1 Objective

This document is intended to describe the procedure to be followed in order to collect accurate data during unloading operations. Unloaded energy quantities are measured using that data in accordance with the Sell and Purchase Agreement

2 Scope

This procedure is applicable to every unloading operation from LNG carriers at the Sines LNG Terminal.

3 Definitions

Designation	**Description**
Agent	A local office with authority to act on behalf of the Cargo Owner or the Shipping Company to arrange or administer port services and/or other shipping related services.
APS	Administração do Porto de Sines, S.A.; Port authority.
Cargo Owner (Shipper)	The entity contracting with the Terminal, under the Tolling Agreement (1) the receipt of LNGC and the unloading of LNG from LNGC berthed at the Jetty, (2) the storage and processing of LNG and (3) the making available for delivery of NG and LNG at the Supply Points.
Custody Transfer	Documents that indicate the quantities, in mass and energy, that are transfered to/from the Terminal, among other relevant information.
Global Technical Manager	Entity responsible for the Global Technical Management of the National System of Natural Gas.
Heel	Part of the cargo that remains in the Ship's tanks after unloading in order to maintain a cold temperature and be available for pipe cooling for the next loading operation. It is sometimes used as Ship's fuel.
List	Ship's transversal inclination.
Ship's Master	Highest-ranking officer on the ship.
SPA Agreement	*Sell and Purchase Agreement* – Agreements registered in applicable commercial contracts.
Surveyor	An independent person that surveys the custody transfer.
Trim	Longitudinal equilibrium of the Ship.

4 Responsabilities

Ship Master

Responsible for all the activities in the Ship. Responsible to take any measure necessary to obtain the registry data on board precise and reliably.

Shift supervisor - Loading Master

Represents the Terminal on board the ship. Certifies and validates all the documents produced on board for the fiscal transfer. Guarantees the stability, reliability and safety of the operation. Monitors the correct operation of the jetty chromatograph.

Operations and Port Security

Responsible for issuing the custody transfer report after each unloading operation in coordination with the customer's representative.

The Custody Transfer report should be issue within 48 working hours after the Ship's departure.

Responsible for Control and Instrumentation

Guarantees the accuracy and precision of the chromatograph and all associated equipment.

5 Activities Description

Prior to Ship arrival

Expected quality analysis

The Ship or its Agent shall send a Certificate of Loading with quantities and the characteristics of the loaded LNG and its expected composition on arrival, proving that they fulfill the contractual limits. Sines LNG Terminal shall notify the Global Technical Manager and the cargo owner if the LNG quality does not comply with the specifications.

The composition mentioned in the Loading Certificate or composition expected at arrival shall not be considered for any use than the above mentioned.

In particular, these compositions cannot be used as references to compare with the composition determined during unloading operation.

Preparation of the Chromatograph and the sampling bottles

The person in charge of Instrumentation and Control verifies the jetty chromatographs once a month, calibrating the system whenever necessary and assuring the correct operating conditions such as the pressures in the reference gas bottle and the carrier gas's.

The Operations team provides 6 sampling bottles per Ship. Each bottle must be labeled and available at the jetty's building.

After boarding the Ship

Primary actions

After free practices are granted by the competent entities, the Shift Supervisor shall proceed to a pre-discharge meeting with the Ship's representative. A safety/security meeting followed by a safety/security inspection shall also take place.

During arms connection

Before cooling down of the cargo arms the Shift supervisor, representing the Terminal, the Ship's representative and the designated inspector shall register and validate the following data:

- LNG quantity (in m3) stored in the Ship tanks;
- LNG temperatures (in ºC) in the Ship tanks;
- The level of the gas for auto-consumption counter installed in the Ship (preferably with a copy of the displays);
- Tank Gauging Certificate, checking whether it complies with the last stay at the dock;
- Other measurements such as the temperature and pressure of the vapour.

N.B.: These measurements shall take place while the unloading arms are connected, with all the valves (liquid and vapor) closed and with the gas feeding to the Ship's engine room closed.

During discharge

LNG Quality

The jetty is equipped with two chromatographs, of which results are obtained online during the ship unloading process. In case of failure of one of the chromatographs, the chromatograph that remains operational guarantees the functioning of the online sampling system to obtain results. The installed capacity is thus 2 x 100%. The Operations Team shall monitor the chromatograph measurements continuously. If the data is out of specification, the Shift Supervisor must be immediately informed and the discharge stopped if necessary.

The results of online gas chromatographs, during the unloading operation, shall determine the composition to be considered for Custody transfer. However if any party wants to contest the results of gas chromatograph analysis, gas samples are available, during 15 days, to allow composition comparison.

Sampling

Three sampling shall be collected during the discharge. Three hours after full rate, halfway through the unloading operation and approximately one hour before initiate de flow ramp down. For each sampling two bottles must be filled; one to be used for future analysis and another to be kept by the Terminal.

After unloading

Measurement after discharge

The Shift Supervisor as well as the parties mentioned in paragraph 6.2 shall validate the following data:

- Quantity of LNG (in m3) existing in the Ship's tanks after discharge (heel);
- Temperature of the vapor area of the tanks (in ºC) after unloading;
- Average vapor pressure (in mbar) in the tanks after discharge;
- The level of the gas for auto-consumption counter installed in the Ship (preferably with a copy of the displays) after the completion of the discharge comparing it with the level prior to the operation;
- Unloading Times registration verifying its conformity with the values recorded by the Panel Operator.

N.B.: The data shall be collected after purging the discharge arms and being assured that all the Ship's valves are closed.

Unloading Certificate

The Ship's representative issues a third report (Unloading Certificate) indicating the discharge volume based on the opening and closing unloading reports. All the parties shall validate this report.

Chromatograph Data

The data is checked before printing and accepting the results of the analysis performed by the chromatograph. The first and last hours of the discharge (at full rate) shall not be considered. The data sheet with 10 minutes intervals available in Server 1 shall be used. Inconsistent data can be disregarded provided that they are correctly justified, such as the presence of vapor bubbles in the discharge line, periods in which the sampling occurred or equipment failures. The report issued (IP-0103-Chromatograph Report) must be sent to the surveyor within 24 working hours.

