K-GAUGE DPMS

LNG DENSITY PROFILE MEASUREMENT SYSTEM

The KONGSBERG Density Profile Measurement System is an extension module to the K-Gauge CTS, allowing the Radar Tank Gauge to be used as a combined level gauge and densimeter. The system offers a world's first in-situ and online LNG density measurement system, and comes with built-in LNG aging tool. The function both estimates the current LNG composition and predicts future composition. Gross Calorific Value (GCV) and the theoretical LNG density value by revised Klosek McKinley equation..

Functional description

K-Gauge DPMS offers a cost effective way to gain improved knowledge and information of the LNG stored. Online and continuous LNG density monitoring and trend functions provide an added value for the users of the K-Gauge Custody Transfer Measurement System for LNG carriers and LNG FSRUs.

By use of the KONGSBERG Radar Tank Gauges and standpipes installed in the tanks for level gauging, the DPMS software module provides density monitoring and reporting, LNG aging calculation and GCV estimation.

For LNG carriers, the LNG density, aging and GCV information are helpful tools to prepare for the Custody Transfer operation, and an easy verification when getting the official composition report from the terminal. For LNG FSRUs the density profile monitoring and trend function are helpful tools to continuously monitor the boil-off process and the density and temperature profile in the tanks to prevent roll-over incidents to happen.

The possibility to accurate measure the density offers a backup, and verification, to the currently dominating method to determine the density in cargoes transferred to/from LNG carriers and FSRUs.

Aging and the possibility to monitor the profile of density in the cargo down the tank can help to predict a possible roll-over accident by improving the decision basis for the operator. The operator performing cargo operation will, by means of the density information together with level and temperature measurement, become better equipped to make the correct decisions to prevent roll-over accidents.

Rollover prediction

A danger associated with LNG storage is the phenomenon of rollover. The conditions for rollover are set when a tank's liquid contents stratify with high density in the lower part below a less dense liquid in the upper part of tank.

Heat entering the top layer through the tank walls cause boil-off from the free surface of LNG to compensate for the heat ingress. The temperature is thus kept quite constant, but due to the aging effect (lighter components boils off most rapidly) the density of the upper layer increase. Heat also enter the lower layer through both tank walls and tank bottom, but when trapped below the lower layer, no free surface exist from where LNG can boil off. The heat ingress thus leads to a temperature increase. When the temperature of LNG increases the volume also increases, hence the density decreases.

When the decreasing density of the bottom layer meets the increasing density of the top layer, the interface becomes unstable and the two layers mix relatively rapidly. Superheated LNG from the bottom layer then comes to the top where it boils off at rates considerably higher than normal. The vapour pressure then increases leading to lifting of relief valves and the release to atmosphere of considerable quantities of LNG vapour.

The conditions for a possible rollover incident is illustrated by the following figure

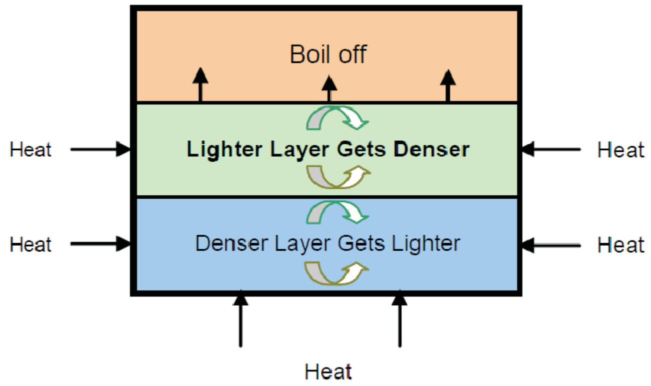

Figure 3: Conditions with layering set for rollover

KONGSBERG radar based densimeter continuously measure the density profile down the tank, and together with level, temperature and pressure inputs, the system will give the operator instant information status of the situation in the tanks.

For more detailed information about rollover, see SIGTTO document "Guidance for the Prevention of Rollover in LNG Ships".

