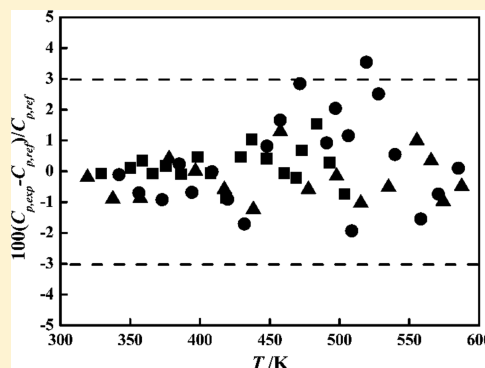


# Design of a Flow Calorimeter for Hydrocarbon Fuel at Temperatures from (330 to 900) K and Pressures up to 6.0 MPa

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**ABSTRACT:** The isobaric specific heat capacity of a kerosene type hydrocarbon fuel was measured online using a flow calorimeter, which was based on the energy conservation theory. The test temperatures covered from (330 to 900) K and operating pressures changed from (1.96 to 4.93) MPa. The isobaric specific heat capacity data have an expanded relative uncertainty of 2.54 % with a coverage factor of 2. The reliability and accuracy of the flow calorimeter measurement was verified by the water, *n*-hexane, and binary mixtures of *n*-heptane + *n*-octane and methanol + acetone, respectively. Finally, the isobaric specific heat capacities of a type of endothermic hydrocarbon fuel were measured and  $C_p$ - $T$  diagrams were plotted at sub- and supercritical pressure.



## INTRODUCTION

Hydrocarbon fuel plays an important role in the heat management technology for a scramjet engine.<sup>1–3</sup> As a representative application, it is applied as not only a fuel in the combustion chamber but also a primary coolant in a regenerative cooling protection of the scramjet engine. In the cooling process, high heat flux, large temperature difference, and limited mass rate posed a severe challenge for heat transfer of the hydrocarbon fuel.<sup>4</sup> Thus, a fundamental understanding of thermophysical properties of the hydrocarbon fuel are deeply demanded. Specific heat capacity, density, viscosity, and critical parameters are the primary basis of the theoretical analysis and numerical simulation for the hydrocarbons. In this paper, the specific heat capacity measurement of hydrocarbon fuel was conducted.

As an important parameter, specific heat capacity has always attracted numerous researchers' attention in the power and engineering applications. Plentiful specific heat capacities of pure and multicomponent substances were investigated experimentally and different calculation equations were summarized. Flow calorimeter,<sup>5–9</sup> differential scanning calorimeter (DSC), adiabatic calorimeter, radiation calorimeter, and metal-bellows calorimeter were the most common instruments for the specific heat capacity measurement. However, most of the test calorimeters were used off-line and could not apply in a high temperature process.

Hydrocarbon fuel is a complex mixture, containing hundreds of components.<sup>10</sup> Some researchers investigated the heat capacity of different kerosene propellants. Abdulagatov<sup>11</sup> measured the isobaric heat capacity of rocket propellant (RP-1 fuel) at (293 to 671) K and up to 60 MPa by a vacuum adiabatic calorimeter immersed in a precision liquid thermostat. Deng et al.<sup>9</sup> used a vacuum flow-calorimeter to measure the

isobaric specific heat capacity of kerosene RP-3 in the near-critical and supercritical regions. The estimated uncertainty of their measurement was lower than 2.11%. The heat capacities of jet fuels JP-8 and S-8 were measured with a commercial differential scanning calorimeter by Bruno et al.<sup>12</sup> On the basis of test data, the least-squares generated equations of two fuels were performed for the heat capacity at ambient pressure. Bruno et al.<sup>13</sup> also conducted research on the heat capacity measurement for jet fuel JP-10 and summarized the calculations of the thermodynamic properties.

In present paper, the specific heat capacity of a kerosene type hydrocarbon fuel was studied experimentally with a flow calorimeter, which was based on the energy conservation theory. In tests, the reliability and accuracy of the flow calorimeter measurement was verified first. Then the isobaric specific heat capacity of the fuel was measured at a pressure from (1.96 to 4.93) MPa and temperature from (330 to 900) K.

## EXPERIMENTAL SECTION

**Experimental System.** Experiments were performed in a multiphase flow test platform in our laboratory. The schematic diagram of the experimental system is shown in Figure 1. The system consists of the following components: a precision constant flow pump, a two-stage heater, the calorimeter cell, and a pressure regulation system.

