Technical Note to Energy Regulators

GasPTi Measurement of Natural Gas Quality

A submission to support product approval
on behalf of Orbital Gas Systems, UK

Contents

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Introduction

The purpose of this note is to demonstrate how GasPT, an inferential gas properties transmitter, can meet international standards in the measurement of the quality of natural gas.

Worldwide, the expanding market for natural gas is generating the need for improved monitoring and energy accounting, as natural gas is traded across international boundaries through pipeline interconnectors or shipped liquefied natural gas (LNG) before delivery to new customers. Increased international trading and new unconventional gas sources (shale gas, biomethane) are resulting in downstream users seeing greater variation in natural gas quality. This has triggered the development of the GasPT which provides gas quality information in real time, so that control and fiscal metering of natural gas can be performed to a level previously unachievable.

Although it is not a gas chromatograph (GC), and does not work in the same way as a GC, the GasPT instrument provides fast and accurate information on the key physical properties of natural gas such as calorific value (CV), relative density (RD) and Wobbe Index (WI).

GasPT has been designed by GL Industrial Services (formerly British Gas R&D UK) and it is now licensed worldwide and exclusively to Orbital Gas Systems. In addition, a unique gas sampling and gas conditioning system has been developed and integrated with the GasPT instrument to give accurate and rapid gas quality monitoring (GasPTi). The advantages of GasPTi over GCs in speed of response, near-zero maintenance and cost are leading to a wide application of GasPTi across the production, supply and end-use of natural gas with an overall improvement in energy accounting.

An international network of distributors for GasPT has been organised in order to provide knowledgeable and immediate local support to customers worldwide.

This note provides a description of how the GasPT instrument operates and details the international regulatory approvals and safety certification gained to date, together with some examples demonstrating the range of applications of the GasPTi system worldwide.

At Orbital Gas Systems we believe the information provided in our note gives a compelling argument for the approval of GasPT for both process control and fiscal metering applications as it has met the international standards all our current customers have requested. We would be very pleased to provide a GasPTi system complete with gas conditioning for further testing either in the laboratory or in the field, as required by government agencies.

Description of Operation

The GasPT employs the concept of the “effective composition.” This is the idea that a gas composed of hydrocarbons, nitrogen and carbon dioxide can be represented by a simpler gas mixture employing fewer hydrocarbons. GasPT uses correlative techniques to infer an equivalent five-component gas mixture (methane, ethane, propane, nitrogen and carbon dioxide). All of the hydrocarbons (including C4+) are resolved into the three “effective” hydrocarbons by using a simple process that balances the hydrogen and carbon atoms. The physical measurements made by GasPT are speed of sound, thermal conductivity and carbon dioxide. The speed of sound measurement is made via use of a unique acoustic resonator and speed of sound has a good correlation with relative density. Thermal conductivity is measured at ambient and an elevated temperatures with good correlation to calorific value.

Carbon dioxide is measured by an NDIR sensor and this is done because the molecular weights of carbon dioxide (CO_2) and propane (C_3H_8) are equivalent. In an earlier version of the instrument, this equivalency required additional calibration to suit an expected set of gas compositions. GasPT now has CO2 measurement, thereby improving its accuracy and giving the widest application to all natural gases without customised calibration.

From the inferred effective gas mixture of methane, ethane, propane, nitrogen, and measured carbon dioxide, the GasPT uses ISO6976 to calculate the gas quality characteristics of calorific value (CV), relative density (RD), Wobbe index (WI), compression factor (Z), motor octane number (MON) and methane number (MN).

The instrument does not provide a full compositional analysis of the gas sample, as a gas chromatograph would; however, test results show the GasPT measurements of CV and Wobbe are better than $\pm$0.5% error (OIML R140 Class A instrument).

See Appendix A for a description of the GasPT components.

See Appendix B: GasPT Specification for details on operational range and performance.

Certification

GasPT has been certificated by Baseefa, the UK approvals service, as flameproof equipment suitable for safe use in Zone 1 and Zone 2 hazardous areas.

Certification has been gained demonstrating compliance with ATEX, IECEx and CSA regulations.

The ATEX Directive requires certified products to be marked with the CE mark (confirms compliance with mandatory European Commission Electro Mechanical Compatibility regulations and the Low Voltage Directive for equipment containing mains voltages). GasPT has all these approvals and is marked accordingly with ATEX, CE, IECEx and CSA marks.

The CE mark for GasPT2 is CE 1180 which represents Baseefa as our notified approvals body.

GasPT Safety Interface

10 ATEX 0157 Ex II(1)G [Ex ia Ga] IIB (-20ºC $\leq$ Ta $\leq$+50ºC)
EN 60079-0 : 2009 EN 60079-11: 2007

IECEx BAS 10.0084 Ex ia Ga IIB (-20ºC ≤ Ta ≤+50ºC)
IEC 60079-0:2004 Ed 4.0 IEC 60079-0:2007-10 Ed 5 IEC 60079-11:2006 Ed 5
CSA Certificate No. 2429362 Ex ia Ga Iib

GasPT MU Probe

10 ATEX 0176 Ex II(2)G [Ex d ia Gb] IIB T4 (-20ºC ≤ Ta ≤+55ºC)
EN 60079-0 : 2009 EN 60079-1 : 2007EN 60079-11:2007
IECEx BAS 09.0093 Ex d ia IIB T4 Gb (-20ºC ≤ Ta ≤+50ºC)
IEC 60079-0:2004 Ed 4.0 IEC 60079-0:2007-10 Ed 5 IEC 60079-1:2007-04 Ed 6
IEC 60079-11:2006 Ed 5
CSA Certificate No. 2429362 Ex d IIb T4 Gb

GasPT AU Probe

02 ATEX 0139X Eex ia IIB T4 (-40ºC ≤ Ta ≤+70ºC)
EN 50014:1997 Am1/2 EN 50020:2002 EN50284:1999
IECEx BAS 12.0008X Ex ia IIB T4 Gb (-40ºC ≤ Ta ≤+70ºC)
IEC 60079-0:2004 Ed 4.0 IEC 60079-0:2007-10 Ed 5 IEC 60079-1:2007-04 Ed 6
IEC 60079-11:2006 Ed 5
CSA Certificate No. 2429362 EX ia IIb

American Bureau of Shipping: ABS approval has been gained for GasPT applications aboard LNG tankers. Certificate No. 13-LD1105876-PDA

Copies of certificates are shown in Appendix C: GasPT Certificates.

Baseefa, ATEX, IECEx and CSA test reports can be provided if required.

An independent laboratory report confirming satisfactory electromagnetic compatibility (EMC) with tolerance to cable and air-borne interference can also be provided if required
.

Countries with GasPT Installations

Europe: UK, Eire, France, Belgium, Netherlands, Denmark, Germany, Poland, Italy, Spain, Portugal, Turkey

Americas: USA, Canada, Columbia, Chile, Mexico

Far East: Thailand, S. Korea, Japan, China

Types of Application

There is a wide range of diverse applications where GasPT systems have been installed, reflecting the many benefits of GasPT over conventional technology in rapid response, accuracy, cost and low maintenance.

Gas Transmission Networks

National Grid	UK
Snam Retegas	Italy
Fluxys	Belgium
PTT	Thailand
Alliance Pipelines	USA

Xcel USA

GasPT has been used for control of mixing and blending gas streams to obtain required gas specifications for transmission pipeline gas. Custody transfer between networks.

Gas Distribution Networks

GdF Suez France
SoCal Sempra USA
Shizuoka Gas Japan
United Utilities UK
Scottish & Southern UK

Used for custody transfer and fiscal metering on grid off-takes to gas distribution networks or large commercial and industrial customers.