TECHNICAL SPECIFICATIONS

Measuring range:	400-500 kg/m³ (at observed temperature), averaged density over the liquid column.
RMS accuracy:	Down to 0.1 %
Ex classification:	Ex ia IIC T4
Ex certification:	CE 0044 IECEx SIR 14.0025X Sira 14ATEX2056X
Quality standard:	ISO 9001
EMC standard:	Emission: EN50081-1 Immunity: EN50082-2
Frequency:	X-band (10 GHz)
Radiated power:	Smaller than 0.3 mW (-5 dBm)
Operating temperature:	-45 °C to +85 °C
Tank temperature:	Down to -165 °C
Tank pressure:	Maximum 20 bar g

Materials

Body:	AISI 316(L)
Lens:	PTFE or PEEK
Standpipe:	AISI 316L or Al alloy 5083 i
Protection:	IP 66/67
Weight:	10.7 kg

Safety data

Max. input voltage:	Ui = 14.3 VDC
Max. input power:	Pi = 2.1 W
Max. input current:	Ii = 560 mA
Max. internal capacitance:	Ci = 347 nF
Max. internal inductance:	Li = negligible
Type approval:	ABS, BV, CCS, DNV-GL, KRS, LRS, NK

Specifications subject to change without any further notice.

376818 Rev. B

KONGSBERG MARITIME
Switchboard: +47 815 73 700
Customer support: +47 815 35 355
E-mail sales: km.sales@km.kongsberg.com
E-mail support: km.support@kongsberg.com

km.kongsberg.com

KONGSBERG

Density measurements
Density is a measurement of mass per unit of volume. Because LNG is not a pure substance, the density varies between the different gas fields due to different composition.

The traditional way of obtaining the density of LNG as input to the CTS report, is by taking liquid samples that are vapourized and sent to a gas chromatograph to analyze the composition. The density is then calculated by using the revised Klosek McKinley equation, where the composition of the LNG found by the gas chromatograph forms the input.

The chemical composition of LNG is a function of the source and type of processing/aging. It is a mixture of mainly methane, ethane, propane and butane with small amounts of heavier hydrocarbons. Besides the hydrocarbons, mainly Nitrogen exist, which is an important component to watch due to its altered properties compared to the hydrocarbons. Methane is by far the major component, usually over 85 % by volume.

Chemical	Chemical Formula	Low	High
Methane	CH_4	85%	99%
Ethane	C_2H_6	<1%	10%
Propane	C_2H_8	<1%	5%
Butane	C_4H_{10}	<1%	>1%
Nitrogen	N_2	0.1%	1%
Other Hydro-carbons	Various	Trace	Trace

Table 1: Typical chemical composition of LNG

With KONGSBERG radar based densimeter, the density of the LNG is monitored continuously as long as the sensing part of the pipe is immersed in LNG. This is done at each immersed segment in the tank, and can be presented for each tank or averaged over several tanks. By knowing only the N_2 content to certain accuracy, the uncertainty of the density measurement is reduced to a level well below the uncertainty of today's accepted standards.

Accurate density measurement is possible regardless of the tank atmospheric conditions. High instrument accuracy and flexible software ensure continuously monitoring of the density and its change both in cases with natural and forced boil-off and re-liquefaction.

The density calculated from the gas composition found at laboratories (by use of gas chromatograph), can be verified by the radar based density measurement, hence it will also be a confirmation of the input to the gross calorific value (GCV) calculation. The density meter has a built in aging model that is continuously adjusted by the updated inputs from the accurately measured temperatures and the day-by-day change of the density, thus being a useful feature for the spot marked, combined with other systems for following up on LNG composition, aging and prediction.