Test fluid was driven by a constant flow pump (P500) with 500 mL/min supply capacity. The pump delivered accurate volumetric flow rates and the fluid mass flow rates were monitored by a mass flow meter (MASS 2100 DI 1.5). A 40  $\mu$ m

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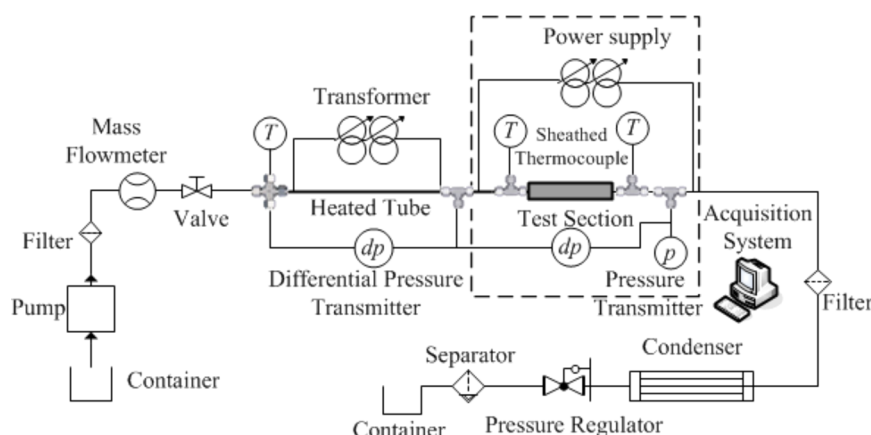


Figure 1. Schematic diagram of experimental system.

filter was attached to the pump to protect the devices from entrained impurity. Fluid was heated to a desired operating temperature in a preheated tube located upstream from the calorimeter cell. Then it entered into the calorimeter cell for the specific heat capacity measurement. The test hot fluid is cooled by a condenser (KANSAs ICA5) and separated into a waste chamber. The operating pressure of system was regulated by a back-pressure valve (BY3).

The detail configuration of calorimeter cell is shown in Figure 2. The calorimeter cell consists of a test tube and an

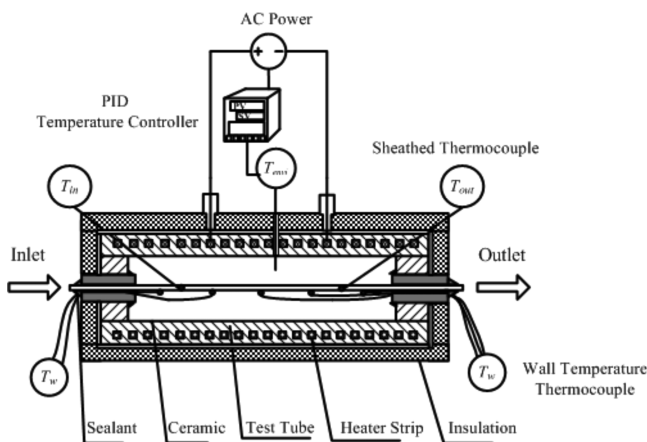


Figure 2. Detailed configuration of test section.

isothermal chamber. The test tube was made of GH3128 high temperature nickel alloy pipe with 380 mm length and 2.0 mm inside diameter. The fluid flowed through the test tube and absorbed the heat flux, which was adjusted by a DC power. The heating voltage was measured with a voltage transmitter (TAIK S4T-DT-V4A4A) with an accuracy of  $\pm 0.2\%$ . And the current was measured by a Hall current sensor (LEM LT 58-S7) with an accuracy of  $\pm 0.8\%$ . In experiments, as soon as the inlet temperature was stable, the heating power was adjusted to the desired outlet temperature. Both temperatures were measured by a K-type sheathed thermocouple (Omega TJ2), which was calibrated by JOFRA temperature calibrator (650SE). The uncertainty of the sheathed thermocouples was within  $\pm 0.83$  K at the temperatures from (273.2 to 873.2) K. Meanwhile, five thermocouples (Omega GG-K) with an accuracy of  $\pm 0.4\%$  were spot-welded on the outside surface of the test tube to measure wall temperature. At the outlet, a pressure transducer

(Rosemount 3051) was applied to measure the operating pressure with a scale of 10 MPa and an uncertainty of 0.075%. All the information was recorded using a computerized data acquisition system (IMP3595).