Gas Production and Process Plant

BP UK
Perenco UK
Air Products UK

GasPT used to monitor the export gas CV and Wobbe from gas production plants prior to injection into the high pressure gas transmission grid.

OEM Instrumentation

Emerson Daniels USA
Hydrafact Germany
Flonidan Denmark
Vestas Controls Denmark
Amlorit UK
4C Measurement UK
Anatrol UK

GasPT used in parallel backup operation to gas chromatographs to record CV and Wobbe when GC fails and to monitor peaks in CV which cannot be recorded by GCs because of slow scan time.

Glass Production

Pilkington UK
Owens Corning UK
PPG China
Santos Barosa Portugal

GasPT used to control combustion air/fuel ratio in response to changing gas supply quality to ensure consistent burner flame shape and temperature on glass production process.

Steel Manufacture and Metal Heating

Corus UK
PPG China

Formerly British Steel, Corus has used GasPT to adjust air/fuel ratio on large industrial burners for metal reheating furnaces on steel production process.

Industrial Research

NationalInstitute AIST Japan
Applied Technology Japan

GasPT used to study combustion control in response to gas quality variations.

Gas Turbines

GE Power & Water Italy
IHI Corporation Japan
KBK Chitose Airport Japan

Mitsubishi Power Japan
EoN Netherlands
AFC Energy UK
GasPT used for fast scanning of gas quality variation and adjustment of multiple fuel injection points on large gas turbines.

Combined Heat & Power Gas Engines
Yanmar Japan
Niigata Power Japan
Rapid Flame UK
GasPT used to control ignition timing on large CHP gas engines where ignition requirements will vary with gas quality.

LNG Importation Terminals
Tokyo Gas Japan
Osaka Gas Japan
POSCO S. Korea
Shell UK
Qatar Gas UK
National Grid UK
GasPT used to monitor CV and Wobbe of boil-off gas from LNG tanks and to control CV and Wobbe of terminal export gas into the medium pressure distribution network.

Marine LNG Tanker Transportation
Cryostar/CNOOC France/China
GasPT used in marine applications to monitor CV of boil-off gas from ship LNG tanks and control of gas Wobbe prior to supply to ship power generation system. This is a very harsh environment where GCs are unable to be installed. American Bureau of Shipping ABS approval was gained for these applications (see Appendix C).

BioMethane Production
National Grid UK
Scotia UK
Severn Trent UK
GTS NL
GasPT used to monitor the export gas from biogas production plants as part of gas clean up (CO_2 removal or LPG enrichment) and the CV and Wobbe downstream of the mixing point with the national grid gas.

Gas Compressors
Dominion USA
Centrica UK
GasPT used to monitor CV and calculate molar mass for compressor control on high pressure gas transmission pipelines.

Key Benefits

Fast Scan and Response time:

- GasPTi response time T90 from the sample point to the analysis output is approximately 10 seconds (T90 is 90% of final value in response to a step change).
- The GasPTi scan time can be as fast as one reading every 2 seconds and this compares typically with more than 5 minutes for the Gas Chromatograph.

The impact of this is significant in terms of energy accounting on gas transmission systems.

Flow measurement is instantaneous but GCs are generally measuring CV of gas which, over 5 minutes, has travelled considerable distance down the pipeline. Therefore, energy metering has traditionally mismatched flow and CV measurement. This may not have been an issue when energy sources and CV were generally stable but as gas quality variations increase, speed of measurement to ensure accurate energy accounting becomes more important. The delayed CV measurement from GCs may also result in errors in the calculation of compressibility (z) and speed of sound for ultrasonic meter calibration.

The speed of response is also critical for process control applications where product quality can be affected by variations in gas heating value. Typical examples are float glass, glass bottle and glass fibre production, ceramics and metal heating plants where flame shape and flame temperature will change with gas quality variations.

Low/zero maintenance:

- GasPT requires one validation check with a known sample gas taking less than one hour every year. This compares with the considerable effort required to keep a GC in calibration with skilled labour (works chemist) and use of carrier gases and reference gases.

Easy to Install, Configure and Use:

- Typically GasPTi systems are installed and configured in about one hour. All communications and operational parameters can be changed on line via laptop PC and setup is very simple. The communications with modems, supervisory computers and datalogging systems is via RS485 serial interface using the international industry standard MODBUS protocol. Ethernet or analogue I/O signals can be provided.

Integrated System with Sample Probe and Gas Conditioning Enclosure:

- GasPTi-F is mounted directly on the pipeline. A unique vortex eliminating sample probe is provided which gives fast response, small sample and zero probe vibration. This can be seen as having operational, environmental and safety benefits over traditional GC installations.

- There is no requirement for gas sample lines, additional housings or gas cylinder storage as with GCs. This eliminates the need for civil engineering works (foundations for housings) and means the amount of gas flowing through GasPT2 and vented is typically 10 times less than a GC system.

Low cost:

- Initial purchase cost and installation cost of GasPTi are considerably less than GCs and in addition, the overall lifetime cost of ownership is further reduced by the GasPTi advantages over GCs in significantly lower operational and maintenance costs.

See Appendix D: Cost of Ownership

Laboratory Tests and Field Trials

GasPT has undergone numerous laboratory tests and field trials across the world as gas transmission companies and government regulatory authorities prove the performance of our instrument:

United Kingdom (National Grid and OFGEM)

The test programme for this approval, carried out by independent laboratory SGS Ltd on behalf of the UK government agency Ofgem, was in three phases:

Phase 1: Assessing the accuracy, repeatability and response time of the GasPT with respect to its derivation of calorific value. The requirement was for CV measurement of 10 gas samples to 0.2MJ/m3 accuracy with repeatability between 2 gas samples and response time to within 0.2MJ/m3 within 4 minutes.

Phase 2: Testing the single-stream sampling system with particular reference to operational characteristics including alarms, sample flow variation, sample pressure variation, temperature dependence (-10 to +50 DegC), power loss, electromagnetic compatibility and an automated 35 day gas examiners test.

Phase 3: Inspecting the security and integrity of supply plus data and reporting procedures.

GasPT has successfully passed the tests with CV error less than ± 0.5% over a wide gas sample range (CV between 37.32 to 43.06 MJ/m3) and at present has been given limited approval by Ofgem for applications in the UK.

Italy (Snam Rete Gas and AEEG Autorita Energia)

These tests were performed at a metering and compressor site in Mesura, Italy and consisted of a 12 months trial comparing GasPT measurements with a Daniels gas chromatograph Model 500. Over 12 months the GasPT was fully operational 100% of the time but the GC was offline for 14% of the time.

- Six gas samples were collected by Snam from various points on their transmission system and the results of CV performance tests every 3 months with these samples are shown as average values in Appendix E.

- The results obtained from the tests of accuracy and durability, using daily data and hourly data show that the GasPT is considered to be a Class A instrument for CV determination according to the Recommendation OIML R140: 2007 (E) which provides an Maximum Permissible Error for CV of ± 0.5%.

Periodic tests to verify the accuracy of measurement and endurance tests showed no drifts in calibration over the 12 months trial period. A 24 month field trial followed, of 4 units installed at separate locations on distribution networks in N.Italy and this demonstrated accuracy of Calorific Value (CV) and Wobbe measurements typically better than 0.2% error and always better than 0.5% as required by the International Organisation of Legal Metrology (OIML) and the American Gas Association (AGA). A 6 month comprehensive review of the output data was then undertaken by The University of Milan to confirm durability and accuracy.

