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CARGO LOADING RATE ASSESSMENT FOR CC4 MIXTURES CARRIED ON BOARD LPG SHIPS

This paper presents a method of calculations in order to assess possible cargo loading rate for CC4 cargo when its composition is taken into account.
Cargo loading rate is essential in use of LPG carriers. After short description of C4-Crude (CC4) cargoes, composition of sample cargo is shown. Example of LPG carrier loading log is discussed and explained. Reliquefaction system used on board ship is taken into account and its refrigeration capacity is discussed.
Microsoft Excel is used to calculate total cargo loading rate for CC4 cargoes. Assumptions for preparing its formulas are explained, final result as a diagram is shown. Conclusions are discussed.

Keywords: *LPG carrier, cargo process, cargo loading rate, C4-Crude cargo.*

INTRODUCTION

LPG – liquefied petroleum gas is the general name given for propane, butane and mixtures of the two. The main production of LPG is found within petroleum producing countries. LPG is extracted from natural gas or crude oil streams coming from underground reservoirs. Of course, these products are obtained as a by-product [3].

Table 1. An example of composition of C4-Crude cargo [7]

Characteristics	Units	Value	Test Method
1,3-Butadiene	% wt	min. 32	GC
C3 and Lighter	% wt	max. 0.6	GC
C4 Acethylenes	% wt	max. 2.0	GC
Propadiene & Methylacethylene	% wt	max. 0.4	GC
Isobutene	% wt	min. 17	GC
Saturated C4	% wt	max. 24	GC
C5 and Higher	% wt	max. 0.4	GC
Total Sulphur	ppm wt	max. 1	ASTM D3246
Carbonyls (as acetaldehyde)		max. 200	GC
Water		no free	Visual
Other C4 components present but not specified in this specification are: 1-Butene, 2-Butenes, 1,2-Butadiene			

C4-Crude cargoes are mixtures of various liquefied gases and are not listed in the IGC Code. In this paper, based on some ships owner practice, four components are taken into account: Butylene (C_4H_8), 1,3 – Butadiene (C_4H_6), Isobutane (C_4H_{10}) and nButane (C_4H_{10}). Below in Table is shown an example of composition of cargo.

Because of different compositions of CC4, which depends on supplier, the biggest problem facing LPG carrier before loading is to determine the cargo loading rate. There are no similar trials like described below in available literature [3, 8, 9].

1. THE CARGO LOADING RATE OF LPG CARRIER

There are many factors which determine how fast cargo could be loaded on board the ship. Below in Table 2 cargo loading rate is shown during loading operation on board one LPG carrier. Excluding CC4 composition, which impact during loading is constant, ship`s cargo manifold temperature is the main factor from supplier side which influences on the loading rate. Of course, lower temperature – higher rate. On the other hand reliquefaction plant on board the ship determine its total refrigeration capacity, which causes how fast already loaded CC4 is cooled down and if pressure in the cargo tanks is kept in proper range.

Table 2. An example of loading sheet of C4-Crude cargo [7]

Pump Log

Vessel:	„XXXXX"	**Port:**	XXXXXX	**Grade:**	CC4	**Liqid Syftems:**	**No 2**
Voyage:	2013-01	**Terminal:**	xxxxxxx	**Connection:**	8"x300ASA	**Before:**	**59**
Date:	23.04.2013	**Berth:**	xxxxxxx	**Operation:**	Loading	**To Load**	9300
				ConnecUon Vap:	N/A		

