



Ship to Ship LNG bunkering operations under various conditions

LNG Shipping London, 11th September 2019
Johannes Dziuba



Company introduction – TGE Marine Gas Engineering GmbH

- 40 years of experience with liquefied gas
- More than 200 gas carrier systems contracted
- Four (4) LNG bunker vessels in operation
- Market leader in the small scale LNG fleet
- 1st 28,000 cbm LNG FSRU under construction
- Shareholder: Mitsui Engineering & Shipbuilding Co., Ltd. (MES)



Key references: small LNG carriers

7,500 m³ LNG/LEG carrier:

Owner: Anthony Veder
Yard: Remontowa
Classification: BV
Completion: 2009

TGE 's scope:

- cargo system
- fuel gas system
- cargo tanks
- ship design

18,000 m³ LNG carrier:

Owner: Anthony Veder
Yard: Meyer-Werft
Classification: BV
Completion: 2018

TGE 's scope:

- cargo system
- fuel gas system

30,000 m³ LNG carrier:

Owner: CNOOC
Yard: Jiangnan
Classification: CCS
Completion: 2015

TGE 's scope:

- cargo system
- fuel gas system
- cargo tanks



CORAL METHANE



CORAL ENERגיע



HAI YANG SHI YOU 301

Ship to ship bunker operations before 2017

LNGF "Seagas"

- Owner: Sirius Shipping, Sweden
- Yard: Løland Verft / Fiskerstrand Verft
- Conversion: 2013
- Capacity: 167 m³



Source: Siriusshipping.eu

15,600 m³ LNG carrier:

"Coral Energy"

- Owner: Anthony Veder, The Netherlands
- Yard: Meyer-Werft, Germany
- Classification: BV
- Completion: 2013
- TGE's scope: Complete gas handling system and fuel gas system

Picture: Coral Energy used for bunker operations in the Baltic region



Key references: LNG bunker vessels

6,500 m³ LNG bunker vessel

"Cardissa":

- Owner: Shell, United Kingdom
- Yard: STX, Korea
- Classification: LR
- Completion: 2016
- Scope: Cargo handling system with cargo tanks, LNG fuel supply system



5,800 m³ LNG bunker vessel

"Coralius":

- Owner: Sirius Veder Gas AB, Sweden/The Netherlands
- Yard: Royal Bodewes, The Netherlands
- Classification: BV
- Completion: 2017
- Scope: Cargo handling system with cargo tanks, LNG fuel gas system



Key references: LNG bunker vessels

5,100 m³ LNG bunker vessel

"ENGIE ZEEBRUGGE":

- Owner: Engie, Fluxys, Mitsubishi Corporation, NYK
- Yard: Hanjin, Korea
- Classification: BV
- Completion: 2017
- Scope: Cargo handling system with cargo tanks, LNG fuel supply system



7,500 m³ LNG/LEG/LPG carrier

"Coral Methane":

- Owner: Anthony Veder, The Netherlands
- Yard: Remontova, Poland
- Classification: BV
- Completion: 2009
- Scope: EPCS-contract, gas handling system, fuel gas system & cargo tanks, ship design development

2018:

- **New charter to Shell for Bunker Operations**
- **Conversion with integration of transfer and chiller system**
- **TGE scope: Integration design**



LNG bunker vessels 2018

2,200 m³ LNG bunker barge:

"Clean Jacksonville"

- Owner: WesPac Midstream LLC, US
- Yard: Conrad Orange Shipyard, USA
- Classification: ABS
- Completion: 2018



Source: Press release 8.2018

7,600 m³ LNG bunker vessel:

"Kairos"

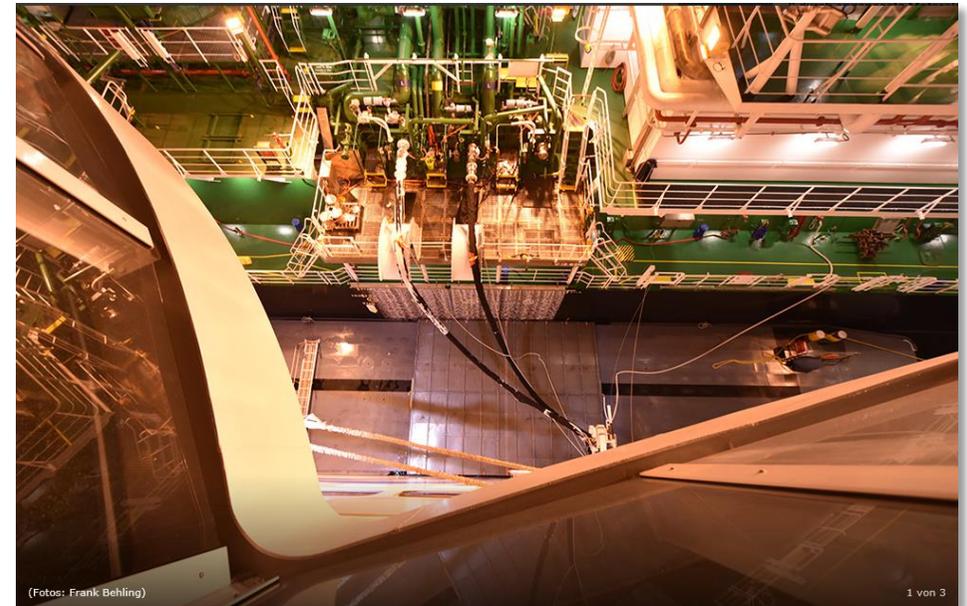
- Owner: Babcock Schulte Energy
- Yard: Hyundai Mipo Shipyard, Korea
- Classification: LRS
- Completion: 2018