This has resulted in Snam Retegas placing an initial order in February 2016 for 400 GasPT devices to be deployed across the Italian gas network, including 65 high pressure gas transmission installations. All 400 systems will be delivered by September and an installation programme is under way via our Italian distributor. This part of a large project approved by the Italian Regulatory Authority for Electricity Gas and Water requiring several thousand additional metering points on Italy networks

France (Engie and GRTgaz)

Engie Crigen R&D, St Denis, Paris has tested the GasPTi system on behalf of GRTgaz and performance over many gas samples and temperature range -10 to +40degC was better than ±0.2% error on CV.

The tests have resulted in a field trial now being run in N.France by GRTgaz.

Spain (Enagas and Repsol)

Both Enagas (gas transmission) and Repsol (gas producer and shipper) have completed laboratory tests and have forwarded the results to their respective operational departments.

In both cases, the GasPT performance was less than ± 0.5% error on CV measurement.

Poland (GazSystem and PGNiG)

GazSystem (gas transmission) arranged a field trial at a pipeline mixing point in Krakow. This provided the opportunity to compare GasPT with a gas chromatograph (Daniels 700) under pipeline conditions with 3 gas samples being switched continuously over a 2 week period.

The GasPT performance was typically better than ± 0.2% error on CV and as a result further laboratory testing has been performed by PGNiG, Warsaw to demonstrate that GasPT complies with OIML R140: 2007 (E) recommendations in all aspects. These results have shown GasPT to be within errors of ± 0.15% on CV across a range of gas samples from CV of 26 to 40 MJ/m3.

Netherlands (DNV GL, Gasunie and NMi)

DNV GL in Netherlands have performed laboratory test on GasPT on behalf of Gasunie (gas transmission).

The tests successfully showed that GasPT meets the expected performance level of less than ± 0.5% error on CV measurement. As a result a set of field trials has been arranged by Gasunie to test the operational configuration and durability of GasPTi in the field.

NMi Certin BV independent test and approvals laboratory in Rotterdam has tested GasPT to OIML R140 performance and approved GasPT as a Class A instrument (better than ±0.5% error on CV) – see test certificate TC8670 in Appendix C.
The test results passed OIML requirements -10degC to +50degC although OIML standard approval bands limit this to +40 degC.
As part of the evaluation there was considerable EMC testing which was successfully passed and also evaluation to WELMEC 8.8.

Canada (NovaChem and TransCanada)

These tests have been performed by NovaChem (R&D) on behalf of TransCanada (gas transmission) at a compressor site operated by TransCanada.

The results of testing some 18 different gas samples with CV between 36 and 42 MJ/m3 and with CO2 content between zero and 5% show GasPT2 has a CV measurement with error typically less than ± 0.2%.

Colombia (CDTdeGas and TGI)

These tests were performed by CDTdeGas on behalf of the gas transmission company TGI. The tests were based on the Standard ASTM D3764-09[1] and the results obtained were then analyzed by following the Standards ASTM D6299 [2] and ISO 10723[3].

[1] ASTM D3764-09. Standard Practice for Validation of the Performance of Process Stream Analyzer Systems
[2] ASTM D6299-10. Standard Practice for Applying Statistical Quality Assurance and Control Charting Techniques to Evaluate Analytical Measurement System Performance
[3] ISO 10723. Natural Gas — Performance evaluation for on-line analytical systems.

The results showed GasPT acceptable repeatability, reproducibility and linearity with CV error less ± 0.5%.

Mexico (Tejasgas and Fermaca)

These test were carried out by Tejasgas on behalf of the gas transmission company Fermaca at their gas pipeline metering station in Atlacomulco supplying Mexico City.

The results showed a maximum error of + 0.18% in CV of the GasPTi sampling and analysis system compared with a Danalyser GC.

USA (Energy Transfer Partners)

Trials were carried out by ETP in Houston on a section of their gas transmission pipeline. The tests demonstrated satisfactory accuracy and response.

USA (Colorado State University and Pipeline Research Council International)

Laboratory tests were performed by Colorado State University on behalf of PRCI and these compared GasPT with other technologies. GasPT proved best on both accuracy and response time tested over a range of natural gases. The University has taken GasPT forward for a gas engine test programme.

Thailand (PTT)

Laboratory tests were completed in the Opertaional Centre of PTT, Bangkok, using several gas samples with CV varying between 838 btu/ft3 and 1001 btu/ft3. Results showed CV error of the GasPT to be less than ±0.5% compared with a GC. GasPT has been placed on the PTT vendor list of products for future projects.

Future Trials

Test programmes are being developed with the gas transmission companies and Government Energy Regulators for Turkey (IGDAS), Germany (Eon), and Czech Republic (Net4Gas).

In addition to the laboratory performance tests there have been EMC Electro Magnetic Compatibility tests carried out by an independent test house. The following tests have been performed to demonstrate compliance with European standards and CE marking:

- Radiated field immunity to EN61000-4-3
- Conducted RF immunity to EN61000-4-6
- Electrical fast transients to EN61000-4-4
- Electrostatic discharge to EN61000-4-2
- Power surge to EN61000-4-5
- Voltage dips and interruptions to EN61000-4-11
- Power frequency magnetic field to EN61000-4-8

All test data and reports can be provided if required.

Regulatory Approvals

Europe

Within the European Union, the Directives of the European Commission generally take precedence over national legislation and regulations. The existence of a Directive on Gas Quality Measurement would therefore set our standard for GasPT performance testing and approvals.

The Measuring Instruments Directive (MID) 2004/22/EC includes gas metering (volume) accuracy requirements but does not include gas quality measuring accuracy.

The European Commission required the specification of a set of standards on Gas Quality in order to create a competitive single European gas market according to the Directive 2003/55/EC. The technical group CEN were given a mandate (M/400 EN) to create a common standard for European gas quality but this has focused on Wobbe and CV high and low limits and it does not define the accuracy of measurement for either parameter.

So, in the absence of a European standard, most European countries are using the recommendations of the International Organisation of Legal Metrology (OIML).

This is text from OIML R 140: 2007 (E) Measuring Systems for Gaseous Fuel prepared by the OIML Technical Subcommittee TC 8/SC 7 *Gas metering* 2007

Section 8.8.1 Types of calorific value determining devices (CVDD):
"The calorific value of natural gas can be determined using different techniques which fall into the following categories:
direct measurement, i.e. direct combustion, catalytic combustion,
indirect measurement, i.e. stoichiometric combustion,
inferential determination, i.e. correlation with other measured properties, composition based calculation."

This section demonstrates that inferential techniques such as GasPT2 are acceptable to OIML.

Section 7.4.1 Time interval for determination of CV:
"In principle, the energy to be determined should be the sum of the instantaneous energies delivered. However, in practice this is not possible and it is acceptable not to associate the instantaneous calorific value to the instantaneous corresponding volume…"

Until now, it has not been possible to determine instantaneous energy flow but with near real-time CV measurement GasPT provides the opportunity to improve overall energy measurement by direct communications with flow computers.

Section 6.3.1 Maximum permissible errors (CV Measurement - only CVDD): Table 2:
Class A ± 0.50 %
Class B ± 1.00 %
Class C ± 1.00 %

Comprehensive laboratory tests and field trial results from different countries have shown GasPT to be much better than ±0.5%, the requirement for Class A instruments.

North America
International regulatory bodies such as the American Gas Association (AGA) recognize inferential techniques as a valid alternative to gas chromatograph analysis for heating value measurement in relation to gas custody transfer.

