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Critical Heat Flux near the Critical Pressure in Heater Rod Bundle Cooled by R-134a Fluid: Effects of Unheated Rods and Spacer Grid

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Introduction

Background

- When the SCWRs are operated with a sliding pressure start-up mode, the CHF should be avoided during the power-increasing phase under sub-critical pressure conditions.
- The safety analyses for abnormal pressure transients including a LOCA; It is necessary to understand the CHF characteristics near the critical pressure.
- There has been no information on the CHF near the critical pressure.

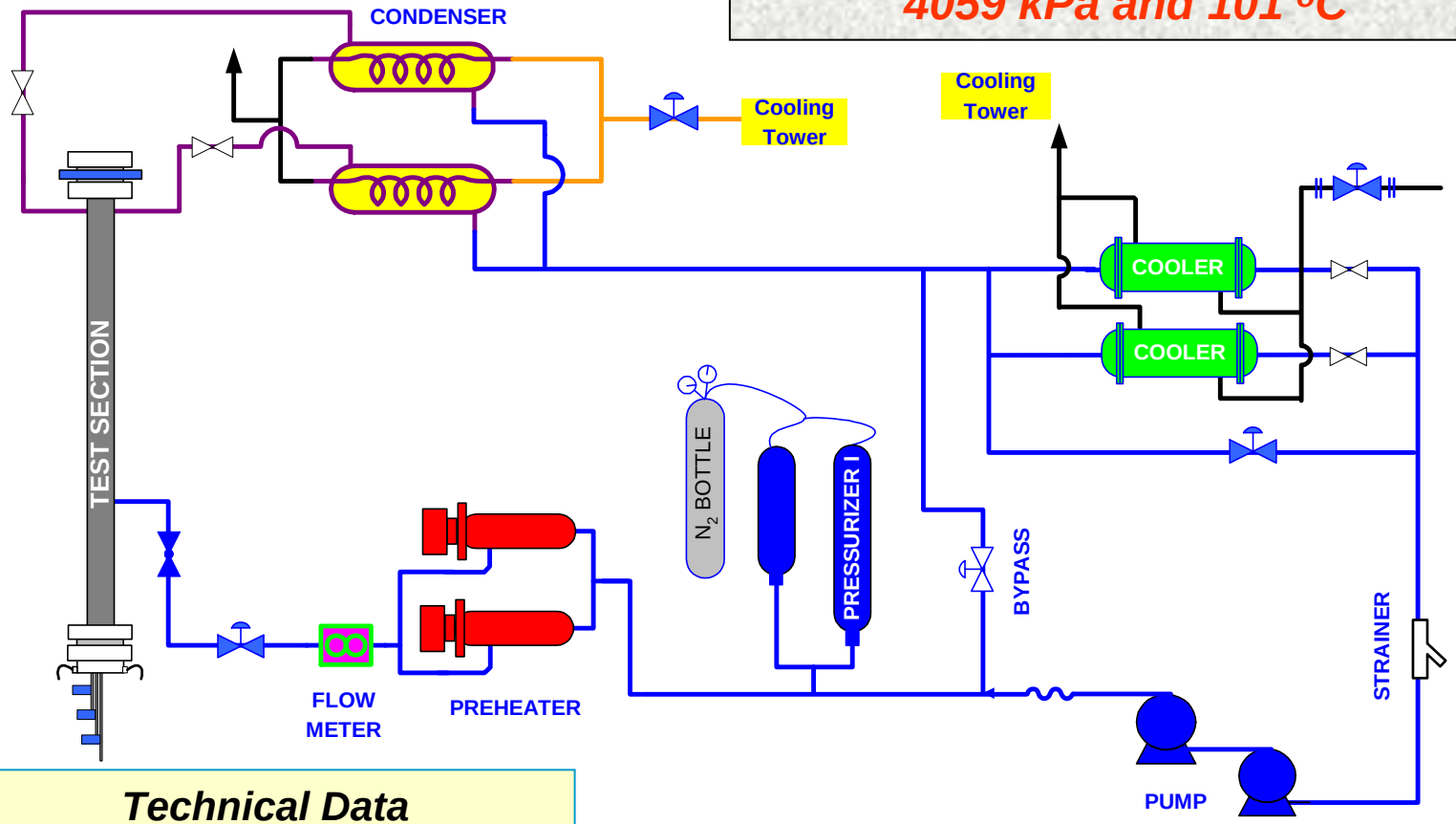
Objectives

- To obtain novel information about the CHF phenomenon near the critical pressure,
  - The CHF in a 5x5 heater rod bundle cooled by R-134a fluid has been carefully measured under sub-critical pressure conditions near the critical point.