The isothermal chamber was arranged in the calorimeter to minimize the heat loss for accurate measurement. The temperature of the thermostatic environment was measured by a K-type sheathed thermocouple (Omega TJ2) and adjusted by a PID regulator (SHIMADEN FP23) with an AC power source. Convective heat transfer was eliminated by an enclosed space around the test cell. Radiative heat transfer was minimized by the consistent temperature between tube wall and enclosed environment. Meanwhile, a 750 mm heating tube in the calorimeter cell could reduce the temperature gradient to minimize the conductive heat transfer along the tube. As a result, a small temperature difference between the inlet and outlet of the test tube was controlled within 5 K.

**Materials.** The physical properties of test fluids are listed in Table 1. Hydrocarbon fuel I is made up of a blend of

Table 1. Sample Description

chemical name	source	initial mole fraction purity	purification method
water	own product	0.9995	pure deionized
<i>n</i> -hexane	Sinopharm Chemical Reagent Co., Ltd.	0.995	distillation
<i>n</i> -heptane	Sinopharm Chemical Reagent Co., Ltd.	0.995	distillation
<i>n</i> -octane	Sinopharm Chemical Reagent Co., Ltd.	0.995	distillation
methanol	Sinopharm Chemical Reagent Co., Ltd.	0.995	distillation
acetone	Sinopharm Chemical Reagent Co., Ltd.	0.998	distillation
fuel	Karamay Oil		distillation

hydrocarbons, with  $w = 0.8140$  cycloalkanes,  $w = 0.0475$  alkanes,  $w = 0.0488$  alkenes,  $w = 0.0400$  aromatics, and  $w = 0.0497$  others. The critical parameters and detailed compositions of the hydrocarbon fuel were given in our previous work.<sup>14</sup>

**Theory.** The isobaric specific heat capacity measurement is based on the energy conservation equation as described in previous researches:<sup>9,15</sup>

$$Q_{\text{total}} = UI = m \int_{T_{\text{in}}}^{T_{\text{out}}} C_p dT + Q_{\text{loss}} = m\dot{C}_p \Delta T + Q_{\text{loss}} \quad (1)$$

$Q_{\text{total}}$  and  $Q_{\text{loss}}$  stand for the total heat flux and heat loss of test tube.  $m$ ,  $U$ , and  $I$  represent mass flow rate, heating voltage, and current of test section.  $\Delta T$  is the bulk temperature difference between the inlet and outlet, and  $T$  is the qualitative temperature expressed as the average value of inlet fluid temperature  $T_{\text{in}}$  and outlet fluid temperature  $T_{\text{out}}$ .

The heat loss is defined as a function of temperature difference between the outside wall temperature  $T_w$  and environmental temperature  $T_{\text{envi}}$ .

$$Q_{\text{loss}} = U'I' = f(T_w - T_{\text{envi}}) \quad (2)$$

$U'$  and  $I'$  are the electrical voltage and current supplied in heat loss experiments.

Consequently, the isobaric specific heat capacity equation can be established:

$$\dot{C}_p = \frac{UI - U'I'}{m\Delta T} \quad (3)$$

According to eq 4, the combined standard uncertainty of measured isobaric specific heat capacity  $u_c(\dot{C}_p)$  is

$$u_c^2(\dot{C}_p) = \left(\frac{\partial \dot{C}_p}{\partial U}\right)^2 u^2(U) + \left(\frac{\partial \dot{C}_p}{\partial I}\right)^2 u^2(I) + \left(\frac{\partial \dot{C}_p}{\partial U'}\right)^2 u^2(U') + \left(\frac{\partial \dot{C}_p}{\partial I'}\right)^2 u^2(I') + \left(\frac{\partial \dot{C}_p}{\partial m}\right)^2 u^2(m) + \left(\frac{\partial \dot{C}_p}{\partial \Delta T}\right)^2 u^2(\Delta T) \quad (4)$$

In this work, the electrical voltage of the calorimeter was measured with a voltage transmitter with full scales of 10 V and an uncertainty of  $\pm 0.02$  V. The current of test section was measured by a Hall current sensor with full scales of 50 A and an uncertainty of  $\pm 0.4$  A. The fluid was supplied by constant flow pump with 500 mL/min capacity and an uncertainty of  $\pm 1.5$  mL/min. The temperature difference  $\Delta T$  was within 5 K and an uncertainty of  $\pm 0.03$  K. Thus, the combined standard uncertainty of the specific heat capacity is about 1.27 %. The relative expanded uncertainty of isobaric specific heat capacity is identified as 2.54 % (coverage factor  $k = 2$ ).

