

LNG LIQUEFACTION PROCESS SELECTION: ALTERNATIVE REFRIGERANTS TO REDUCE FOOTPRINT AND COST

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1 ABSTRACT

This paper describes recent work at ExxonMobil Upstream Research Company to identify novel refrigerants and processes for production of liquefied natural gas (LNG) in large-scale floating and onshore LNG facilities. The goal of the research was to reduce the footprint and cost of baseload LNG plants through the use of non-flammable or reduced flammability refrigerants.

Process results are presented and discussed for two novel liquefaction cycles: a mixed refrigerant process and a cascade process. The performance aspects of each process are discussed, and tradeoffs in process complexity and equipment flexibility are considered.

2 BACKGROUND

2.1 Incentives

The design of an efficient refrigeration system is of paramount importance for effective and economic LNG production. Several commercially available refrigeration cycles are currently in use at baseload LNG plants. Most of these cycles share a common feature: the use of flammable hydrocarbon refrigerants, such as methane, ethane or ethylene, propane, isobutane, isopentane, and their mixtures (often with nitrogen as well).

Facility space is significantly more costly for floating LNG (FLNG) plants than for onshore plants. The use of flammable refrigerants and the requirement for appropriate spacing and other measures to prevent adverse consequences in the event of refrigerant release increases the capital costs of FLNG projects. Requirements for safe refrigerant makeup, handling, storage, and import on to floating vessels also increase FLNG costs relative to onshore plants.

Replacing hydrocarbon refrigerants with non-flammable, or reduced flammability, refrigerants offers the potential for reducing the capital costs of FLNG projects. There are also potential cost reductions for onshore LNG plants, as requirements for "buffer zone" land surrounding and within plant sites may be reduced. These economic benefits can only be realized if the liquefaction cycles using the alternate refrigerants have comparable thermal efficiency and equipment requirements relative to the conventional liquefaction processes.

2.2 Alternative Refrigerants

In considering alternative refrigerants for baseload LNG projects, we evaluated several classes of refrigerants, including hydrofluorocarbons (HFCs), noble gases, and fluorocarbon refrigerants with reduced greenhouse warming potential.

A list of selected conventional and alternative refrigerant candidates appears in Table 1. The table uses the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) "R-code" numbering system, which numerically identifies refrigerants based on their chemical structure.¹ The R-codes will be used to refer to specific refrigerants in the balance of this paper. Table 1 also lists the chemical name, chemical formula, molecular weight, normal boiling point, melting point, critical temperature, safety group, and greenhouse warming potential for each of the refrigerants.

Lng Liquefaction Process Selection Alternative

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Lng Liquefaction Process Selection Alternative:

Advances in Natural Gas: Formation, Processing, and Applications. Volume 6: Natural Gas Transportation and Storage

Mohammad Reza Rahimpour, Mohammad Amin Makarem, Maryam Meshksar, 2024-04-04 Advances in Natural Gas Formation Processing and Applications is a comprehensive eight volume set of books that discusses in detail the theoretical basics and practical methods of various aspects of natural gas from exploration and extraction to synthesizing processing and purifying producing valuable chemicals and energy The volumes introduce transportation and storage challenges as well as hydrates formation extraction and prevention Volume 6 titled Natural Gas Transportation and Storage is separated into three sections The first section discusses different natural gas transportation technologies such as LNG CNG ANG GTS etc The second section introduces related apparatus for natural gas transportation and storage including measurement systems compressors pumps etc as well as pipelines and controlling equipment The last section explains challenges of natural gas transmission including inhibition of pipeline corrosion cracking and wax deposition accompanied with pipeline cleaning challenges Introduces various natural gas transportation technologies LNG CNG ANG Describes different apparatus for natural gas transportation and storage Includes various challenges of natural gas transportation such as pipeline corrosion and wax deposition

Preprints of the Annual Automotive Technology Development Contractors' Coordination Meeting

,1991

Guidebook for Evaluating, Selecting, and Implementing Fuel Choices for Transit Bus Operations

