

## Chapter 9

# Capillary Tube as an Expansion Device in a CO<sub>2</sub> (R744) Transcritical Heat Pump System

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### **ABSTRACT**

*Natural refrigerants which are ecologically safe and were in use extensively in the pre-CFC era are witnessing a revival of CO<sub>2</sub> (R744). Inherently being a low critical temperature (31.2 °C) refrigerant, the CO<sub>2</sub> cycle based system operates in transcritical mode offers an opportunity to obtain an optimum operating condition. Capillary tubes which are extensively used in small size vapour compression systems work very differently in a CO<sub>2</sub> transcritical heat pump system. In this chapter it is described that installation of a capillary tube having an appropriately designed length replacing an expansion valve will result in a natural adjustment of the gas cooler pressure, so that the system balance always shifts to a favourable COP direction; this is contrary to the scepticism that exists on the capability of a capillary tube to attain the optimal pressure operation. There is an optimal length of capillary tube for a given diameter at which the heat pump runs optimally.*

### **INTRODUCTION**

The refrigeration and air-conditioning industry is in an unprecedented transition phase, caused by environmental concerns with the impacts of refrigerant emission. Natural refrigerants based technology is on an increasing demand globally. Natural refrigerants are ecologically safe since they are part of the environment. The preferred natural refrigerants are air, water, noble gases, hydrocarbons, ammonia, nitrogen and carbon dioxide. Among these, carbon dioxide is the preferred choice owing to its non-toxicity and non-flammability character along with its eco-friendly nature.

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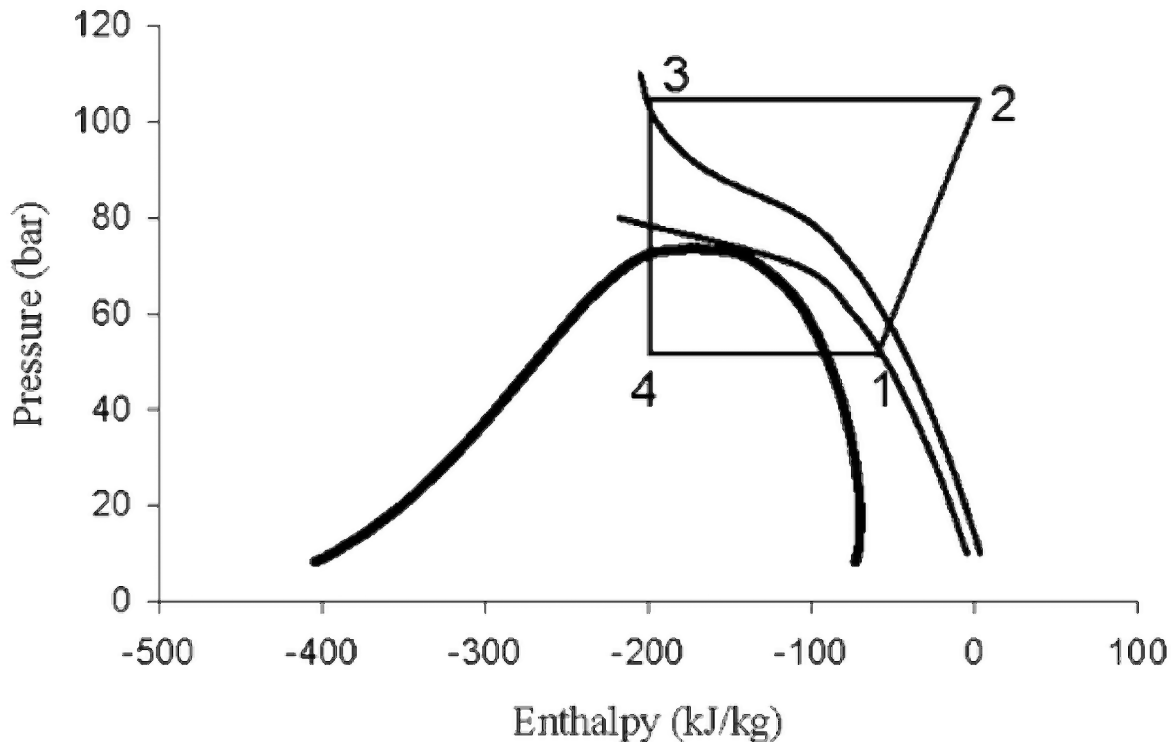
### Capillary Tube as an Expansion Device in a CO<sub>2</sub> (R744) Transcritical Heat Pump System

Norwegian Professor Gustav Lorentzen was the first one to reassess the old refrigerant CO<sub>2</sub> (R744) for its use in refrigeration, air conditioning and heat pump systems, when he proposed an all new CO<sub>2</sub> cycle for automobile air conditioning which operates in a transcritical mode (Figure 1) (Lorentzen & Pettersen, 1993; Lorentzen, 1994). The properties of CO<sub>2</sub> are unique and different from conventional refrigerants. The most distinguishing feature of CO<sub>2</sub> is its low critical temperature (31.2 °C) with relatively higher critical pressure (73.8 bar). Owing to its low critical temperature, CO<sub>2</sub> systems operate at high pressure transcritical region, typically at pressures 5-10 times higher than that with conventional refrigerants, as it is not possible to transfer heat to the ambient above this critical temperature by condensation.

In a CO<sub>2</sub> transcritical cycle, there exists an optimum gas cooler pressure for a given gas cooler exit temperature where the system performs optimally due to the unique behavioural pattern of CO<sub>2</sub> properties around the critical point and beyond (Pettersen & Skaugen, 1994). A number of correlations are available in the open literature for optimum gas cooler pressure and optimum COP (Kauf, 1999; Liao et al., 2002; Sarkar et al., 2004; Chen & Gu, 2005). An approximate correlation has also been reported based on numerical and analytical studies to predict the optimal heat rejection pressure in transcritical systems (Cecchinato et al., 2010).

Capillary tube is a type of refrigerant flow control device and is widely accepted as a simple low cost expansion device in small vapour compression refrigerating and air conditioning systems (up to 10 TR). Flow inside the capillary tube is a complex flashing process leading to phase change. An expansion device in a transcritical CO<sub>2</sub> system is expected to control the high side pressure to operate the system

Figure 1. P-h diagram of transcritical CO<sub>2</sub> cycle



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