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Testing Supercritical Carbon Dioxide Flowing Up Vertical Tube

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1. Introduction

Supercritical fluid is referred to a substance at a temperature and pressure above its critical point. Hence the occurrence of the critical heat flux due to the liquid-gas phase transition can be avoided. In addition, close to the critical point, minute changes in pressure or temperature cause large changes in density or specific heat. Thus, the supercritical carbon dioxide (SCO_2) is currently being considered as working fluid for power conversion in some Generation IV Nuclear Energy Systems. SCO_2 has such advantages as high density, easy accessibility, low price and no toxicity compared against other fluids. Nevertheless one of the most marked characteristics is its low critical point, which renders change from CO_2 to SCO_2 easier than other fluids. These benefits lead SCO_2 to be used in power stations instead of water [1].

2. Experiment

2.1 Problem Statement

The Pressure Applied CO_2 Operation (PACO) aims to determine thermophysical characteristics of SCO_2. To achieve this goal, a vertical small circular tube is used to guide the upward flow. The tube wall temperatures are obtained at a fixed pressure by varying other parameters such as the inlet temperature, heat flux and flow rate. PACO is schematically shown in Fig. 1.

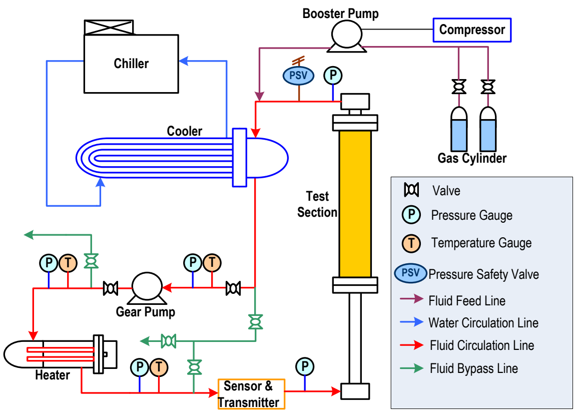

Fig. 1. Schematic of PACO test loop.

2.2 Experimental Setup

The critical temperature and pressure of CO_2 are 31.06 °C and 7.38MPa, respectively. The pressure and inlet temperature in PACO are fixed at 8.1 MPa and 34°C, respectively to obtain a supercritical condition. The mass flow rate and electric power are varied by 0.02 kg/s and 0.04 kg/s, and from 16 W to 27.4 W, respectively.

The PACO test section shown in Fig. 2 is a circular tube with the inner diameter of 8.1 mm, where CO_2 flows upward. The outer diameter of the tube is 14.5 mm. A total of 39 thermocouples are installed at the outer wall of the pipe. Six red circles mean the heating cartridges. The total height is 2100 mm, of which 800 mm is for the entrance and 100 mm for the exit.

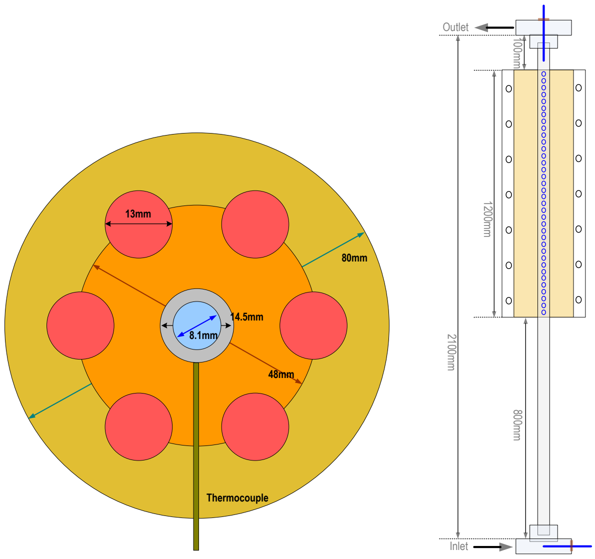

Fig. 2. Dimensions of PACO test section.