## RESULTS AND DISCUSSION

**Calibration of the Flow Calorimeter.** To verify the accuracy and reliability of the test method to the specific heat capacity, the isobaric specific heat capacity of water and  $n$ -hexane were measured first. The binary mixtures  $n$ -heptane +  $n$ -octane and methanol + acetone were tested further. Heat capacities of the reference fluids in experiments were compared with the data available at NIST<sup>16</sup> and IAPWS.<sup>17</sup> In calculation, the percentage deviation (PD), the average absolute deviation (AAD), and the maximum absolute deviation (MAD) of the results were defined to check the accuracy of test measurement.

The specific heat capacity of water was measured at a constant pressure  $p = 5.03$  MPa with a temperature range (329.2 to 503.6) K in the liquid state. The test results are compared with the reference data<sup>17</sup> as shown in Table 2. Good agreement is obtained with 1.54 % MAD and 0.43 % AAD in

Table 2. The relative errors of the isobaric specific heat capacity data are within  $\pm 1.6$  % error band.

**Table 2. Experimental Values and Reference Data of Specific Heat Capacity  $C_p$  at Temperature  $T$ , Pressure  $p$ , and Relative Differences  $\Delta C_p/C_p = (C_{p,\text{exp}} - C_{p,\text{ref}})/C_{p,\text{ref}}$  for Water<sup>a</sup>**

$T$ K	$C_{p,\text{exp}}$ kJ·kg <sup>-1</sup> ·K <sup>-1</sup>	$C_{p,\text{ref}}$ kJ·kg <sup>-1</sup> ·K <sup>-1</sup>	$\Delta C_p/C_p$ %
$p = 5.03$ MPa			
329.2	4.169	4.172	-0.07
350.0	4.189	4.184	0.11
358.7	4.205	4.191	0.35
366.1	4.194	4.197	-0.08
375.5	4.214	4.207	0.17
386.4	4.217	4.221	-0.09
398.4	4.260	4.240	0.47
407.6	4.255	4.257	-0.05
418.8	4.245	4.282	-0.86
429.3	4.329	4.309	0.46
437.0	4.376	4.331	1.03
447.8	4.385	4.367	0.41
460.4	4.414	4.417	-0.06
469.0	4.446	4.455	-0.21
473.0	4.505	4.475	0.68
483.7	4.603	4.534	1.54
493.0	4.606	4.592	0.29
503.6	4.636	4.670	-0.74

<sup>a</sup>Standard uncertainties  $u$  are  $u(T) = 0.83$  K,  $u(p) = 7.5$  kPa, and combined expanded uncertainty  $U_c$  is  $U_c(C_p) = 0.11$  kJ·kg<sup>-1</sup>·K<sup>-1</sup> (0.95 level of confidence).

$n$ -Hexane was measured at a constant pressure  $p = 3.07$  MPa and varied temperature (342.0 to 585.2) K. As the temperature rose, the fluid went through a liquid state and a supercritical state at supercritical pressure. The experimental specific heat capacities and reference values<sup>16</sup> of  $n$ -hexane are shown in Table 3. The MAD was 3.54 % and the AAD was limited to 1.22 %. All relative errors are within  $\pm 3.6$  % error band and the bigger error appeared in the vicinity of the pseudocritical temperature.

The isobaric specific heat capacity of  $w = 0.500$   $n$ -heptane and  $w = 0.500$   $n$ -octane mixture were measured at a fixed pressure 5.01 MPa with temperature from (319.4 to 587.6) K. The experimental data are compared with reference values<sup>16</sup> and the results are illustrated in Table 4. The MAD and AAD are limited to 1.29 % and 0.66 %, and all data points are within  $\pm 1.3$  % error band. Moreover, different mole-fraction binary mixtures of methanol and acetone were performed in test experiments. The results were compared with experimental data reported in the literature<sup>6</sup> as shown in Table 5. The MAD and AAD are 1.51 % and 0.60 %, respectively. The excellent agreement confirms the reliability and accuracy of the flow calorimeter measurement for binary mixtures.

The isobaric specific heat capacity measurement of water,  $n$ -hexane, binary mixtures proved that the flow calorimeter was feasible and accurate for the specific heat capacity measurement. As an application promotion, the isobaric specific heat capacity of a kerosene type hydrocarbon fuel was measured at sub- and supercritical pressures in the following part.