Final documents

The final discharge report (Custody Transfer) is issued to the cargo owner within 48 working hours after the Ship's departure, in conformity with the method described in Appendix B.

In all Portuguese National Grid and infrastructure of NG, energy is reported at 25ºC of initial combustion temperature,

REN Atlântico is a regulated company, and as terms of reference for the purpose of quality of service regulation, should be considered that the custody transfer calculation are in accordance with ISO 6976:2016 and ISO 6578:2017, to the standard conditions (15ºC and 1,01325 bar abs) and finally converted to 25ºC.

Disputing results

In view of the inexistence of norms, rules, recommendations and/or international standards established for these issues of contesting chromatographic results, and in order to facilitate the approval for all parties, it is important to create a set of rules that make the way in which such a process unfolds transparent and fair.

It is extremely important to establish the responsibilities and the methodology to be adopted, creating a level playing field for all the Shippers who have an access contract to the Sines LNG terminal infrastructure. In this way, regardless of the origin of the LNG received, equal treatment with the different Shippers is guaranteed.

Within 120 hours following the issuance of the provisional unloading report, Shippers may contest the results obtained by sending a written complaint to the Terminal.

From the moment the dispute is received, the Terminal will make available to the Shipper the sample bottles collected during the ship's unloading.

Installed equipment and philosophies for sampling are as follows:

• 2 Chromatographs, AT10067 and AT 10068, of which results are obtained online during the ship unloading process. In case of failure of one of the chromatographs, the chromatograph that remains operational guarantees the functioning of the online sampling system to obtain results. The installed capacity is thus 2 x 100%.

• Only the AT10067 chromatograph has a vaporizer and a physical sampling point.

In case of failure of this chromatograph, the obtaining of results will be carried out through the online measurements of the AT 10068 chromatograph.

• Samples are collected using the 10067 chromatograph vaporizer.

The samples are taken at the following moments of the unloading operation - 25%, 50% and 75%.

In the laboratory, a bottle of each moment of the above is analyzed.

So that there is redundancy in case of loss of pressure in one of the bottles, at each moment 2 samples are taken and the respective bottles are saved.

In this way the philosophy is 2 x 100%.

The respective Shipper must send the sample bottles to be analyzed in an independent laboratory, accredited and certified for this purpose.

The costs inherent to this service should take into account current practice in this type of market.

The results of the laboratory analysis must be presented within 24 hours of the time from which the bottles are collected at the Terminal.

The analysis of laboratory results will be carried out with the determination of the average of the results obtained in the analysis of valid samples concerning the different moments of the ship's unloading (25%/50%/75%).

The tolerance to apply originates from the application of the calculation method that counts in the reference document GIIGNL - LNG CUSTODY TRANSFER HANDBOOK Sixth edition - version 6.0 - 7.5 UNCERTAINTY OF GAS ANALYSIS, as follows:

0.15% = Terminal chromatograph tolerance

0.09% = Laboratory chromatograph tolerance

$\sqrt{0{,}15^2 + 0{,}09^2}$ = 0,17%

After the analyzes performed on the samples (25%, 50% and 75%) the respective PCS of each sample will be calculated, as shown in the example below:

	Samples				TGNL Cromatograph
	1 25%	2 50%	3 75%	average	
Methane	97,1760	97,2713	97,3703	97,2725	97,3524
Ethane	2,5354	2,4664	2,3904	2,4641	2,4334
Propane	0,1186	0,1129	0,1106	0,1140	0,0969
N-Butane	0,0146	0,0140	0,0129	0,0138	0,0000
I-Butane	0,0192	0,0184	0,0181	0,0186	0,0000
N-Pentane	0,0034	0,0038	0,0031	0,0034	0,0041
I-Pentane	0,0054	0,0059	0,0052	0,0055	0,0050
Hexane	0,0087	0,0083	0,0094	0,0088	0,0044
Nitrogen	0,1188	0,0990	0,0801	0,0993	0,1038
Carbon Dioxide	0,0000	0,0000	0,0000	0,0000	0,0000
Total (%)	100,0001	100,0000	100,0001	100,0001	100,0000
PCS (MJ/Kg)				**55,288**	**55,296**