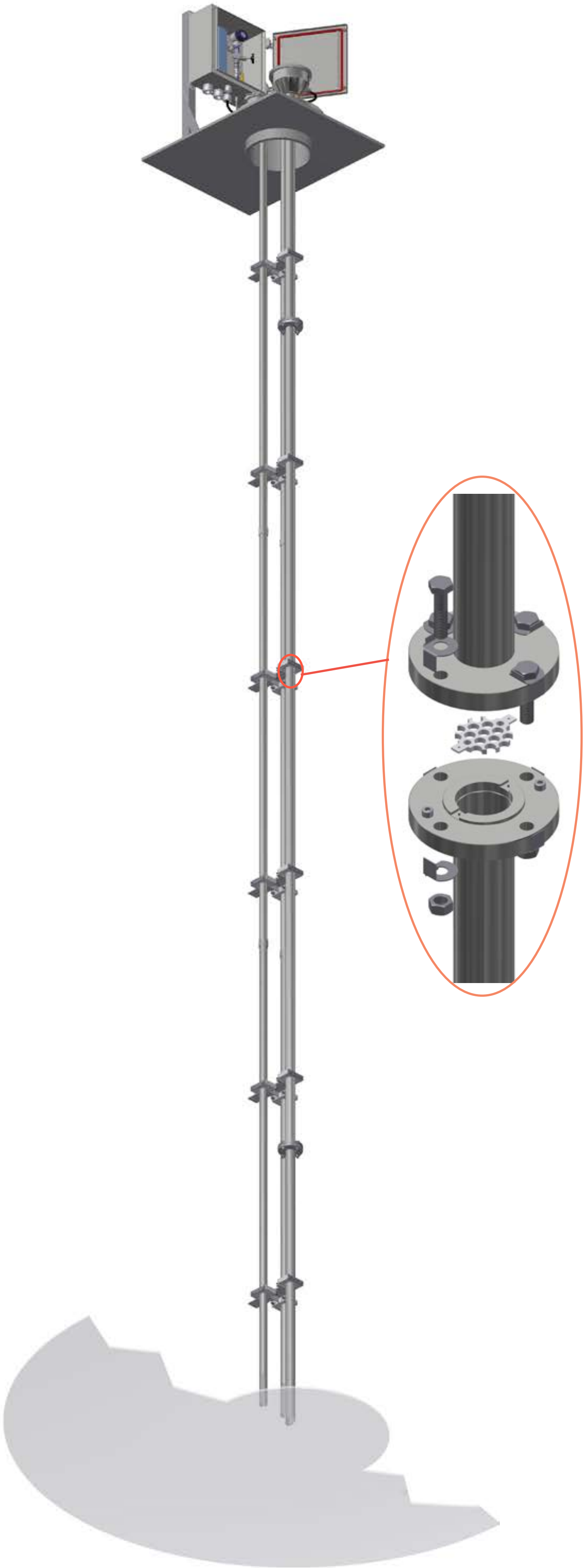

Figure 1: RTG and standpipe installation with marker

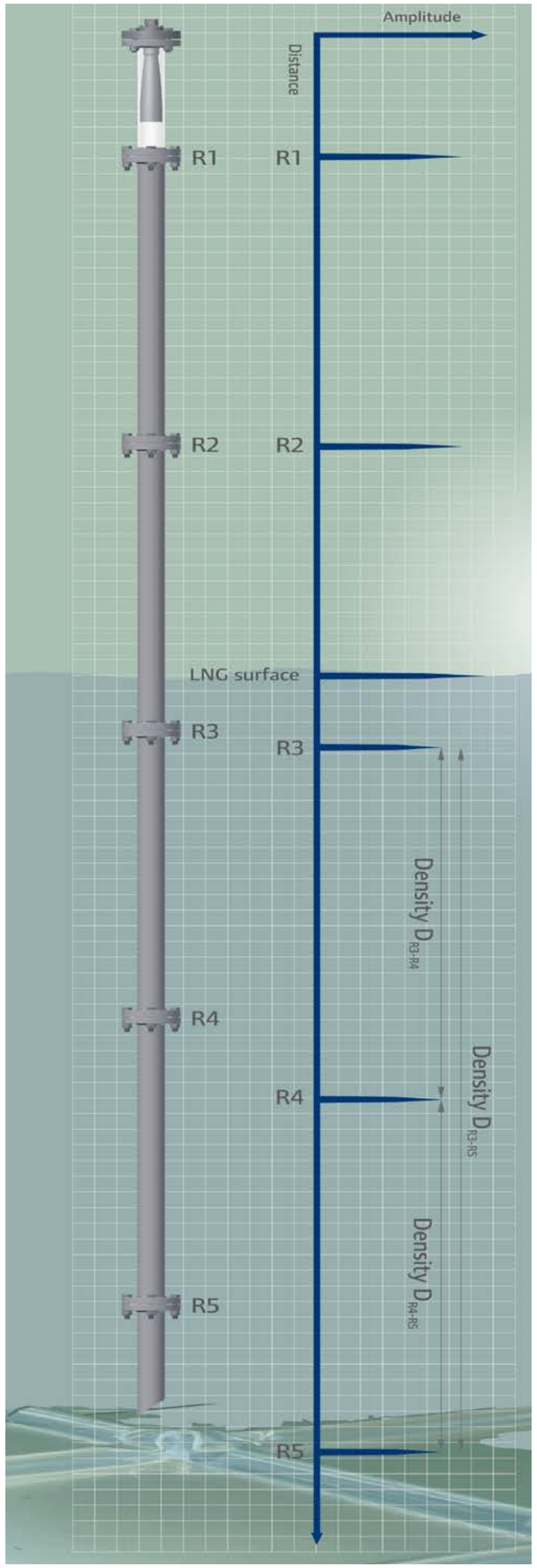

Figure 2: Functional illustration of LNG densimeter

The system measures the position of fixed markers inside a standpipe with customized length. A frequency sweeping microwave signal is emitted by the radar through the pipe, where the sensing part(s) of the pipe consist of specially designed markers at both ends. The radar receives a reflected signal from both the upper and the lower marker, and by measuring the position of these carefully calibrated references, the density of the liquid filling the sensing part of the pipe is calculated.

Each densimeter is connected to a dedicated signal processing unit. Density is measured tank by tank, and the system can present the ship average density.

Density profile
LNG is stored in refrigerated tanks, at temperatures around -160 °C and pressures slightly over atmospheric. Heat leaks, even in well insulated tanks, will cause boil–off which makes the composition of the LNG to slowly change (aging). Under normal conditions, heat transfer and vessel motions will ensure circulation