PVT PROPERTIES AND VAPOR PRESSURES OF HFO-1336MZZ(E)

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ABSTRACT

Experimental data of PVT properties and vapor pressures are presented for trans-1,1,1,4,4,4-hexafluoro-2-butene (HFO-1336mzz(E)). HFO-1336mzz(E) can be an alternative for conventional working fluids. However, reliable property information on the refrigerant is scarce at this time.

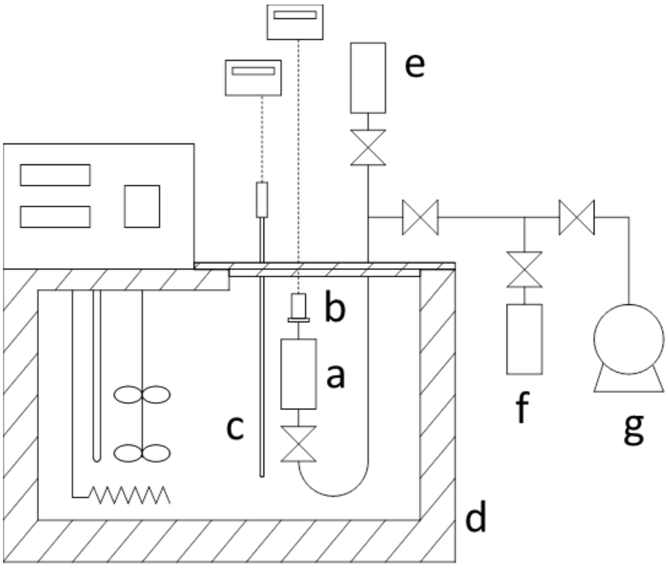
This work performed measurements of the PVT properties at temperatures from 323 K to 443 K and pressures up to 10 MPa, including supercritical region. An isochoric method was employed with a constant volume cell designed for operation at high temperatures and high pressures. The critical temperature, pressure, and density were estimated from the PVT properties in the critical region. The saturation properties were also obtained.

1. INTRODUCTION

Regarding effective energy utilization, organic Rankine cycle systems are expected for power generation systems using waste heat energy which is relatively low-temperature heat sources. And then, several kinds of working fluids should be able to be selected according to temperature of heat sources. HFO-1336mzz(E) (CAS registry no.66711-86-2, molecular weight is 164.05) is definitely one of possible candidates for the working fluid whose boiling point is near and less than room temperature. HFO-1336mzz(E) is geometrical isomer of HFO-1336mzz(Z) whose boiling point is more than room temperature. In this study, PVT properties and vapor pressures for HFO-1336mzz(E) were measured to develop the thermophysical property data base of working fluids for organic Rankine cycle systems.

2. EXPERIMENTAL

A schematic diagram of the experimental apparatus is shown in Figure 1. Sample of HFO-1336mzz(E) producted by SynQuest Laboratories, Inc. was used. Measurements of PVT (Pressure-Volume-Temperature) properties were conducted by the isochoric method. The sample was filled in a sample cell with constant volume. The mass of sample was determined from difference in the mass of a sample bomb before and after filling the sample. The density was obtained from the volume of the cell and the mass of sample. Temperature of the sample was controlled by a thermostat oil bath. Pressure of the sample was measured by a pressure sensor. PVT properties were obtained along several isochoric lines by changing the mass of sample filled in the sample cell.



a: Sample cell, b: Pressure sensor, c: Temperature sensor, d: Thermostat oil bath, e: Filling bottle, f: Sample bottle, g: Vacuum pump

Figure 1 Schematic diagram of the apparatus

3. RESULTS AND DISCUSSIONS

3.1 PVT properties

The data of PVT properties for HFO-1336mzz(E) was obtained at temperatures from 323 K to 443 K at 10 K interval and pressures up to 10 MPa, along 17 isochores as shown in Figure 2. The data arranged along isotherms are shown in Figure 3.