Deviation (%)
0,0145

$$Er\% = \left|\frac{VT - VE}{VT}\right| x100$$

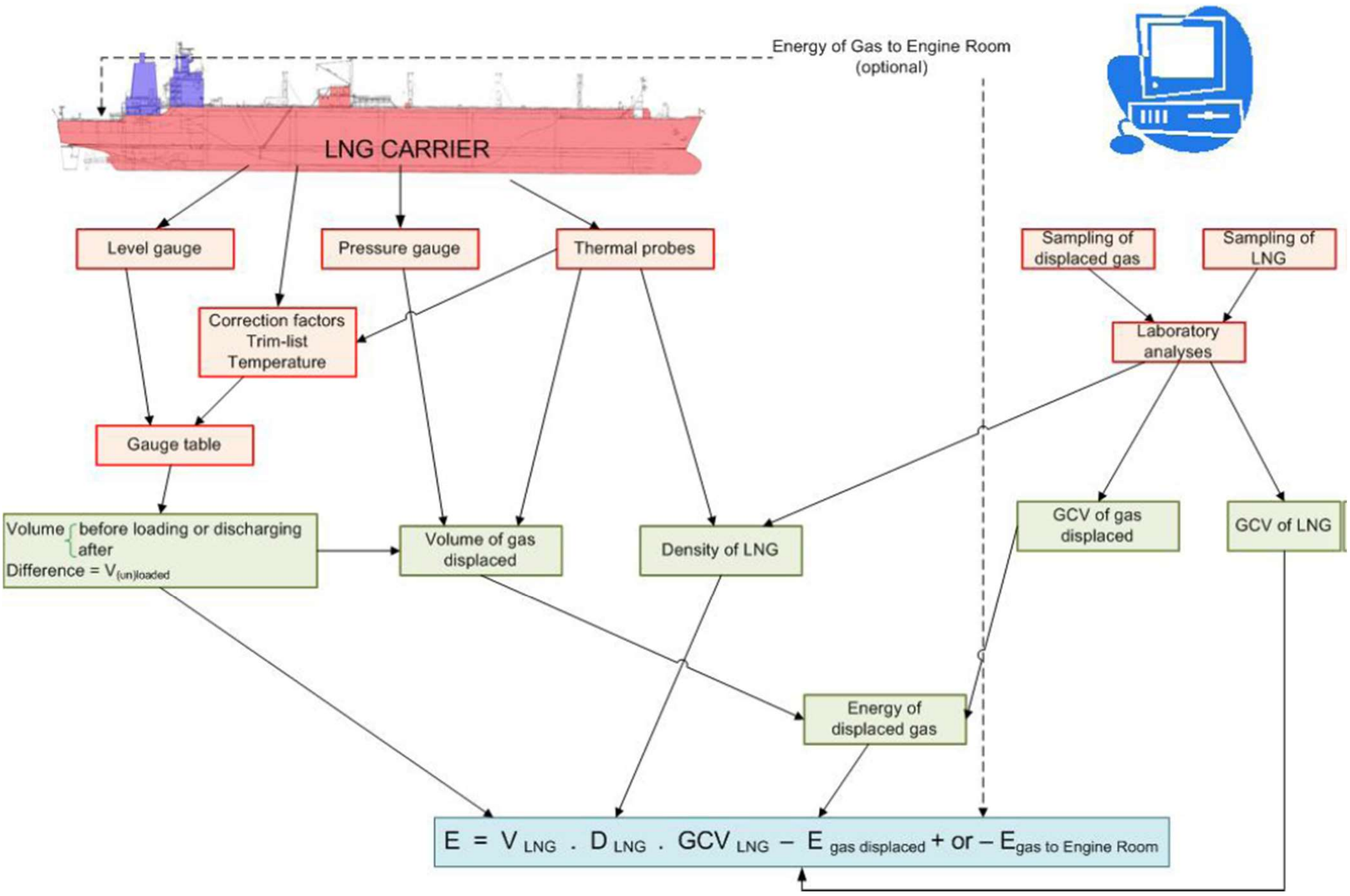
The mean of the PCS of the samples will then be compared, with the PCS calculated through the analyzes carried out in the online chromatographs, in the following terms:

- If the difference in the mean PCS of the analyzed samples, compared to the PCS value obtained in the online chromatographs, reveals a difference equal to or less than 0.17%, the readings of the online chromatographs are considered valid;
- If this difference is greater than 0.17%, the readings of the online chromatographs will be considered invalid, and the mean PCS of the PCS's obtained from the three samples will be considered valid.

Given the above, the proposed methodology does not consider any criterion based on the individual variation of components of the GN mixture, based only on the variation of the PCS measured through the available equipment (online and laboratory chromatographs).

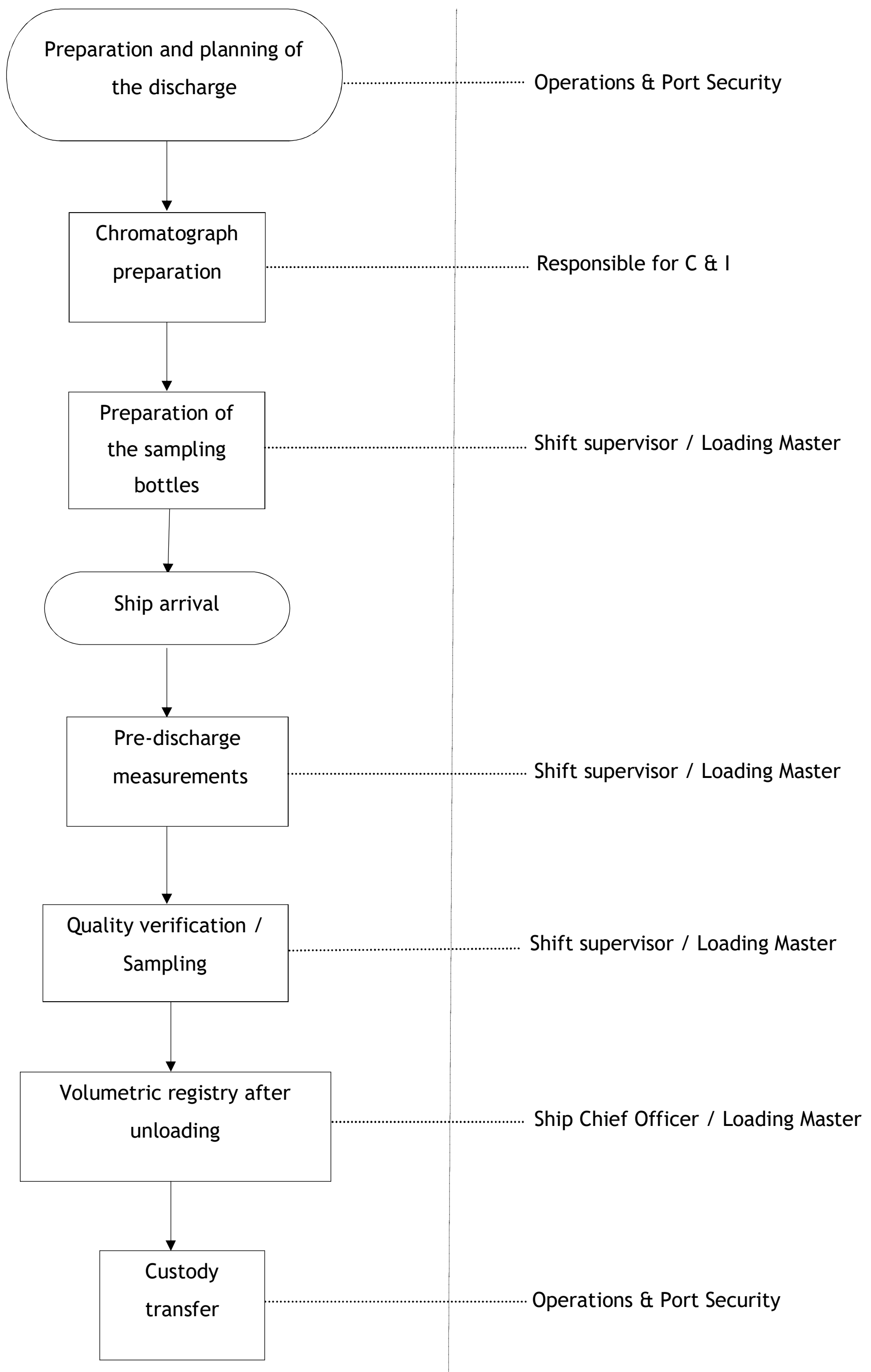
The costs related to the verification of results, analysis of samples in the laboratory, will be assumed by REN Atlântico if the results of the on-line chromatographic analysis are found to be invalid, and by the Shipper if the validity of the results initially obtained is verified.

