

AN INTRODUCTION TO LNG BUNKERING

Nigel Draffin



AN INTRODUCTION TO LNG BUNKERING



Dedication

This book is dedicated to the thousands of marine engineers who have safely transported LNG cargo, burned the methane gas in their ships' engines and demonstrated that LNG and methane fuel are safe, efficient and effective. They have done so since 1964 with an almost unblemished safety record.

It is also dedicated to the engineers and naval architects who made the concept into a practical reality, especially L.R. Prew (Roy) and Roger C. Ffooks.

Nigel Draffin



AN INTRODUCTION TO LNG BUNKERING

by

Nigel Draffin

M.I.Mar.E.S.T.

First Edition

Foreword by

Mogens Schrøder Bech
Danish Maritime Authority

Published by

Petrospot Limited

England

2013

Published in the United Kingdom by

Petrospot Limited
Petrospot House, Somerville Court, Trinity Way,
Adderbury, Oxfordshire OX17 3SN, England

www.petrospot.com
Tel: +44 1295 814455
Fax: +44 1295 814466

© Nigel Draffin 2013

First published 2013

British Library Cataloguing in Publication Data

A catalogue record for this book is available from
the British Library

ISBN 978-1-908663-15-3

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means electronic, mechanical, photographic, recorded or otherwise, without the prior written permission of the publisher, Petrospot Limited.

This publication is designed to provide accurate and authoritative information in regard to the subject matter covered. It is sold with the understanding that the publisher is not engaged in rendering legal, accounting, or other professional service. If legal advice or other expert assistance is required, the services of a competent professional person should be sought.

Petrospot books are available at special quantity discounts for use in corporate training programmes or onboard ships

Petrospot Limited (www.petrospot.com)
Designed by Cheryl Marshall, Petrospot Limited
Printed in the United Kingdom
by Stephens Print Solutions
(www.stephensprintsolutions.com)

Foreword

Shipping has been under tremendous stress in recent years. Overcapacity in most segments as a result of many orders for new ships in the first decade of the 21st century and a fall in the volumes expected to be carried by sea are the main reasons for this. The picture does, of course, vary for each individual shipping segment.

In addition, shipping continues to be hit by soaring oil prices, as do other highly energy intensive industries. Consequently, ship owners must look for more energy efficient ships and/or alternative fuels.

At the same time, international regulation has stipulated stricter emission requirements with the aim of improving the environment and the health of citizens.

From 1 January 2015, shipping will be faced with a requirement for a 0.1% sulphur content in fuel in some sea areas, such as Northern Europe, the United States and Canada, whereas international shipping will be required to meet a 0.5% limit from 2020 or 2025 if lower sulphur fuel is not available in sufficient quantities. At the same time, lower emissions of nitrogen oxides will be required in some sea areas from 2016.

An obvious answer to these demands is to use LNG as a ship's fuel. But the answer is not easy as there are other fuel options and new ones will emerge from laboratories in the future.

The use of LNG as a ship's fuel is supported by the fact that LNG production facilities are in place to meet the global demand and that efficient logistical import terminal systems are serving hinterland gas grids. Furthermore, natural gas reserves seem abundant and new production facilities are being planned and constructed.

This backbone of production and terminals creates a good basis for establishing an infrastructure of small and medium-scale terminals, bunker vessels and trucks for supplying LNG as a bunker fuel. Such an infrastructure is costly and the only way forward for creating low unit costs for the infrastructure element of the LNG bunker price is a combination of economies of scale and flexible migration strategies.

And as regards price, a spread has developed between oil-based fuels and LNG. Two years ago, ship owners looked for the price of LNG to be pegged to oil and they were reluctant to take advantage of a possible upside from such a price spread. Today, however, many ship owners are seeking to take advantage of this situation.

Looking to the future and the price of LNG compared to oil-based products, I think of the words of a famous Danish humourist: 'It's tough to make predictions,

especially about the future.’ Much uncertainty prevails about LNG pricing; however, the ship owner must take a decision.

The turnaround time in ports is also a critical issue for ship owners, and bunkering procedures must be seen from an economic perspective, including turnaround costs, as well as from a safety point of view. LNG is a new fuel for shipping and, in its early days, its use will create uncertainties for regulatory authorities as well as for the wider public. In this context, I warmly welcome *An Introduction to LNG Bunkering* by Nigel Draffin.

