Setting the Standard for Automation™

A New Method for LNG Energy Determination

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- Beng, Msc from University of Bath, Manchester
  - Specialising in materials
- 7 years Aerospace Engineering
  - Including 4 years in Bristol, UK and 3 years in Toulouse, France
- 1 year Production & Export @ EnDet / VE Technology
  - Produced and exported new advanced gas sampling technology
- 4 years (and counting!) International Sales @ Orbital
  - Manage global sales network and responsible for growth of sales of two patented product lines: VE Technology® and GasPT®

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LNG Energy Determination
Background

- Liquefied Natural Gas (LNG) is becoming increasingly important to meet the world's energy demand

- LNG comes from many different sources and is of varying quality (to other sources, and over time: 'aging')

- A single LNG vessel can carry $5-15M worth of LNG

- Faster, more accurate and more reliable monitoring of LNG quality would be worth millions of dollars per year

LNG Measurement

- ISO 8943:2007, is recognised as an industry guide to LNG sampling and measurement, also G.I.I.G.N.L. LNG Custody Transfer Handbook

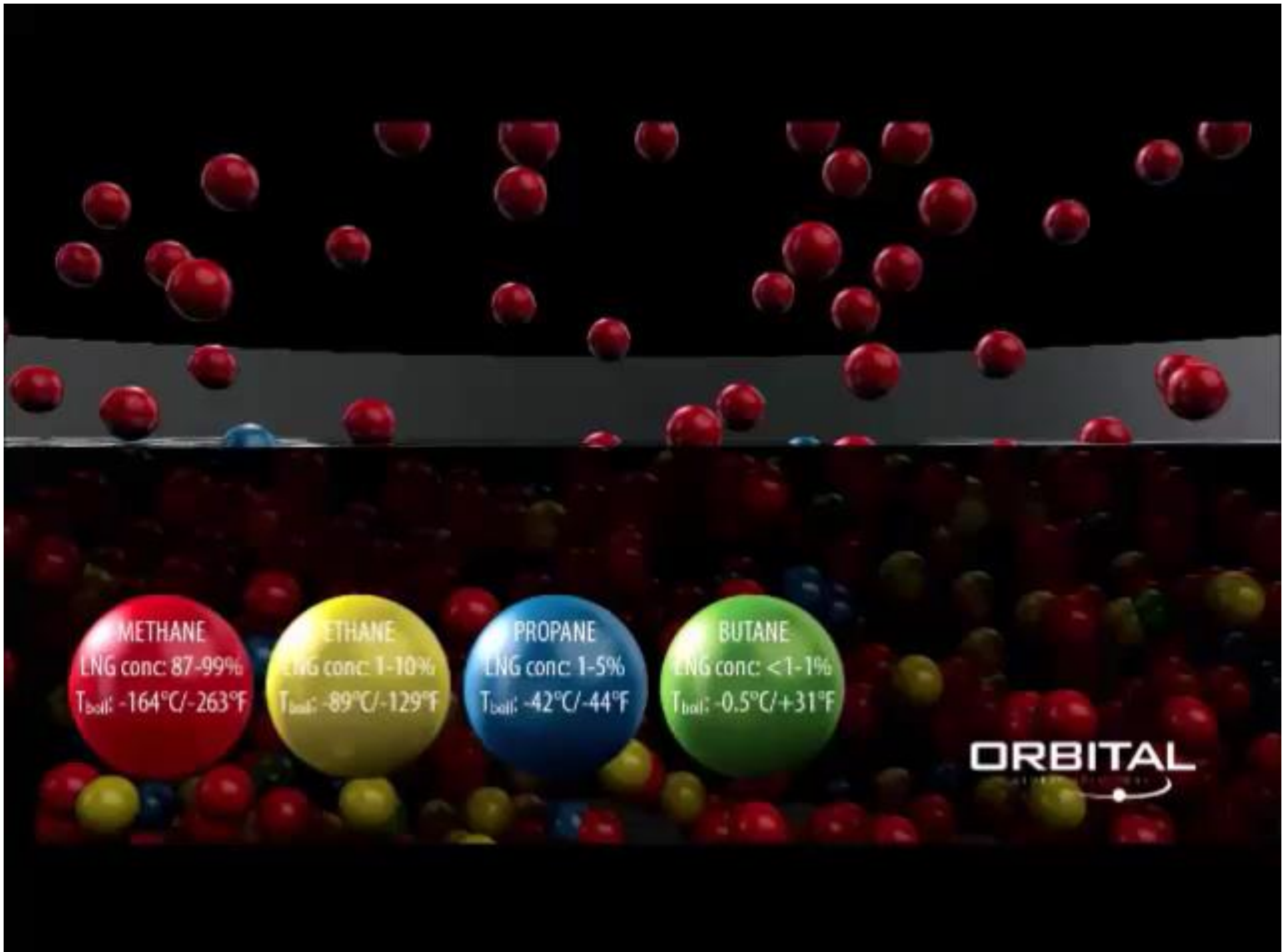
- **Continuous measurement** of LNG during transfer is essential to accurately account for total energy flow

- Gas chromatography (GC) is established in the gas industry as a means for calculating energy content and written into international standards and user specifications
  - Despite being accurate, it is slow, cyclic (NOT continuous), complicated to install and expensive to operate and maintain