### Isobaric Specific Heat Capacity of Hydrocarbon Fuel.

The isobaric specific heat capacity of the hydrocarbon fuel was measured with temperature range of (330 to 900) K and

**Table 3. Experimental Values and Reference Data of Specific Heat Capacity  $C_p$  at Temperature  $T$ , Pressure  $p$ , and Relative Differences  $\Delta C_p/C_p = (C_{p,\text{exp}} - C_{p,\text{ref}})/C_{p,\text{ref}}$  for  $n$ -Hexane<sup>a</sup>**

$T$ K	$C_{p,\text{exp}}$ kJ·kg <sup>-1</sup> ·K <sup>-1</sup>	$C_{p,\text{ref}}$ kJ·kg <sup>-1</sup> ·K <sup>-1</sup>	$\Delta C_p/C_p$ %
$p = 3.07$ MPa			
342.0	2.436	2.439	-0.11
356.2	2.490	2.508	-0.70
372.9	2.568	2.592	-0.92
385.1	2.663	2.657	0.24
394.2	2.687	2.706	-0.68
408.6	2.788	2.789	-0.02
419.8	2.831	2.857	-0.90
431.8	2.887	2.937	-1.71
447.9	3.084	3.059	0.82
457.5	3.197	3.145	1.67
471.7	3.405	3.311	2.84
490.7	3.793	3.758	0.92
497.1	4.224	4.139	2.04
506.4	8.217	8.123	1.16
508.8	27.305	27.843	-1.93
519.3	4.511	4.357	3.54
528.0	3.831	3.738	2.51
539.8	3.441	3.422	0.55
558.2	3.187	3.237	-1.54
570.8	3.163	3.186	-0.74
585.2	3.159	3.156	0.10

<sup>a</sup>Standard uncertainties  $u$  are  $u(T) = 0.83$  K,  $u(p) = 7.5$  kPa and combined expanded uncertainty  $U_c$  is  $U_c(C_p) = 0.12$  kJ·kg<sup>-1</sup>·K<sup>-1</sup> (0.95 level of confidence).

**Table 4. Experimental Values and Reference Data of Specific Heat Capacity  $C_p$  at Temperature  $T$ , Pressure  $p$ , and Relative Differences  $\Delta C_p/C_p = (C_{p,\text{exp}} - C_{p,\text{ref}})/C_{p,\text{ref}}$  for  $w = 0.500$   $n$ -Heptane and  $w = 0.500$   $n$ -Octane Mixture<sup>a</sup>**

$T$ K	$C_{p,\text{exp}}$ kJ·kg <sup>-1</sup> ·K <sup>-1</sup>	$C_{p,\text{ref}}$ kJ·kg <sup>-1</sup> ·K <sup>-1</sup>	$\Delta C_p/C_p$ %
$p = 5.01$ MPa			
319.4	2.300	2.305	-0.20
337.6	2.356	2.377	-0.89
357.2	2.438	2.459	-0.87
377.9	2.559	2.548	0.41
396.8	2.633	2.632	0.01
417.4	2.710	2.726	-0.59
438.3	2.789	2.824	-1.24
457.6	2.956	2.918	1.29
477.7	3.003	3.021	-0.59
497.9	3.128	3.133	-0.15
515.3	3.207	3.241	-1.03
535.1	3.367	3.384	-0.51
555.5	3.608	3.573	1.00
565.6	3.701	3.689	0.34
574.2	3.766	3.803	-0.97
587.6	3.993	4.012	-0.49

<sup>a</sup>Standard uncertainties  $u$  are  $u(T) = 0.83$  K,  $u(p) = 7.5$  kPa, and combined expanded uncertainty  $U_c$  is  $U_c(C_p) = 0.08$  kJ·kg<sup>-1</sup>·K<sup>-1</sup> (0.95 level of confidence).

different test pressures, which included a subcritical pressure 1.96 MPa and two supercritical pressure 3.46 and 4.93 MPa. All data is shown in Table 6 and the curves of  $C_p$ - $T$  were

**Table 5. Experimental Values and Reference Data of Specific Heat Capacity  $C_p$  at Temperature  $T$ , Pressure  $p$ , and Relative Differences  $\Delta C_p/C_p = (C_{p,\text{exp}} - C_{p,\text{ref}})/C_{p,\text{ref}}$  for the Methanol and Acetone Mixtures<sup>a</sup>**