Summary of the activities for the calculation of the Custody Transfer



Activity Flow Diagram

DESCRIPTION PERSON IN CHARGE



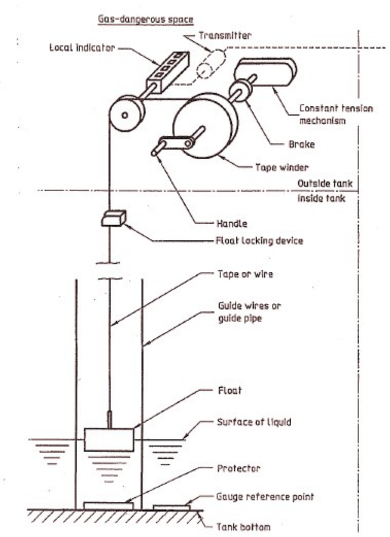
6 Record

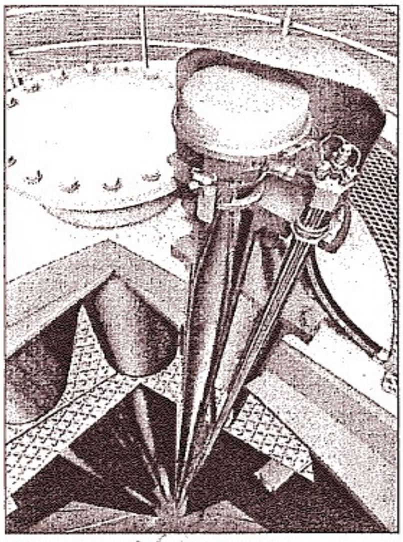
- IP-0103 – Cromatograph Report
- Custody Transfer Report

7 Annex

Annex A - Use of Gauge Tables

Every ship must possess at least two liquid level gauging devices (main types are: radar gauge, electrical capacitance gauge, float gauge and laser gauge) designated as primary and secondary. On modern ships digital systems perform the necessary corrections and issue reports with the corrected liquid volume. On older ships or in case the automatic device is not operational the Ship's gauging tables shall be utilized. Every ship must possess such tables as well as their certification.



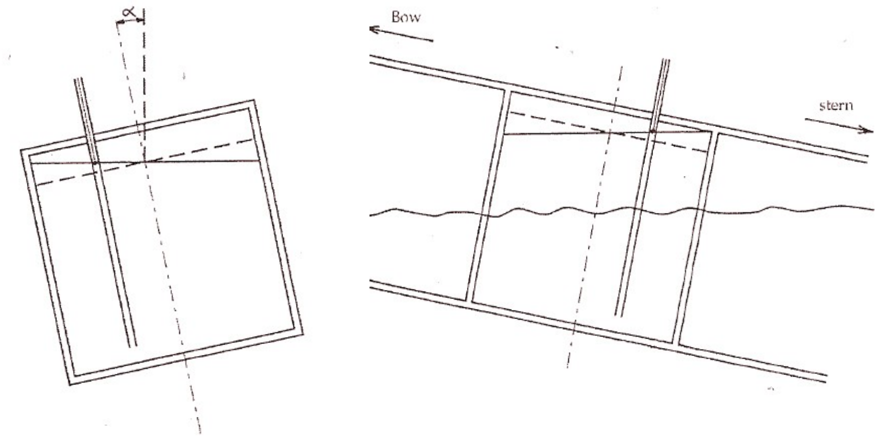


The above Figure represents the typical diagram of a float type gauge (left) and the ultrasonic Saab Tank Radar, widely used in the LNG industry.

Due to the Ship's constant movement, it is common practice to measure five times each tank's liquid level, the final value being the average of each measurement.

Some corrections must be applied to the measured levels. A temperature correction balances the effect of the vapor temperature, especially for ultrasonic devices due to the density change of the vapor and for floating devices because of the ribbon contraction. The list and trim of the Ship must also be considered as correction factors.

The Figures below show an example of the deviations of the cargo due to the Ship's position. A negative List is shown on the right side and a negative Trim is illustrated on the right side.



The volume is obtained after applying an LNG temperature correction to the value taken from the gauging tables so that the contraction factor of the tank's walls is accounted for.

N.B.: For each type level indicators there is a specific calibration table.

Example of a manual calculation using gauging tables:

Tank n.1

Level indicator (radar) – 32.385 m

Average liquid temperature - -158.6ºC

Average vapor temperature - -135.7ºC

Trim – 2.35 m to stern / List – 0.20º starboard

LNG density (expected) – 468.2 kg/m^3

Acoording to the tables in appendix D the following corrections are necessary:

Trim: 7 mm (table 1) / List: 1 mm (table 2)

Temperature correction (-135.7ºC): -145 mm (table 3)

Corrected level: 32.248 m

Volume without correction: 30 749.245 m^3 (interpolation from table 4)

Tank contraction factor (-158.6ºC): 1.00004 (table 5)

Corrected volume: 30 756.989 m^3

N.B.: For floating devices an LNG density correction factor is also considered.