This is the text from AGA Report No.5: Natural Gas Energy Measurement:
Prepared by the Transmission Measurement Committee March 2009:
Section 5.3: Heating Value from Inferential (Correlative) Methods
"Inferential methods can provide cost savings over the traditional gas chromatograph installation and near real-time gas property determination at locations where spot or composite sample analyses are traditionally used…..Although this (inferential method) is a relatively new technology, it is considered to be fundamentally sound and capable of providing accuracies acceptable for custody transfer measurement."

Section 4.1: Uncertainty – Acceptance Criteria, AGA Report No.5 requires that in custody transfer applications the estimated uncertainty including error in heating value determination should be less than ±0.5%.

Conclusions

1. GasPT has undergone comprehensive laboratory testing and field trials on gas transmission pipelines to show accuracy of CV and Wobbe measurement better than ±0.5%.

2. GasPT meets the performance recommendations of OIML R 140: 2007 (E): Measuring Systems for Gaseous Fuel as a Class A instrument for CV measurement.

3. GasPT complies with the performance requirements of AGA Report No.5 Natural Gas Energy Measurement for CV determination.

4. Both OIML R140: 2007 (E) and AGA Report No.5 specifically state that inferential techniques *(such as GasPT)* are capable of providing accurate CV measurement and as such can be considered for use as custody transfer measurement and fiscal metering devices.

5. GasPT has safety approval from ATEX, IECEx and CSA for use in hazardous areas (Zone 1 and Zone 2).

6. As a lower cost solution than gas chromatographs to on-line gas quality measurement, GasPT can be employed much wider across gas transmission and

distribution networks together with end-user application and a resulting improvement in overall network monitoring, control and energy accounting.

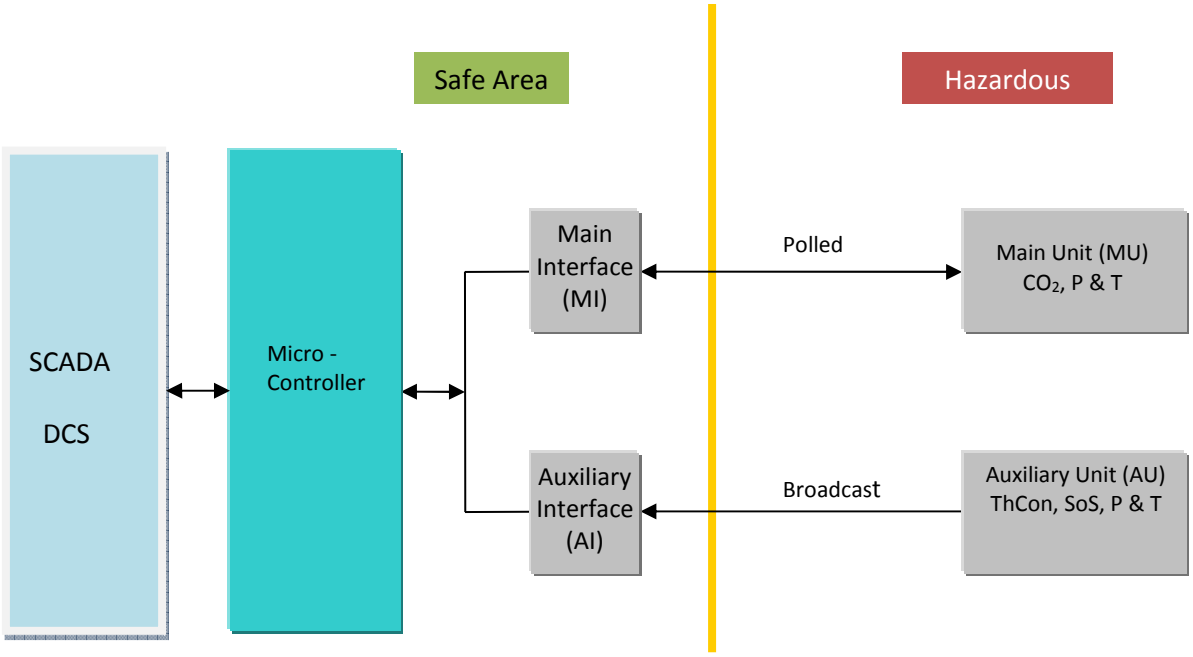
At Orbital Gas Systems we believe the information provided in our memorandum gives a compelling argument for the approval of GasPTi for both process control and fiscal metering applications as it has met the international standards all our current customers have requested. We would be very pleased to provide a GasPTi system complete with gas conditioning for further testing either in the laboratory or in the field, as required by government agencies.

Appendix A: Description of Components

The **Main Unit (MU)** contains the main processor along with sensors for CO2, temperature and pressure. This is the unit in which the values for the gas properties are calculated and it is the one that communicates with the user via laptop, DCS or SCADA system.

The **Ancillary Unit (AU)** contains speed of sound, thermal conductivity, temperature and pressure sensors. This unit sends information to its associated Main Unit.

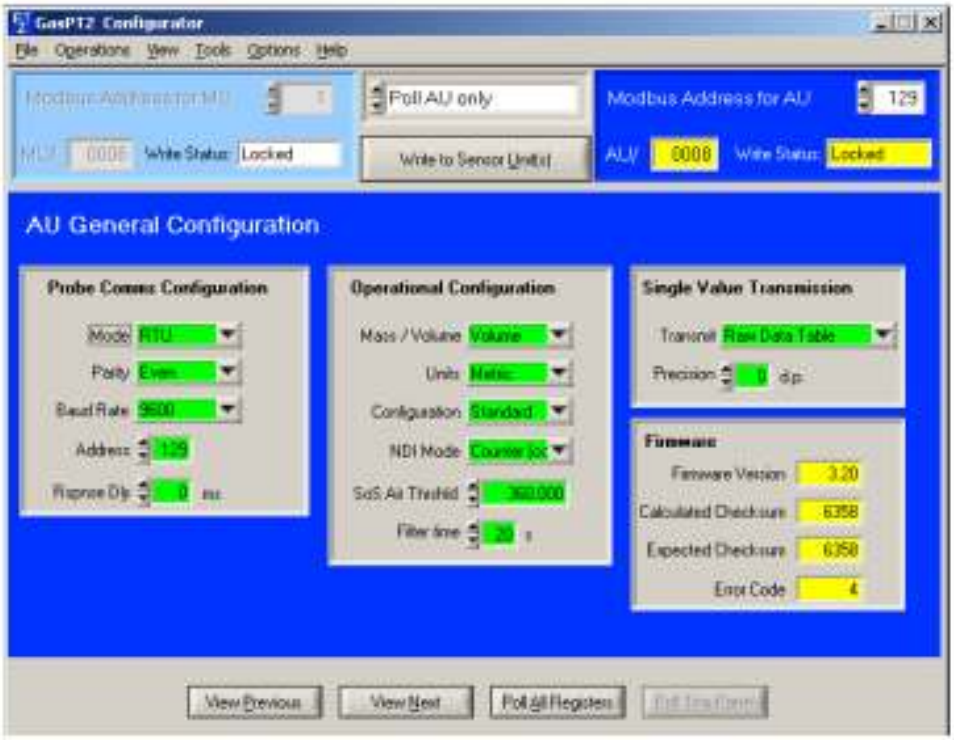
Purpose-designed and certificated safety interfaces provide galvanic isolation for the sensor units. The power supply section of the interface uses a transformer as the isolating element and the serial communication signals are opto-isolated. In addition, each interface limits the voltages, currents and power supplied to its sensor unit. By limiting these parameters, the sensor units can be operated in a hazardous area as they do not represent a source of ignition.



