INTERNATIONAL JOURNAL OF REFRIGERATION 62 (2016) 72–84

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/ijrefrig

Integrated receivers with bottom subcooling for automotive air conditioning: Detailed experimental study of their filling capacity

F. Cola [a,b], *M. De Gennaro* [a], *D. Perocchio* [c], *E. Canuto* [c], *S. Daniele* [c], *P. Napoli* [c], *G. Toscano Rivalta* [c], *E. Chiavazzo* [a], *M. Fasano* [a], *P. Asinari* [a,*]

[a] *Department of Energy, Politecnico di Torino, Turin 10129, Italy*
[b] *School of Mechanical & Aerospace Engineering, Nanyang Technological University, Singapore*
[c] *DENSO Thermal Systems/Technical European Centre, Poirino 10046, Italy*

A R T I C L E   I N F O

Article history:
Received 13 January 2015
Received in revised form 25 August 2015
Accepted 28 August 2015
Available online 26 October 2015

Keywords:
Automotive air conditioning
Condenser
Integrated receiver
Efficiency

A B S T R A C T

The use of the integrated receiver in condensers for common automotive air conditioning – A/C – systems is widespread, because of its thermodynamic and operational advantages. Many studies have been already conducted on estimating the effect of the subcooling value. However, this study aims at determining the most important factors affecting the length of the refrigerant stable operating plateau and how the receiver filling is affected by geometrical and thermodynamic boundary conditions, by means of an experimental campaign built using design of experiments – DOE – techniques. Results demonstrate how the receiver diameter and the axial spacing between its inlet and outlet holes have the highest influence on the receiver operation. Finally, these results have been used to set up a numerical model able to accurately estimate the filling efficiency of the integrated receiver, in terms of volume of the operating plateau compared to the net available receiver volume.

Réservoirs intégrés avec un sous-refroidissement de fond pour le conditionnement d'air d'automobile: étude expérimentale détaillée de leur capacité de remplissage

Mots clés : Conditionnement d'air automobile ; Condenseur ; Réservoir intégré ; Efficacité

* *Corresponding author.* Department of Energy, Politecnico di Torino, Turin 10129, Italy. Tel.: +39 011 0904434; Fax: +39 011 0904499.
E-mail address: pietro.asinari@polito.it (P. Asinari).

http://dx.doi.org/10.1016/j.ijrefrig.2015.08.021

Nomenclature

D	diameter of the receiver [m]
ε	efficiency [–]
h	height of the volume from the receiver base [m]
hv	net height of the volume from the receiver base without plug [m]
ΔH	distance between inlet and outlet holes [m]
V	volume [m^3]

1. Introduction

The integrated receiver (Fig. 1a–1b) made its first appearance in the 1990s, as an improvement of the parallel flow condenser with flat tubes and multiple louvered fins (Fig. 2), which represents the state-of-art of modern technology in this field, according to Shah (2006). Many studies aimed at optimizing the louver performance, such as the one of Ferrero et al. (2013) and Jang and Cheng (2013), other focused their attention on the integrated receiver use.

Yamanaka et al. (1997) and Burk (1995) proved the many advantages of this technology; they discovered that, from a thermodynamic point of view, the receiver ensured a more stable operation of the refrigerant cycle: this is because, by imposing a certain degree of subcooling, a refrigerant flow with liquid phase only could enter the expansion valve, thus reducing the operation instabilities of this component. As a result, a flow with lower vapour quality could enter the evaporator, enhancing its cooling performance.

Other assets of this technology found by Yamanaka, Burk and later by Pomme (1999) involve costs and weight savings, and most importantly refrigerant saving; in particular Yamanaka demonstrated that the use of an integrated receiver could save around 150 g of refrigerant, which was previously added in order to force the subcooling and reduce the vapour quality of the flow entering the evaporator. Qi et al. (2010) studied an air conditioning system that uses microchannel heat exchangers and an integrated receiver condenser. A condenser weight and volume reduction of about 15% was estimated, with respect to standard condensers; furthermore, refrigerant saving of 50 g was measured.

Studies were conducted aiming at optimizing the operation of both the separate and the integrated receiver condensers, focusing in particular on the role of subcooling; a good review of the various strategies to provide subcooling in vapour compression systems is brought by Qureshi and Zubair (2013), though here we will concentrate mainly on subcooling strategies for automotive applications. Khan and Zubair (2000), while addressing the improvement offered by mechanical subcooling in separate receiver condenser, proposed a model capable of estimating its optimal value; results showed that such value is related to the saturation temperature of the subcooler used, whose optimal value is about halfway between condensation and evaporation temperatures. Lee and Yoo (2000), instead of using a subcooler, studied optimal performance in relation with refrigerant charge; an overcharge of 10% was found to be the best operating condition for the whole air conditioning system.

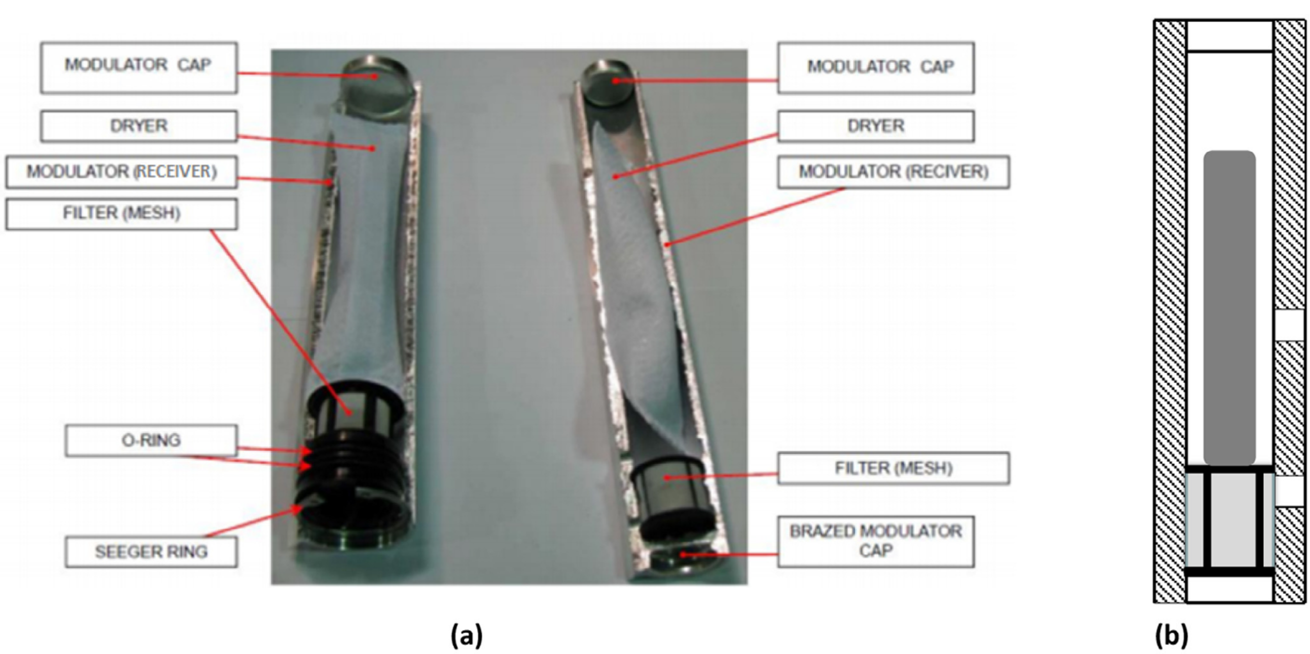

Fig. 1 – Cross section of a receiver: (a) main features and (b) receiver scheme.