Experimental Apparatus (1/3)

Freon Loop

Critical Press. and Temp. of R-134a
4059 kPa and 101 °C



Technical Data

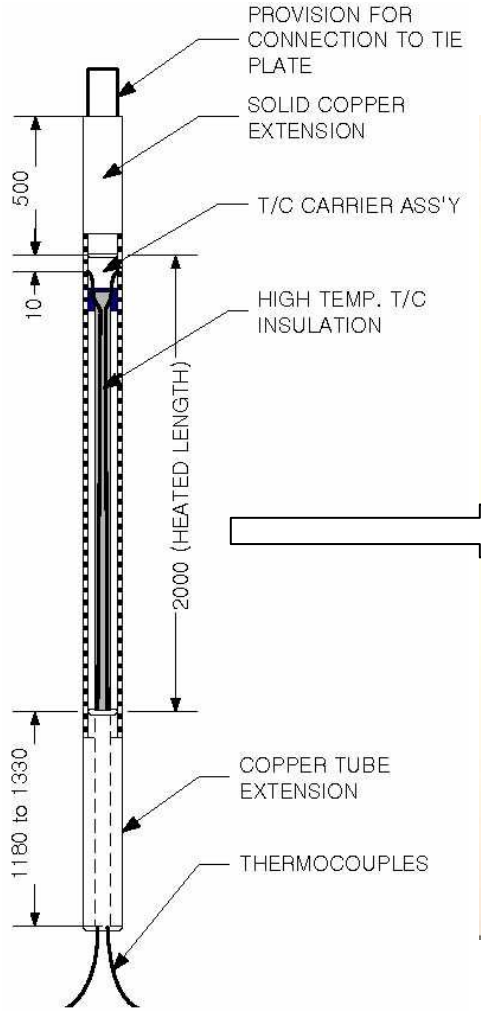
- Max. operation press.: 4.5 MPa
- Max. operation temp.: 150 °C
- Flow rate: 15 kg/s
- Test section power: 720 kW DC
- Working fluid: R134a

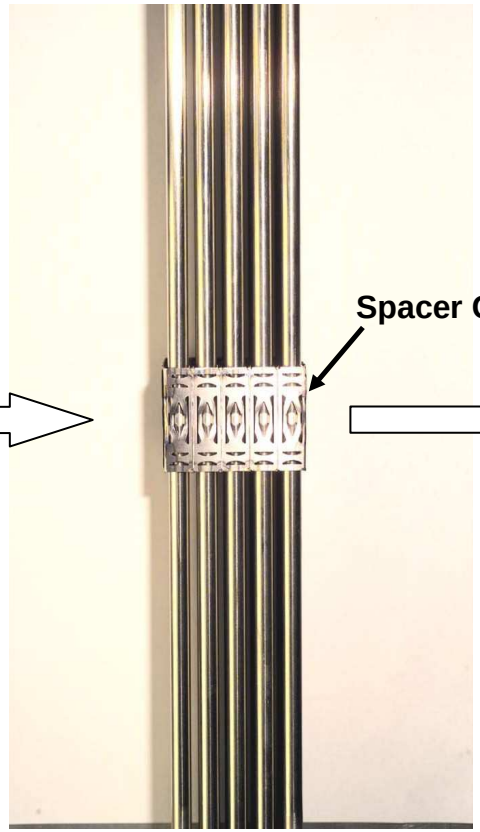
Water Equivalent Data

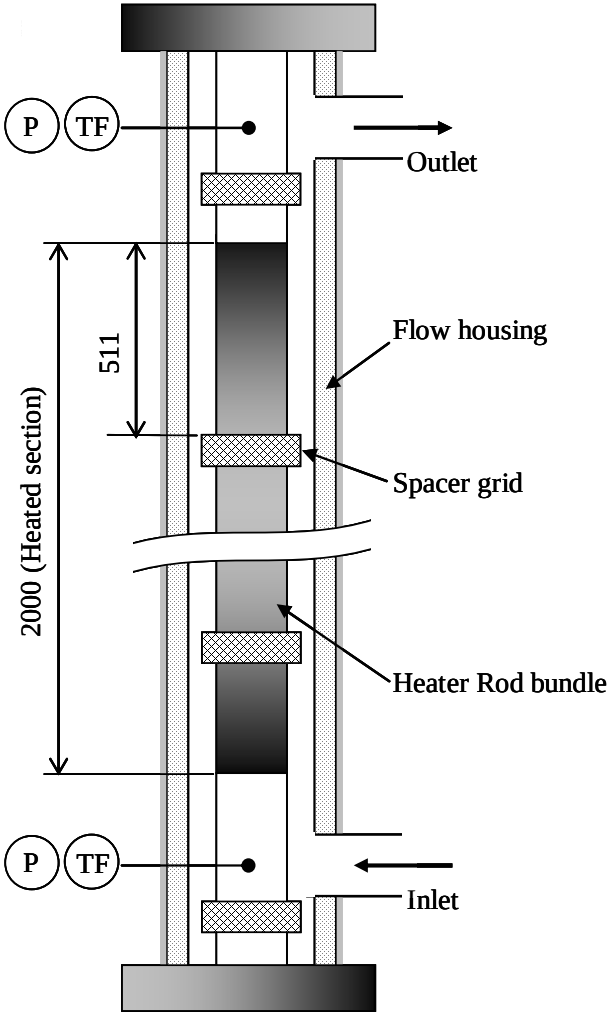
- Pressure: 27.5 MPa
- Flow rate: 21 kg/s
- Power: 9360 kW DC