„Coral Methane“ & „Cardissa“ bunkering „AIDA Nova“

Anthony Veder's "Coral Methane" & Shell's "Cardissa"

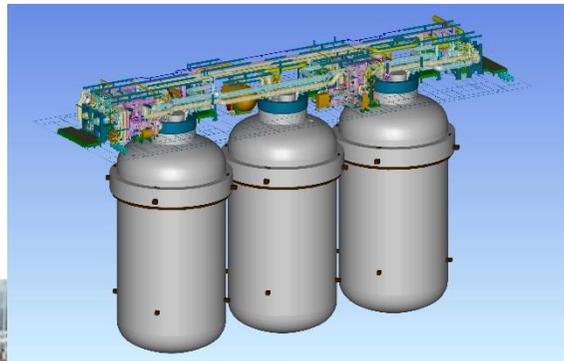
First liquefied natural gas (LNG) bunkering operation on the world's first LNG-powered cruise ship at Santa Cruz de Tenerife in the Canary Islands.



„Cardissa“ bunkering „Containerships Nord“

Shell's "Cardissa"

First liquefied natural gas (LNG) bunkering operation on the world's first LNG-powered container vessel new building in Rotterdam.



The Small Scale LNG fleet

Vessel	Capacity	Delivery	Owner/Operator
Kayoh Maru	1,517	1988	Daiichi Tanker Co.
Lucia Ambition (Aman Bintulu)	18,928	1993	Farenco Shipping (MISC)
Surya Aki	19,474	1996	MOL
Aman Sendai	18,928	1997	MISC
Aman Hakata	18,800	1998	MISC
Surya Satsuma	23,096	2000	MOL
Shinju Maru No.1	2,513	2003	Shinwa Marine
Pioneer Kutsen	1,100	2004	Knutsen Shipping
North Pioneer	2,512	2005	Japan Liquid Gas
Sun Arrows	19,100	2007	MOL
Kakurei Maru	2,536	2008	NA
Shinju Maru No.2	2,500	2008	Japan Utilities
Coral Methane	7,500	2009	Anthony Veder
Norgas Innovation	10,000	2010	NGC
Norgas Creation	10,000	2010	NGC
Norgas Vision	12,000	2011	NGC
Norgas Invention	10,000	2011	NGC
Norgas Unikum	10,000	2011	NGC
Norgas Conception	10,000	2011	NGC
Akebono Maru	3,500	2011	United

Vessel	Capacity	Delivery	Owner/Operator
Coral Energy	15,600	2012	Anthony Veder
Coral Anthelia	6,500	2012	Anthony Veder
NB Fenghun	14,000	2018	
Engie Zebrugge	5,100	2017	Gas4Sea
Coralius	5,800	2017	Sirius Veder Gas AB
Cardissa	6,500	2017	Shell
Coral Energice	18,000	2017	Anthony Veder
Clean Jacksonville	2,200	2018	WesPac
Kairos	7,500	2018	Babcock Schulte
Flex-Fueler	1,500	2018	Titan
NB Samsung	7,500	2019	Kogas
NB Samsung	7,500	2019	Kogas
NB Keppel	7,500	2019	Stolt
NB Keppel	7,500	2019	Stolt
NB Hudong	18,300	2020	MOL
VT Halter	4,000	2020	QLNG
NB DSIC	8,500	2020	ENN
NB HMD	30,000	2020	Knutsen
NB SOE	20,000	2020	Avenir
NB SOE	20,000	2020	Avenir
NB SOE	7,500	2020	Avenir
NB SOE	7,500	2020	Avenir
NB Keppel	5,800	2021	Shturman Koshelev

The Small Scale LNG fleet

Vessel	Capacity	Delivery	Owner/Operator	Vessel	Capacity	Delivery	Owner/Operator
Kayoh Maru	1,517	1988	Daiichi Tanker Co.	Coral Energy	15,600	2012	Anthony Veder
Lucia Ambition (Aman Bintulu)	18,928	1993	Farenco Shipping (MISC)	Coral Antheia	6,500	2012	Anthony Veder
Surya Aki	19,474	1996	MOL	NB Fenghun	14,000	2018	
Aman Sendai	18,928	1997	MISC	Engie Zebrugge	5,100	2017	Gas4Sea
Aman Hakata	18,800	1998	MISC	Coralius	5,800	2017	Sirius Veder Gas AB
Surya Satsuma	23,096	2000	MOL	Cardissa	6,500	2017	Shell
Shinju Maru No.1	2,513	2003	S		18,000	2017	Anthony Veder
Pioneer Kutsen	1,100	2004	K		2,200	2018	WesPac
North Pioneer	2,512	2005	J		7,500	2018	Babcock Schulte
Sun Arrows	19,100	2007	MOL	Flex-Fueler	1,500	2018	Titan
Kakurei Maru	2,536	2008	NA	NB Samsung	7,500	2019	Kogas
Shinju Maru No.2	2,500	2008	Japan Utilities	NB Samsung	7,500	2019	Kogas
Coral Methane	7,500	2009	Anthony Veder	NB Keppel	7,500	2019	Stolt
Norgas Innovation	10,000	2010	NGC	NB Keppel	7,500	2019	Stolt
Norgas Creation	10,000	2010	NGC	NB Hudong	18,300	2020	MOL
Norgas Vision	12,000	2011	NGC	VT Halter	4,000	2020	QLNG
Norgas Invention	10,000	2011	NGC	NB DSIC	8,500	2020	ENN
Norgas Unikum	10,000	2011	NGC	NB HMD	30,000	2020	Knutsen
Norgas Conception	10,000	2011	NGC	NB SOE	20,000	2020	Avenir
Akebono Maru	3,500	2011	United	NB SOE	20,000	2020	Avenir
				NB SOE	7,500	2020	Avenir
				NB SOE	7,500	2020	Avenir
				NB Keppel	5,800	2021	Shturman Koshelev