Date	Time	Ship's Manifold		Cargo (mt)				Remarks
		Temp. C	Pres. Bg	OBQ(mt)	Loaded	To Load	Rate	
24-Apr-13	0:00	0.0	0.2	74	15	9286		2312 Commenced loading CC4
24-Apr-13	1:00	0.0	0.0	74	15	9285	0	0025 Loadlng suspended
24-Apr-13	10:00	4.0	0.2	102	43	9257	28	0942 Loadlng resumed
24-Apr-13	11:00	4.0	0.2	176	117	9183	74	
24-Apr-13	12:00	4.0	0.2	269	210	9090	93	
24-Apr-13	13:00	6.0	0.2	354	295	9005	85	
24-Apr-13	14:00	8.0	0.5	438	379	8921	84	
24-Apr-13	15:00	6.0	0.5	517	458	8842	79	
24-Apr-13	16:00	8.0	1.0	615	556	8744	98	
24-Apr-13	17:00	8.0	1.0	708	649	8651	93	
24-Apr-13	18:00	9.0	1.1	793	734	8566	85	
24-Apr-13	19:00	8.0	1.0	869	810	8490	76	
24-Apr-13	20:00	8.0	0.8	947	888	8413	77	
24-Apr-13	21:00	8.0	0.5	1029	970	8330	82	
24-Apr-13	22:00	8.0	0.5	1114	1055	8245	85	

In Table 3 are shown parameters of Burckhardt compressors 2K 160 type, which are operating during loading CC4. After short analysis these parameters it is clear, that compressors are operating with one-stage cycle without cargo economizer [4]. Of course used cycle of compressors, which may operate as one or two stages machine with or without interstage cooling of vapour, is essential.

Appropriate thermodynamic properties of processes [5, 6] shall be followed by general good condition of reliquefaction plant, especially compressors where mass flow capacity influence on final refrigeration capacity (for example theoretical and real volume capacity of compressor essential [1, 2]) and for some cargoes discharge temperature is limited by polymerization hazard.

Refrigeration capacity of reliquefaction plant enables to keep pressure in cargo tanks in proper range. According to cargo requirements, appropriate temperature should be obtained and kept before, during and after loading in order to not exceed allowed pressures in cargo tanks. It is strongly related with loading rate, where required lower temperatures in cargo tanks mean lower loading rate.

Table 3. Compressors parameters during loading C4-Crude cargo [7]

Vessel xxxxxxx			**COMPRESSOR** Voyage Number : 01-2013						**Gas Cargo Voyage Report Machinery Section**						
Load Port : xxxxx Product : CC4	**Discharge Port**								**Voyage Unladen**						
	P	**C**	**S**	**P**	**C**	**S**	**P**	**C**	**S**	**P**	**C**	**S**	**P**	**C**	**S**
Date	2013-04-27			2013-04-28			2013-04-28			2013-04-29					
Time	1800Hrs			0900Hrs.			1800Hrs			0900Hrs.					
Load 100% / 50%	100	100	100	100	100	100	100	100	100	100	100	100			
Motor Hours Run															
Volts	450	450	450	450	450	450	450	450	450	450	450	450			
Amperes	260	260	260	250	250	250	260	260	260	270	270	270			
Motor Room Temp	18			13			20			14					
Pressure PI Suction	0.05	0.1	0.1	0.05	0.05	0.1		0.1	0,15	0.1	0,15	0,2			
PI Stg 1 Discharge	5.2	5.3	5.4	5.5	5.4	5.5		5.1	5.6	5.0	5.1	5.1			
PI Stg 2 Discharge	5.3	5.4	5.5	5.6	5.5	5.6		5	5.7	5.1	5.2	5.2			
Temp TI Stg 1 Suction	10	13	10	9	11	11		12	11.5	8	10	6			
TI Stg 1 Disch	89	90	90	89	90	87		88	84	84	79	76			
TI Stg 2 Suction	11	10	10	10	10	10		8	9	8	8	7			
Ti Stg 2 Disch	89	90	90	88	91	87		91	88	89	84	81			

2. THE CARGO LOADING RATE DIAGRAM

Because of CC4 cargoes are quite different depends of supplier, and their composition change very often, it is necessary on board LPG ships and in owners` offices to have some tools for quick assessing expected cargo loading rate especially when some grade is being loaded first time.

Microsoft Excel is common used in offices and also on board ships worldwide, so it was chosen to be employed for this task. Detailed parameters of pure components e.g.: Butylene (C_4H_8), 1,3 – Butadiene (C_4H_6), Isobutane (C_4H_{10}) and nButane (C_4H_{10}) was taken from the gas plant manufacturer. Based on this data loading rate curves were created for each component and some formulas were written in Excel to calculate total loading rate when the percentage composition a mixture changes. Logarithmic scale is used for more convenient reading values of loading rate.