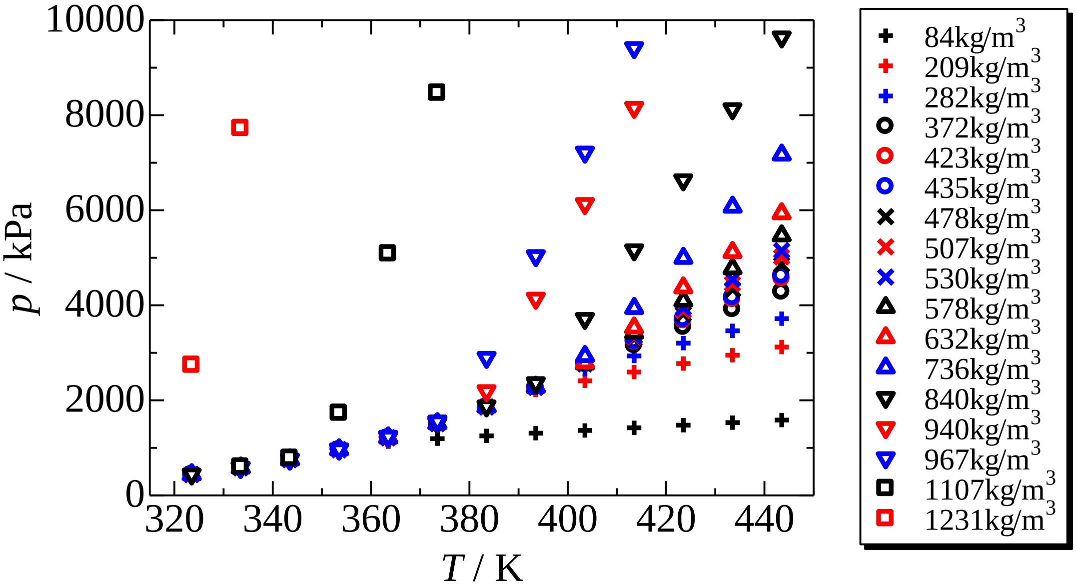


Figure 2 Experimental PVT data on pressure-temperature diagram

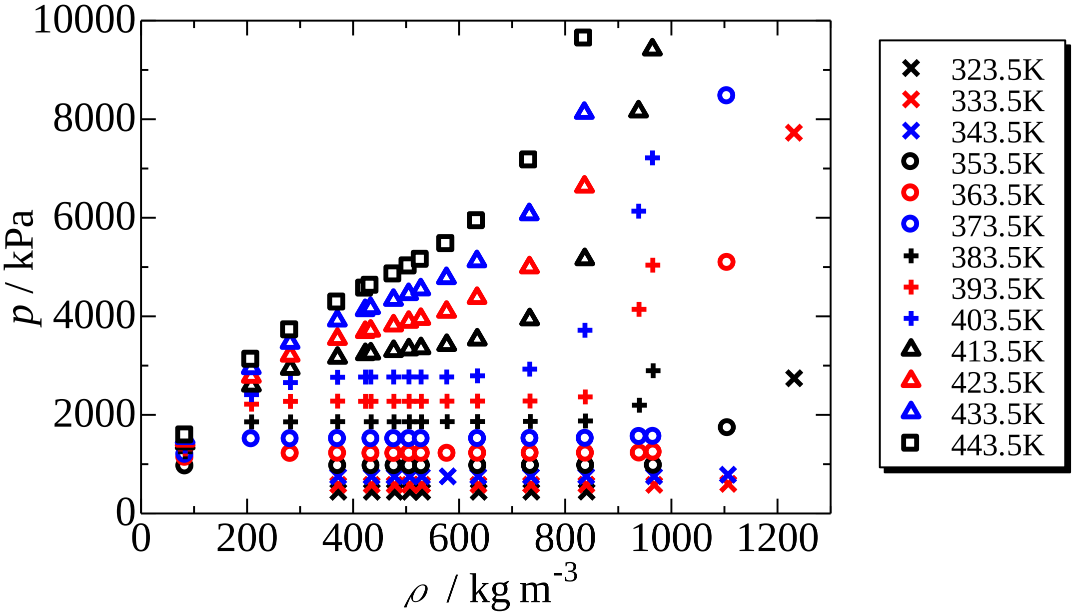


Figure 3 Experimental PVT data on pressure-density diagram

Figure 4 is an enlarged view of the critical region in Figure 3. The isotherm of 403.5 K includes data in two-phase region, because the pressure is constant in the density range from 400 kg/m^3 to 600kg/m^3. The isotherm of 413.5K consists of only data in the super critical region, because the pressure increases monotonously. These observations suggest that the critical temperature is located between 403 K and 413 K and that the critical density is to be found between 400 kg/m^3 and 600 kg/m^3.