ARCADIS Geraghty & Miller, Inc, Transit Cooperative Research Program, 1998 *Natural Gas Processing from Midstream to Downstream* Nimir O. Elbashir, Mahmoud M. El-Halwagi, Ioannis G. Economou, Kenneth R. Hall, 2019-02-04 A comprehensive review of the current status and challenges for natural gas and shale gas production treatment and monetization technologies Natural Gas Processing from Midstream to Downstream presents an international perspective on the production and monetization of shale gas and natural gas The authors review techno economic assessments of the midstream and downstream natural gas processing technologies Comprehensive in scope the text offers insight into the current status and the challenges facing the advancement of the midstream natural gas treatments Treatments covered include gas sweetening processes sulfur recovery units gas dehydration and natural gas pipeline transportation The authors highlight the downstream processes including physical treatment and chemical conversion of both direct and indirect conversion The book also contains an important overview of natural gas monetization processes and the potential for shale gas to play a role in the future of the energy market specifically for the production of ultra clean fuels and value added chemicals This vital resource Provides fundamental chemical engineering aspects of natural gas technologies Covers topics related to upstream midstream and downstream natural gas treatment and processing Contains well integrated coverage of several technologies and processes for treatment and production of natural gas Highlights the economic factors and risks facing the monetization technologies Discusses supply chain environmental and safety issues associated with the emerging shale gas industry

Identifies future trends in educational and research opportunities directions and emerging opportunities in natural gas monetization Includes contributions from leading researchers in academia and industry Written for Industrial scientists academic researchers and government agencies working on developing and sustaining state of the art technologies in gas and fuels production and processing Natural Gas Processing from Midstream to Downstream provides a broad overview of the current status and challenges for natural gas production treatment and monetization technologies **Port safety and liquefied gas safety and siting** United States. Congress. House. Committee on Merchant Marine and Fisheries. Subcommittee on Coast Guard and Navigation,1980 *Gas Engineering and Management* ,1995 *Sundesert Nuclear Power Plant Units 1-2, Construction* ,1978 **Marine Technology 80** Marine Technology Society. Conference & Exposition,1980 *Fossil Energy Update* ,1977 Final Site Environmental Statement Relative to Determination of the Suitability of the Proposed Site for Eventual Construction of Sundesert Nuclear Plant, Units 1 and 2, San Diego Gas and Electric Company, Docket Nos. 50-582 and 50-583 U.S. Nuclear Regulatory Commission. Office of Nuclear Reactor Regulation,1978 *Federal Register* ,2013-08 **Handbook of Liquefied Natural Gas** Saeid Mokhatab,John Y. Mak,Jaleel V. Valappil,David Wood,2013-10-15 Liquefied natural gas LNG is a commercially attractive phase of the commodity that facilitates the efficient handling and transportation of natural gas around the world The LNG industry using technologies proven over decades of development continues to expand its markets diversify its supply chains and increase its share of the global natural gas trade The Handbook of Liquefied Natural Gas is a timely book as the industry is currently developing new large sources of supply and the technologies have evolved in recent years to enable offshore infrastructure to develop and handle resources in more remote and harsher environments It is the only book of its kind covering the many aspects of the LNG supply chain from liquefaction to regasification by addressing the LNG industries fundamentals and markets as well as detailed engineering and design principles A unique well documented and forward thinking work this reference book provides an ideal platform for scientists engineers and other professionals involved in the LNG industry to gain a better understanding of the key basic and advanced topics relevant to LNG projects in operation and or in planning and development Highlights the developments in the natural gas liquefaction industries and the challenges in meeting environmental regulations Provides guidelines in utilizing the full potential of LNG assets Offers advices on LNG plant design and operation based on proven practices and design experience Emphasizes technology selection and innovation with focus on a fit for purpose design Updates code and regulation safety and security requirements for LNG applications *Air Pollution Control* Jeff Kuo,2018-11-23 Air pollution control and air quality engineering are some of the key subjects in any environmental engineering curriculum This book will cover topics that are fundamental to pollution control engineers and professionals including air pollution and its management through regulatory approaches calculating and estimating emissions and appying con Marine Technology 80 Marine Technology Society,1980 **Energy Abstracts for Policy**