Experimental Apparatus (2/3)

Test Section Configuration





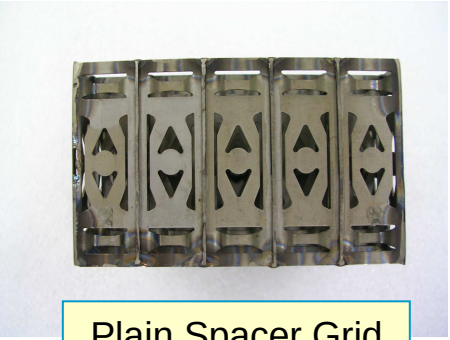


Heater Rod | Heater Rod Bundle | Test Section

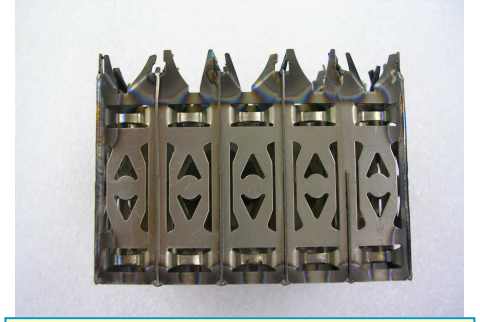
Experimental Apparatus (3/3)

Type of Test Bundle

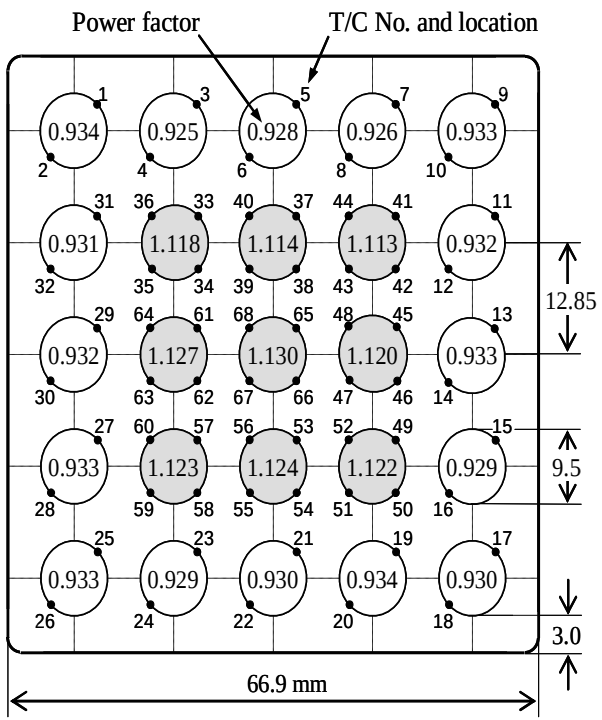
- D=9.5 mm, Pitch=12.85 mm
- *Radial Power distribution* : *Non-uniform*
- Axial Power distribution : Uniform

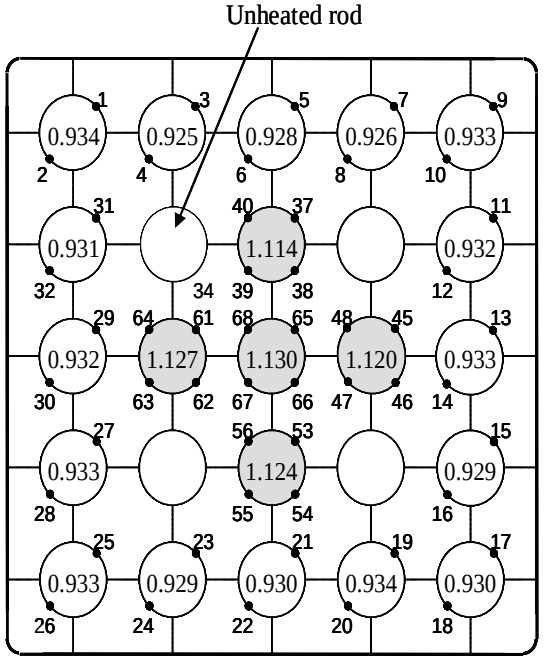


Plain Spacer Grid



Mixing Vane Spacer Grid





- **TB-1 : with All Heated Rods and Plain Spacer Grids**
- **TB-2 : with All Heater Rods with Mixing Vane Spacer Grids**
- **TB-3 : with 4 Unheated Rods and Plain Spacer Grids**