Gas Chromatography for LNG
Principles of Measurement

- Gas chromatography requires a sample of the LNG to be vaporised without changing its composition in any way
- A tiny slice of this sample is taken every few minutes, separated into constituent components and concentration calculated via peak identification and integration
- From these component concentrations, the gas properties such as CV, RD and others can be calculated using ISO 6976.
- Data output frequency is subject to analyser cycle time which can be 3-5 minutes for the latest micro GC instruments

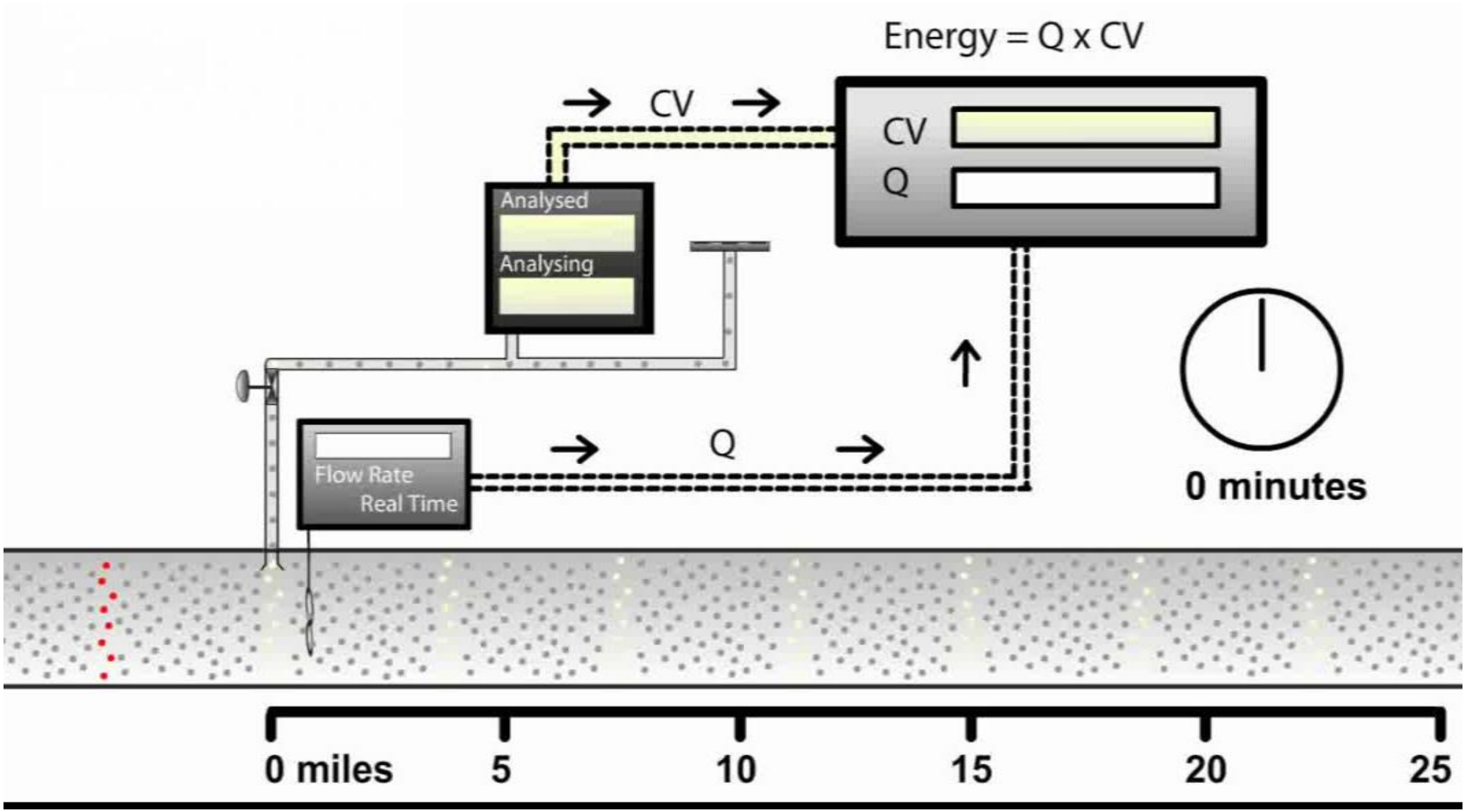
Gas Chromatography for LNG
Limitations for LNG Application



Gas Chromatography for LNG
Limitations for LNG Application

- NOT continuous – a series of 'snapshots' that are not matched to the respective LNG flow data
- High CAPEX cost due to requirement for shelter, base, tube runs (and space to fit all of those items into a working LNG terminal!)
- High OPEX due to requirement for continuous supply of carrier and calibration gas, regular (skilled) maintenance

