RSW SYSTEMS WITH CO_2 AS REFRIGERANT

MAIN RESULTS – JANUARY 2007

Introduction

The most commonly used refrigerant in RSW (refrigerated seawater) systems in fishing vessels today is HCFC-22 (R-22). The *Montreal Protocol* dictates the abolishment on HCFC refrigerants, known to deplete the ozone layer if released to the atmosphere. HCFC-22 is no longer tolerated for use in new systems neither in Norway, nor EU.

Two groups of refrigerants are the alternatives today, that is the HFC's and natural refrigerants. HFC's are synthetic refrigerants foreign to nature and known to have relatively large global warming potentials. The other group is the *natural refrigerants* which are substances already circulating in our biosphere. Possible refrigerants for fishing vessels are ammonia and carbon dioxide (CO_2). Ammonia is slightly toxic and flammable, thus requiring extra safety precautions which are cost driving. CO_2 is non-toxic and non-flammable. If an energy efficient CO_2 system can be developed at acceptable cost figures, it represents a very interesting alternative for ship owners, and also for Norwegian suppliers of refrigeration equipment.

Objectives of the present project

The main objective of the present project was to develop a CO_2 RSW system for laboratory use. Sub-goals included:

- Design of key components, control system and overall system configuration for a CO_2 RSW system capable to operate sub- and trans-critically depending on sea water temperatures
- Build a small capacity mobile test system
- Experimental test campaign in order to gain practical experience, verify theoretical results obtained by simulation and to compare the results to systems with alternative refrigerants

The reference group to the present project has been Torfinn Torp from Teknotherm AS (Halden) and Oddbjørn Troland from the Møgster Group (Austevoll).

The Norwegian Research Council and The Fishery and Aquaculture Industry Research Fund has financed the project.

Results

A prototype CO_2 RSW system for laboratory use has been designed built and tested experimentally. The main components were a semi-hermetic piston compressor from MYCOM, a tube in shell RSW cooler and a water cooled multi-pass gas-cooler/condenser. The heat exchangers were developed and designed by using a combination existing simulation tools and

development of new design programs. According to specifications, the RSW cooler was produced by Teknotherm AS and the gascooler/condenser was manufactured by HPH srl (Milano, Italy). Both heat exchanger manufacturers have actively been involved in the development work. An air cooled gascooler/condenser was also designed and included in the RSW system for use in cases where cooling water is not available.

Both cool down of RSW water and steady state experiments (keeping RSW water at -1°C) have been performed. The system high pressures were varied from 50bar to 90 bar. Cooling water temperatures were varied from 10°C to 25°C. Measured cooling capacities at steady state varied between 13kW to 33kW. The variation of cooling capacity was sensitive to the system high pressure. Highest cooling capacity was measured at 10°C cooling water temperature and 80 bar high pressure. The Coefficient of Performance (COP) also varied with pressure and temperature. Best COP was recorded to be 2.8 at 70 bar high pressure and 10°C cooling water, see figure.

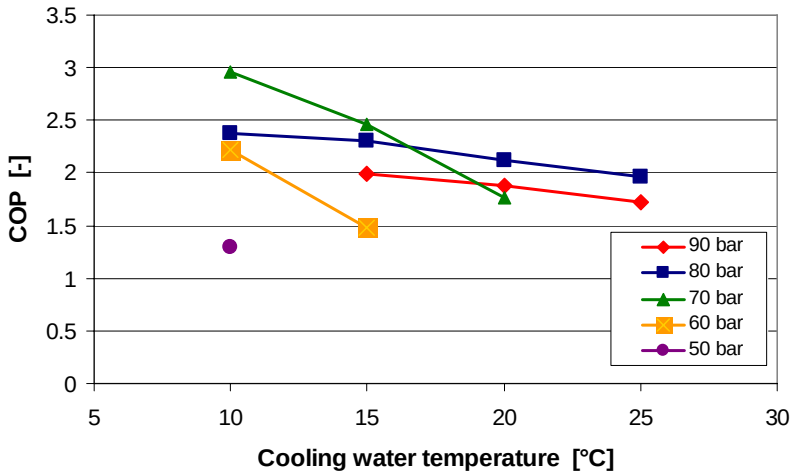

Figure - COP at varying cooling water temperatures and high pressures.

This initial study shows that the CO_2 RSW technology is promising. However, there is room for performance improvements both with regard to the components and the system. Besides improving energy efficiency, it is of course vital to identify a cost competitive design.

The R&D tasks carried out in the project were:

- Develop new heat exchanger concepts adapted for CO_2 - RSW (cleanable) and CO_2 - sea water
- Develop simulation tools for the heat exchanger design
- Design the overall process to become efficient and cost effective
- Perform experimental campaign
- Analysis of experiments
- Reporting

Project execution
The project time period was originally planned to 20 months, from January 2005 to August 2006. Due to time delay in the manufacturing of one of the heat exchangers and the system installation, it was applied for a 4 month time extension of the project. This was granted, and final reporting is January 2007.

The total budget frame was 2.000.000,- NOK, divided into 1.100.000,- for 2005 and 900.000,- for 2006. The project was carried out within the economical frame.

Value of research
The present project has made a firm basis for the development of CO_2 RSW systems and liquid chillers. New design programs are developed for design of new types of heat exchangers. Testing of heat exchanger prototypes made it possible to calibrate design models. Calibrated models are vital for design of new heat exchangers and the up-scaling in capacity. Heat exchangers manufacturers will take advantage of this for the future production. The system design was also tested experimentally, which is decisive for improved and system performance and operational safety of future systems.

The knowledge developed by Teknotherm, HPH and SINTEF in present project is a contribution to a more sustainable refrigeration industry, both nationally and internationally. If a cost effective full scale system can be developed, it represents a considerable opportunity for Norwegian refrigeration industry.

Next steps
Identify and carry out a pilot project. Results and findings in the present project will be used for redesign and preparation of a full scale system, preferably on shore before going to fishing vessels.

The results was presented and published in IIR Congress of Refrigeration in Beijing 2007. It was also presented at Norsk Kjøleteknisk Møte 2007.

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