CHF Experiments

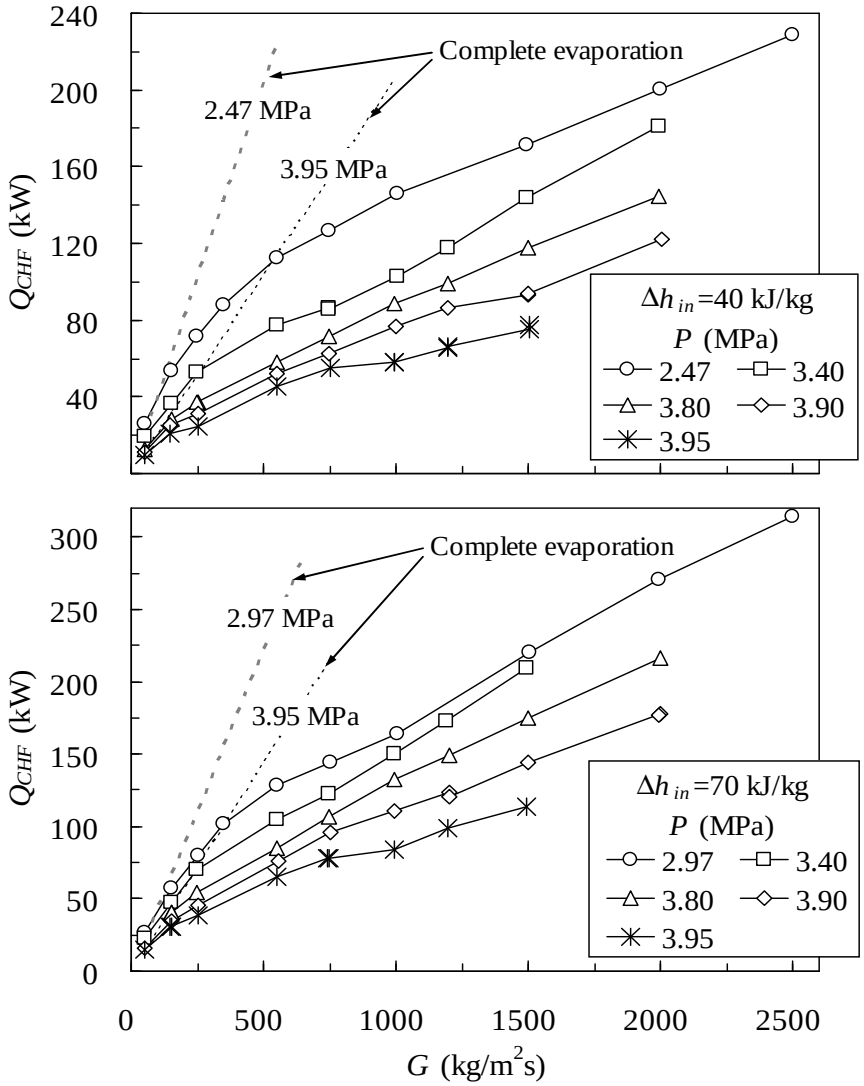
Experimental Conditions

- Test Section Outlet Pressure : 2.47 ~ 4.03 MPa (*P/Pc* : 0.6 ~ 0.99)
- Mass Flux : 50 ~ 2000 kg/m^{2}s
- Inlet Subcooling : 40 ~ 84 kJ/kg
  - Critical quality (cross-sectional average thermodynamic quality at CHF occurrence location): -2.6 ~ 0.78 (-)