**- LNG carriers with type C cargo tanks -
(32 out of 43)**

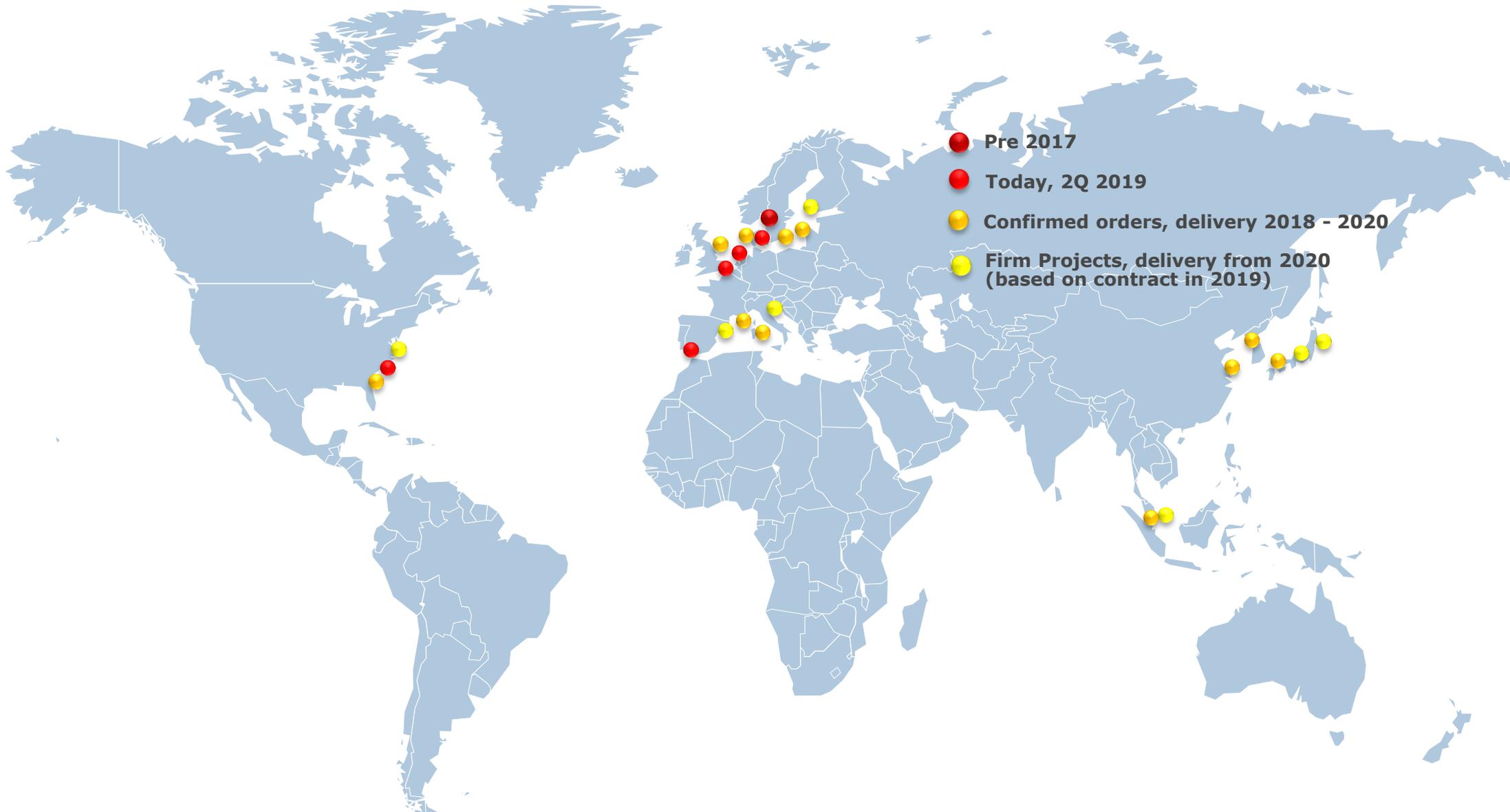
The Small Scale LNG fleet

Vessel	Capacity	Delivery	Owner/Operator	Vessel	Capacity	Delivery	Owner/Operator
Kayoh Maru	1,517	1988	Daiichi Tanker Co.	Coral Energy	15,600	2012	Anthony Veder
Lucia Ambition (Aman Bintulu)	18,928	1993	Farenco Shipping (MISC)	Coral Anthelia	6,500	2012	Anthony Veder
Surya Aki	19,474	1996	MOL	NB Fenghun	14,000	2018	
Aman Sendai	18,928	1997	MISC	Engie Zebrugge	5,100	2017	Gas4Sea
Aman Hakata	18,800	1998	MISC	Coralius	5,800	2017	Sirius Veder Gas AB
Surya Satsuma	23,096	2000	MOL	Cardissa	6,500	2017	Shell
Shinju Maru No.1	2,513	2003	S		18,000	2017	Anthony Veder
Pioneer Kutsen	1,100	2004	K		2,200	2018	WesPac
North Pioneer	2,512	2005	J		7,500	2018	Babcock Schulte
Sun Arrows	19,100	2007	MOL	Flex-Fueler	1,500	2018	Titan
Kakurei Maru	2,536	2008	NA	NB Samsung	7,500	2019	Kogas
Shinju Maru No.2	2,500	2008	J		7,500	2019	Kogas
Coral Methane	7,500	2009	A		7,500	2019	Stolt
Norgas Innovation	10,000	2010	M		7,500	2019	Stolt
Norgas Creation	10,000	2010	M		18,300	2020	MOL
Norgas Vision	12,000	2011	NGC	VT Halter	4,000	2020	QLNG
Norgas Invention	10,000	2011	NGC	NB DSIC	8,500	2020	ENN
Norgas Unikum	10,000	2011	NGC	NB HMD	30,000	2020	Knutsen
Norgas Conception	10,000	2011	NGC	NB SOE	20,000	2020	Avenir
Akebono Maru	3,500	2011	United	NB SOE	20,000	2020	Avenir
				NB SOE	7,500	2020	Avenir
				NB SOE	7,500	2020	Avenir
				NB Keppel	5,800	2021	Shturman Koshelev

**- LNG carriers with type C cargo tanks -
(32 out of 43)**

> 16 LNG Bunker vessels by 2020

Bunker Vessel Operation Areas



Customers – Where does the bunker LNG go?

	Coastal Vessel	Passenger Vessel	Large Container Vessel
LNG volume	50 - 500 m ³	2,000 – 3,000 m ³	up to 13,000 m ³
Tank type	Vacuum insulated or conventional insulated	Type C tanks or atmospheric tanks	Atmospheric or type C tanks
Bunker time	max. 4 h	4 h	approx. 4 - 11 h
Bunker rate	25 - 200 m ³ /h	750 m ³ /h	up to 1,500 m ³ /h
Bunker connection	abt. 6"	abt. 8"	estimated min. 8"
Bunker manifold height	max. 4 m above waterline	3 – 4 m above waterline	6 – 8 m above waterline
Bunker station location	approx. 50 m from steven	midships	¼ of ship length