Final result is shown in Fig. 1. There is the diagram which generated curves of loading rate for mixture: 20% Butylene (C_4H_8), 60% 1,3 – Butadiene (C_4H_6), 20% Isobutane (C_4H_{10}) and 0% nButane (C_4H_{10}).

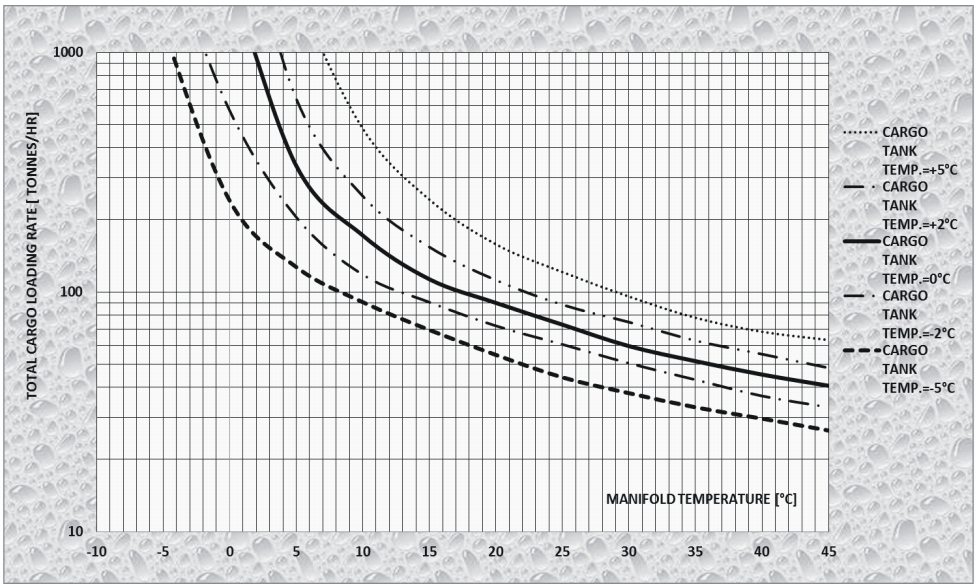

Fig. 1. Cargo loading curves for mixture: 20% Butylene, 60%1,3 – Butadiene, 20% Isobutane

Depend on both: manifold and required cargo tanks temperature, the diagram shows appropriate loading rates, which are possible to be reached. There are two assumptions which has to be taken into account:

- resultant curves are based on data prepared by manufacturer for specific type of ship;
- resultant curves are based on specific type of reliquefaction plant.

It means that the diagram is useful for one type of LPG carrier and closely depend on technical condition of ship.

CONCLUSIONS

The diagram described above is currently checked in practice. As it was mentioned before, theoretical curves created by producer and transferred by Excel formulas have to stand comparison with real condition of operation of LPG carrier.

Each time when the percentage composition of a mixture is changed, immediately new cargo loading rate curves are created on the diagram.

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OKREŚLANIE RATY ZAŁADUNKOWEJ DLA MIESZANIN CC4 TRANSPORTOWANYCH NA GAZOWCACH LPG

Streszczenie

W publikacji zaprezentowano metodę obliczeniową służącą do określania raty załadunkowej dla ładunku CC4, kiedy jego skład chemiczny jest brany pod uwagę.
Rata załadunkowa jest istotną wielkością przy eksploatacji gazowców LPG. Po krótkim opisie ładunków C4-Crude czyli CC4 przedstawiono jego przykładowy skład chemiczny. Przedyskutowano i wyjaśniono okrętowe parametry załadunkowe istotne przy tej operacji. Przeanalizowano wpływ instalacji skraplania ładunku statku.
Wyjaśniono założenia przyjęte w arkuszu kalkulacyjnym Excel, dzięki któremu oblicza się raty załadunkowe, do budowy zastosowanych formuł obliczeniowych. Przedstawiono wykresy możliwe do wykorzystania w praktyce. We wnioskach przedyskutowano uzyskane rezultaty.

Słowa kluczowe: *gazowiec LPG, proces ładunkowy, rata załadunkowa, ładunek C4-Crude.*