

# Chapter 6

## A Point of View on How to Achieve a More Sustainable Marine Refrigerated Transport

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### **ABSTRACT**

*It is specific for our modern society to consume an important amount of food transported from one part of the earth to another. A sustainable refrigerated transport is described by indicators like profitability, product quality, technological change, and environmental impact. Sustainable development is connected with the minimisation of irreversibilities. This is why exergy analysis is used as a powerful tool to obtain sustainable development. In this context, this chapter deals with the exergy analysis specific to the most common type of refrigerating plants on board ships. Regulations on old refrigerants, inducing technological change, are presented along with solutions for the replacement of the refrigerant R-22. The chapter also mentions the fishing industry where ammonia is the dominant refrigerant.*

### **INTRODUCTION**

The aim of the refrigerated transport is to provide safe and high quality perishable goods to the consumers, all over the world. Foodstuffs or non-food goods like plants (flowers), pharmaceutical and chemical products are carried at specific temperatures. There are three kinds of refrigerated transport: sea transport, land transport

(road or rail) and air transport. As population in developing countries grows, food demand also grows, refrigerated transport being vital for the food quality and safety. The transport of the food is one of the most important uses of refrigeration. Food transport demand will increase in the future due to the fact that world population, which in present means 7 billion inhabitants, will meet about 9 billion inhabitants in 2050. To be more specific, this increase will be mostly registered in developing countries.

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Marine transport of refrigerated goods may be one of the two types: containerized transport and conventional refrigerated shipping. There are currently 715000 TEUs worldwide. In 1998, sales of TEUs reached a level of 96500, more specific 500 insulated containers and 96000 refrigerated containers. The trend is towards self-contained refrigerated containers. They can transport perishable products for weeks, or even months, under very stable temperatures, humidity and controlled atmospheric conditions. For the maritime transport of chilled products, R134a (HFC 134a) is used as a refrigerant. For the maritime transport of frozen products, either R 134a is used or R 404 A (HFC 404 A) can be employed. On reefers, besides R 22 (HCFC 22), the main refrigerants used are R 410 A (HFC 410 A), R 407 C (HFC 407 C), and R 404 A. In 1993, five refrigerating ships using ammonia were built. Since then, ammonia has no longer been used, except on fishing boats.

Today, the main objective of marine refrigerated transport is the minimization of its operational impact on the environment. Developing sustainable solutions for this sector is translated by searching for solutions referring to technologies (aiming the use of the most energy efficient equipments), refrigerants (it is about the selection of environmentally friendly refrigerants), leakage (non-natural refrigerant leakage has an environmental effect, but also reduces the efficiency of the plant), maintenance (heat exchangers have to be kept clean by having regular preventive maintenance regimes and checking refrigerant leakage at regular intervals).

The use of exergy analysis is a tool useful to achieve a sustainable marine refrigerated transport. By applying this method to the single stage vapor compression cycles, commonly used in marine refrigerated transport, it will be possible to identify thermodynamic imperfections. Attempts in reducing exergy losses will be materialized in technological changes able to achieve this objective.

Other aspect of the sustainable marine refrigerated transport is the use of HFCs in this sector. HFCs are substitutes for ozone-depleting refrigerants, which were the refrigerant choice for many years. Although HFCs have zero ODP (Ozone Depletion Potential), they still present high GWP (Global Warming Potential), making HFCs to be included on the Kyoto list of gases whose emission need to be diminished. Despite this, HFCs are accepted as an environmental solution in refrigeration.

This chapter is addressed to engineers dealing with process design, optimization, and understanding. These specialists should be familiarized with exergy analysis since it is one of the keystones for obtaining sustainable development through technological change.

## **Prior Work**

During the last decades, exergy analysis was used as an important tool for design, analysis and improvement of thermal systems as stated by Ibrahim Dincer and Marc A. Rosen in “EXERGY: Energy, Environment and Sustainable Development”, 2007. According to Patrick Canning et al, food processing implies significant energy consumption, the replacement of older equipments with more energy effective new equipments being seen as a priority (in “Energy use in the U.S. Food System”, 2010).

Exergy analysis reveals important information about the total irreversibility distribution on the components of a plant. Several works are dealing with it, providing experience for this study: Bejan A. et al. in “Thermal design and optimization” (1996), Morosuk T. and Tsatsaronis G. in “How to calculate the parts of exergy destruction in an advanced exergetic analysis” (2008), Memet F. et al. in “Exergy and environmental analysis of the one stage vapor compression marine refrigerating machine working with ammonia” (2010). Exergy losses are responsible for a decrease in the useful

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