Analysis ,1986 *Naval Oil Shale Reserves* ,1982 Offshore Floating Production Max Lemanski,Simon Moore,Stuart Beadnall,2023-02-10 This is the first book to focus on the law and practice relating to offshore oil and gas floating production It deals with all legal and commercial risk management issues from initial concept through design construction modification installation acceptance production and offloading including ancillary legal topics JV consortiums financing insurance decommissioning and intellectual property Floating production projects are a popular method of achieving offshore oil and gas production utilising vessels sitting over the offshore reservoir receiving well fluids which are then processed stored and offloaded to tankers They operate in deep water harsh conditions and marginal fields and may be redeployed once the reservoir is depleted There are numerous legal issues which arise in the context of floating production due to its specific characteristics presenting a unique combination of challenges with the attendant risks and potential liabilities This book analyses these risks and liabilities and considers how they may be allocated between the parties how the consequences are avoided or mitigated and how disputes are in practice resolved It illustrates these issues and competing legal arguments by focusing on each stage of the relationship between the oil and gas company and a specialist floating production contractor The book will be of special interest to project managers and in house lawyers at oil companies offshore contractors design consultants construction companies suppliers vessel operators banks insurers and investors It will also be of particular use to private practice lawyers in all jurisdictions where these projects occur because contracts used in this industry are often written under English law and contracts which are governed by local law follow a similar pattern *Energy: a Continuing Bibliography with Indexes* ,1981 **Green H2 Transport through LH2, NH3 and LOHC** Laura A. Pellegrini,Elvira Spatolisano,Federica Restelli,Giorgia De Guido,Alberto R. de Angelis,Andrea Lainati,2024-07-31 This book explores the opportunities and challenges of hydrogen transport through different carriers i e liquefied hydrogen ammonia toluene and dibenzyltoluene Each value chain analyzed includes renewable H2 conversion to the carrier storage of the hydrogenated carrier its seaborne transport reconversion of the carrier to produce H2 and hydrogen distribution The conversion and reconversion processes are the cost drivers of the whole value chain These stages are investigated through an in depth techno economic assessment to highlight the critical issues and the need for further investigation low TRL The alternatives are examined considering different H2 applications industrial and mobility sector different costs of utilities present and future scenarios and different distances from the loading to the unloading terminal All these scenarios are discussed and compared by means of the levelized cost method to understand which is the most cost effective choice for each case study As a result H2 application to the industrial sector shows the lowest costs with ammonia being the best alternative for transporting and storing hydrogen in this case Liquefied hydrogen is the most expensive H2 carrier for the industrial application as a consequence of the high liquefaction costs while holding promises for the mobility sector **Handbook of Research on Advances and Applications in Refrigeration Systems and Technologies** Gaspar, Pedro Dinis,da Silva,

Pedro Dinho,2015-08-28 In recent years the sustainability and safety of perishable foods has become a major consumer concern and refrigeration systems play an important role in the processing distribution and storage of such foods To improve the efficiency of food preservation technologies it is necessary to explore new technological and scientific advances both in materials and processes The Handbook of Research on Advances and Applications in Refrigeration Systems and Technologies gathers state of the art research related to thermal performance and energy efficiency Covering a diverse array of subjects from the challenges of surface area frost formation on evaporators to the carbon footprint of refrigerant chemicals this publication provides a broad insight into the optimization of cold supply chains and serves as an essential reference text for undergraduate students practicing engineers researchers educators and policymakers

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Table of Contents Lng Liquefaction Process Selection Alternative

1. Understanding the eBook Lng Liquefaction Process Selection Alternative
 - The Rise of Digital Reading Lng Liquefaction Process Selection Alternative
 - Advantages of eBooks Over Traditional Books
2. Identifying Lng Liquefaction Process Selection Alternative
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Lng Liquefaction Process Selection Alternative
 - User-Friendly Interface
4. Exploring eBook Recommendations from Lng Liquefaction Process Selection Alternative
 - Personalized Recommendations
 - Lng Liquefaction Process Selection Alternative User Reviews and Ratings
 - Lng Liquefaction Process Selection Alternative and Bestseller Lists
5. Accessing Lng Liquefaction Process Selection Alternative Free and Paid eBooks
 - Lng Liquefaction Process Selection Alternative Public Domain eBooks

- Lng Liquefaction Process Selection Alternative eBook Subscription Services
- Lng Liquefaction Process Selection Alternative Budget-Friendly Options
- 6. Navigating Lng Liquefaction Process Selection Alternative eBook Formats
 - ePub, PDF, MOBI, and More
 - Lng Liquefaction Process Selection Alternative Compatibility with Devices
 - Lng Liquefaction Process Selection Alternative Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Lng Liquefaction Process Selection Alternative
 - Highlighting and Note-Taking Lng Liquefaction Process Selection Alternative
 - Interactive Elements Lng Liquefaction Process Selection Alternative
- 8. Staying Engaged with Lng Liquefaction Process Selection Alternative
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Lng Liquefaction Process Selection Alternative
- 9. Balancing eBooks and Physical Books Lng Liquefaction Process Selection Alternative
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Lng Liquefaction Process Selection Alternative
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Lng Liquefaction Process Selection Alternative
 - Setting Reading Goals Lng Liquefaction Process Selection Alternative
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Lng Liquefaction Process Selection Alternative
 - Fact-Checking eBook Content of Lng Liquefaction Process Selection Alternative
 - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks

14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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