ASSESSMENT OF SUPERCRITICAL HEAT TRANSFER PREDICTION METHODS

H. Zahlan[1], D.C. Groeneveld[1], S. Tavoularis[1],
S. Mokry[2] and I. Pioro[2]
[1]University of Ottawa, Ottawa, Ontario, Canada
[2]University of Ontario Institute of Technology, Oshawa, Ontario, Canada

Abstract

A large supercritical water databank has been compiled at the University of Ottawa (UO). This databank originally contained 36,030 tube data points. After a thorough screening process, during which duplicate and unreliable data and obvious outliers were removed, a final databank was assembled, containing more than 24,000 screened data points. This databank is the result of the combination of four different databases, the more recent one being the University of Ontario Institute of Technology database. The UO combined databank covers a wide range of near-critical and supercritical heat transfer (SCHT) conditions and is used for the assessment of existing SCHT correlations and the derivation of the transcritical heat transfer look-up table. Twelve SCHT correlations and four single-phase heat transfer correlations have been applied to the combined UO databank. The assessed SCHT prediction methods include four correlations that were developed recently, with one of these correlations published in 2010. An error analysis and an examination of the parametric trends were performed for the most promising correlations. The result of the assessment showed that the heat transfer coefficient was predicted more accurately by the recent correlations in the three supercritical heat transfer regions: (i) close to the critical or pseudo-critical point, (ii) the high-density or liquid-like state and (iii) the low-density or gas-like state. The most accurate correlations will be used in the construction of the skeleton look-up table that is currently under development at UO.

Keywords: SCHT, Supercritical heat transfer, Water data, Prediction methods

1. Introduction

Thermo-physical properties of fluids at near-critical conditions exhibit sharp changes within a narrow range of temperature, resulting in significant variations in fluid properties within a cross-section of a tube. This will lead to significant prediction errors when using SCHT correlations based on average property values (assuming a linear profile). Away from the critical point, such property changes become smaller at supercritical pressures but remain evident near the pseudo-critical temperature. Because of these abnormal changes in the properties, the near-critical heat transfer coefficient is difficult to predict, especially in the range of relatively low mass velocities and high heat fluxes.

More than twenty correlations are available in the literature for predicting the heat transfer in the near-critical and supercritical region; most of the available correlations are modified versions of the Dittus-Boelter (1930) equation. Although these correlations account for the changes in properties in the near critical region, they usually do not account for heat transfer enhancement or deterioration in the vicinity of the pseudo-critical temperature T_{pc}. Some prediction methods considered the enhancement and deterioration in heat transfer when $T_b < T_w < T_{pc}$, where T_w is the wall temperature and T_b is the bulk temperature. The objectives of the current study are (i) to find the best SCHT correlations which will be used in the construction of a trans-critical heat transfer look-up table (LUT), covering a wide range of flow conditions, in contrast to current correlations, each of which is bounded by a much narrower validity range) and (ii) to analyse the predicted SCHT trends and to compare these trends with the experimental data.

2. Super-critical heat transfer database

The UO team has compiled a large subcritical and supercritical database (Groeneveld and Zahlan, 2009; Zahlan et al., 2009). The database includes data for water and other fluids and different geometries. Additional water data sets, tabulated and/or identified by Lowenberg et al. (2005, 2008; University of Stuttgart), and by Cheng (2009; Shanghai JiaoTong University) have been included in the expanded UO trans-critical heat transfer database. Recently, UO received an additional SCHT water database compiled at the University of Ontario Institute of Technology (UOIT) containing 10479 SCHT data points (Pioro, 2010). The main contributor to the UOIT data base for vertical upflow in circular tubes is Kirillov (2005), although their database also includes data from other authors. The UOIT database was subject to careful review, heat balance test and screening for duplicates and obvious outliers. The intention of the authors is to make all data publicly available, unless they are subjected to proprietary restrictions.

Table 1 shows a summary of the SCHT water data compilations from different sources and Table 2 describes all data sets from all sources and the range of their parameters. Figure 1 presents the numbers of data points for different tube diameter ranges for the combined SCHT water database. Some of these data sets were extracted from graphs using data digitization software (as were some of the data included in the original UO database), which introduces additional uncertainties (Zahlan et al., 2009). Frequently, more than one set of SCHT data set covers the same flow conditions; this will enhance the reliability of the LUT.