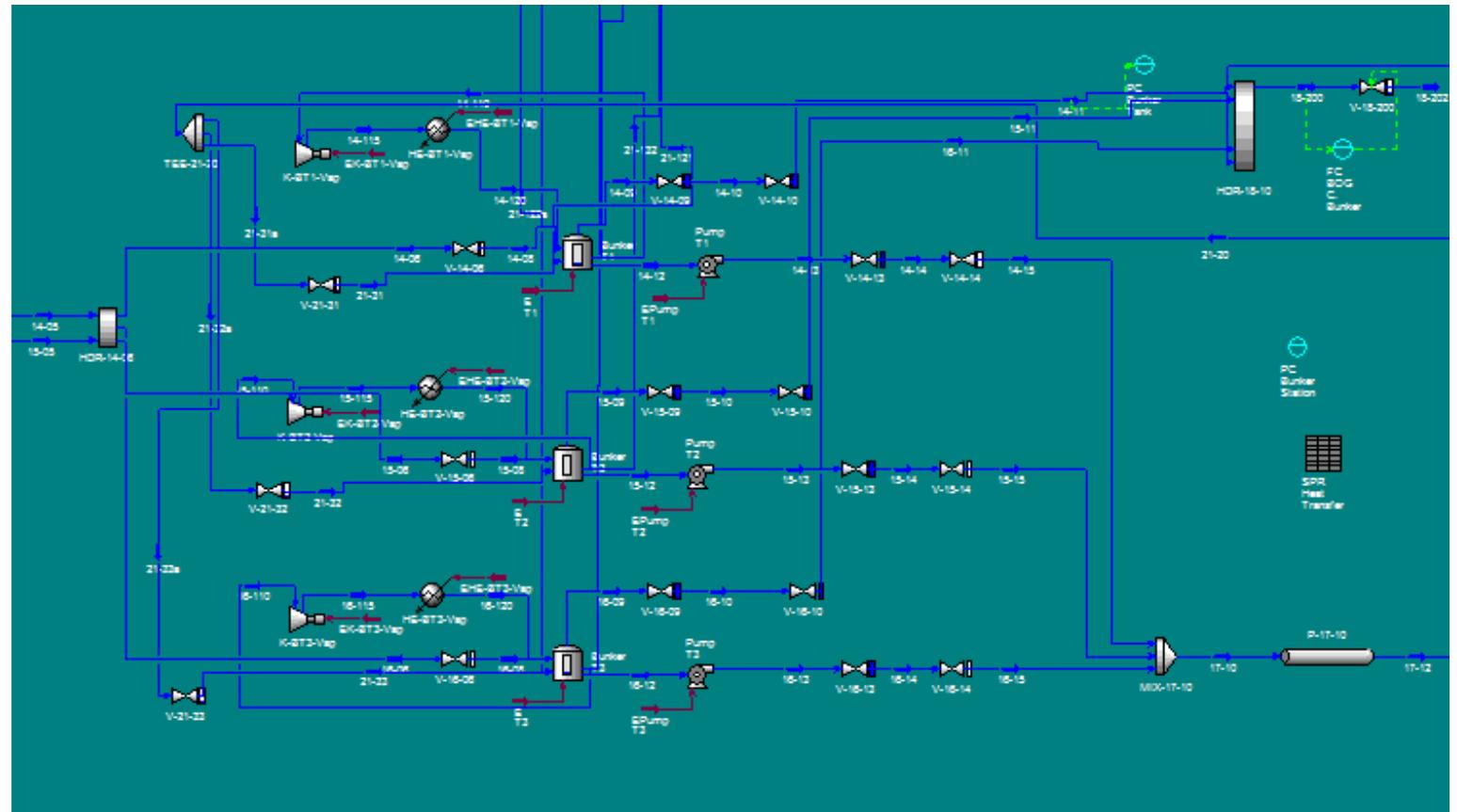


Dynamic Simulation of STS bunkering process

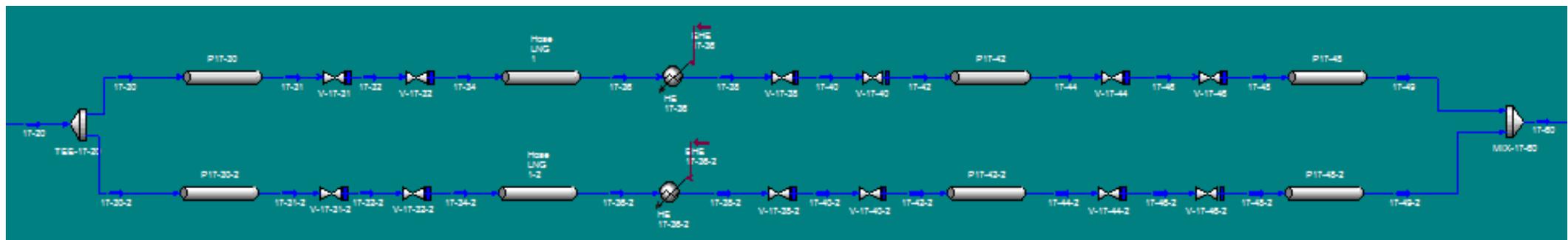
- Dynamic simulation of bunkering process is performed by means of UniSim. UniSim provides:
 - Comprehensive thermodynamics
 - Detailed unit operation models
 - Dynamic simulation
 - Realistic results
- Piping:
 - Two 8 inch hoses for liquid from bunker to client vessel