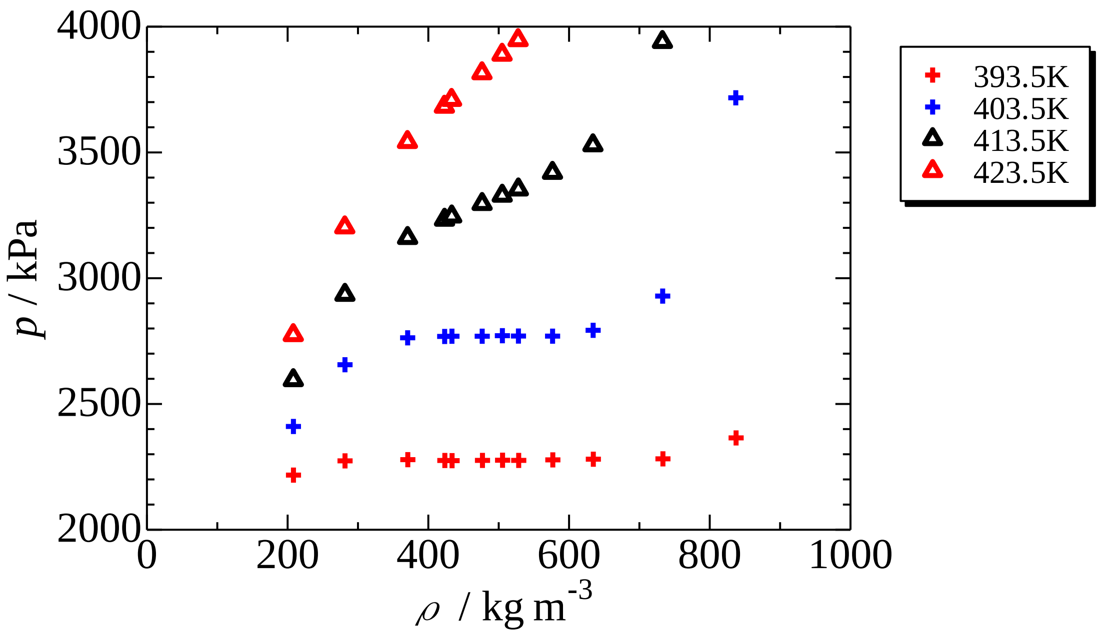


Figure 4 Experimental PVT data on pressure-density diagram in the temperature range from 393.5 K to 423.5 K

3.2 PVT properties near the critical point

In order to find more accurate location of the critical point, additional PVT measurements were performed in the critical region. PVT properties in the temperature range from 403.5 K to 413.5 K at 1K interval and in the density range from 384 kg/m^3 to 605 kg/m^3 along seven isochores were obtained. The data is shown in Figure 5 on the pressure-temperature diagram. They are also shown in Figure 6 on the pressure-density diagram, and its enlarged figure is shown in Figure 7 in the temperature range from 403.5 K to 405.5 K. These figures indicate that the critical point is located between 403.5 K and 404.5 K for temperature, between 2770 kPa and 2820 kPa for pressure, and between 476 kg/m^3 and 528 kg/m^3 for density.