Annex B - Calculation method at the Sines LNG Terminal - Unloading

The units considered for the custody transfer are the following:

- LNG density (kg/m^3)
- Gross calorific value (MJ/kg and MJ/m^3)
- Wobbe Index ($MJ/m^3(n)$)
- Energy transfered (kWh and MJ)

Unloading Data

The data collected in unloading operation, follow the next principles:

- *Terminal Chromatograph Report - the molar percentage of each component is rounded to 4th decimal;*
- *LNG Gross Volume Discharged – is rounded to 3rd decimal;*
- *Average Vapour Temperature - average of all not immersed probes, and rounded to 2nd decimal;*
- *Average Liquid Temperature - average of all immersed probes, and rounded to 2nd decimal;*
- *Average ship tank pressure - average of each ship tank pressure, and rounded to 2nd decimal;*
- *Vapour consumed in ship during unloading (kg) – is rounded to 2nd decimal;*
- *Vapour consumed in ship during unloading (m3) – is rounded to 3nd decimal;*

The LNG density is calculated according to International Standard ISO 6578 Second Edition (2017-10), using the formula below:

$$\rho_t = \frac{\Sigma(x_i M_i)}{\Sigma(x_i V_i) - V_c}$$

LNG Density is expressed in kg/m^3, and rounded to 2nd decimal

V_i = Molar volume of each component of the LNG in m^3/kmol (from Table B.2)

M_i = Molecular weight of each pure component in kg/mol (from Table E.1)

V_c = is the reduction in volume on mixing components (rounded to 6th decimal)

X_i = Mole fraction of each component, determined by Terminal chromatograph (rounded to 6th decimal)

$\Sigma(x_i V_i)$ = rounded to 6th decimal

$\Sigma(x_1 M_i)$ = rounded to 3rd decimal

Note: in absence of hexane values in table B.2 of ISO 6578, is assumed the same molar volume as n-Pentane.

and

$$V_c = \left[k_1 + (k_2 - k_1) \frac{x_2}{0{,}0425} \right] x_1$$

Where:

X_1 = Mole fraction of methane in the LNG, determined by Terminal chromatograph (rounded to 6th decimal)

X_2 = Mole fraction of nitrogen in the LNG, determined by Terminal chromatograph (rounded to 6th decimal)

K_1 = correction factor in m^3/kmol, due to the presence of hydrocarbons and based on the average molar mass and temperature of the mixture, and obtained by interpolation and rounded to 6th decimal.

K_2 = correction factor in m^3/kmol, due to the presence of nitrogen and based on the average molar mass and temperature of the mixture, and obtained by interpolation and rounded to 6th decimal.

LNG gross calorific values are calculated according to International Standard ISO 6578 Second Edition (2017-10).

The gross calorific value on a mass basis, is calculated by the following formula:

$$H_{s,m} = \Sigma H_{s,m,i} \left[\frac{x_i M_i}{\Sigma(x_i M_i)} \right]$$

Is expressed in MJ/kg, and rounded to 3rd decimal

X_j = Mole fraction of each component, determined by Terminal chromatograph (rounded to 6th decimal)

M_i = Molecular weight of each pure component in kg/mol (from table E.1)

$H_{s,m,i}$ = Gross calorific value on a mass basis of component i given in table D.1

Where

$$M = \sum_{j=1}^{N} x_j \cdot M_j$$

Is the molar mass of the composition, is expressed in kg/k_{mol} and is rounded to 3rd decimal.

The gross calorific value on a volume basis, is calculated by the following formula:

$$H_{s,\mathrm{vol}} = \frac{\Sigma x_i H_{s,V,i}}{Z_{\mathrm{mix}}}$$

Is expressed in MJ/m^3, and rounded to 3rd decimal

X_j = Mole fraction of each component, determined by Terminal chromatograph (rounded to 6th decimal)

$H_{s,v,i}$ = Gross calorific value on a mass basis of component i given in table D.1 (at 101,325 kPaA, 15ºC)

Z_{mix} = Compression factor of the mixture, rounded to 6th decimal

$\Sigma x_i H_{s,V,I}$ = rounded to 3rd decimal

Where

$$Z_{\mathrm{mix}} = 1 - [\Sigma x_i (1 - Z_i)^{1/2}]^2$$

$(1\text{-}Z_i)^{1/2}$ = Summation Factor of various components are given in Table E.1

$[\Sigma x_i\ (1\text{-}Z_i)^{1/2}$ = rounded to 6th decimal

During unloading operations

To calculate the energy transferred to Terminal (Net Delivered), is used the following formula:

$$E = (V \, . \, \rho_t \, . \, H_{s,m}) - Q_r - E_{gas}$$

Expressed in MJ and rounded to integer number

Where:

ρ_t = LNG density expressed in kg/m^3

V = Gross Volume of LNG unloaded expressed in m^3, and rounded to 3rd decimal

$H_{s,m}$ = = LNG gross calorific value expressed in MJ/kg

(V . ρ_t . $H_{s,m}$) = expressed in MJ and not rounded (Gross Delivered)

Q_r = Quantity of energy in gaseous form displaced during unloading

E_{gas} = Quantity of energy in gaseous form consumed in vessel during unloading

The quantity of energy displaced during the unloading is calculated using:

$$Q_r = V \cdot \frac{(288.15)}{(273.15 + T_v)} \cdot \frac{P}{1013.25} \cdot GCV_{gas}$$

Expressed in MJ and not rounded

Where:

V = Gross Volume of LNG unloaded expressed in m^3, and rounded to 3rd decimal

P = Mean absolute pressure in the tanks after unloading expressed in mbar and rounded to 2nd decimal

T_v = Mean temperature of the temperature probes not immersed in LNG. Expressed in Celsius degrees and rounded to 2nd decimal

GCV_{gas} = Gross Calorific Value of the gas displaced to the ship expressed in MJ/m^3 at 15 ºC and 1013.25 mbar. It is assumed to be pure methane. Value given by Table D.1 in ISO 6578:2017

The LNG carrier, subject to agreement of buyer and seller, may consume or burn gas during the unloading operation, between the opening and closing CTS. This amount of energy is determined by the measurement of the total volume (or mass) of gas V_g (or M_g) consumed (certified gas flow meter on board the LNG carrier) and the gross calorific value of the gas (GCV_{gas}), as follows:

$$E_{gas} = V_g \cdot GCV_{gas}$$

Expressed in MJ and not rounded

V_g = All Volume of gas consumed or burned on board expressed in m^3, and rounded to 3rd decimal

GCV_{gas} = Gross Calorific Value of the gas consumed on board expressed in MJ/m3 at 15 ºC and 1013.25 mbar. It is assumed to be pure methane. Value given by Table D.1 in ISO 6578:2017

If the measurement of the amount of gas consumed on board is presented in mass (kg), the formula to use is the following:

$$E_{gas} = M_{g.} GCV_{gas}$$

Expressed in MJ and not rounded

M_g = All Mass of gas consumed or burned on board expressed in kg, and rounded to 2nd decimal