Gas Chromatography for LNG
Limitations for LNG Application



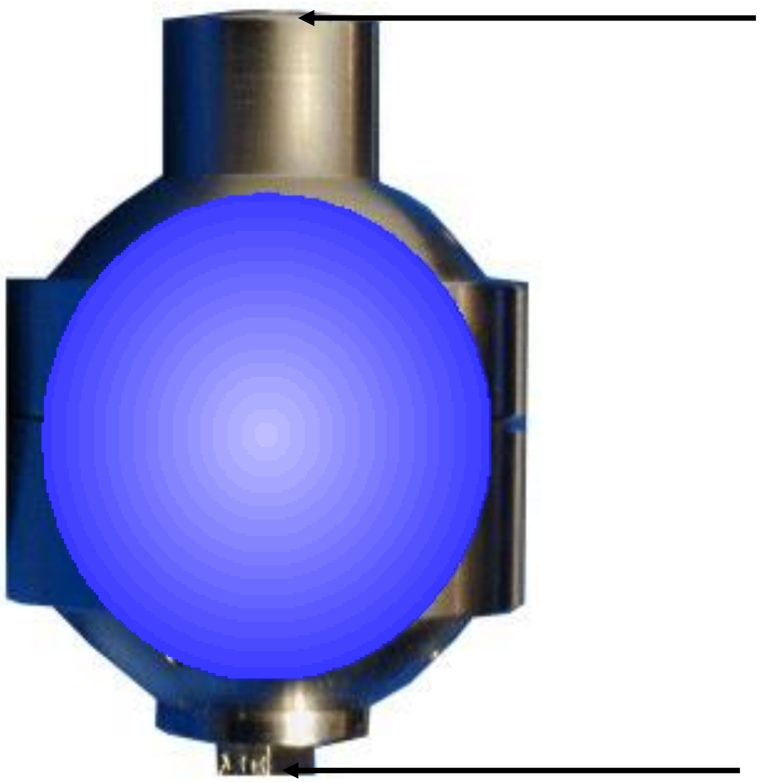
A New Method for LNG Energy Determination

- A fast, accurate and reliable method of determining natural gas quality has been developed

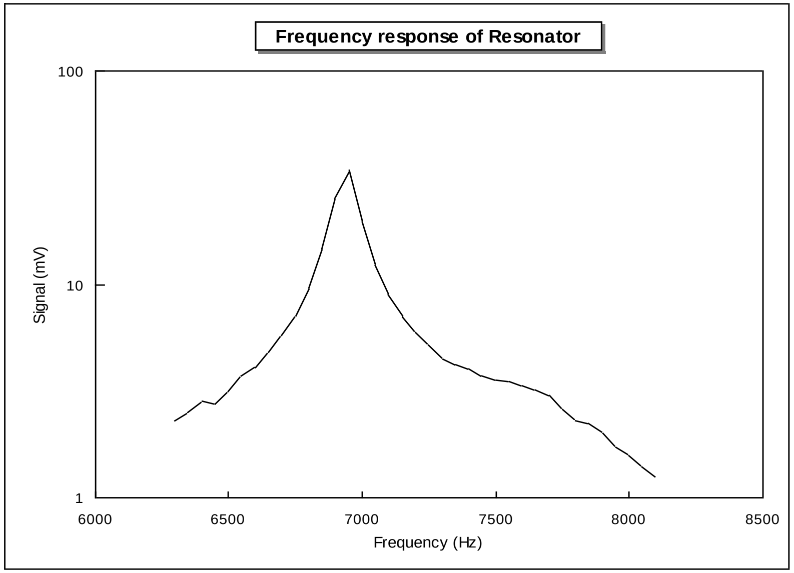
- It uses sensor technology and complex algorithms to continuously monitor gas quality and derive an equivalent gas composition from which the physical properties can be calculated (using ISO 6976)

- It directly measures:
  - Speed of sound
  - Thermal conductivity
  - Pressure
  - Temperature

A New Method for LNG Energy Determination

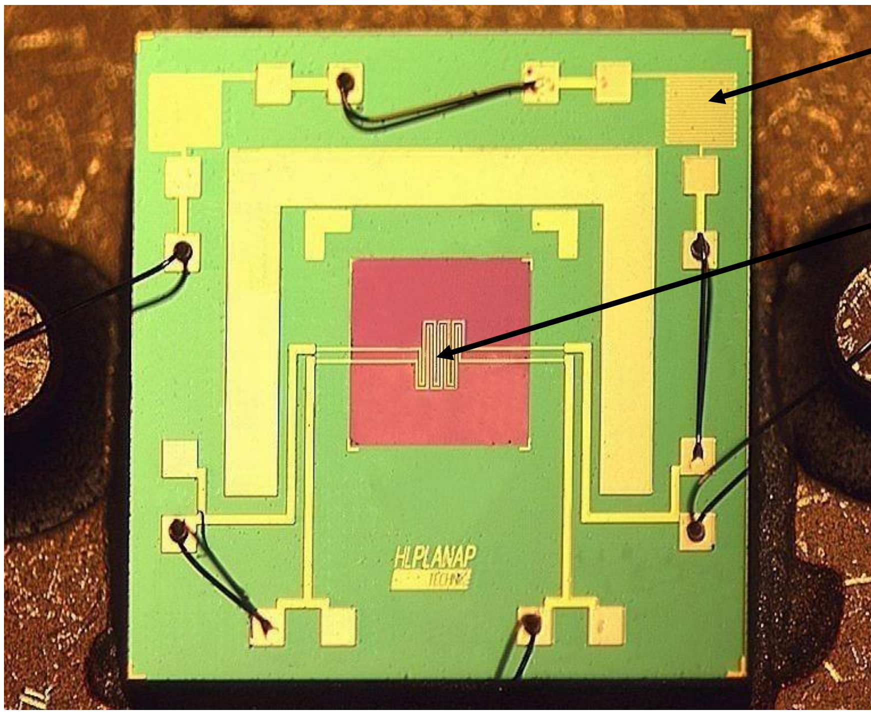


Microphone: Detects amplitude of oscillation



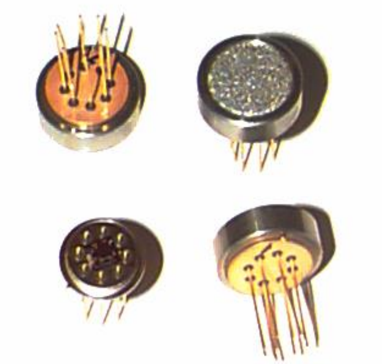
Miniature Speaker drives the resonance

A New Method for LNG Energy Determination



Ambient temperature sensor

Heated above ambient



Thermal conductivity sensing resistor.

