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Experimental evaluation of the inter-stage conditions of a two-stage refrigeration cycle using a compound compressor

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ARTICLE INFO

Article history:
Received 27 November 2007
Received in revised form
26 March 2008
Accepted 6 May 2008
Published online 18 May 2008

Keywords:
Refrigerated system
Two-stage system
Compression system
R404A
Experiment
Performance

ABSTRACT

The aim of the present paper is to detail an analysis, based on experimental data, of the inter-stage working conditions of a two-stage vapour compression facility equipped with a compound compressor, which operates with the most usual inter-stage configurations (two-stage with direct liquid injection and two-stage with subcooler) in medium- and low-capacity commercial refrigeration applications. The experimental analysis is performed in an evaporating temperature range between −36 and −20 °C, and in a condensing temperature range between 30 and 47 °C, using one of the fluids most widely-used in Europe for low-temperature applications, the R-404a. The inter-stage working temperature/pressure obtained in the tests has been contrasted with the two usual criterion of the optimum working conditions definition: the arithmetical mean of the refrigerant condensing and evaporating temperatures and the criterion of equal pressure ratios in both stages. This paper presents the differences and affinities with the criterion and analyses the influence of the intermediate systems (direct liquid injection and subcooler) on the inter-stage operating conditions.

Evaluation expérimentale des conditions entre les étages dans un cycle frigorifique biétagé muni d’un compresseur compound

Mots clés : Systéme frigorifique ; Systéme biétagé ; Systéme à compression ; R404A ; Expérimentation ; Performance

1. Introduction

In many cool generation applications in which the temperature difference between evaporation and condensation is below 40 °C simple vapour compression system are appropriate enough, as temperature difference increases, the volumetric efficiency decreases (specially when dealing with reciprocating compressors), the discharge temperature rises and there is an increment in the vapour ratio at the inlet of the evaporator. Hence, for higher temperature difference, advantages of

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doi:10.1016/j.ijrefrig.2008.05.006

Nomenclature

BASE	Two-stage cycle without inter-stage systems
COP	coefficient of performance
INJ	Two-stage cycle with direct liquid injection system
M	ratio of condensing and evaporating refrigerant mass flow rates
$\dot{m}$	mass flow rate ($kg\,s^{-1}$)
P	pressure (kPa)
R	ratio of volumetric efficiencies of high and low compression stages
R_v	volumetric efficiency
Rt	(t_H/t_L) coefficient of compression ratios
SUBC	Two-stage cycle with subcooler
T	temperature (°C)
t	compression ratio
V	ratio of specific suction volumes at low and high stages
z	number of cylinders
Z	quotient of cylinders at high and low stages

Greek symbols

θ	reduced inter-stage temperature
ρ	density ($kg\,m^{-3}$)
υ	specific volume ($m^3\,kg^{-1}$)

Subscripts

0	evaporator
H	high compression stage
suc	compressor suction
L	low compression stage
K	condenser
I	inter-stage level
opt	optimum

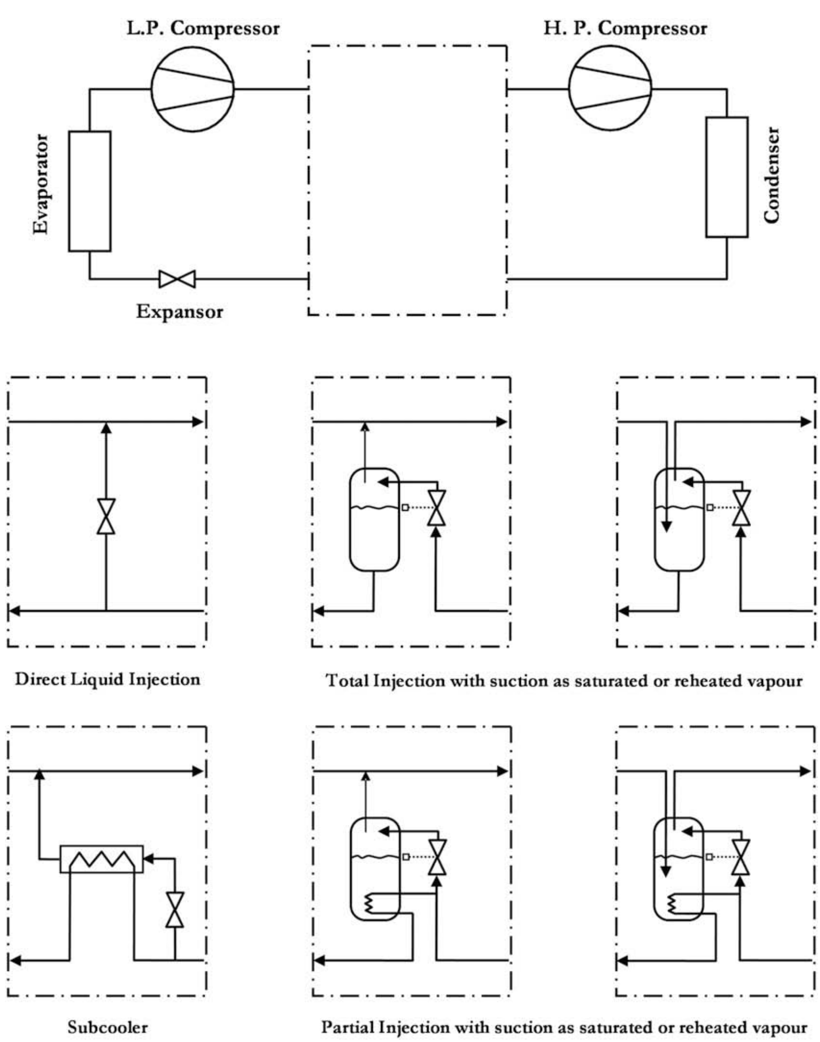

Fig. 1 – Two-stage system configurations.