Mogens Schrøder Bech
Danish Maritime Authority

April 2013

Preface

Over the past few years, I have been asked questions about the prospects for the use of methane as a fuel for merchant ships – especially those that are not dedicated LNG tankers. It became clear to me that there was a need for a small book that would explain the practical issues involved with the use of this fuel and the technology and operational requirements for its safe storage and use.

This book is intended for people with a working knowledge of ships and bunkering operations but little or no experience of gas as a fuel or LNG as a storage medium. It focuses on the storage and transfer of the fuel in liquid form although it does discuss the option for storage as a compressed gas.

The use of methane for non-LNG tankers is still in its infancy and, as the practice develops, some of the topics discussed here may become either redundant or unnecessary. However, at this stage it seems prudent to cover all options.

I am sure that there will be some topics I have failed to cover in sufficient detail and others which are given in more detail than needed, but as much of the technology is still novel I hope readers will forgive any shortcomings.

There are over 300 LNG tankers burning methane fuel in boilers and diesel engines and more than 35 other LNG fuelled vessels now in service. Once the International Gas Fuelled Ship Code (IGF Code) is finalised by the International Maritime Organization (IMO) (which we anticipate will be in 2014), we can expect to see an exponential rise in the number of vessels using methane to meet the requirements of reducing sulphur oxides, nitrous oxides, particulate matter and greenhouse gases in their exhausts.

It is common to hear pundits explaining that this is 'not rocket science'. Well, in the case of LNG, a large part of it *is* rocket science as much of the equipment and many of the techniques have come from the development of space rockets. It is a tried and tested solution, used extensively at sea and onshore, and will become a valuable addition to conventional marine technology.

Any fuel that can be used as fuel for large trucks delivering goods to supermarkets in cities around the world should hold no terrors for the marine industry.

Nigel Driffin

April 2013

About the author

With the publication of an *Introduction to LNG Bunkering*, Nigel Draffin cements his position as a highly respected and prolific author on the marine fuels industry. This new book is a timely and valuable addition to his five titles on bunkering already published. Nigel's bunker books have sold all over the world and contribute enormously to the knowledge and understanding of both new and experienced members of the bunker fuels industry.

Nigel has been involved in shipping for almost 50 years and with the commercial bunker market for over 25 years. After joining Shell Tankers as an apprentice engineer in 1966, he progressed through the ranks, serving on all classes of vessel, including very large crude carriers (VLCCs) and liquefied natural gas (LNG) tankers.

He came ashore in 1979 to join the newbuilding department of Shell International Marine. After two years of new construction in Ireland, South Korea and the Netherlands, he transferred to Shell's Research & Development unit, specialising in control systems, fuel combustion and safety systems.

In 1986, Nigel moved to the commercial department as a bunker buyer and economics analyst. In 1988, he was promoted to be Head of Operational Economics, responsible for all of the fuel purchased for the Shell fleet, the operation of the risk management policy and the speed/performance of the owned fleet. In March 1996, he joined the staff of E.A. Gibson Shipbrokers Ltd in the bunker department, and became the manager. In 2006, this department merged with US-based broking house LQM Petroleum Services, where Nigel is currently Senior Broker and Technical Manager.

Nigel is a founder member of the International Bunker Industry Association (IBIA) and has served several times on its council of management and executive board. Most recently, he served as the association's Chairman. He is the author of IBIA's *Basic Bunkering Course* and Director of Petrospot's leading training events, the *Oxford Bunker Course*, the *Oxford Bunker Course (Advanced)*, and *An Introduction to LNG Bunkering*. Nigel is a member of the Institute of Marine Engineering, Science and Technology and Past Master of the Worshipful Company of Fuellers.

Llewellyn Bankes-Hughes
Managing Director
Petrospot Limited

April 2013

Acknowledgements

I must thank the team at Petrosport whose hard work has produced a book that is well laid out and easy to use. All of the heavy lifting has been done by Cheryl Marshall and Lesley Bankes-Hughes who have worked tirelessly to correct my 'prose' and produce the drawings and diagrams.