GCV_{gas} = Gross Calorific Value of the gas consumed on board expressed in MJ/kg. It is assumed to be pure methane. Value given by Table D.1 in ISO 6578:2017

Conversion Factors

MJ/m^3 to kWh/m^3 - 3,6

$E_{25ºC} = E_{15ºC}$ / 1,001

To calculate real-gas Wobbe Index of the regasified LNG the following formula is used according to ISO 6976:2016 and is expressed in MJ/m^3(st)

$$W_G(t_1;t_2,p_2) = \frac{(Hv)_G(t_1;t_2,p_2)}{\sqrt{G(t_2,p_2)}}$$

Is expressed in MJ/m^3, and rounded to 3rd decimal

Where

$(H_v)_g\ (t_1;t_2;p_2) = H_{s,vol}$ = gross calorific value on a volume basis

$G(t_2,p_2)$ = Real-gas relative density of regasified LNG

And to calculate the real-gas relative density, is used the following formula:

$$G(t_2,p_2) = \frac{G^o \cdot Z_{air}(t_2,p_2)}{Z(t_2,p_2)}$$

Is rounded to 6th decimal

Where:

$Z(t_2,p_2) = Z_{mix}$ = Compression factor of the mixture

G^0 = Ideal-gas relative density

$Z_{air}\ (t_2.p_2)$ = Compression factor of dry air of reference composition

The next formula is used to calculate the ideal.gas relative density

$$G^o = \frac{M}{M_{\text{air}}}$$

Is rounded to 6th decimal

Where:

M = molar mass of the composition is expressed in kg/k$_{mol}$ and is rounded to 3rd decimal

M_{air} = Dry air molar mass = 28,96546 kg/k$_{mol}$, according to TableA.3 of ISO 6976:2016

And to calculate the compression factor of dry air, is used the formula:

$$Z_{\text{air}}(t_2, p_2) = 1 - \frac{p_2}{p_0} \cdot [1 - Z_{air}(t_2, p_0)]$$

Is rounded to 6th decimal

Where:

P_2 = 101,325 kPa (15ºC)

P_0 = 101,325 kPa (ISO)

$Z_{air}(t_2,P_0)$ = Z_{air}(15ºC, P_0) = 0,999595

Annex C - Chromatograph Report

Chromatograph Report
LNG Terminal

Ren Atlântico

Number:	IP - 0103
Revision:	0
Date:	21-Jul-20

Ship:
Cargo n°:

Dates: **to**

NATURAL GAS AVERAGE COMPOSITION

Components		**% Mol**
Methane	CH_4	
Ethane	C_2H_6	
Propane	C_3H_8	
N-Butane	$n\text{-}C_4H_{10}$	
I-Butane	$i\text{-}C_4H_{10}$	
N-Pentane	$n\text{-}C_5H_{12}$	
I-Pentane	$i\text{-}C_5H_{12}$	
Hexane	$n\text{-}C_6H_{14}$	
Nitrogen	N_2	
Carbon Dioxide	CO_2	

X *Chromatograph certificate of inspection confirmed*

Observations:
The results were obtained with the registry sheet available in the server at 10 minutes intervals. Inconsistent readings might be disregarded, provided they are duly justified, such as the formation of vapor pockets in the discharge line, time periods when samples are collected or equipment failure.

Annex D - Custody Transfer Report

REN

Ren Atlântico, Terminal de GNL

UNLOADING DATA

CLIENT ....:
LOADING TERMINAL .... :
SHIP .... :
CARGO .... :

START UNLOADING .... : (Gangway on board)
COMPLETE UNLOADING .... : (Arms disconnected)
TERMINAL REFERENCE .... : 1st Edition
REPORT DATE .... :

CUSTODY TRANSFER DATA

	Before	After	Final
LNG Volume (m3) :			0,000
Average liquid temperature (ºC) :	#DIV/0!	#DIV/0!	-----
Average vapour temperature (ºC) :	#DIV/0!	#DIV/0!	-----
average tanks pressure (mbar) :	#DIV/0!	#DIV/0!	-----
Vapour Consumed (kg) :			0,00
Vapour Consumed (m3) :			0,000

CROMATOGRAPH ANALYSIS

j		Component	% Mol
1	CH4	Methane	
2	C2H6	Ethane	
3	C3H8	Propane	
4	n-C4H10	n-Butane	
5	i-C4H10	i-Butane	
6	n-C5H12	n-Pentane	
7	i-C5H12	i-Pentane	
9	n-C6H14	n-Hexane	
52	N2	Nitrogen	
54	CO2	Carbon Dioxid	
			0,0000

Analytical determination on vapour samples drawn by means of automatic sampler online during discharge and analysed in the local gas chromatographic equipment.

Terminal Signature :

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Ren Atlântico, Terminal de GNL