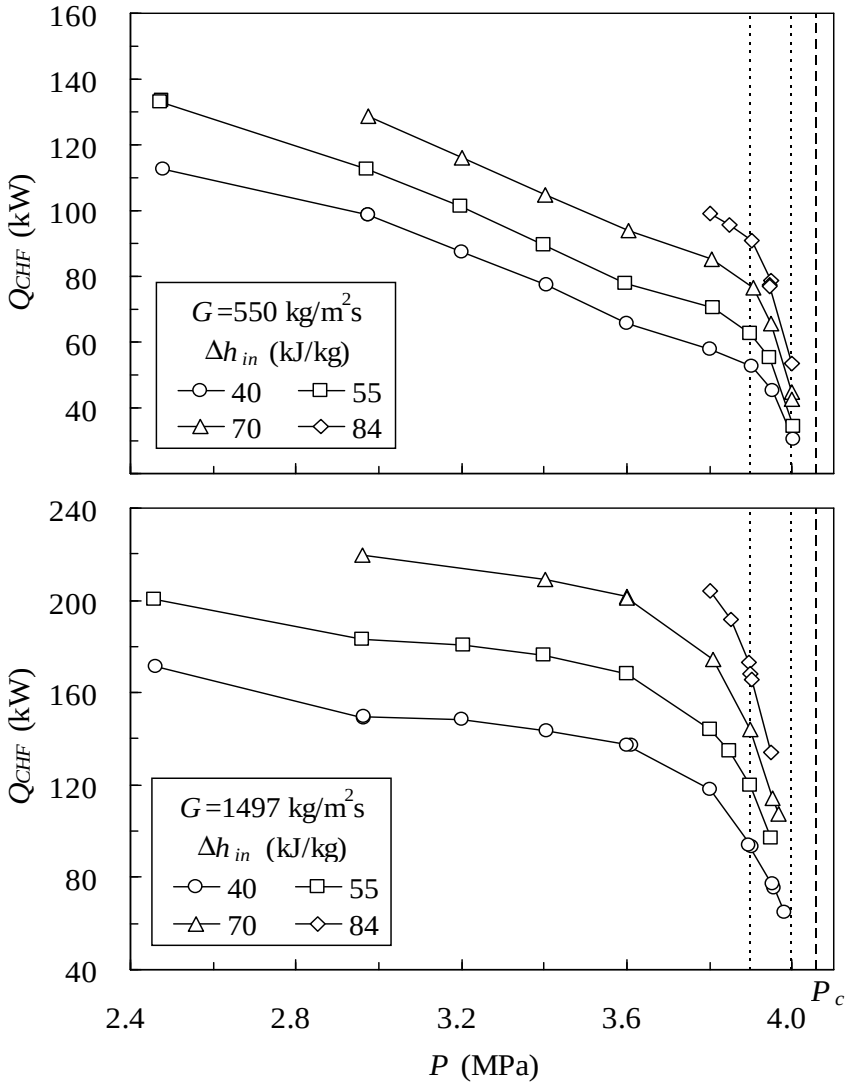
Measurements

- Measurement Uncertainty
  - Temperature : ±0.7 K
  - Pressure : ±0.25 %
  - Mass Flux : ±0.6 %
  - Bundle Power : ±1.8 %
- The critical power Q_{CHF} (bundle total power at CHF conditions) has been observed.

Experimental Results : CHF Characteristics (1 / 2)



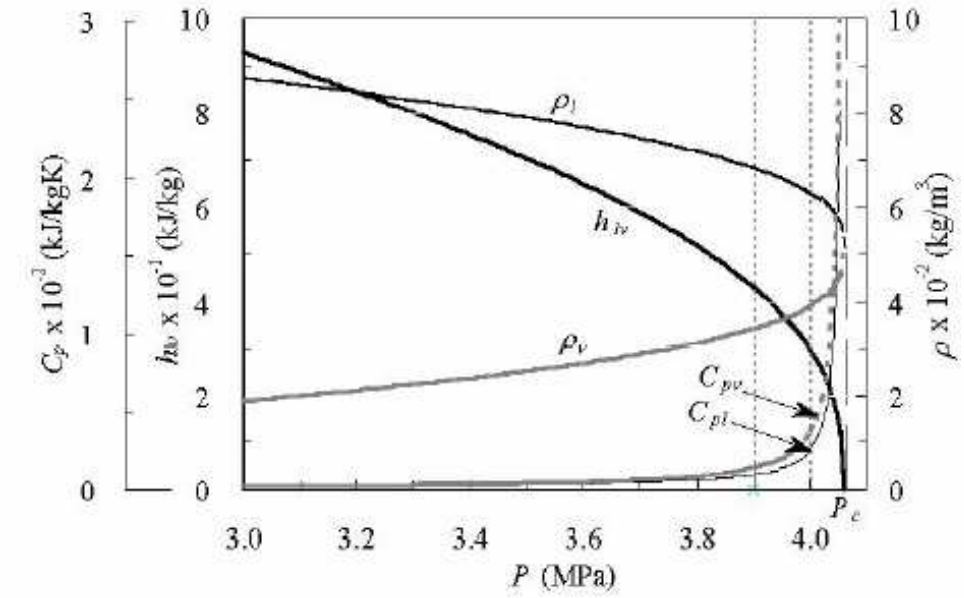
Critical power as a function of the mass flux (TB-1)