 - One 8 inch hose for vapour from client to bunker vessel
- Parameters with impact on BOG gas amount:
 - Bunkering rate (1600 m³/h)
 - BOG displacement out of client tank (~ 3100 kg/h)
 - Client tank BOG flash gas (~ 490 kg/h)
 - Heat ingress
 - Initial conditions of LNG in bunker and container tanks

Dynamic Simulation model

Bunker vessel – tanks and pumps:



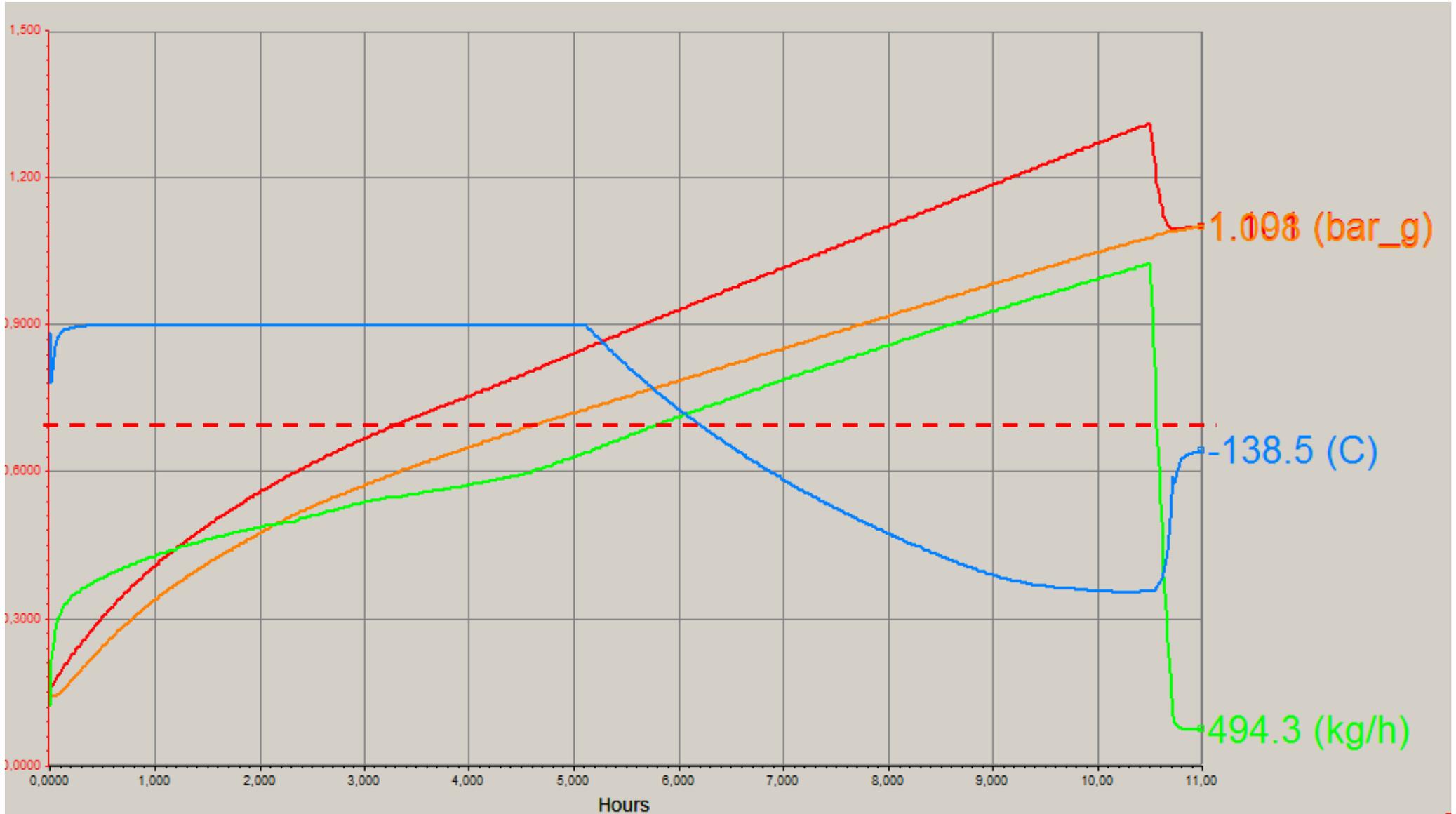
Extract of piping from bunker to client vessel:



Dynamic Simulation – the cases

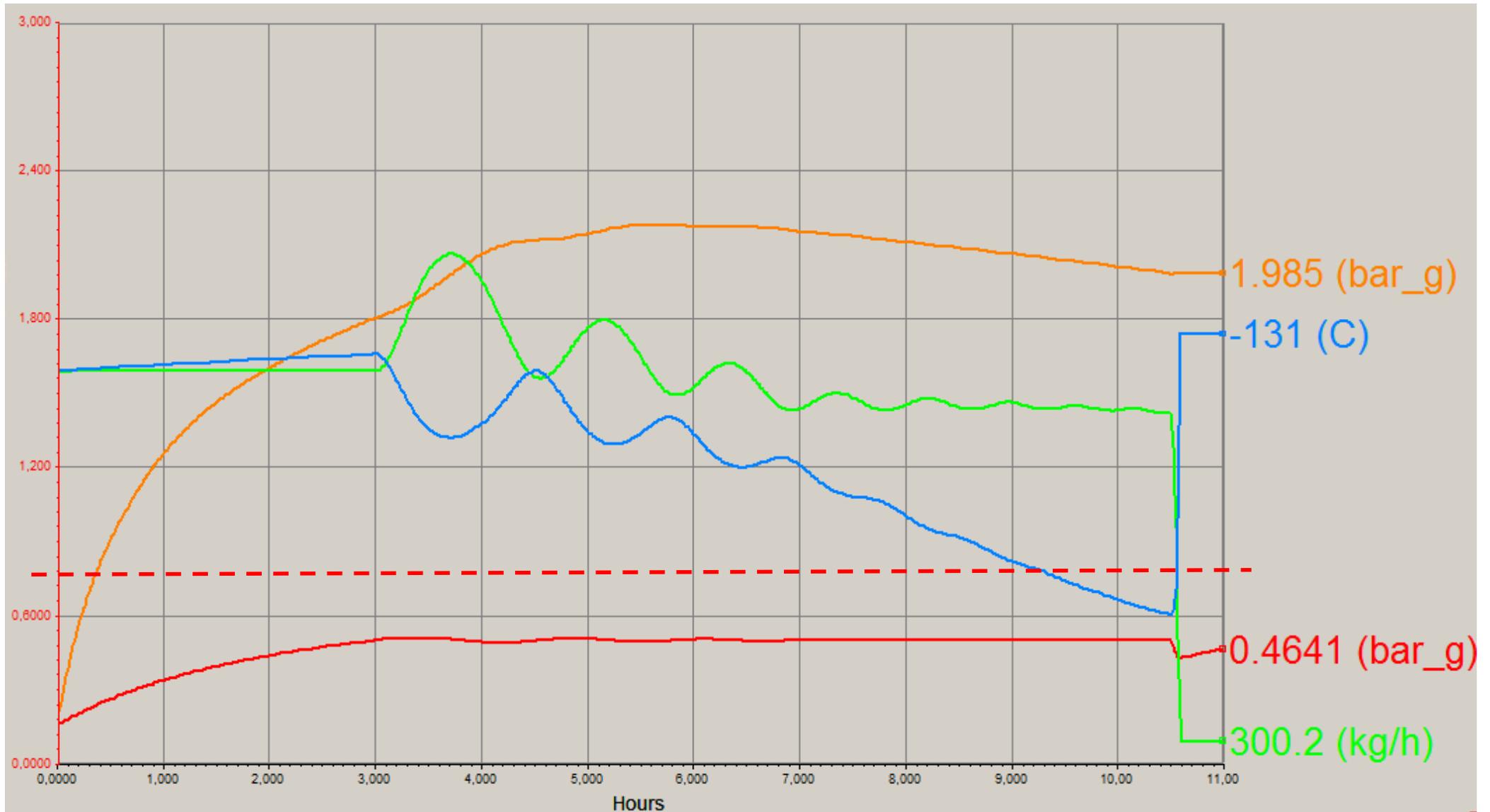
- Thermodynamic equilibrium (TDE): Liquid and vapour phases of all tanks are not in TDE
- Simulation case Free Flow: BOG flows in free flow from client to bunker vessel
- Simulation case BOG Compressor 150 mbarg (easy case):
 - BOG compressor is used to return vapour to bunker vessel tanks
 - Initial condition: bunker tank pressure = 150 mbarg, client tank pressure 150 mbarg
- Simulation case BOG Compressor 300 mbarg (difficult case):
 - BOG compressor is used to return vapour to bunker vessel tanks
 - Initial condition: bunker tank pressure = 300 mbarg, client tank pressure 400 mbarg
- Simulation cases are not an exact copy of the condition during real life operation, but can be used for realistic estimation of the 'behaviour' of the system

