'

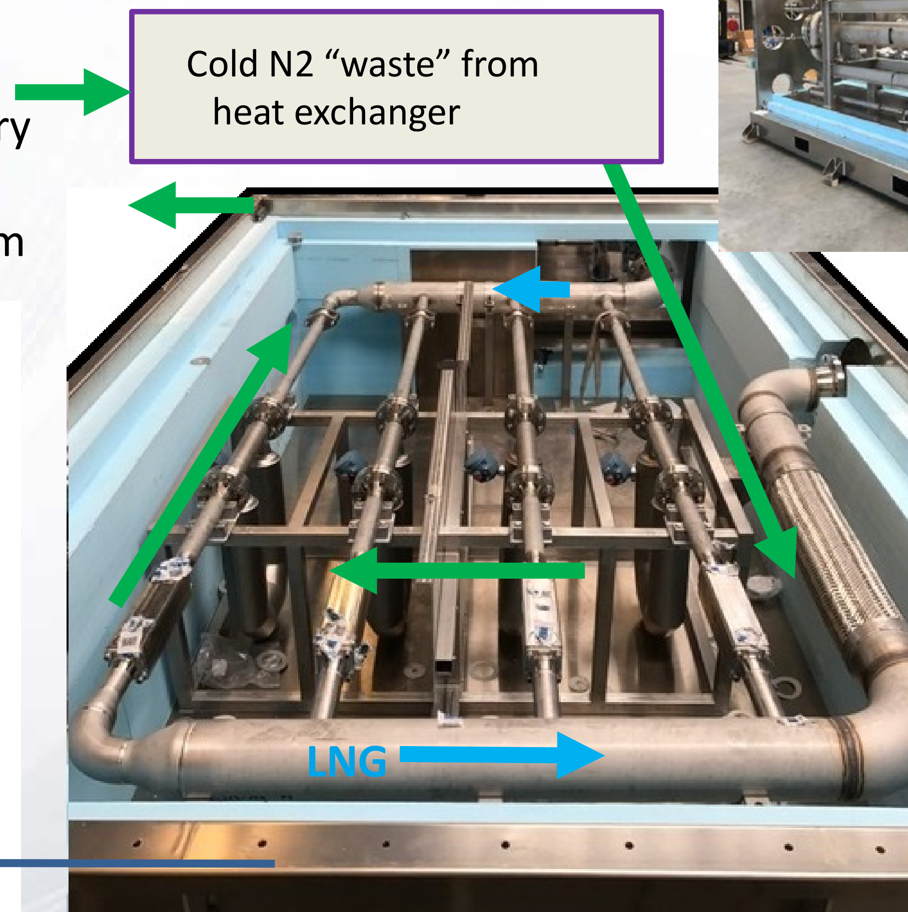


World metrology day 2017 conference
Singapore, May 2017

Working Standards Cold Box

- Four CMFs in parallel each 50 m^3/h (Total flow rate up to 200 m^3/h).
- Meters are traceable to gravimetric primary standard
- Cold box is refrigerated with N2 waste from heat exchanger





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LNG home

Welcome to the *Metrology for LNG* site!

This website is dedicated to the European Research projects "Metrology for LNG" and intends to provide information to and bring together stakeholders from the LNG industry.

In the navigation menu we provide information about project aims and results obtained, about the partners involved and industrial stakeholders that are contributing to the project. **So, why is this important?**

- Whenever there is a trade, there are measurements involved to quantify the transfer of goods.
- Whenever there are measurements, there are errors and uncertainties involved.
- Metrology is all about providing standards that are internationally accepted and allow one to quantify the error or uncertainty of any measurement. Without quantification of the associated uncertainty any measured value has no meaning; one would be left in the dark.

The LNG projects aim to improve and develop the metrology for LNG custody transfer measurements, leading to smaller measurement uncertainties, reduction of financial risks of transactions and more transparency in the trade of LNG.

These projects are defined as so-called Joint Research Project (JRP) and carried out as a part of the European Metrology Research Program (EMRP) that is jointly supported by the European Commission and the participating countries within the European Association of National Metrology Institutes (EURAMET e.V.).

Cordially yours,
Gerard Nieuwenkamp
Project Coordinator

EMRP
European Metrology Research Programme
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The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union

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Thanks for Attention