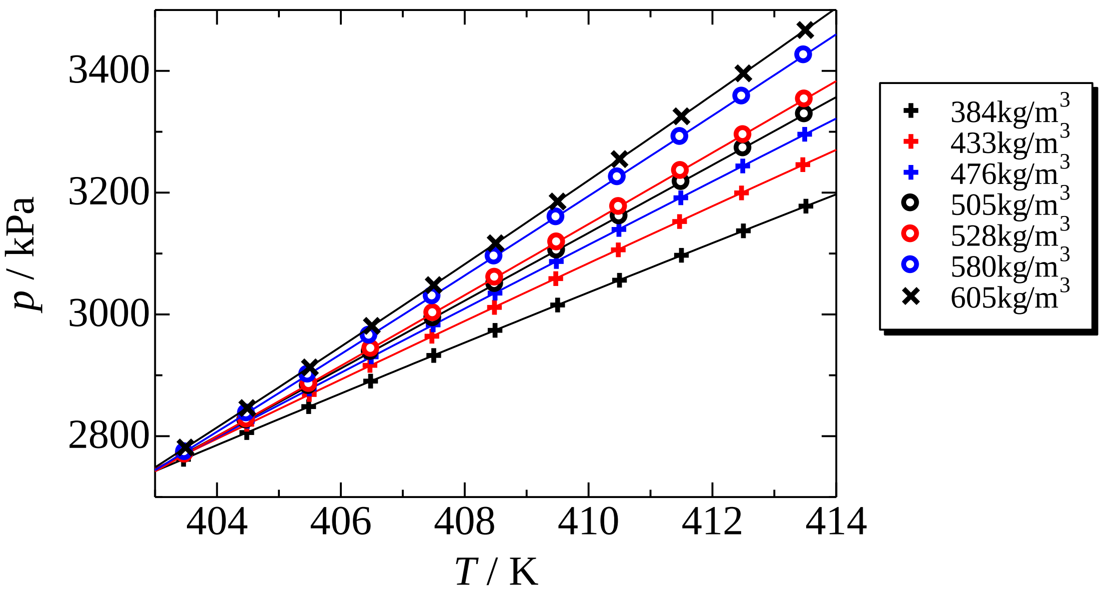


Figure 5 Experimental PVT data on pressure-temperature diagram near critical point