Dynamic Simulation – Free flow



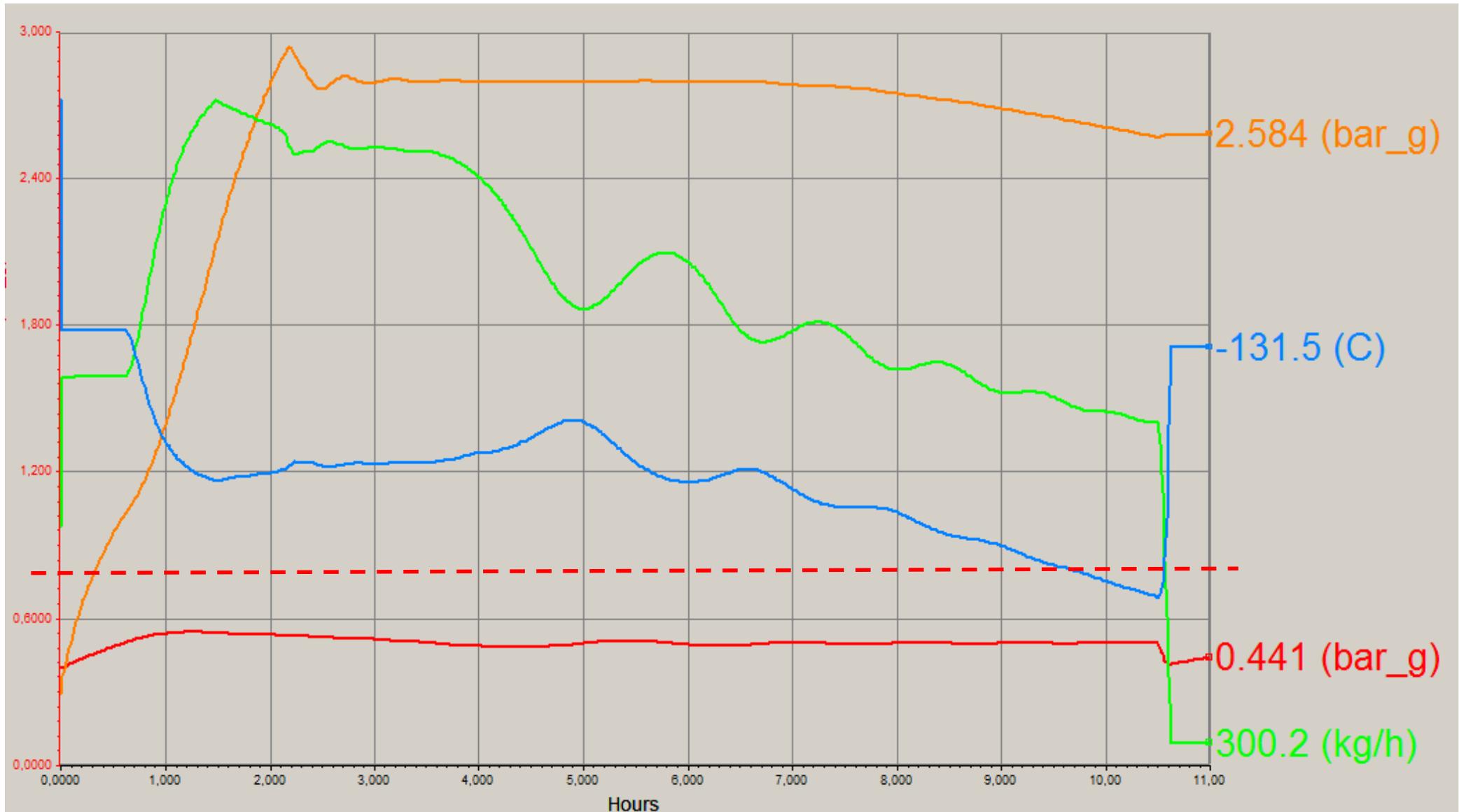
Red curve: Client vessel tank pressure; **red dashed line:** Client tank design pressure (700 mbarg);
Orange curve: Bunker vessel tank pressure; **Green curve:** Flow client vessel -> bunker vessel (vapour return)
Blue curve: Temperature of flow bunker vessel -> client vessel

Dynamic Simulation – Case BOG Compressor 150 mbarg



Red curve: Client vessel tank pressure; **red dashed line:** Client tank design pressure (700 mbarg);
Orange curve: Bunker vessel tank pressure; **Green curve:** Flow client vessel -> bunker vessel (vapour return)
Blue curve: Temperature of flow bunker vessel -> client vessel