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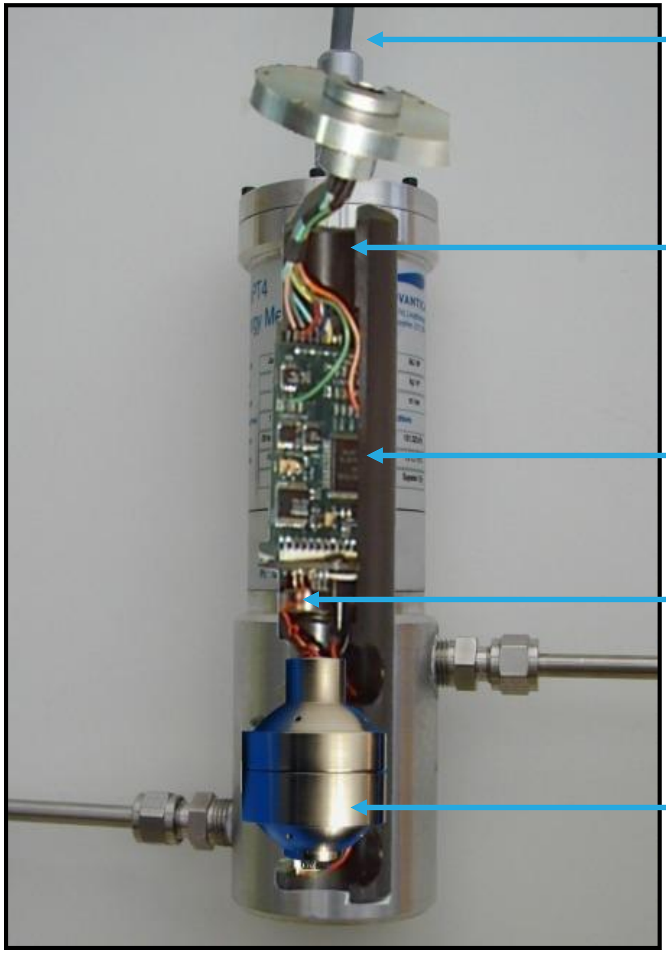


Electrical Connections

Insulating Sleeve

Processor Board

Thermal Conductivity Sensor

Spherical Resonator

A New Method for LNG Energy Determination

A Calibration map is made in the PT for the signals from the sensors

- For each unit 7 temperatures are used (-10 to +50C)
- For each temperature 10 gases are used
- For each gas 3 pressures are used

This provides 210 calibration reference points

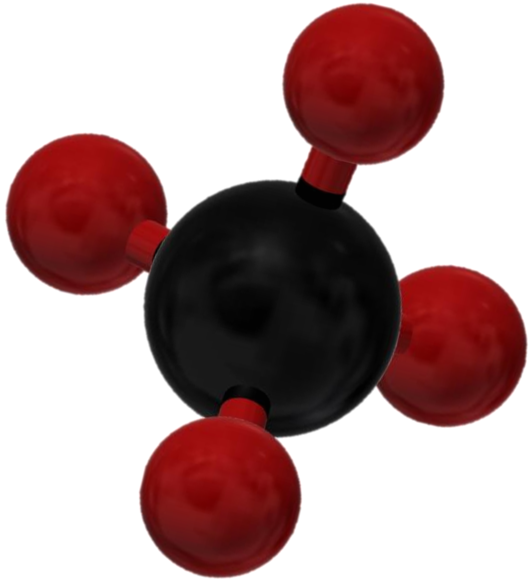
Using the sensors, this complex calibration process and an algorithm developed over 15 years a simplified composition can then be derived which accurately matches the sample gas characteristics

A New Method for LNG Energy Determination – Hydrocarbon Equivalence

All hydrocarbons typically found in a natural gas can be represented by a mix of effective methane (CH_4), effective ethane (C_2H_6) and effective propane (C_3H_8) that yields the same number of Carbon and Hydrogen atoms.

$$C_4H_{10} = C_2H_6 + C_3H_8 - CH_4$$

(1 mol. Butane = 1 mol. Ethane + 1 mol. Propane - 1 mol. Methane)



Principle Used for Years By Gas Companies World Wide to simplify Gas Composition:

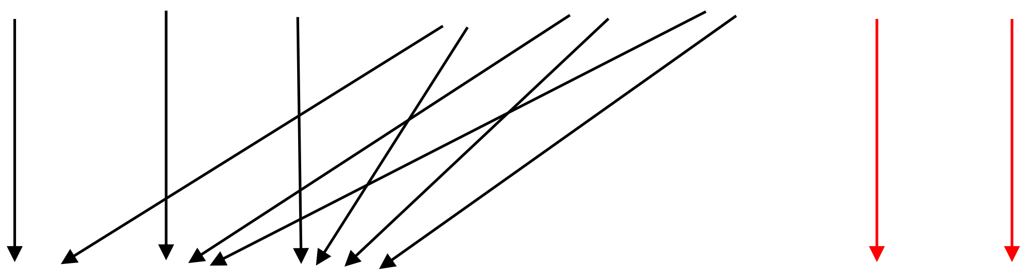
Network modelling

Interchangeability

A New Method for LNG Energy Determination

Calculated Calorific Value = 38.731 MJ / m^3

Chromat	CH_4	C_2H_6	C_3H_8	C_4H_{10}	C_5H_{12}	C_6H_{14}	CO_2	N_2		Total
Composition	94.451	3.11	0.512	0.198	0.17	0.0001	0.647	0.912		100



Gas PT	CH_4	C_2H_6	C_3H_8	C_4H_{10}	C_5H_{12}	C_6H_{14}	CO_2	N_2		Total
Composition	93.998	3.478	0.965	0.0	0.0	0.0	0.647	0.912		100

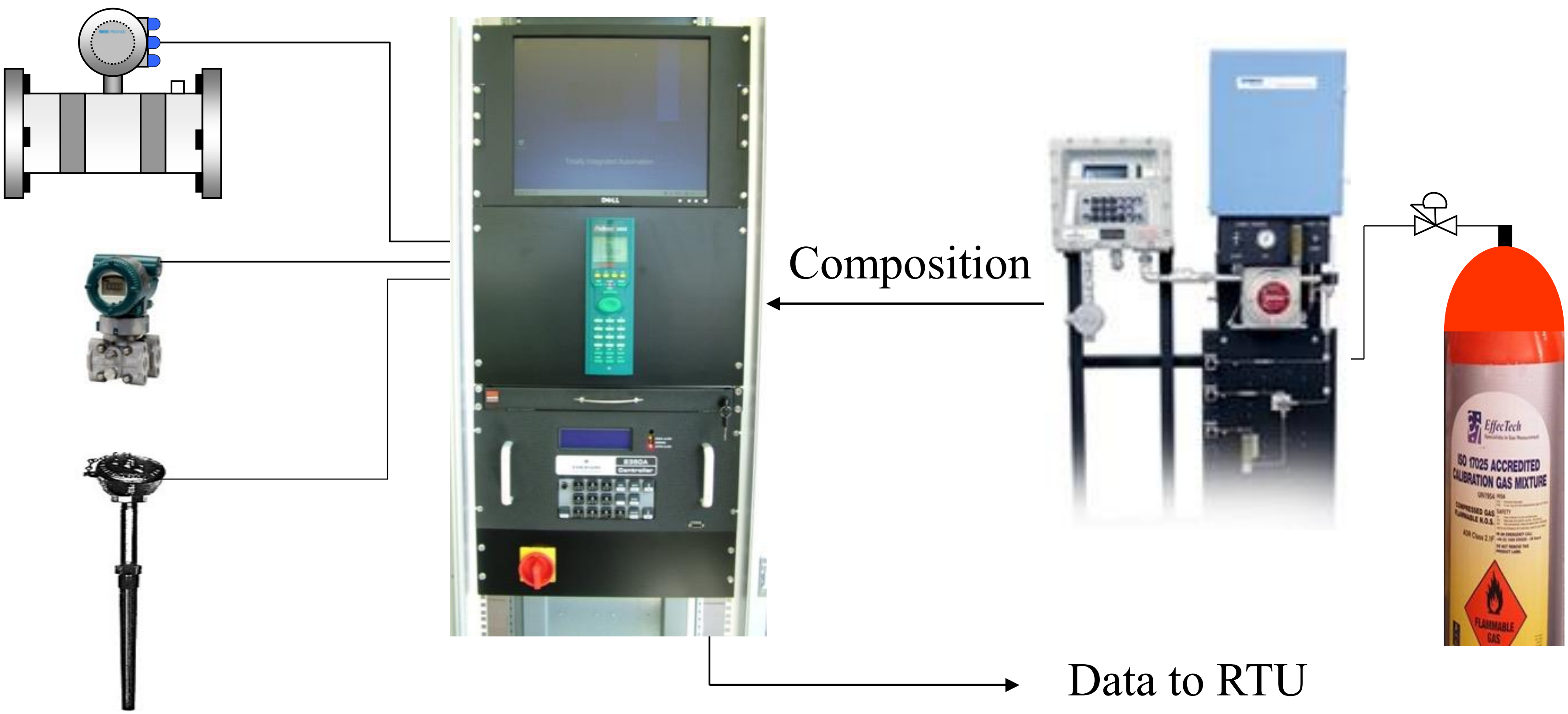
Calculated Calorific Value = 38.725 MJ / m^3