The figure above shows the manner in which the various elements of a GasPT system relate to each other. The connections between the elements are all two-wire RS485 using a MODBUS® message protocol.

The output from the Microcontroller can be Ethernet (TCP/IP), Serial (RS485 or RS232) or analogue (4-20mA, 1-5Vdc).

GasPT is provided with configuration and display software such that setup can be completed within one hour and all parameters can be viewed and recorded as necessary with scan rates down to readings once every two seconds if needed.



The Microcontroller can be used as a datalogging device storing either to permanent memory or to flash card. We have also used the Microcontroller to provide calculate and output parameters such as molar mass, carbon emission factor and specific heat ratio which are not standard GasPT outputs.

Appendix B: Specification

Operational Range

Sensor Units

Sample Gas Temperature	- 20 to +55 degC
Humidity	Non-condensing
Max Pressure (absolute)	1300 mbara(300 mbarg) 18.82 psia (4.3 psig)
Sample Gas Flowrate	0.1 l/min to 1.0 l/min 0.21ft3/hr to 2.1 ft3/hr
Hazardous Area Classification	Suitable Zone 1 and Zone 2 Hazardous Areas

Safety Interfaces

Ambient Temperature	-20 to +50 degC
Humidity	Non-condensing
Hazardous Area Classification	Non-hazardous (Safe) Area
Power Requirement	22 Vdc @ 200 mA

Performance

Calorific Value (over normal range)	
- Accuracy	Better than ± 0.5 %
- Repeatability	0.04 MJ/m^3
- Drift	Less than ± 0.1 MJ/m3 per year,
Relative Density	±0.0016 (< 0.25% Error)
Sample Gas Temperature	±0.3°C (< 0.54°F)
Sample Gas Pressure	± 2 mbar
Gas property update time	2 to 20 seconds (default 8 seconds)
Gas property averaging time constant	2 to 255 seconds (default 20 seconds)

Appendix C: Certificates of Approval

Certificate Number
Baseefa10ATEX0176

Issued 28 October 2010

1 **EC - TYPE EXAMINATION CERTIFICATE**

2 **Equipment or Protective System Intended for use in Potentially Explosive Atmospheres Directive 94/9/EC**

3 EC - Type Examination Certificate Number: **Baseefa10ATEX0176**

4 Equipment or Protective System: **CO2 Gas PT2 Probe**

5 Manufacturer: **GL Industrial Services UK Limited T/A GL Noble Denton**

6 Address: **Holywell Park, Ashby Road, Loughborough, Leicestershire, LE11 3GR**

7 This equipment or protective system and any acceptable variation thereto is specified in the schedule to this certificate and the documents therein referred to.

8 Baseefa, Notified Body number 1180, in accordance with Article 9 of the Council Directive 94/9/EC of 23 March 1994, certifies that this equipment or protective system has been found to comply with the Essential Health and Safety Requirements relating to the design and construction of equipment and protective systems intended for use in potentially explosive atmospheres given in Annex II to the Directive.

The examination and test results are recorded in confidential Report No. **GB/BAS/ExTR10.0219/00 & GB/BAS/ExTR10.0220/00**

9 Compliance with the Essential Health and Safety Requirements has been assured by compliance with:

EN 60079-0: 2009 EN 60079-1: 2007 EN 60079-11: 2007

except in respect of those requirements listed at item 18 of the Schedule.

10 If the sign "X" is placed after the certificate number, it indicates that the equipment or protective system is subject to special conditions for safe use specified in the schedule to this certificate.

11 This EC - TYPE EXAMINATION CERTIFICATE relates only to the design and construction of the specified equipment or protective system. Further requirements of the Directive apply to the manufacturing process and supply of this equipment or protective system. These are not covered by this certificate.

12 The marking of the equipment or protective system shall include the following :

⟨Ex⟩ II 2 G Ex d ia IIB T4 Gb (-20°C ≤ T_a ≤ +55°C)

This certificate may only be reproduced in its entirety, without any change, schedule included.

Baseefa Customer Reference No. **5023**

Project File No. **10/0224**

This certificate is granted subject to the general terms and conditions of Baseefa. It does not necessarily indicate that the equipment may be used in particular industries or circumstances.

pp D BREARLEY

R S SINCLAIR
DIRECTOR
On behalf of
Baseefa

Baseefa
Rockhead Business Park, Staden Lane,
Buxton, Derbyshire SK17 9RZ
Telephone +44 (0) 1298 766600 Fax +44 (0) 1298 766601
e-mail info@baseefa.com web site www.baseefa.com
Baseefa is a trading name of Baseefa Ltd
Registered in England No. 4305578. Registered address as above.

1 # EC - TYPE EXAMINATION CERTIFICATE

2 **Equipment or Protective System Intended for use in Potentially Explosive Atmospheres Directive 94/9/EC**

3 EC - Type Examination Certificate Number: **Baseefa02ATEX0139X**

4 Equipment or Protective System: **Gas PT Probe**

5 Manufacturer: **ADVANTICA TECHNOLOGY LIMITED**

6 Address: **Ashby Road, Loughborough, Leicestershire, LE11 3GR**

7 This equipment or protective system and any acceptable variation thereto is specified in the schedule to this certificate and the documents therein referred to.

8 Baseefa (2001) Ltd. Notified body number 1180, in accordance with Article 9 of the Council Directive 94/9/EC of 23 March 1994, certifies that this equipment or protective system has been found to comply with the Essential Health and Safety Requirements relating to the design and construction of equipment and protective systems intended for use in potentially explosive atmospheres given in Annex II to the Directive.

The examination and test results are recorded in confidential Report No. **02(C)0200**

9 Compliance with the Essential Health and Safety Requirements has been assured by compliance with:

EN50014:1997 +Amds 1 & 2 **EN50020:2002** **EN50284:1999**

except in respect of those requirements listed at item 18 of the Schedule.

10 If the sign "X" is placed after the certificate number, it indicates that the equipment or protective system is subject to special conditions for safe use specified in the schedule to this certificate.

11 This EC - TYPE EXAMINATION CERTIFICATE relates only to the design and construction of the specified equipment or protective system. Further requirements of the Directive apply to the manufacturing process and supply of this equipment or protective system. These are not covered by this certificate.

12 The marking of the equipment or protective system shall include the following :

⟨Ex⟩ II 1G EEx ia IIB T4 ($-40°C \leq T_a \leq 70°C$)

This certificate may only be reproduced in its entirety, without any change, schedule included.

Baseefa (2001) Ltd. Customer Reference No. **5023** Project File No. **02/0200**

This certificate is granted subject to the general terms and conditions of Baseefa (2001) Ltd. It does not necessarily indicate that the equipment may be used in particular industries or circumstances.

R S SINCLAIR
DIRECTOR
On behalf of
Baseefa (2001) Ltd.

Baseefa (2001) Ltd.
Health and Safety Laboratory Site, Harpur Hill,
Buxton, Derbyshire SK17 9JN
Telephone +44 (0) 1298 28255 Fax +44 (0) 1298 28216
e-mail info@baseefa2001.biz web site www.baseefa2001.biz
Registered in England No. 4305578 at 13 Dovedale Crescent, Buxton, Derbyshire, SK17 9BJ

EC - TYPE EXAMINATION CERTIFICATE

2 **Equipment or Protective System Intended for use in Potentially Explosive Atmospheres Directive 94/9/EC**

3 EC - Type Examination Certificate Number: **Baseefa10ATEX0157**

4 Equipment or Protective System: **Gas PT2 Safety Interface**

5 Manufacturer: **GL Industrial Services UK Limited T/A GL Noble Denton**

6 Address: **Holywell Park, Ashby Road, Loughborough, Leicestershire, LE11 3GR**

7 This equipment or protective system and any acceptable variation thereto is specified in the schedule to this certificate and the documents therein referred to.