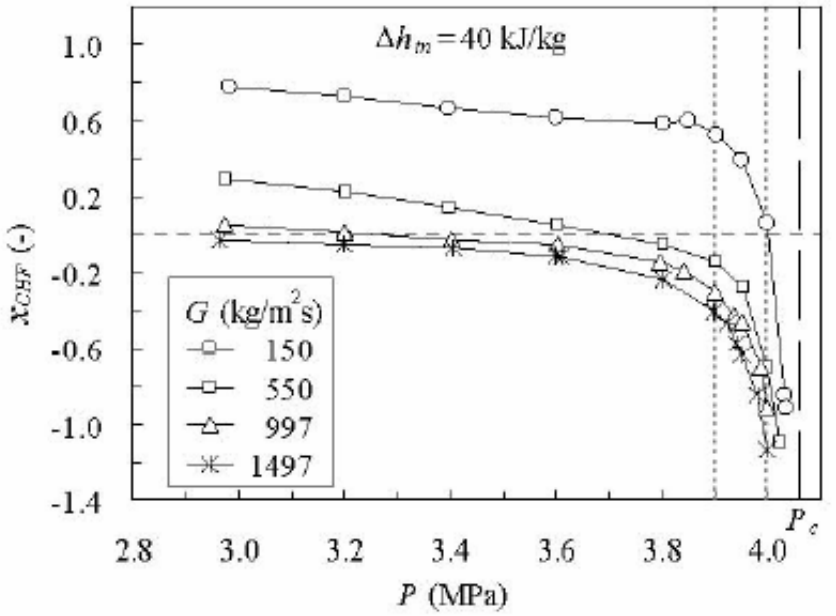
Effect of pressure on critical power (TB-1)

Experimental Results : CHF Characteristics (2/3)

Sharp Variations in the Thermodynamic Properties near the Critical Pressure



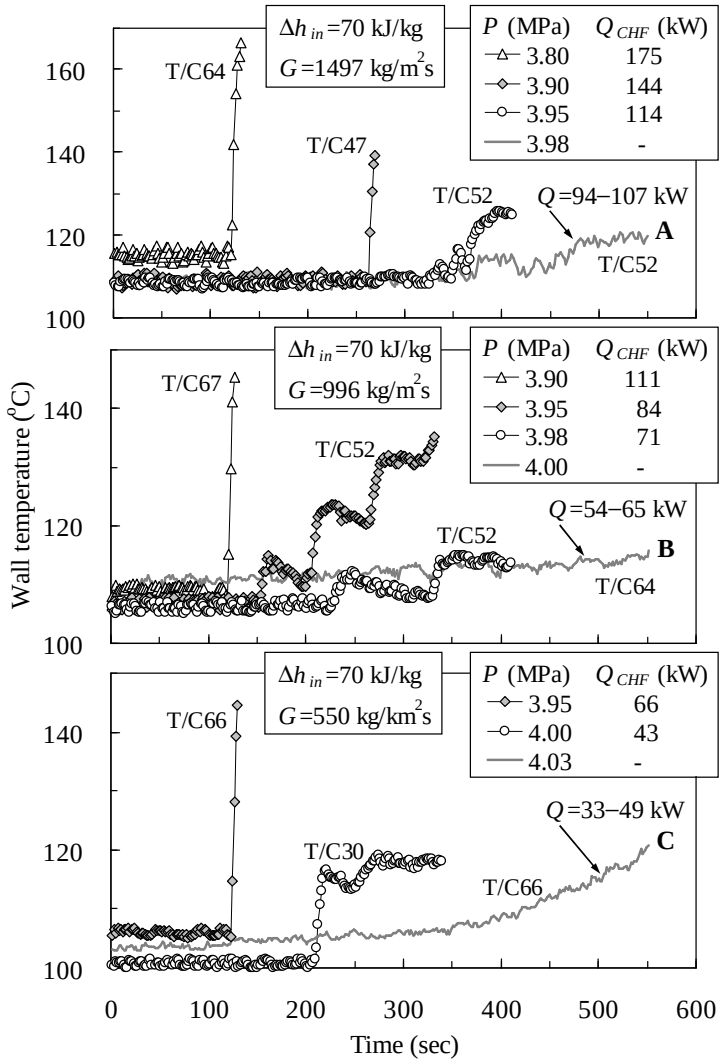
Thermodynamic properties with the pressure (TB-1)