Difference of: - 0.006 MJ / m^3

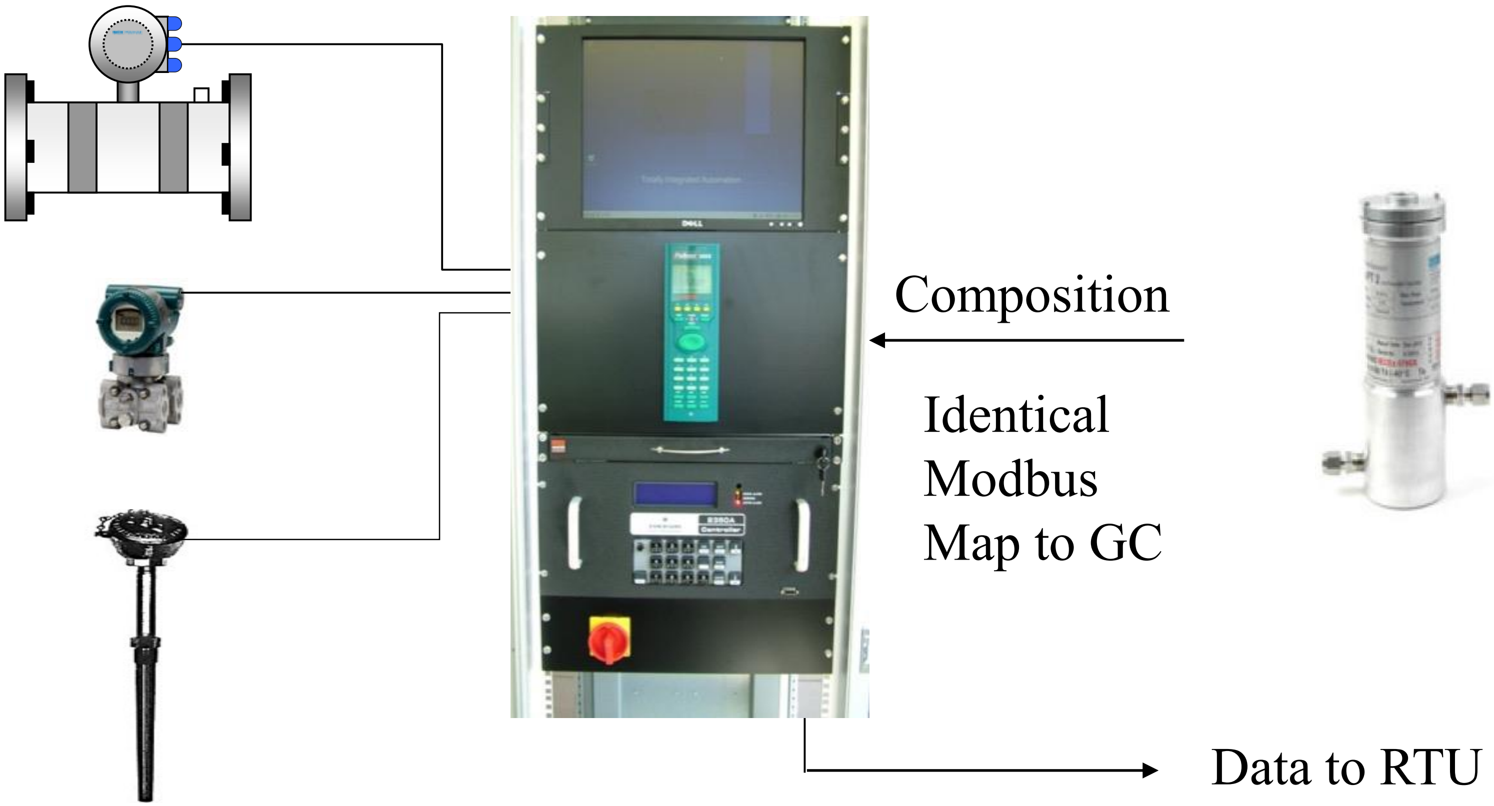
A New Method for LNG Energy Determination

Physical Property Calculations	11 Components	5 Components	Δ Difference
Compressibility @ 15 ^{O}C	0.9978	0.9978	0.0000
Density @ 0 ^{O}C	0.7245	0.7245	0.0000
Relative Density @ 15 ^{O}C	0.5912	0.5912	0.0000
Gross CV @ 15 ^{O}C	38.7308	38.7335	0.0027
Net CV @ 15 ^{O}C	34.9212	34.9239	0.0027
Carbon Emission Factor	45.9882	45.9882	0.0000
Theoretical Air Requirement	9.7865	9.7865	0.0000
Wobbe @ 15 ^{O}C	50.3719	50.3756	0.0037