8 Baseefa, Notified Body number 1180, in accordance with Article 9 of the Council Directive 94/9/EC of 23 March 1994, certifies that this equipment or protective system has been found to comply with the Essential Health and Safety Requirements relating to the design and construction of equipment and protective systems intended for use in potentially explosive atmospheres given in Annex II to the Directive.

The examination and test results are recorded in confidential Report Nos. **GB/BAS/ExTR10.0182/00** & **GB/BAS/ExTR10.0210/00**

9 Compliance with the Essential Health and Safety Requirements has been assured by compliance with:

EN 60079-0: 2009 EN 60079-11: 2007

except in respect of those requirements listed at item 18 of the Schedule.

10 If the sign "X" is placed after the certificate number, it indicates that the equipment or protective system is subject to special conditions for safe use specified in the schedule to this certificate.

11 This EC - TYPE EXAMINATION CERTIFICATE relates only to the design and construction of the specified equipment or protective system. Further requirements of the Directive apply to the manufacturing process and supply of this equipment or protective system. These are not covered by this certificate.

12 The marking of the equipment or protective system shall include the following :

Ⓔx II (1) G [Ex ia Ga] IIB ($-20°C \leq T_a \leq +50°C$)

This certificate may only be reproduced in its entirety, without any change, schedule included.

Baseefa Customer Reference No. **5023**

Project File No. **10/0523**

This certificate is granted subject to the general terms and conditions of Baseefa. It does not necessarily indicate that the equipment may be used in particular industries or circumstances.

PP DBREARLEY

R S SINCLAIR
DIRECTOR
On behalf of
Baseefa

Baseefa
Rockhead Business Park, Staden Lane,
Buxton, Derbyshire SK17 9RZ
Telephone +44 (0) 1298 766600 Fax +44 (0) 1298 766601
e-mail info@baseefa.com web site www.baseefa.com
Baseefa is a trading name of Baseefa Ltd
Registered in England No. 4305578. Registered address as above.

IECEx Certificate of Conformity

INTERNATIONAL ELECTROTECHNICAL COMMISSION
IEC Certification Scheme for Explosive Atmospheres

for rules and details of the IECEx Scheme visit www.iecex.com

Certificate No.:	IECEx BAS 10.0093 issue No.:0	Certificate history:
Status:	**Current**	
Date of Issue:	**2010-10-28** Page 1 of 3	

Applicant: **GL Industrial Services UK Ltd T/A GL Noble Denton**
Holywell Park
Ashby Road
Loughborough
Leicestershire
LE11 3GR
United Kingdom

Electrical Apparatus: **CO2 Gas PT2 Probe**
Optional accessory:

Type of Protection: **Flameproof & Intrinsic Safety**

Marking: **IECEx BAS 09.0093**
Ex d ia IIB T4 Gb (-20°C ≤ Ta ≤ 55°C)

Approved for issue on behalf of the IECEx Certification Body: R.S. Sinclair pp DBREARLEY

Position: Managing Director

Signature:
(for printed version) DBrearley

Date: 29/10/10

1. This certificate and schedule may only be reproduced in full.
2. This certificate is not transferable and remains the property of the issuing body.
3. The Status and authenticity of this certificate may be verified by visiting the Official IECEx Website.

Certificate issued by:

Baseefa
Rockhead Business Park
Staden Lane
Buxton
Derbyshire
SK17 9RZ
United Kingdom

Baseefa

IECEx Certificate of Conformity

INTERNATIONAL ELECTROTECHNICAL COMMISSION
IEC Certification Scheme for Explosive Atmospheres

for rules and details of the IECEx Scheme visit www.iecex.com

Certificate No.:	IECEx BAS 10.0084	issue No.:0	Certificate history:
Status:	**Current**		
Date of Issue:	**2010-10-28**	Page 1 of 3	

Applicant: **GL Industrial Services UK Ltd T/A GL Noble Denton**
Holywell Park
Ashby Road
Loughborough
Leicestershire
LE11 3GR
United Kingdom

Electrical Apparatus: **Gas PT2 Safety Interface**
Optional accessory:

Type of Protection: **Intrinsic Safety**

Marking: **IECEx BAS 10.0084**
[Ex ia Ga] IIB (-20°C ≤ Ta ≤ +50°C)

Approved for issue on behalf of the IECEx Certification Body: R.S. Sinclair PP D BREARLEY

Position: Managing Director

Signature:
(for printed version) T Brearley

Date: 29/10/10

1. This certificate and schedule may only be reproduced in full.
2. This certificate is not transferable and remains the property of the issuing body.
3. The Status and authenticity of this certificate may be verified by visiting the Official IECEx Website.

Certificate issued by:

Baseefa
Rockhead Business Park
Staden Lane
Buxton
Derbyshire
SK17 9RZ
United Kingdom

Baseefa

CSA INTERNATIONAL

Certificate of Compliance

Certificate: 2429362 **Master Contract:** 252631

Project: 2429362 **Date Issued:** December 13, 2011

Issued to: **CUI Global Inc.**

SW 112th. Ave
Tualatin, OR 97062
US
Attention: William Clough

The products listed below are eligible to bear the CSA Mark shown with adjacent indicators 'C' and 'US' for Canada and US or with adjacent indicator 'US' for US only or without either indicator for Canada only.

C US

Dennis Jeffrey

Issued by: Dennis Jeffrey

PRODUCTS

CLASS 2258 04 - PROCESS CONTROL EQUIPMENT - Intrinsically Safe, Entity - For Hazardous Locations

CLASS 2258 84 - PROCESS CONTROL EQUIPMENT - Intrinsically Safe, Entity - - For Hazardous Locations - Certified to US Standards

Ex d ia IIB T4 Gb

Class I Zone 1 AEx d ia IIB T4 Gb

Main Unit Gas PT2 Probe (MU) with Input parameters: U_i = 7.14V, I_i = 364mA, P_i = 0.98W, C_i = 134µF, L_i = 0. Ambient Temperature Range -20°C ≤ Ta ≤ 55°C. Install per the GasPT2 Installation and User Manual.

Ex ia IIB T4

Class I Zone 0 AEx ia IIB T4

Ancillary Unit Gas PT2 Probe (AU) with Input parameters: U_i = 7.14V, I_i = 302mA, P_i = 0.888W, C_i = 53µF, L_i = 0. Ambient Temperature Range -40°C ≤ Ta ≤ 70°C. Install per the GasPT2 Installation and User Manual.

Certificate Number: 13-LD1105876-PDA
04/MAR/2014

Confirmation of Product Type Approval

Please refer to the "Service Restrictions" shown below to determine if Unit Certification is required for this product.

This certificate reflects the information on the product in the ABS Records as of the date and time the certificate is printed.

Pursuant to the Rules of the American Bureau of Shipping (ABS), the manufacturer of the below listed product held a valid Manufacturing Assessment (MA) with expiration date of 23/JAN/2019. The continued validity of the Manufacturing Assessment is dependent on completion of satisfactory audits as required by the ABS Rules.

And; a Product Design Assessment (PDA) valid until 13/NOV/2018 subject to continued compliance with the Rules or standards used in the evaluation of the product.

The above entitle the product to be called Product Type Approved.

The Product Design Assessment is valid for products intended for use on ABS classed vessels, MODUs or facilities which are in existence or under contract for construction on the date of the ABS Rules used to evaluate the Product.