$p$ MPa	$T$ K	$C_p$ kJ·kg <sup>-1</sup> ·K <sup>-1</sup>	$p$ MPa	$T$ K	$C_p$ kJ·kg <sup>-1</sup> ·K <sup>-1</sup>	$\Delta C_p/C_p$ %
$x = 0.25$ methanol and $x = 0.75$ acetone						
this work			Mulia and Yesavage <sup>6</sup>			
1.10	423.1	2.178	1.10	423.15	2.1841	-0.28
2.01	423.1	2.823	2.00	423.15	2.840	-0.60
3.95	423.3	2.761	3.92	423.15	2.771	-0.36
3.10	493.2	2.824	3.12	493.15	2.839	-0.53
4.78	493.0	18.85	4.78	493.15	19.14	-1.51
5.01	493.1	8.697	5.00	493.15	8.780	-0.95
6.00	493.2	4.266	5.98	493.15	4.290	-0.56
$w = 0.50$ methanol and $w = 0.50$ acetone						
this work			Mulia and Yesavage <sup>6</sup>			
1.11	423.2	2.227	1.10	423.15	2.240	-0.19
2.90	423.0	2.977	2.93	423.15	2.987	-0.33
4.00	423.2	2.919	4.01	423.15	2.933	-0.47
2.90	483.3	2.745	2.89	483.15	2.759	-0.51
4.67	483.2	12.50	4.67	483.15	12.62	-0.93
4.97	483.4	6.691	4.96	483.15	6.763	-1.07
6.07	483.0	4.007	6.09	483.15	4.019	-0.31
$w = 0.75$ methanol and $w = 0.25$ acetone						
this work			Mulia and Yesavage <sup>6</sup>			
1.13	423.2	2.328	1.14	423.15	2.338	-0.43
3.00	423.3	3.076	3.01	423.15	3.103	-0.87
6.10	423.2	2.902	6.11	423.15	2.925	-0.79
3.42	498.0	3.041	3.44	498.15	3.058	-0.56
4.91	498.2	4.951	4.91	498.15	4.976	-0.51
5.35	498.1	5.755	5.36	498.15	5.763	-0.14

<sup>a</sup>Standard uncertainties  $u$  are  $u(T) = 0.83$  K,  $u(p) = 7.5$  kPa, and combined expanded uncertainty  $U_c$  is  $U_c(C_p) = 0.13$  kJ·kg<sup>-1</sup>·K<sup>-1</sup> (0.95 level of confidence).

presented in Figure 3. The isobaric specific heat capacity of hydrocarbon fuel varied nonmonotonically with temperature increase. In low temperature range, the specific heat capacity increased gradually and the test values had little difference at different pressures. Pressure had no effect on the specific heat capacity in this region. When the fluid temperature entered the vicinity of critical region at subcritical pressure, the specific heat capacity changed sharply and a maximum occurred at the critical temperature. The same phenomenon was also observed at the supercritical pressures, but the maximum heat capacity was much lower than that at the subcritical condition. Above the critical region, the pressure began to effect the increase of the heat capacity. The bigger test value was obtained at a higher pressure. When the test temperature got over 830 K, the chemical endothermic reactions began to intensify and the specific heat capacity increased obviously. At the moment, the pressure took an important part in the chemical endothermic reactions of the fuel.

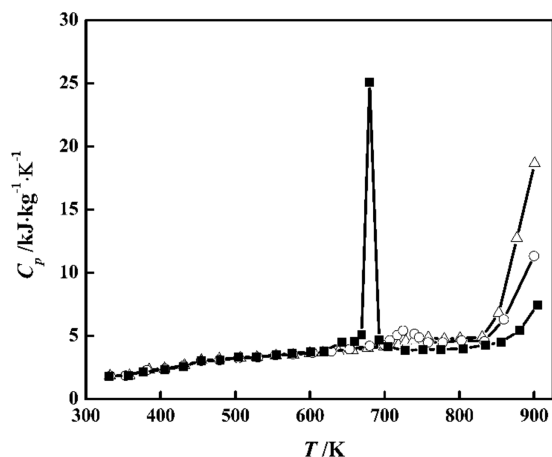
## CONCLUSION

A flow calorimeter measurement is proposed that is based on the energy conservation theory for the isobaric specific heat capacity. The measurement theory and experimental system were described in detail. The accuracy of the flow calorimeter was calibrated by water,  $n$ -hexane, and binary mixtures of  $n$ -heptane +  $n$ -octane and methanol + acetone. The specific heat