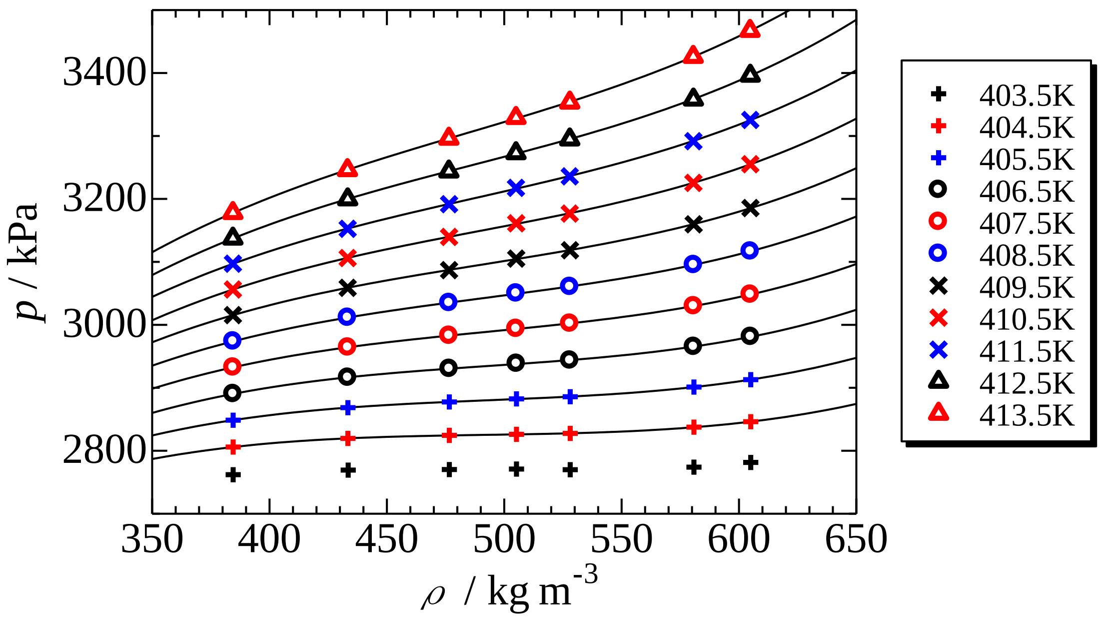


Figure 6 Experimental PVT data on pressure-density diagram near critical point

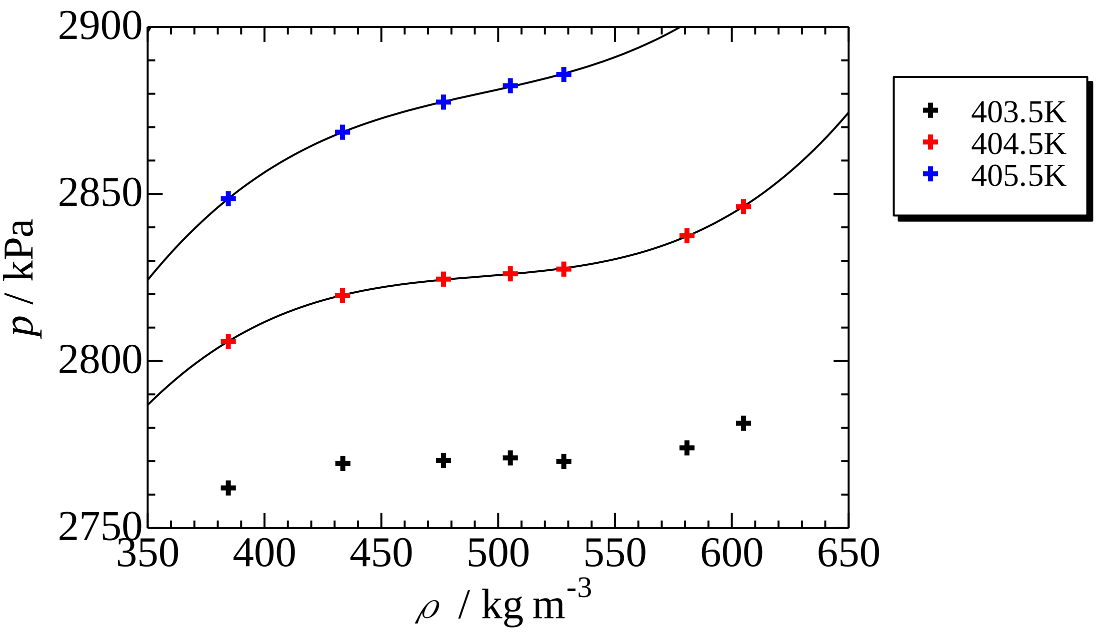


Figure 7 Experimental PVT data on pressure-density diagram near critical point (from 403.5 K to 405.5 K).

3.3 Vapor pressure

Vapor pressures are obtained from two-phase region data in the isotherms. Temperature dependence of the vapor pressures is shown in Figure 8.

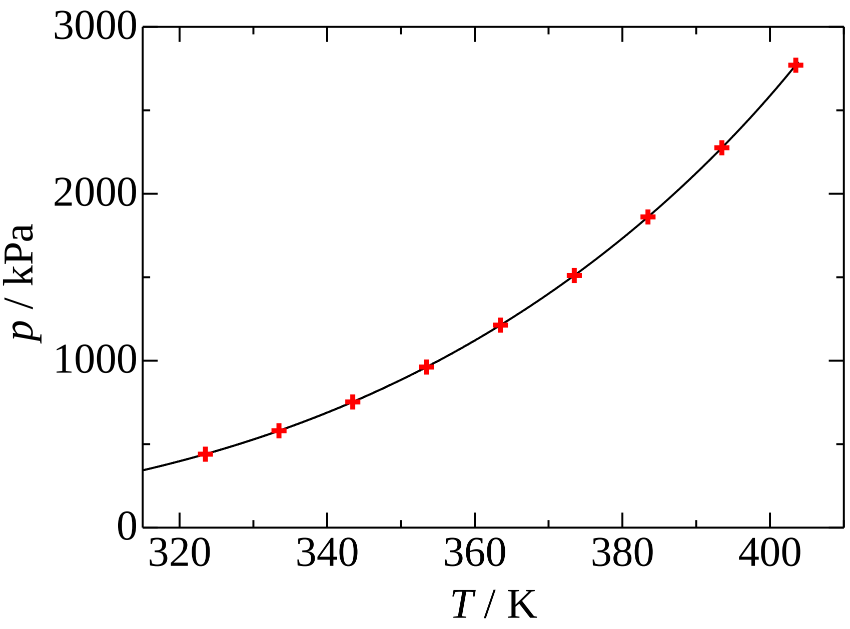


Figure 8 Vapor pressure of HFO-1336mzz(E)

3.4 Saturated densities

The saturated liquid or vapor densities were determined from intersections of the vapor pressure curve and several isochores, as shown in Figure 9. Eleven data points of saturated densities were obtained as shown in Figure 10.