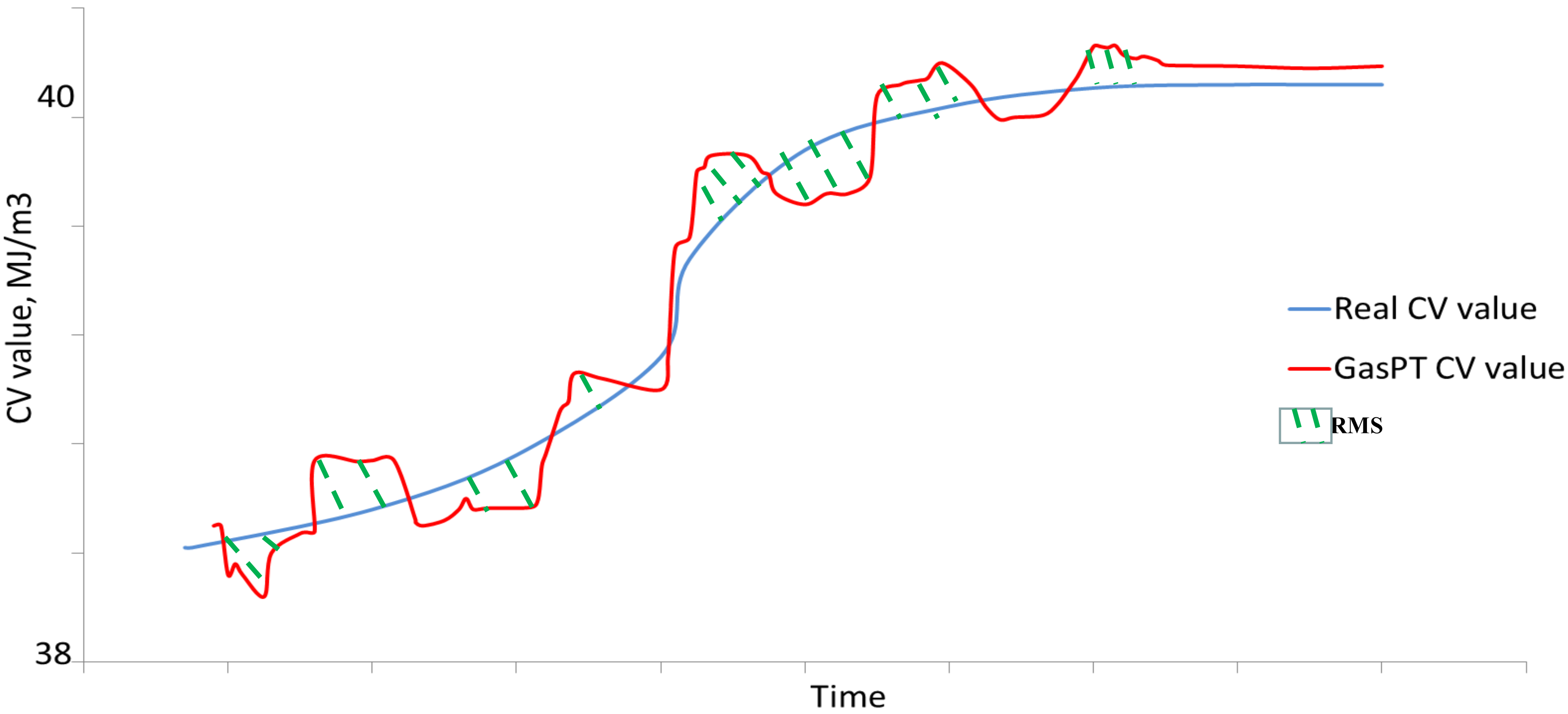
Integration into Metering Systems



Integration into Metering Systems



RMS Error



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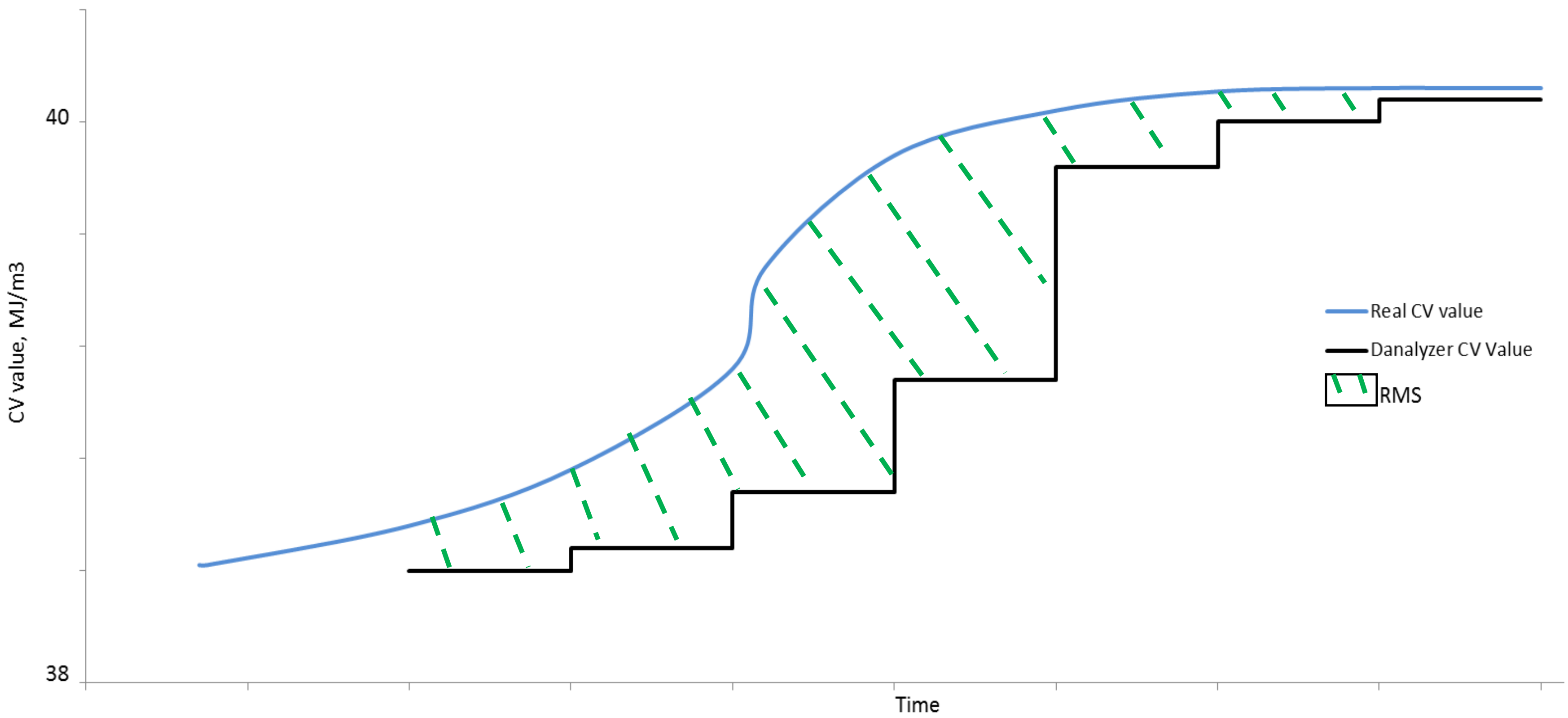