ABS makes no representations regarding Type Approval of the Product for use on vessels, MODUs or facilities built after the date of the ABS Rules used for this evaluation.

Due to wide variety of specifications used in the products ABS has evaluated for Type Approval, it is part of our contract that; whether the standard is an ABS Rule or a non-ABS Rule, the Client has full responsibility for continued compliance with the standard.

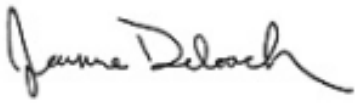
Product Name: Gas Sampling System
Model Name(s): Gas PT2

Presented to:
ORBITAL
COLD MEECE, SWYNNERTON
STONE
STAFFORDSHIRE
United Kingdom

Intended Service:	Sample and analysis the quality of Boil Off Gas taken from LNGC tanks
Description:	The unit is contained in a GRP enclosure and consists of two sensor units arranged in a serial configuration to sample and analyse the quality and composition of the LNG boil off gas. The gas is sampled from a ½" OD inlet pipe through a cryogenic isolation valve and a solenoid valve with a temperature equalisation tube coil in between. A VE conditioning unit and ATEX certified electric heater is installed inside the cabinet to maintain the ambient and sampled gas temperature. Pressure regulators and metering valves are installed to control the sample pressure and flow. A temperature sensor, pressure switch and a flow switch are included in the sampling line and send out signals to external control systems to shut off the flow in the event of high pressure or low temperature and alarm in the event of low flow. The GasPT2 uses correlative techniques to infer an equivalent five-component gas mixture (methane, ethane, propane, nitrogen and carbon dioxide) from which it calculates the gas properties using ISO6976. The data is transmitted via serial link RS 485 to remote data acquisition devices for further processing. All instrumentation is certified to Ex ia standards, where appropriate safety barriers located in safe areas are used to interface with these instruments.
Ratings:	Supply Voltage: 100-240V; Accuracy: +/-0.3 MJ/M3 Calorific value

Service Restrictions:	Unit Certification is not required for this product. If the manufacturer or purchaser request an ABS Certificate for compliance with a specification or standard, the specification or standard, including inspection standards and tolerances, must be clearly defined.
Comments:	Not Applicable
Notes / Documentation:	No. 17291 Gas PT2 Flow Diagram, Gas Pt2 Data Sheet, Gas PT2 User Manual.
Term of Validity:	This Product Design Assessment (PDA) Certificate 13-LD1105876-PDA, dated 14/Nov/2013 remains valid until 13/Nov/2018 or until the Rules or specifications used in the assessment are revised (whichever occurs first). This PDA is intended for a product to be installed on an ABS classed vessel, MODU or facility which is in existence or under contract for construction on the date of the ABS Rules or specifications used to evaluate the Product. Use of the Product on an ABS classed vessel, MODU or facility which is contracted after the validity date of the ABS Rules and specifications used to evaluate the Product, will require re-evaluation of the PDA. Use of the Product for non ABS classed vessels, MODUs or facilities is to be to an agreement between the manufacturer and intended client.
ABS Rules:	The Manufacturer has provided a declaration about the control of, or the lack of Asbestos in this product. The Rules applicable to this assessment are: 2013 Steel Vessel Rules, 1-1-4/7.7, 4-9-1/9, & 4-9-7/13
National Standards: **International Standards:**	ISO 6976, AGA-5, IEC 60079
Government Authority: **EUMED:** **Others:**	

Model Certificate	Model Certificate No	Issue Date	Expiry Date
PDA	13-LD1105876-PDA	14/NOV/2013	13/NOV/2018



ABS Programs

Evaluation Certificate

Number **TC8670** revision 0
Project number 14200680

Issued by	NMi Certin B.V.
In accordance with	– WELMEC guide 8.8 – OIML R140 Edition 2007 (E) "Measuring systems for gaseous fuel".
Producer	Orbital Meece Rd, Swynnerton, Stone Staffordshire ST15 0QN United Kingdom

Measuring instrument: A model of a **calorific value determining device (CVDD)**, intended to be used as a part of a measuring system for gaseous fuel

Type	:	GasPT2
Producer's mark or name	:	Orbital
Destined for the measurement of	:	calorific value, compressibility, Wobbe, relative density, density and concentration of CO_2
Accuracy class	:	A / 0,5
Environment classes	:	M1 / E2
Temperature range gas	:	-10 °C / +40 °C
Temperature range ambient	:	see Description paragraph 1.2.2
Destined for	:	non condensing humidity

The intended location for the instrument is closed.

Further properties and test results are described in the annexes:
- Description TC8670 revision 0;
- Documentation folder TC8670-1.

Issuing Authority

NMi Certin B.V.
28 September 2015

C. Oosterman
Head Certification Board

NMi Certin B.V.
Hugo de Grootplein 1
3314 EG Dordrecht
The Netherlands
T +31 78 6332332
certin@nmi.nl
www.nmi.nl

INSPECTION
RvA I 122

Appendix D: Cost of Ownership

Component Requirements:

Orbital GasPTi Device	Gas Chromatograph
✔ **Installation ($1,000)** ***(safety interfaces installed, plug and play)***	✔ Gas Conditioning & Safety Interfaces
✔ **Annual Calibration (est. $1,000)**	✔ Installation (Sample Lines, Cable Trays est. $5,000)
	✔ Access Road
	✔ Housing Shed, Foundations, Pathways, Civil Engineering/Permitting
	✔ Chemist/Technician
	✔ Calibration Gas & Cylinder Rental
	✔ Helium (Carrier Gas) & Cylinder Rental
	✔ Validation Gas & Cylinder Rental
	✔ Annual Service (est. $3,000)
✔ **Ongoing OPEX ~ US$1,000/year**	✔ Ongoing OPEX ~ US$10,000/year

Appendix E: Test Results

Italy (Snam Rete Gas)

	Italy Gas	Algeria Gas	LNG
C1 Methane %	99.4034	86.6349	90.7398
C2 Ethane %	0.0909	7.5175	7.4648
C3 Propane %	0.0297	1.6335	1.0464
C4+ %	0.0389	0.5590	0.1198
CO2 %	0.0415	1.5987	0.0128
N2 %	0.3956	1.9823	0.6164
He %	0.0000	0.0672	0.0000
O2 %	0.0000	0.0069	0.0000
GC Gross CV (MJ/m3)	37.6832	40.0057	40.3253
GasPT2 GrossCV (MJ/m3)	37.6706	40.0204	40.2778
GasPT Gross CV Error	**- 0.033%**	**+ 0.037%**	**- 0.118%**

	Russia Gas	Dutch Gas	Calibration Gas
C1 Methane %	97.2081	90.5673	92.6315
C2 Ethane %	1.2683	4.6036	3.4635
C3 Propane %	0.3921	0.9034	0.8465
C4+ %	0.1724	0.3927	0.5303
CO2 %	0.1565	1.3357	0.5428
N2 %	0.7815	2.1705	1.9854
He %	0.0174	0.0225	0.0000
O2 %	0.0037	0.0043	0.0000
GC Gross CV (MJ/m3)	38.1744	38.6543	38.7481
GasPT GrossCV (MJ/m3)	38.1865	38.6622	38.6733
GasPT Gross CV Error	**+ 0.032%**	**+ 0.020**	**- 0.193%**

Spain (Repsol)