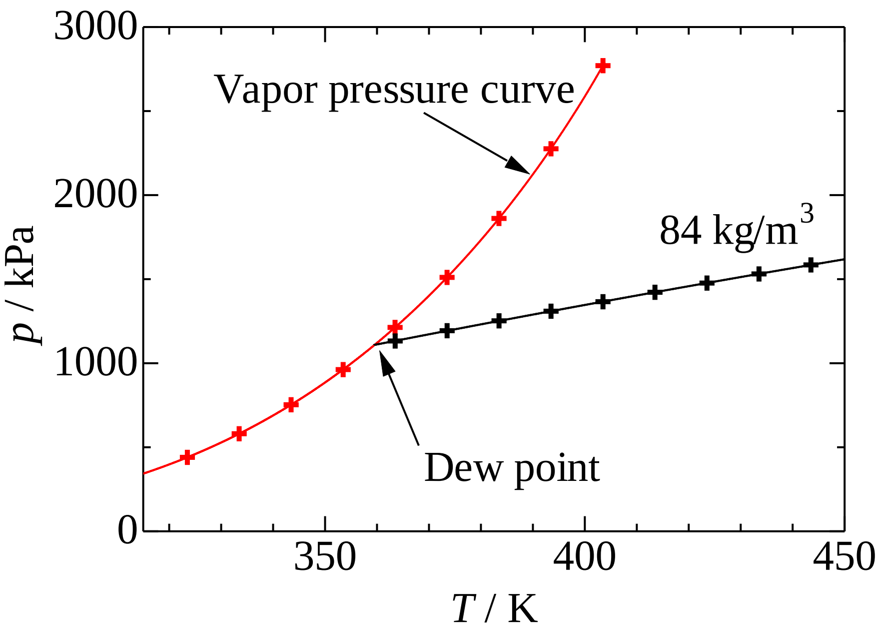


Figure 9 Determination of the saturated densities. Example for isotherm of 84 kg/m^3.

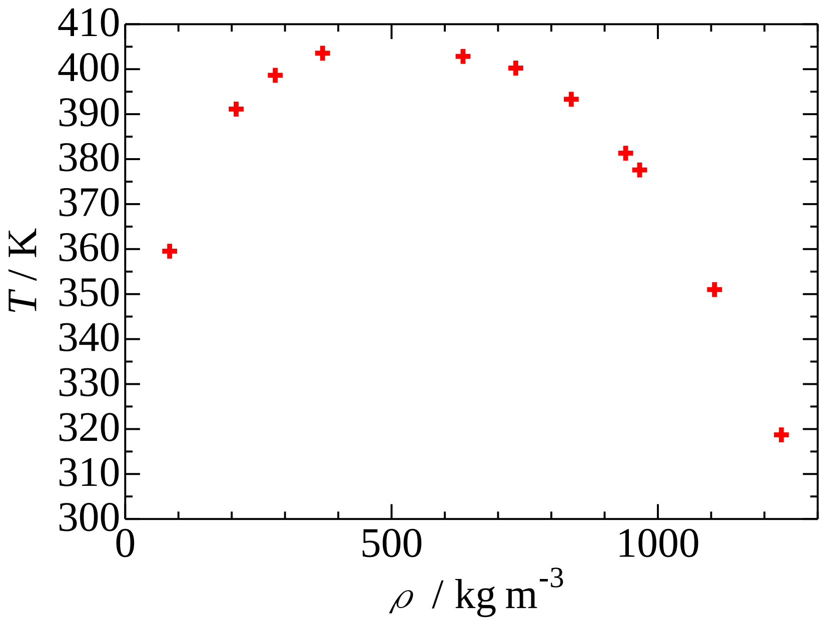


Figure 10 Saturated liquid and vapor densities of HFO-1336mzz(E)

4. CONCLUSIONS

Conclusions of this work are summarized as follows:

- Seventy seven data points of PVT properties for HFO-1336mzz(E) were obtained in a wide ranges of temperature and density, including the critical region.
- Nine data points of the vapor pressures for HFO-1336mzz(E) were obtained from two-phase region data.
- Eleven data points of the saturated densities of HFO-1336mzz(E) were determined from intersections of the vapor pressure curve and isochores.

NOMENCLATURE

p	pressure	(kPa)
T	temperature	(K)
V	volume	(m^3/kg)
ρ	density	(kg/m^3)

ACKNOWLEDGEMENT

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