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ScienceDirect

Energy Procedia 109 (2017) 190 – 202

Energy Procedia

International Conference on Recent Advancement in Air Conditioning and Refrigeration, RAAR 2016, 10-12 November 2016, Bhubaneswar, India

Thermodynamic Modelling and Parametric Study of a Two Stage Compression-Absorption Refrigeration System for Ice Cream Hardening Plant

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Abstract

The present communication introduces a new concept of Two Stage Vapor Compression-Absorption Cascade Refrigeration System (TSVCACRS) for achieving low temperature industrial cooling. The system comprises of Two Stage Vapor Compression Refrigeration System (TSVCRS) having flash intercooler integrated with single stage Vapor Absorption Refrigeration System (VARS); thermally coupled by means of cascade condenser heat exchanger. The cascade condenser heat exchanger works as an evaporator for VARS and the condenser for TSVCRS. The proposed system has been designed and simulated for Havmor Ice cream Limited located at GIDC, Naroda, Ahmedabad; to check the thermodynamic performance feasibility with their existing installed TSVCRS based ice cream hardening refrigeration plant of 525 TR (1850 kW). Ammonia and LiBr-H_2O have been considered as working fluid pair in proposed TSVCACRS. The results show that proposed TSVCACRS system would minimize the compressor work up to 28%, compared to an existing installed TSVCRS. The exergetic efficiency of the VAR, VCR subsystems and integrated TSVCACRS is found to be 32.78%, 60.29% and 53.59%, respectively. Moreover, the optimum generator temperature for the proposed system is found to be 85°C from the energetic and exergetic point of view.

Peer-review under responsibility of the organizing committee of RAAR 2016.

Keywords: Ice cream Plant, Energy, Exergy, Irreversibility, Two stage vapor compression refrigeration system (TSVCRS), Two stage vapor compression absorption refrigeration system (TSVCACRS).

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Peer-review under responsibility of the organizing committee of RAAR 2016.
doi:10.1016/j.egypro.2017.03.091

Nomenclature

c_p	specific heat at constant pressure	COP	coefficient of performance
e	specific Exergy	$\dot{E}$	exergy flow rate
EES	engineering Equation Solver	EV	Expansion Valve
h	enthalpy	HP	High pressure
$\dot{I}$	Irreversibility	$\dot{m}$	mass flow rate
P	pressure	$\dot{Q}$	Heat
r	relative irreversibility	$\dot{s}$	Entropy
T	Temperature	TSVCACRS	Two Stage Vapor Compression Absorption Cascade Refrigeration System
TSVCRS	Two Stage Vapor Compression Refrigeration System	$\dot{W}$	Work

Greek Symbols

Ƞ	efficiency	θ	carnot factor

Superscript/ Subscript

0	environmental state	1, 2…	state points
a	Absorber	c	condenser
cc	cascade condenser	comp	compressor
D	Desorber	e	evaporator
EV	expansion valve	g	generator
HPC	high pressure compressor	gen	generation
i	state point	k	component
LPC	low pressure compressor	m	mechanical
P	Pump	prv	pressure reducing valve
R	rational	s	isentropic
SHE	solution heat exchanger	T	total

1. Introduction

Research by the Netherlands Environmental Assessment Agency has predicts that by around 2060, the amount of energy consumed worldwide in cooling will overtake that consumed in heating. According to the forecast, the world's populations will reach 9 billion by 2050 in which the role of cold in food security will be pivotal. According to the UN Food and Agriculture Organization, global food demand is set to grow by 50% in that time. The cooling and refrigeration sectors are one of the major consumers of energy demand in India. India is the world's leading producer of milk and the second-largest producer of fruits and vegetables, but the country watches nearly 20 percent of that yield, $10 billion worth of food go to waste for lack of a food-supply infrastructure that can keep its food fresh from farm to table.

India faces a more daunting challenge with its cold chain than other parts of the world. Most of the country experiences extreme weather, so cooling technologies are more energy-intensive than that of in milder climates. Peak power outages are also routine, often forcing cold rooms to operate off costly backup generators. Further, it is interesting to note that the India today faces a greater demand for non-electricity applications, i.e., where the primary energy source could have been applied in a more efficient way than use of electricity-driven applications. All of this is to say that energy efficiency is paramount. To address that issue if we just replicate the old technologies, we're heading for environmental disaster. Moreover, with increasing demand, the size of refrigeration and air conditioning unit is also increasing. Unfortunately, while the demand for more energy continues to grow, its scarcity increases and consumption of fossil fuel increases as well. In order to meet the future worldwide energy needs and to slow down the pace of global warming, the improvement of energy efficiency and the creation of sustainable energy sources have to be addressed simultaneously. Therefore the present study analyses the two stage vapor compression absorption system (TSVCACRS) which significantly reduce energy (electricity) consumption and dependency on high grade energy for low temperature industrial cooling applications, food preservation and storage.

There is great potential for reducing high grade energy consumption by combining the Vapor Absorption Refrigeration System (VARS) and Vapor Compression Refrigeration System (VCRS) in series which is known as Vapor Compression Absorption Cascaded Refrigeration System (VCACRS). The application of cascaded