2.3 Experimental Results

The outer wall temperature distribution as a function of distance and the tube length ratio *x/D* for mass flow rates of 0.02 kg/s and 0.04 kg/s are shown in Figs. 3 and 4, respectively. The outer wall temperature soars for the electric power 25.1 kW and 27.4 kW as shown in Fig. 3. Fig. 4 shows a rapid temperature increase at the outer wall given higher electric power. It signifies that CO_2 at the critical temperature becomes excellent heat transfer medium.

Fig. 5 presents the trend of the CO_2 specific heat for varying pressures. The specific heat of CO_2 changes abruptly at the critical point, which greatly enhances the heat transfer capacity.

3. Conclusions

The CO_2 can turn into supercritical fluid easily compared with other fluids. Thus, its property, for example density or specific heat, changes rapidly at the critical point. For optimization of heat transfer, further test and analysis are being done.

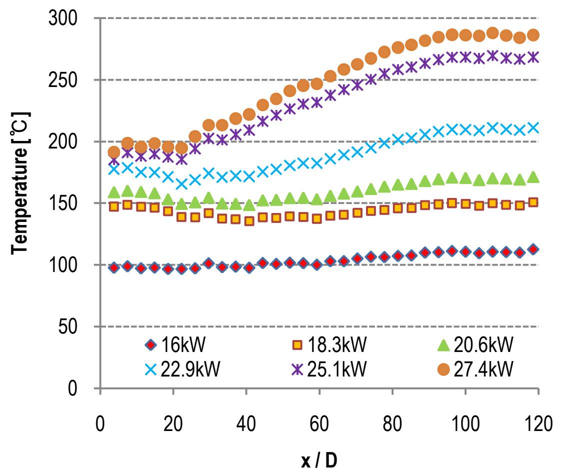

Fig. 3. Outer wall temperature distribution under 0.02 kg/s.

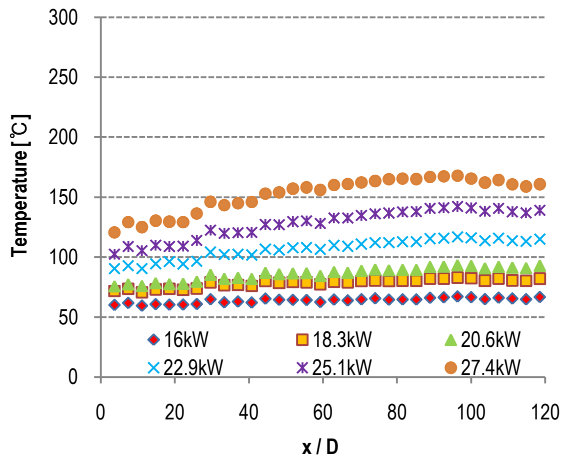

Fig. 4. Outer wall temperature distribution under 0.04 kg/s.

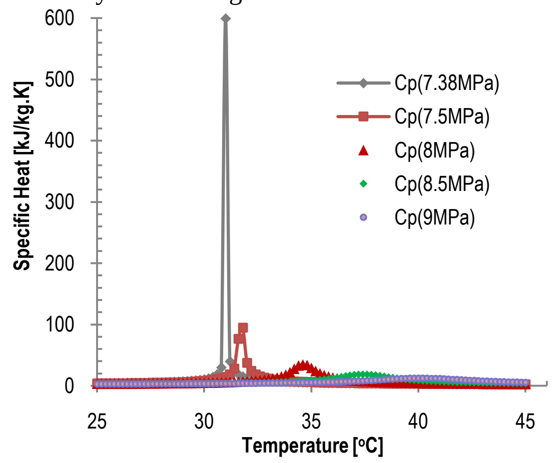

Fig. 5. Trends of specific heat by pressure [2].

Acknowledgments

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REFERENCES

[1] J.K. Kim, Experimental Study on Heat Transfer Characteristics of Turbulent Carbon Dioxide Supercritical Flow in Vertical/Non-circular Tubes, Ph.D. Thesis, Seoul National University, Seoul, Korea, 2006.

[2] NIST Reference Fluid Thermodynamic and Transport Properties-REFPROP, NIST Standard Reference Database 23,Ver.7.1.