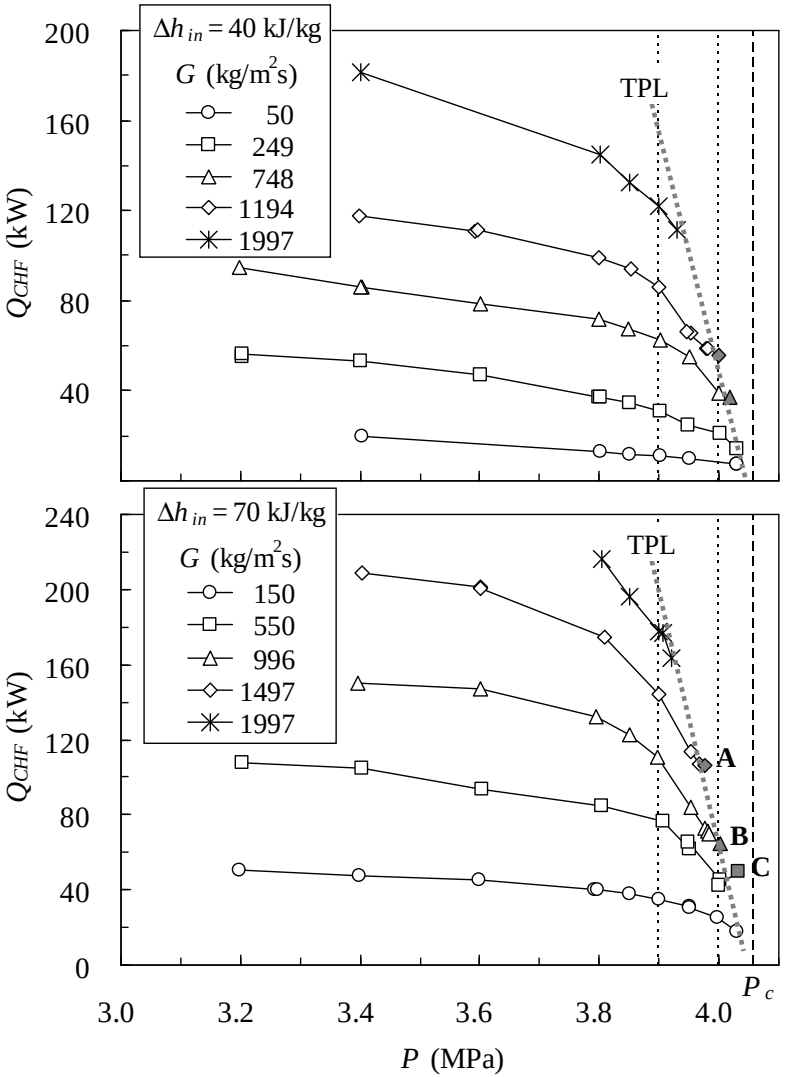
Critical quality with the pressure (TB-1)

Experimental Results : CHF Characteristics (3/3)

Disappearance of CHF Phenomenon near the Critical Pressure : Threshold Pressure



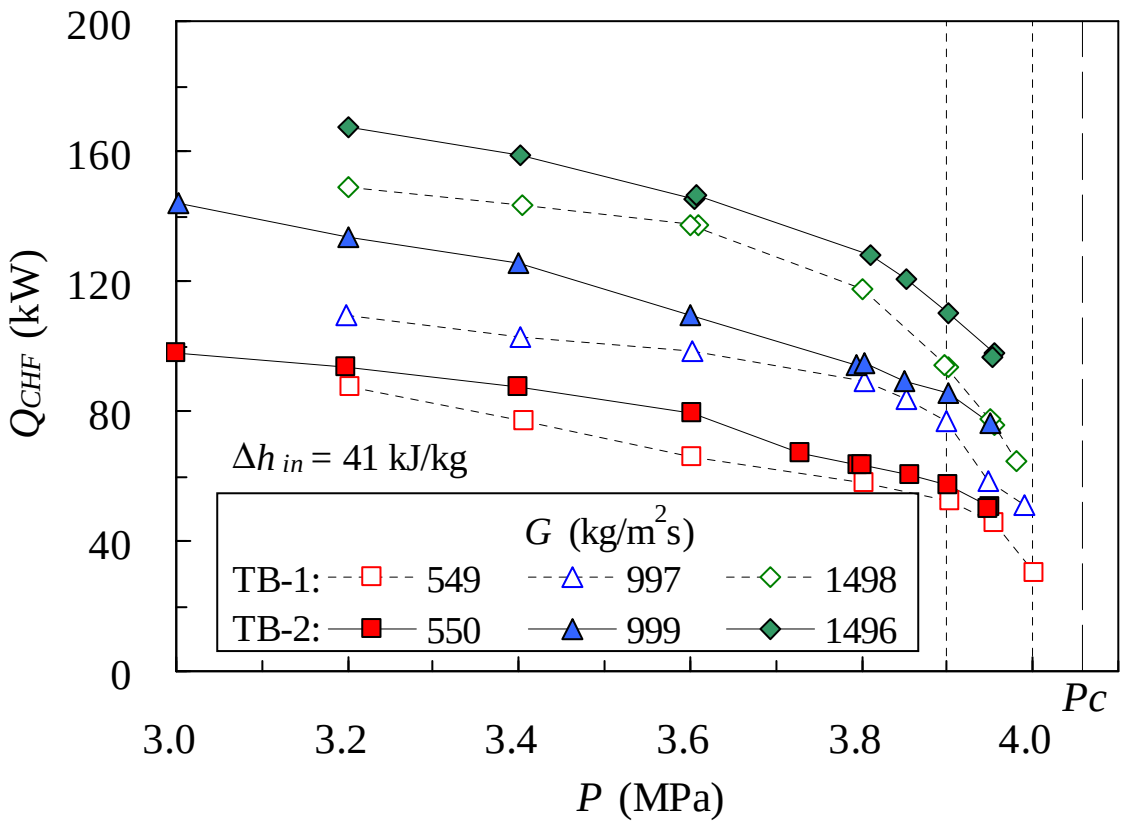
Wall temperature variations at CHF conditions (TB-1)