of the LNG, maintaining a uniform liquid. However, in cases where addition of new LNG with a different temperature and density combined with insufficient circulation can lead to stratification/layering of the LNG.

To avoid layering in an LNG tank, the choice between top and bottom filling is crucial when receiving additional LNG in a partly filled tank. The combination of wrongly filled LNG followed by insufficient circulation can lead to stratification that ends up in a rollover incident.

A method to detect stratification in LNG is to measure both the density and the temperature profile over the tank height. The KONGSBERG radar based densimeter measure density profile continuously over the tank height by measuring the position of fixed markers inside a standpipe. The standpipe consist of several sections flanged together to form the pipe ranging over the full tank height. The density of the liquid filling the column between each two markers is continuously measured and the density profile down the tank are presented for every segment along with the temperature profile.

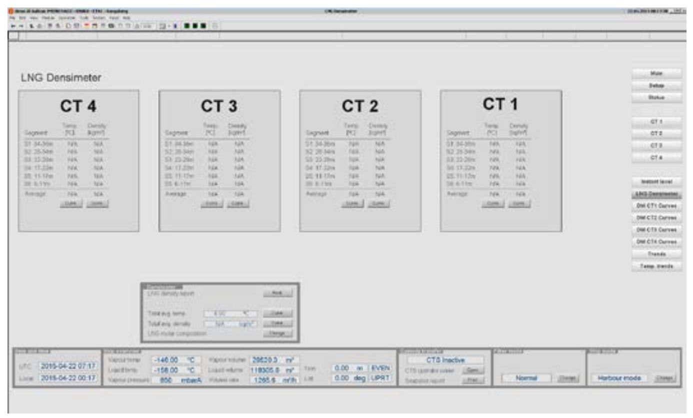

Figure 3: LNG densimeter overview mimic