**Table 6. Experimental Values of Specific Heat Capacity  $C_p$  at Temperature  $T$ , Pressure  $p$  for the Fuel at Sub- and Supercritical Pressure Conditions<sup>a</sup>**

$T$ K	$C_p$ kJ·kg <sup>-1</sup> ·K <sup>-1</sup>	$T$ K	$C_p$ kJ·kg <sup>-1</sup> ·K <sup>-1</sup>	$T$ K	$C_p$ kJ·kg <sup>-1</sup> ·K <sup>-1</sup>
$p = 1.96$ MPa					
331.2	1.826	575.7	3.640	751.6	3.935
356.8	1.866	600.5	3.738	775.3	3.930
376.4	2.149	618.9	3.813	805.5	3.999
405.1	2.318	642.6	4.491	835.0	4.289
430.6	2.585	659.4	4.572	856.0	4.490
454.7	3.032	669.2	5.103	880.6	5.436
479.7	3.064	679.8	25.119	904.5	7.444
504.2	3.317	692.7	4.666		
527.9	3.334	704.5	4.159		
555.3	3.496	727.1	3.844		
$p = 3.46$ MPa					
332.8	1.829	577.2	3.560	746.0	4.877
352.9	1.847	603.6	3.668	758.3	4.485
381.6	2.294	628.6	3.776	777.6	4.499
405.9	2.385	653.1	3.952	802.8	4.634
430.7	2.631	680.1	4.213	833.6	4.581
454.1	3.040	699.7	4.303	859.6	6.317
478.9	3.090	707.0	4.658	899.9	11.333
504.1	3.229	716.8	5.072		
530.4	3.312	724.8	5.420		
553.7	3.470	739.8	5.160		
$p = 4.93$ MPa					
332.1	1.832	577.5	3.503	738.4	4.660
358.4	1.872	600.0	3.638	758.5	4.863
384.7	2.325	617.2	3.689	780.0	4.747
405.1	2.406	638.3	3.771	801.0	4.825
431.8	2.672	657.1	3.847	830.8	4.897
454.5	3.065	677.5	4.052	852.8	6.814
478.5	3.180	699.3	4.155	876.9	12.731
506.7	3.266	708.5	4.290	900.9	18.648
528.8	3.316	718.5	4.302		
554.4	3.450	728.2	4.587		

<sup>a</sup>Standard uncertainties  $u$  are  $u(T) = 0.83$  K,  $u(p) = 7.5$  kPa and combined expanded uncertainty  $U_c$  is  $U_c(C_p) = 0.11$  kJ·kg<sup>-1</sup>·K<sup>-1</sup> (0.95 level of confidence).



**Figure 3.** Specific heat capacity variations of hydrocarbon fuel versus temperature at ■,  $p = 1.96$  MPa; ○,  $p = 3.46$  MPa; △,  $p = 4.93$  MPa.

capacity of water was measured at the temperature range of (329.2 to 503.6) K and a fixed pressure of 5.03 MPa. The measured average absolute deviation (AAD) was 0.43 % and the maximum absolute deviation (MAD) was 1.54 %, respectively. The specific heat capacity of *n*-hexane was measured at 3.07 MPa and (342.0 to 585.2) K. The measured average absolute deviation (AAD) was 1.22 % and the maximum absolute deviation (MAD) was 3.54 %. The specific heat capacity of  $w = 0.500$  *n*-heptane and  $w = 0.500$  *n*-octane binary mixture were measured at 5.01 MPa with a temperature range of (319.4 to 587.6) K. The maximum absolute deviation (MAD) was limited to 1.29 % and the average absolute deviation (AAD) was 0.66 %. Different mole-fraction binary mixtures of methanol and acetone were performed and the results were compared with experimental data reported in the literature. The maximum absolute deviation (MAD) and the average absolute deviation (AAD) were 1.51 % and 0.60 %, respectively. Excellent agreement between measured and literature values confirms the reliability and accuracy of the flow calorimeter measurement. Finally, the specific heat capacity of hydrocarbon fuel was measured at the temperature range of (330 to 900) K at a subcritical pressure 1.96 MPa and two supercritical pressures of 3.46 MPa and 4.93 MPa. The curves of  $C_p$ - $T$  were obtained at different pressures.

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