2.1 Supercritical sub-regions

At an earlier stage of this research, the SCHT data were classified into three distinctive supercritical sub-regions: (i) a high density state (liquid-like) region (T_w, $T_b < T_{pc}$), (ii) a near-critical or near-pseudo-critical region ($T_{pc} < T_w$ and $T_b < T_{pc}$), and (iii) a low density state (gas-like) region ($T_{pc} < T_w$, T_b). This classification was meant to take into consideration the distinct heat transfer mechanisms that apply within each sub-region. However, this approach would be complicated by the fact that the thermo-physical properties change significantly within a range of temperatures near the pseudo-critical value. Therefore, it was deemed to be preferable to redefine the boundaries of the near-critical/pseudo-critical region by introducing a narrow range of temperatures $T_{pc} - \Delta T < T < T_{pc} - \Delta T$, within which the thermo-physical properties change significantly. It was found that this range was described fairly well for different pressures by the empirical relationship $\Delta T/T_{pc} = 3.1\times10^{-3}(P/P_c)$, where the numerical values of all temperatures are in degrees K. Figure 2 shows the variation of C_p vs. temperature near the pseudo-critical value for different pressures and also illustrates the magnitude of ΔT for each pressure. In the current work, each SCW data point was classified in one of these three redefined sub-regions: (i) high density state (liquid-like) region (T_w, $T_b < T_{pc} - \Delta T$), (ii) near-critical or near-pseudo-critical region ($T_{pc} - \Delta T < T_w$ and $T_b < T_{pc} + \Delta T$), and (iii) low density state (gas-like) region ($T_{pc} + \Delta T <$ T_w, T_b).

2.2 Data screening for duplicates

The method for screening the data for (i) duplicates (runs and points between different datasets and within a dataset), (ii) data that did not agree with a simple heat balance, and (iii) obvious outliers was presented by Zahlan et al. (2009). The results are summarized in Table 3. This updated table shows the number of data before and after screening for all datasets for the four combined databases.

3. Prediction methods

Several reviews of SCHT correlations have been published previously. Hall et al. (1968), Jackson and Hall (1979a, 1979b) and Cheng and Schulenberg (2001) have presented overviews of SCHT correlations and assessments of SC heat transfer correlations against both SC water and SC CO_2 data. Pioro et al. (2004) recently presented a more up-to-date review of such correlations that have been applied to SC conditions. The UO assessment covers more correlations and compares them against a much larger database: four single-phase correlations and twelve SCHT correlations have been assessed against the UO combined database.

3.1 Single-phase correlations

The single-phase correlations have a form similar to the Dittus-Boelter (1930) equation, but with different exponents. The Dittus-Boelter equation was originally based on water data only and evaluates the fluid properties at the bulk fluid temperature, whereas the Sieder-Tate (1936) equation includes a viscosity ratio term to account for the difference in fluid viscosity at the wall and in the bulk flow. The Hadaller and Banerjee (1969) equation is based on high-pressure superheated steam data. The most recent single-phase heat transfer equation is that of Gnielinski (1976) for fully developed turbulent flows, which includes a friction factor term to account for the increasing heat transfer with an increase in friction factor. The Gnielinski (1976) correlation includes also a factor to account for the developing boundary layer effect on heat transfer coefficient enhancement. These correlations are described below.

3.2 SCHT correlations

One of the earliest SCHT correlations is that of Bishop et al. (1965) who modified the Dittus-Boelter (1930) equation by including a density ratio (ratio of the density at wall temperature and the density at bulk fluid temperature) and replacing the specific heat in the Prandtl number by the effective integrated specific heat capacity. The Swenson et al. (1965) correlation has similar parameters to those in the Bishop et al. (1965) correlation, except that T_w was used as the reference temperature for Nu, Re, and averaged Pr number. Krasnoscheckov et al. (1967) proposed a modified version of a SCHT correlation previously derived in 1959 and 1960. This correlation showed errors within 15% (for their database) and was recommended for the following ranges:

$$2\times10^4 < \mathrm{Re}_b < 8.6\times10^5,\ 0.85 < \bar{\mathrm{Pr}}_b < 65,\ 0.9 < \frac{\mu_b}{\mu_w} < 3.6,\ 1.0 < k_b/k_w < 6.0 \text{ and } 0.07 < C_p/C_{p,b} < 4.5$$

Jackson's (2002) correlation is basically a modified form of the Krasnoscheckov et al. (1967) equation, the exponent n of the specific heat ratio is (with T in K):

$n = 0.4$, for $T_b < T_w < T_{pc}$ and $1.2T_{pc} < T_b < T_w$

$$n = 0.4 + 0.2(T_w/T_{pc} - 1), \text{for } T_b < T_{pc} < T_w$$

$$n = 0.4 + 0.2(T_w/T_{pc} - 1)(1 - 5(T_b/T_{pc} - 1)), \text{ for } T_{pc} < T_b < 1.2T_{pc}$$