		LNG		
C1 Methane %	90.62	75.77	97.00	96.13
C2 Ethane %	5.85	0.01	0.10	3.40
C3 Propane %	2.00	0	0.05	0.39
C4 Butane %	0.96	0	0	0.07
C4+ %	0.57	0	0	0
N2 %	0	24.22	1.25	0.01
CO2 %	0	0	1.30	0
O2 %	0	0	0.30	0
GasVLe Gross CV (MJ/m3)	41.1853	28.6119	36.7617	39.0299
GasPT Gross CV (MJ/m3)	41.1745	28.7089	36.8522	39.0707
GasPT Gross CV Error	**- 0.026%**	**+ 0.339%**	**+ 0.246%**	**+ 0.104%**

Spain (Enagas)

Table 1. *Repeatability and reproducibility values obtained from measurements made with the system Gas-PT2 on 8 reference gas mixtures.*

	Repeatability	Reproducibility
Calorific Value	< ± 0,07 % (± 0,03 MJ/m^3) [*M.Specification (± 0,04 MJ/m^3)*]	< ± 0,39 % (± 0,16 MJ/m^3). [*M.Specification (± 0,20 MJ/m^3)*]
Relative Density	< ± 0,02 %	< ± 0,09 % (± 0,0007) [*M.Specification (± 0,0016)*]
Wobbe Index	< ± 0,07 % (± 0,04 MJ/m^3)	< ± 0,44 % (± 0,24 MJ/m^3)

Poland (GazSystem)

Stream number	Number of results	Chromatograph value $x_{sr,C}$	Difference in indications, d	Relative difference in indications, d_0	Standard deviation, s	Relative standard deviation s_0
	-	MJ/m^3	MJ/m^3	%	MJ/m^3	%
1	15	40,1637	-0,1197	-0,30	0,006	0,02
	20	40,1717	-0,1240	-0,31	0,008	0,02
	16	40,0425	0,0062	0,02	0,017	0,04
	15	40,0452	0,0422	0,11	0,012	0,03
	11	40,0695	0,0140	0,04	0,008	0,02
	11	40,1295	0,0212	0,05	0,009	0,02
2	20	40,0376	0,0154	0,04	0,008	0,02
	30	40,0388	0,0002	0,00	0,020	0,05
	17	40,0554	0,0006	0,00	0,005	0,01
	15	40,0778	0,0084	0,02	0,017	0,04
	12	40,0613	0,0084	0,02	0,015	0,04
	15	40,805	0,0729	0,18	0,011	0,03
3	13	40,0774	-0,0326	-0,08	0,004	0,01
	11	40,0699	-0,0278	-0,07	0,006	0,01
	8	40,0806	-0,0440	-0,11	0,008	0,02
	12	40,0829	-0,0320	-0,08	0,010	0,02
	20	40,1009	-0,0159	-0,04	0,039	0,10
	10	40,1142	-0,0199	-0,05	0,006	0,01
	15	40,0654	0,0016	0,00	0,014	0,03

Poland (PGNiG)

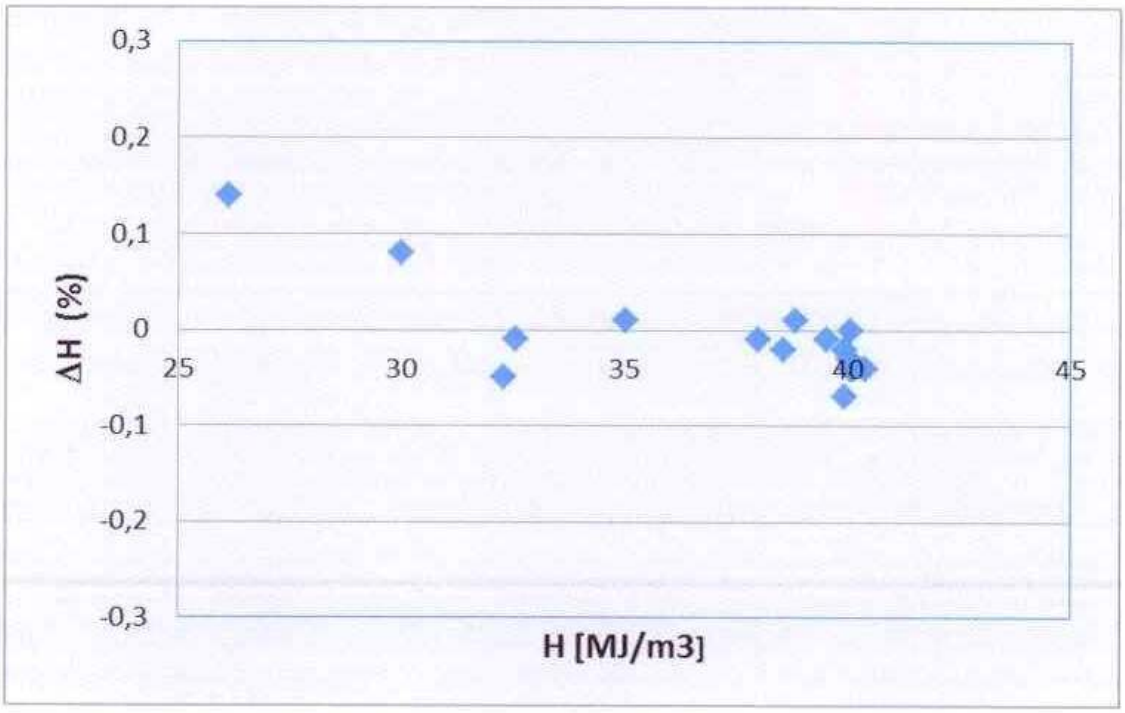


Figure 2. Reproducibility errors of calorific values.

Canada (TransCanada)

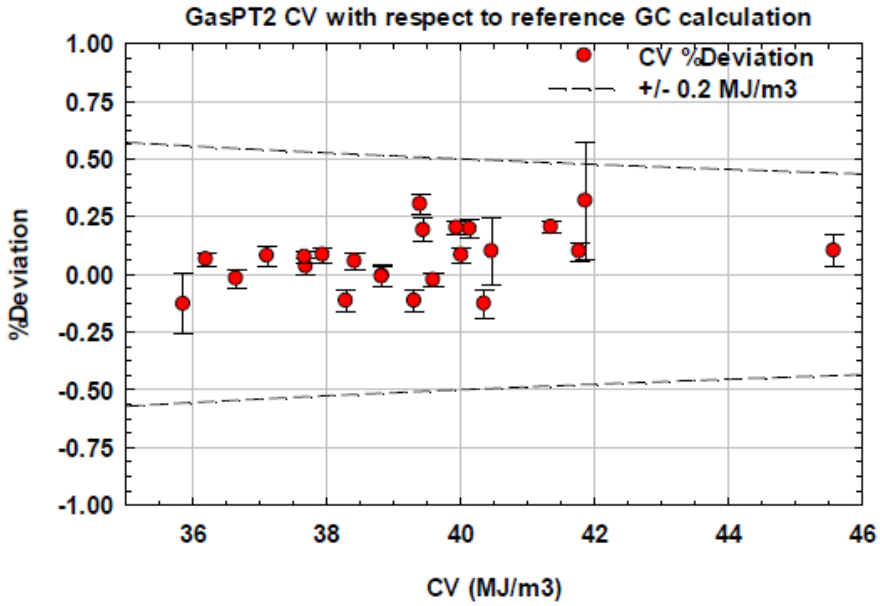


Figure 7 - GasPT2 calorific value (CV) compared with value calculated from Daniel GC components.

Colombia (TGI)

CV Reference Gas Mixture	39.343	37.204	36.976	39.311
CV by GasPT	39.376	37.155	37.110	39.243
CV Error	**+ 0.084%**	**- 0.132%**	**+ 0.362%**	**- 0.173%**

France (Engie)