CALCULATION REPORT

SHIP : 0 CARGO : 0 TERMINAL REFERENCE : 0 1st Edition

COMPOSITION					ISO - 6578 : 2017							
j	Component		% Mol	Molar fraction	(Table E.1) Molar Mass	$M=\sum_{j=1}^{N} x_j \cdot M_j$	(Table E.1) Summation Factor $(1-Z_i)^{1/2}$	$x_i\,(1-Z_i)^{1/2}$	(Table D.1) Gross Calorific Values for Individual Components – mass basis	(Table D.1) Gross Calorific Values for Individual Components – volumetric basis (ideal)	(Formula 12) Gross calorific value - mass basis $H_{s,m}=\Sigma H_{s,m,i}\left[\frac{x_i M_i}{\Sigma(x_i M_i)}\right]$	$x_i H_{s,V,i}$
				Xj	Mj kg / kmol	Xj*Mj kg / kmol	at 101,325 kPaA, 15ºC		Hs,m,i MJ / kg	Hs,v,i MJ / m3	MJ / kg	MJ / m3
1	CH4	Methane	0,0000	0,000000	16,042	0,000000	0,0445	0,000000	55,573	37,704	#DIV/0!	0,000000
2	C2H6	Ethane	0,0000	0,000000	30,069	0,000000	0,0919	0,000000	51,952	66,070	#DIV/0!	0,000000
3	C3H8	Propane	0,0000	0,000000	44,096	0,000000	0,1344	0,000000	50,370	93,940	#DIV/0!	0,000000
4	n-C4H10	n-Butane	0,0000	0,000000	58,122	0,000000	0,1840	0,000000	49,547	121,790	#DIV/0!	0,000000
5	i-C4H10	i-Butane	0,0000	0,000000	58,122	0,000000	0,1722	0,000000	49,389	121,400	#DIV/0!	0,000000
6	n-C5H12	n-Pentane	0,0000	0,000000	72,149	0,000000	0,2361	0,000000	49,046	149,660	#DIV/0!	0,000000
7	i-C5H12	i-Pentane	0,0000	0,000000	72,149	0,000000	0,2251	0,000000	48,950	149,360	#DIV/0!	0,000000
9	n-C6H14	n-Hexane	0,0000	0,000000	86,175	0,000000	0,3001	0,000000	48,718	177,550	#DIV/0!	0,000000
52	N2	Nitrogen	0,0000	0,000000	28,013	0,000000	0,0170	0,000000	0,000	0,000	#DIV/0!	0,000000
54	CO2	Carbon Dioxid	0,0000	0,000000	44,010	0,000000	0,0752	0,000000	0,000	0,000	#DIV/0!	0,000000
	Sum		0,0000	0,0000		0,000		0,000000			#DIV/0!	0,000
						molar mass of composition		summation factor of composition				

ISO - 6578 : 2017	
(Formula 7) Compression Factor	(Formula 11) Gross calorific value - volume basis
$Z_{mix}=1-[\Sigma x_i(1-Z_i)^{1/2}]^2$	$H_{s,vol}=\frac{\Sigma x_i H_{s,V,i}}{Z_{mix}}$
Z= 1,000000	0,000 MJ / m3

ISO 6976 : 2016			
(Formula 13) Ideal-Gas Relative Density	(Formula 17) Real-Gas Relative Density	(Formula 18) Compression Factor of Dry Air of reference composition	(Formula 20) Real-Gas Gross Wobbe Index
$G^o=\frac{M}{M_{air}}$ Table A.3 dry air molar mass 28,96546 Kg/kmol	$G(t_2,p_2)=\frac{G^o \cdot Z_{air}(t_2,p_2)}{Z(t_2,p_2)}$	$Z_{air}(t_2,p_2)=1-\frac{p_2}{p_0}\cdot[1-Z_{air}(t_2,p_0)]$ Constant $Z_{air}(t_2=15\,°C, p_0)=0{,}999\,595;$	$W_G(t_1;t_2,p_2)=\frac{(Hv)_G(t_1;t_2,p_2)}{\sqrt{G(t_2,p_2)}}$
0,000000	0,000000	0,999595	#DIV/0! MJ/m3

ISO 6976 : 2016			
(Formula 8) Ideal molar volume of the mixture	(Formula 11) Real-gas molar volume of the mixture	(Formula 14) Density of Ideal Gas	(Formula 19) Real Gas Density
$Vo=R \cdot T_2/p_2$	$V=Z(t_2,p_2)\cdot R \cdot T_2/p_2$	$D^o(t_2,p_2)=M/V^o$	$D(t_2,p_2)=\frac{D^o(t_2,p_2)}{Z(t_2,p_2)}$
23,6448 m3/mol	0,0236 m3/mol	0,0000 kg/m3	0,0000 Kg / m3

p0 (ISO) (kPa)	101,325
p2 (15ºC) (kPa)	101,325
T2 (K) =	288,15
Gas constant (Table A.1) R (J/mol*k-1) =	8,3144621

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Ren Atlântico, Terminal de GNL

LNG DENSITY REPORT

SHIP : 0 CARGO : 0 TERMINAL REFERENCE : 0 1st Edition

		COMPOSITION		ISO 6578:2017							Linear Interpolation	
				Orthobaric molar volumes of individual componentes of LNG							$y = y_1 + (x - x_1)\frac{y_2 - y_1}{x_2 - x_1}$	
		Component	Molar fraction	Annex B	table B.2			Vj values				
j			(Xj)	Volume molar Vj, m3/kmol					Vj inf (y1)	Vj sup (y2)	Vj (y)	XjVj
				-163,15	-161,15	-159,15	-157,15	-155,15	#DIV/0!	#DIV/0!	#DIV/0!	
1	CH4	Methane	0,000000	0,037735	0,037995	0,038262	0,038536	0,038817	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2	C2H6	Ethane	0,000000	0,047678	0,047845	0,048014	0,048184	0,048356	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
3	C3H8	Propane	0,000000	0,062212	0,062392	0,062574	0,062756	0,062939	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
4	n-C4H10	n-Butane	0,000000	0,076574	0,076765	0,076957	0,077150	0,077344	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
5	i-C4H10	i-Butane	0,000000	0,078035	0,078236	0,078438	0,078640	0,078844	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
6	n-C5	n-Pentane	0,000000	0,091252	0,091462	0,091673	0,091884	0,092095	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
7	i-C5	i-Pentane	0,000000	0,091379	0,091596	0,091814	0,092032	0,092251	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
9	C6+	n-Hexane	0,000000	0,091252	0,091462	0,091673	0,091884	0,092095	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
52	N2	Nitrogen	0,000000	0,045031	0,046231	0,047602	0,049179	0,050885	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
54	CO2	Carbon Dioxid	0,000000									0,000000
				note: in absence of hexane values in table B.2 of ISO 6578, is assumed the same molar volume as n-Pentane								
		SUM	0,0000									#DIV/0!

LNG average temperature (ºC) (before unloading)	#DIV/0!	x	Temperature low	#DIV/0!	x1	
			Temperature high	#DIV/0!	x2	

#N/D	x1	
0,000	x = M	kg / kmol
#N/D	x2	

Annex C	ISO 6578 :2017 Correction factor k1	Table C.1	
k1 x 10³ m3/Kmol			
Σ xiMi	-163,15	-158,15	-153,15
16	-0,008	-0,009	-0,010
17	0,180	0,220	0,250
18	0,375	0,440	0,500
19	0,535	0,610	0,695
20	0,725	0,810	0,920

	Linear Interpolation $y = y_1 + (x - x_1)\frac{y_2 - y_1}{x_2 - x_1}$	
k1 (y1)	k1 (y)	k1 (y2)
#DIV/0!	#DIV/0!	#DIV/0!
#DIV/0!	#DIV/0!	#DIV/0!
#DIV/0!	#DIV/0!	#DIV/0!
#DIV/0!	#DIV/0!	#DIV/0!
#DIV/0!	#DIV/0!	#DIV/0!
#DIV/0!	#DIV/0!	#DIV/0!