I also acknowledge the help and comments given to me by many participants in conference sessions on LNG over the last two years. There are many others who helped, too many to be named here, but without their assistance this book would never have appeared.

Nigel Draffin

April 2013

Contents

Foreword	v
Preface	vii
About the author	ix
Acknowledgements	xi
Introduction	1
A little history	1
Why methane?	2
Chapter 1 - Using gas as a fuel	3
The basics	3
Some physics	3
Some definitions	4
Methane.....	5
Other potential fuel gases.....	6
Gas engines	7
Dual fuel engines.....	8
Gas-diesel engines.....	8
Boilers.....	9
Chapter 2 - Problem areas	11
Chapter 3 - Storage	17
Onshore storage.....	17
Onboard storage.....	17
Shore storage.....	21
Safe zones.....	23
Pumped supply.....	24
Pressure differential supply – shore handling.....	24
Vapour return.....	24
Liquefaction plant	24
Local re-liquefaction	24
Onboard storage.....	24
Chapter 4 - Onboard fuel system	27
Vaporiser	27

AN INTRODUCTION TO LNG BUNKERING

Gas compressor	28
Gas engines	28
Dual fuel systems	29
Boilers.....	31
Gas combustion units (GCU).....	31
Re-liquefaction.....	32
Secondary fuel supply	34

Chapter 5 - Onboard fuel system 35

Hazardous spaces	35
Gas detection	36
Gas extraction	36
Double walled piping	36
Emergency shut down (ESD) systems	36
ESD engine room protection	37
LNG bunker barges	37
LNG road tankers	38

Chapter 6 - Bunkering procedures 39

Establishing safe zones.....	39
Bunker transfer equipment	39
Connection	40
Shore and ship schematic	41
Gassing up delivery side	41
Cooling down delivery side.....	42
Purging ship side and hose	42
Gassing up ship side	43
Loading LNG bunkers.....	43
Reducing tank pressure.....	44
Displacing LNG with methane at completion.....	44
Displacing methane with nitrogen.....	45
Cool down.....	45
Transfer	45
Line inerting	45
Line purging.....	46
Trapped LNG.....	46
Level monitoring	46
Custody transfer	46
Stockholm ferry project.....	47
Safety issues	48

Chapter 7 - Training and regulations	49
Gas escape	49
Fire	50
Cryogenic incidents	50
Dry break couplings.....	50
Connections.....	50
IMO developments	51
SOLAS.....	52
Chapter 8 - The LNG fleet	53
In service	53
On order	53
Future developments.....	54
European Union initiatives.....	54
Short sea shipping.....	54
Domestic.....	54
Coastal	54
Deep sea	56
Chapter 9 - Commercial considerations	57
Pricing.....	57
Energy density, volume and equivalent prices.	61
Invoicing, quantities and BDR	61
Abbreviations	63
Appendix 1 - Where to go for help	65
Appendix 2 - Some data on LNG and methane	69
Index	71