Threshold pressure Line (TB-1)

Experimental Results : Effect of Spacer Grid

TB-1 : with Plain Spacer Grids versus **TB-2 : with Mixing Vane Spacer Grids**



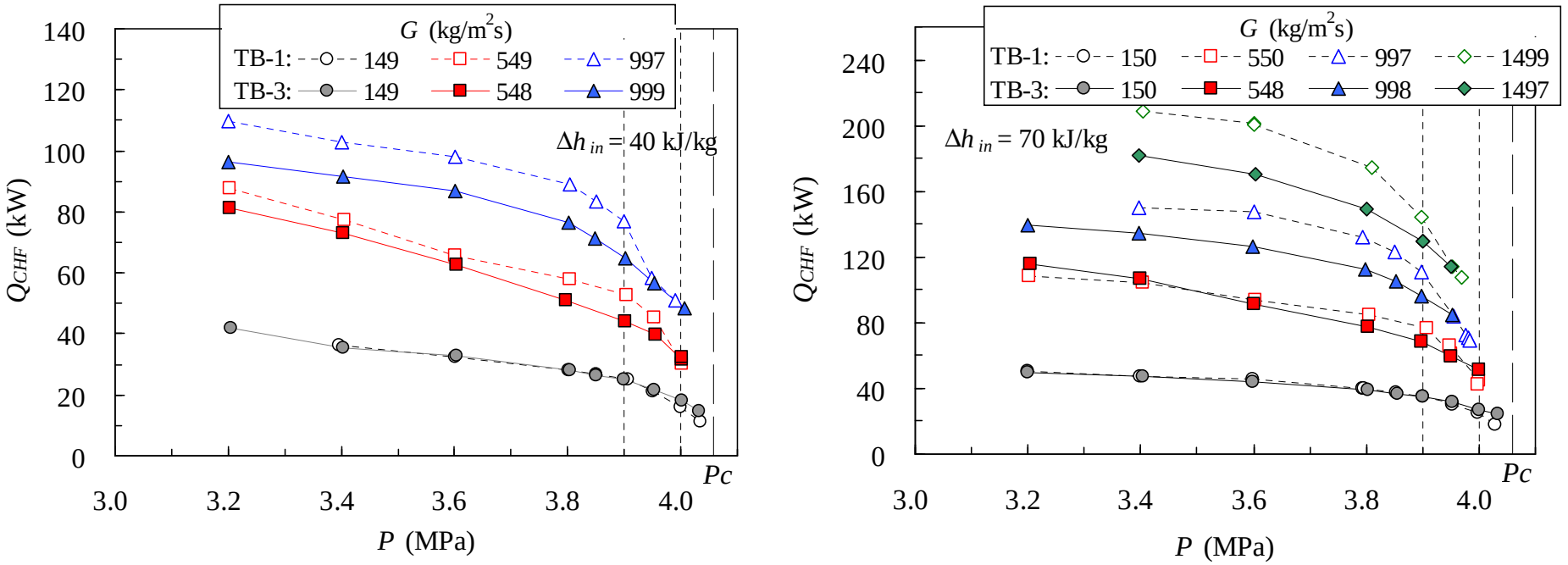
Critical power as a function of the pressure

Experimental Results : Effect of Unheated Rods

TB-1 : with Plain Spacer Grids

versus

TB-3 : with Unheated Rods and Plain Spacer Grids



Critical power as a function of the pressure

Conclusions

- The critical power in a 5x5 heater rod bundle cooled by R-134a fluid has been measured more carefully near the critical pressure.
- As the pressure approaches the critical pressure, the critical power decreases sharply at a pressure of about 3.8-3.9 MPa.
- The existence of a threshold pressure at which the CHF phenomenon disappears has been observed in the sub-critical pressure region near the critical pressure.
- The turbulence effect by the mixing vane of the spacer grid on the critical power is maintained up to a pressure of 3.95 MPa.
- The effect of the unheated rods on the critical power becomes smaller as the pressure approaches the critical pressure.