Linear Interpolation

$y = y_1 + (x - x_1)\frac{y_2 - y_1}{x_2 - x_1}$

#N/D		y1
#N/D	K1 =	#N/D
#N/D		y2

Annex C	ISO 6578 :2017 Correction factor k2	Table C.2	
k2 x 10³ m3/Kmol			
Σ xiMi	-163,15	-158,15	-153,15
16	-0,015	-0,024	-0,032
17	0,320	0,410	0,600
18	0,590	0,720	0,910
19	0,770	0,950	1,230
20	0,920	1,150	1,430

	Linear Interpolation $y = y_1 + (x - x_1)\frac{y_2 - y_1}{x_2 - x_1}$	
k2 (y1)	k2 (y)	k2 (y2)
#DIV/0!	#DIV/0!	#DIV/0!
#DIV/0!	#DIV/0!	#DIV/0!
#DIV/0!	#DIV/0!	#DIV/0!
#DIV/0!	#DIV/0!	#DIV/0!
#DIV/0!	#DIV/0!	#DIV/0!
#DIV/0!	#DIV/0!	#DIV/0!

Linear Interpolation

$y = y_1 + (x - x_1)\frac{y_2 - y_1}{x_2 - x_1}$

#N/D		y1
#N/D	K2 =	#N/D
#N/D		y2

ISO 6578:2017

(Formula 10) Reduction in volume on mixing components		(Formula 9) Density	
$V_c = \left[k_1 + (k_2 - k_1)\frac{x_2}{0,0425}\right]x_1$		$\rho_t = \frac{\Sigma(x_i M_i)}{\Sigma(x_i V_i) - V_c}$	
#N/D	m3	#DIV/0!	Kg / m3

V_c is the reduction in volume on mixing components;

V_i is the molar volume of each component

k_1 is the correction factor, in cubic metres per kilomole, due to the presence of hydrocarbons and based on the average molar mass and temperature of the mixture as given in Table C.1;

k_2 is the correction factor, in cubic metres per kilomole, due to the presence of nitrogen and based on the average molar mass and temperature of the mixture as given in Table C.2.

x_1 mole fraction of methane in the LNG

x_2 mole fraction of nitrogen in the LNG

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REN

Ren Atlântico, Terminal de GNL

GAS DISPLACED & VAPOUR CONSUMED

CLIENT ....:	0	
LOADING TERMINAL ....:	0	
SHIP ....:	0	
CARGO ....:	0	
START UNLOADING ....:	00/01/1900 00:00	
COMPLETE UNLOADING ....:	00/01/1900 00:00	
TERMINAL REFERENCE ....:	0	1st Edition
REPORT DATE ....:	1 de fevereiro de 2021	

GAS DISPLACED

reference combustion temperature at 15ºC

$$Q_r = V \cdot \frac{(288.15)}{(273.15 + T_v)} \cdot \frac{P}{1013.25} \cdot GCV_{gas}$$

V =	0,000	m3	Gross Volume of LNG unloaded
T =	#DIV/0!	ºC	Mean value of the vapour temperature after unload
p =	#DIV/0!	mbar	Mean absolute pressure in tanks
GCV gas =	37,704	MJ/m3	Gross Calorific Value (assumed pure methane)
E =	#DIV/0!	MJ	Energy is gaseous form displaced during unloading
	#DIV/0!	kWh	
	#DIV/0!	Kg	Mass
	#DIV/0!	m3	equivalent LNG

VAPOUR CONSUMED BY VESSEL

reference combustion temperature at 15ºC

$$E_{gas} = M_g . GCV_{gas}$$

Mg =	0,00	Kg	Massa de Gás queimado a bordo
GCV gas =	55,573	MJ/kg	Gross Calorific Value (assumed pure methane)

$$E_{gas} = V_g \cdot GCV_{gas}$$

Vg =	0,000	m3	Volume de Gás queimado a bordo
GCV gas =	37,704	MJ/m3	Gross Calorific Value (assumed pure methane)
E =	0,000	MJ	Energy is gaseous form consumed in vessel
	0,000	kWh	
	#DIV/0!	Kg	Mass
	#DIV/0!	m3	equivalent LNG

Terminal Signature :

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Ren Atlântico, Terminal de GNL

DISCHARGE CERTIFICATE

CLIENT ....:	0	
LOADING TERMINAL ....:	0	
SHIP ....:	0	
CARGO ....:	0	
START UNLOADING ....:	00/01/1900 00:00	(Gangway on board)
COMPLETE UNLOADING ....:	00/01/1900 00:00	(Arms disconnected)
TERMINAL REFERENCE ....:	0	1st Edition
REPORT DATE ....:	21 de julho de 2020	

LNG Properties — *reference combustion temperature at 15ºC*

Molar Mass :	0	kg/mol	GCV (mass) :	#DIV/0!	MJ/kg
Real Gas Density :	0	kg/m3	GCV (Volume) :	0,000	MJ/m3
Liquid Density :	#DIV/0!	kg/m3	Wobbe Index :	#DIV/0!	MJ/m3
Expansion Ratio :	#DIV/0!	m3/m3			

Custody Transfer — *reference combustion temperature at 15ºC*

	Volume	Mass		Energy	
	m3	Kg	MJ	kWh	MMBtu
Gross Delivered	0,000	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Vapour Displaced	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Consumed by Vessel	#DIV/0!	#DIV/0!	0,000	0,000	0,000
Net Delivered	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**

Custody Transfer — *reference combustion temperature at 25ºC*

	Volume	Mass		Energy	
	m3	Kg	MJ	kWh	MMBtu
Net Delivered	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**

note : Energy at 25ºC = Energy at 15ºC / 1,001

Terminal Signature :

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