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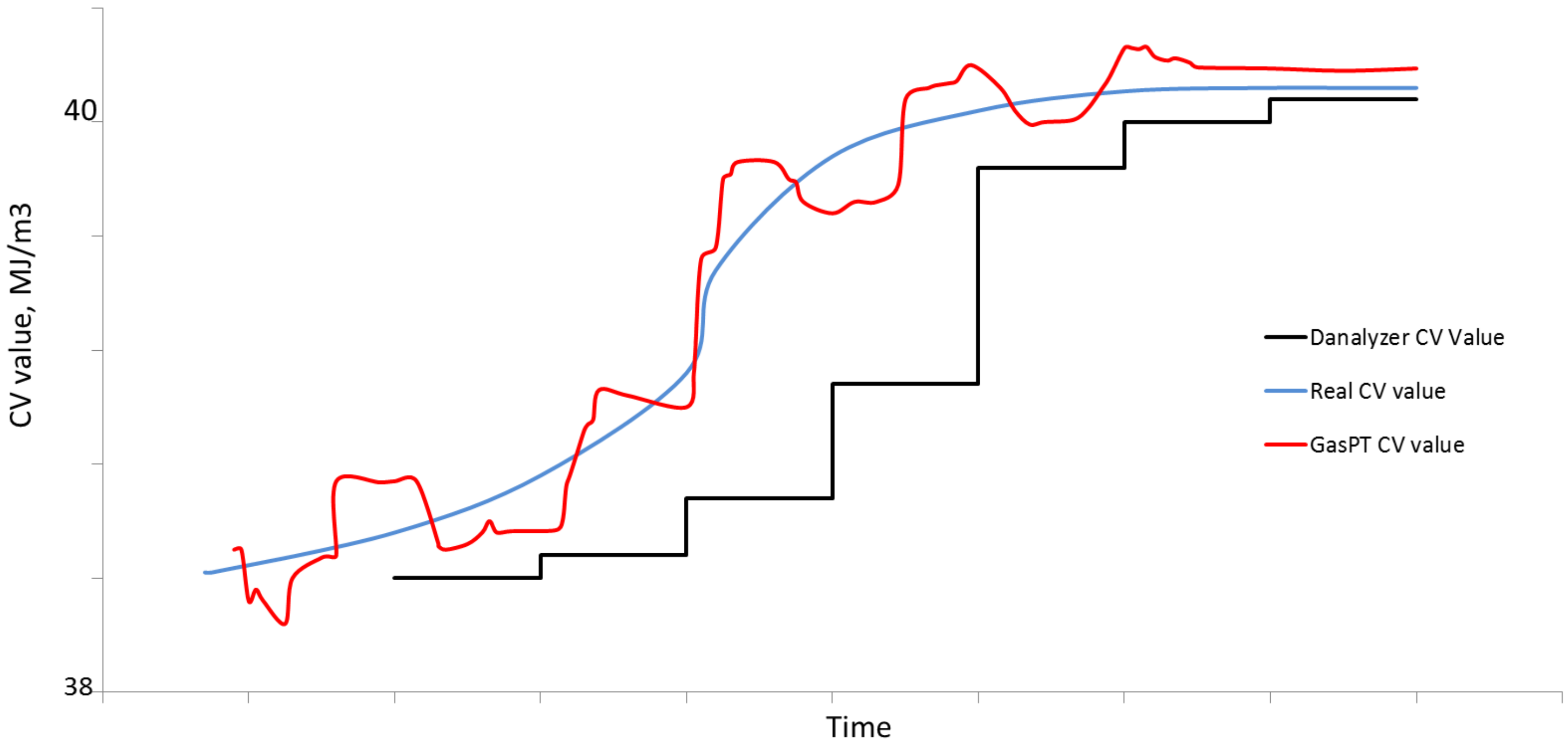

40
38
CV value, MJ/m3
Time
Danalyzer CV Value
Real CV value
GasPT CV value

A New Method for LNG Energy Determination – The Benefits

- Reduced uncertainty of LNG energy measurement versus GC
- Reduced CAPEX versus GC and other methods
- Reduced OPEX and maintenance versus GC and other methods
- Suitable for multiple applications within the LNG value chain
- Fiscal approved technology and proven in the field over years

Thank you for your time and attention