List of Tables and Figures

Table 1.	Storage pressure and boiling temperature.....	4
Figure 1.	A lean burn gas engine	7
Figure 2.	Low pressure gas injection	8
	<i>(Photograph courtesy of Wärtsilä Corporation)</i>	
Figure 3.	High pressure gas injection.....	9
	<i>(Photograph courtesy of Wärtsilä Corporation)</i>	
Figure 4.	Principle of LU/DF register burner	10
Figure 5.	An illustration of how the top layer becomes heavier and the bottom level lighter.....	12
Figure 6.	As the upper layer gets heavier, the lower level gets lighter until..!	13
Figure 7.	As the rupture decreases the internal pressure, the liquid in the container starts to evaporate very rapidly and the volume of gas then overcomes any relief valve capacity.....	14
Figure 8.	Sea NG's patented Coselle for carrying CNG on ships	17
Figure 9.	LNG fuel tank onboard the <i>MF Boknafjord</i>	19
	<i>(Photograph courtesy of Multi Maritime Ship Design & Engineering)</i>	
Figure 10.	Containerised Type C tanks	20
	<i>(Photograph courtesy of Marine Service GmbH)</i>	
Figure 11.	Bi-lobe Type C tank design.....	21
	<i>(Image courtesy of TGE Marine Gas Engineering GmbH)</i>	
Figure 12.	Small LNG carrier loading at Zeebrugge.....	22
	<i>(Photograph courtesy of TGE Marine Gas Engineering GmbH)</i>	
Figure 13.	Halhjem ferry terminal in Norway	22
Figure 14.	Wärtsilä LNGPac fuel system diagram.....	27
	<i>(Diagram courtesy of Wärtsilä Corporation)</i>	
Figure 15.	Wärtsilä gas valve unit	28
	<i>(Photograph courtesy of Wärtsilä Corporation)</i>	
Figure 16.	Rolls-Royce Bergen 35:40 gas engine.....	29
	<i>(This photograph is reproduced with the permission of Rolls-Royce plc, copyright © Rolls-Royce plc 2012)</i>	
Figure 17.	Wärtsilä 50DF engine.....	30
	<i>(Photograph courtesy of Wärtsilä Corporation)</i>	
Figure 18.	MW-GI engine	31
	<i>(Photograph courtesy of MAN Diesel & Turbo)</i>	
Figure 19.	Saacke Type GCU 300.....	32
	<i>(Diagram courtesy of Saacke GmbH)</i>	
Figure 20.	Re-liquefaction process.....	33
Figure 21.	Hamworthy Wärtsilä re-liquefaction system	34
	<i>(Diagram courtesy of Wärtsilä Corporation)</i>	
Figure 22.	Concept LNG barge from Veka Group	37
	<i>(Image courtesy of Veka Group)</i>	
Figure 23.	Gasnor LNG delivery.....	38
	<i>(Photograph courtesy of Gasnor)</i>	

AN INTRODUCTION TO LNG BUNKERING

Figure 24. LNG bunker flow boom concept from TGE.....	40
<i>(Photograph courtesy of TGE Marine Gas Engineering GmbH)</i>	
Figure 25. General arrangement of shore and ship LNG transfer schematic.....	41
Figure 26. Gassing up with methane and cooling down the shore line with LNG	41
Figure 27. Cooling down the shore pump with LNG by circulating LNG back to the shore tank.....	42
Figure 28. Purging the ship-to-shore connections with nitrogen.....	42
Figure 29. Gassing up the ship loading line with methane gas	43
Figure 30. LNG transfer to the ship tank bottom.....	43
Figure 31. Top loading LNG to reduce the tank pressure	44
Figure 32. Displacing liquid with methane gas	44
Figure 33. Purging the ship line and hose with nitrogen.....	45
Figure 34. Time line for replenishing a ferry lifting about 100 m ³ of LNG.....	47
<i>(Diagram courtesy of the Swedish Maritime Technology Forum)</i>	
Figure 35. <i>The Viking Grace</i> and the <i>Seagas</i> . The LNG storage tanks can be seen at the aft end of the ferry.....	48
<i>(Photograph courtesy of Viking Line)</i>	
Figure 36. DC Coupling function.....	51
<i>(Diagram courtesy of Mann-Tek AB)</i>	
Figure 37. Nor Lines Rolls-Royce short sea NVC 405 Ro-Ro.....	53
<i>(Image courtesy of Nor Lines AS)</i>	
Figure 38. Layout of LNG tanks and engines on TOTE containerships for Puerto Rico service.....	55
<i>(Image courtesy of TOTE, Inc. and General Dynamics NASSCO)</i>	
Figure 39. TOTE containership – LNG tanks visible at aft end.....	56
<i>(Image courtesy of TOTE, Inc. and General Dynamics NASSCO)</i>	
Figure 40. US natural gas prices	57
<i>(Source: Energy Information Administration)</i>	
Table 2. Range of Wobbe Index for different gases (using lower heat value)	59
Table 3. DESFA LNG quality specifications	59
Table 4. As an example, based on prices in the first quarter of 2013, we see the following if we price on an energy related basis (\$/MMBtu).....	60
Table 5. Example compositions of natural gas	60
Table 6. Energy content for LNG versus conventional fuels.....	61
Table 7. Volumetric density for LNG versus conventional fuels.....	61
Table 8. Relative pricing per mt of fuels in \$/mt with an allowance for delivery cost based on 2012 assessments.....	61