Dynamic Simulation – Case BOG Compressor 300 mbarg



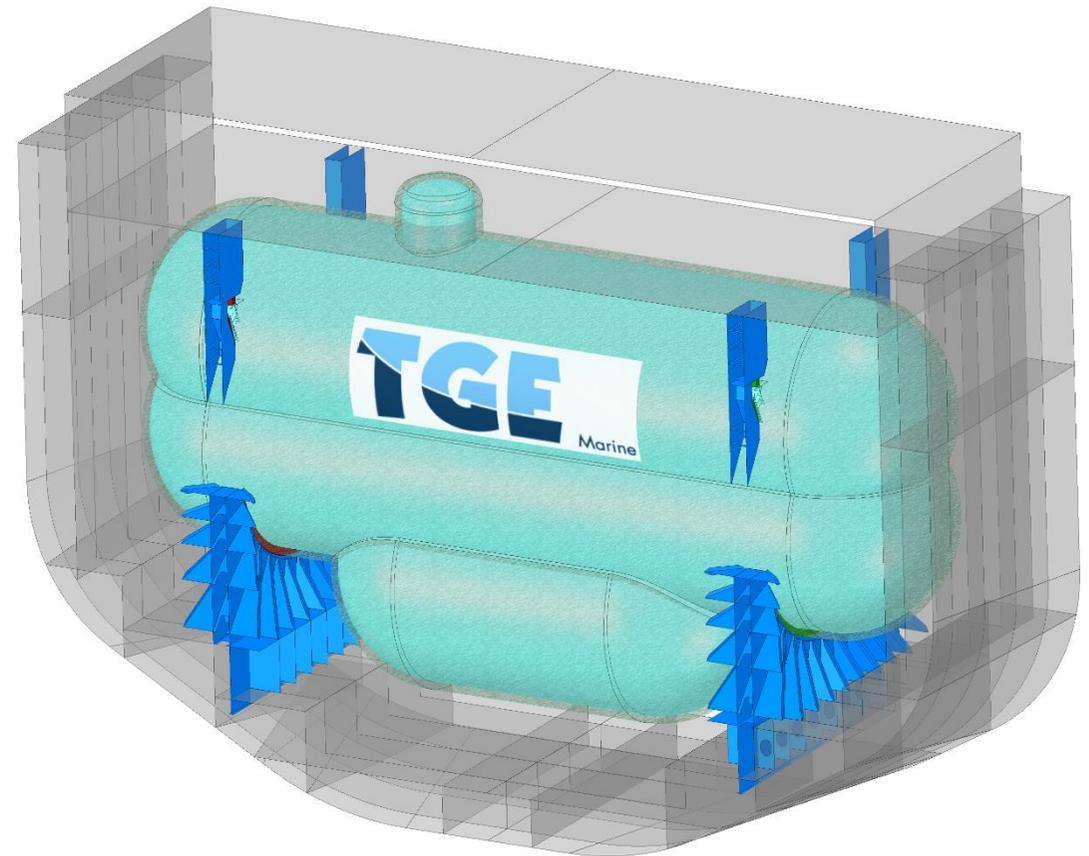
Red curve: Client vessel tank pressure; **red dashed line:** Client tank design pressure (700 mbarg);
Orange curve: Bunker vessel tank pressure; **Green curve:** Flow client vessel -> bunker vessel (vapour return)
Blue curve: Temperature of flow bunker vessel -> client vessel

Dynamic Simulation – Summary

- During bunkering in free flow mode, client vessel tank pressure rises up to approx. 1.3 barg.
- As a result, bunkering in free flow mode requires a tank design of at least 2 barg (approx.) or a vapour return compressor.
- By means of a BOG compressor that increases pressure in bunker tanks, pressure in container ship's tank can be kept at 0.5 barg.
- BOG compressor can be placed on bunker vessel or on client vessel.
- Other means of BOG handling could be used, such as reliquefaction or a GCU.
 - Reliquefaction results in high space requirements and power consumption
 - GCU requires a large amount of space and increase CAPEX due to burning of gas

Type C tank for container vessels

- Suitable especially for medium size to large container vessels (newbuilding's and retrofit's)
- Designed for installation within one 40 ft container bay
- Easy and proven shipside foundation structure
- Short vessel building/retrofit period due to independent tank manufacturing
- Full operational advantages of type C tanks
- Proper space ratio tank/compartment



Ship to Ship Transfer Equipment

Essential / recommended equipment and components:

- Discharge/receiving valves at bunker supply/receiving vessel
- Loading arm or hose for LNG and vapour return
- Emergency break away coupling
- Quick dry connect/disconnect coupling
- Fall arrest system
- Means for draining after completion of bunker transfer
- Means for inerting and gas freeing
- Ship-to-Ship link for communication and automatic/manual ESD
- Vessel separation detection
- Fenders
- Water Curtains



Ship to Ship Transfer Equipment

Loading arms

- FMC arm installed on Shell's 'Cardissa'
- GTT arm installed on 'Clean Jacksonville'
- High space requirements
- Defined operation envelope
- Possible designs for remote or automated connection
- Extensive shore based track record

Hose based systems

- High flexibility
- Lower space requirements
- Installed on 'Coralius', 'ENGIE Zeebrugge', 'Coral Methane', 'Seagas', Kairos
- Track record from large scale STS operations
- Over 2000 LNG bunker operations with 'Seagas' (source: Manntek)
- Over 70 LNG bunker operations with 'Coralius' (source Manntek)



Summary

- 6 LNG bunker vessels are in the water and min. 16 will be in operation by 2020
- The geographical footprint of LNG bunker vessels will drastically increase
- STS transfer operations with hose based systems from type C tank to type C tank are gaining significant operational experience
- STS LNG bunker operations have been carried out in various locations
- Standardization needs to be driven and future bunker vessels can be built simpler and cheaper as ,first followers' in geographical areas with existing bunker vessels.





Thank you for your kind attention
For further information please email:

sales@tge-marine.com

www.tge-marine.com