Yamagata et al. (1972) introduced a correction factor to the Dittus-Boelter equation, which is a function of the Eckert number E (= $(T_{pc}-T_b)/(T_w-T_b)$) and the Prandtl number at the pseudo-critical temperature or the effective integrated specific heat capacity ratio. Watts and Chou (1982) correlated mixed convection (forced and natural) water and CO_2 data for upwards and downwards flows; they used the deterioration criterion of Jackson and Hall (1979b) in the development of their correlations for normal and deteriorated heat transfer. Griem (1996) modified the Dittus-Boelter equation by considering C_p at five reference temperatures from T_b to T_w; the selected $C_{p,sel}$ is based on excluding the largest two C_p values and averaging the other three; $C_{p,sel} = (\sum_{i=1}^{i=5} C_{p,i} - C_{p,1^{st}\max} - C_{p,2^{nd}\max})/3$. Griem (1996) also introduced a correction factor to cover the entire enthalpy range; this factor is a function of H_b. The correlation of Koshizuka and Oka (2000) is based on their earlier numerical study of SC water flow in a 10 mm tube (Cheng and Schulenberg, 2001); they proposed an empirical correlation, in which the pseudo-CHF is equal to 200 $G^{0.5}$; this parameter indicates the deteriorated heat transfer occurrence. Kuang et al. (2008) used their SCHT databank for water in vertical upwards flow in tubes to develop their correlation. They investigated the enhanced and deteriorated heat transfer region based on the normal heat transfer coefficient predicted by Dittus-Boelter (1930). Kuang et al. used the modified Grashof number term Gr^* (there is a negative correlation between HTC and Gr^*), first introduced by Jackson et al. (1989) to account for buoyancy effects (strong variations in density causing mixed instead of pure forced convection). In addition they used the McEligot et al. (2004) non-dimensional heat-flux number q^+ to consider the streamwise thermal acceleration effect from heating on the HTC. Mokry et al. (2008) used the SCHT water data of Kirillov et al. (2005; 89 runs with 81 data points per run) in deriving their correlation. In the development of their correlation, Mokry et al. (2008) excluded the data with both enhanced and deteriorated heat transfer. Cheng et al. (2009) derived a simple SCHT correlation to predict the deviation from the normal heat transfer predicted by the Dittus-Boelter (1930) equation. This correlation is a function of the dimensionless acceleration number π_A, this number is the non-dimensional heat flux number and is the same as q^+ in the Kuang et al. (2008) correlation. Recently, Gupta et al. (2010) modified the Swenson et al. (1965) correlation which considers properties for Nu, Re and average Pr at wall temperature. Gupta et al. (2010) added a viscosity ratio term, to account for viscosity variations between wall and bulk fluid. They included also a correction factor to account for the developing boundary layer effects at the entry region: this was a function decreasing exponentially with an increase of the ratio of the distance from the entrance of the test section and diameter (L/D). The correlations are listed in Table 5.

3.3 Assessment of the heat transfer prediction methods

Error analysis was performed using the 2009-UO combined database (Zahlan et al., 2009). In the current assessment, two new correlations were added to the study: the correlations of Gupta et al. (2010) and Koshizuka and Oka (2000). Twelve SCHT correlations and four single-phase correlations have been applied to the expanded UO database, including the new compilation from UOIT. The overall average error (e_A) and the root mean square error (e_S) were calculated for all correlations. The average and root mean square error are defined as

$$error = \frac{HTC_{pred}}{HTC_{exe}} - 1$$

$$e_A = avg_{error} = \frac{\sum_{i=1}^{l} error_i}{l} \times 100 \qquad (1)$$

$$e_S = rms_{error} = \sqrt{\frac{\sum_{i=1}^{l} error_i^2}{l}} \times 100$$

Table 4 compares the average and rms errors for all correlations in the three supercritical regions. This table shows that the Mokry et al. (2008) correlation has the least rms error in the three SCHT regions. The distributions of average and rms errors for the best correlations, including the one by Mokry et al. (2008), with respect to Re_b, $Pr_{avg,b}$, and P/P_c were presented by Zahlan et al. (2009) in the form of plots for the three supercritical regions for the combined UO, SJTU, and U of S database. Table 6 shows percentages of all combined data predicted by the most promising correlations within an error band of ±10% (e_{10}), ±20% (e_{20}), ±30% (e_{30}), and ±50% (e_{50}). Figure 3 and 4 show the distribution of e_A and e_S vs. D for the near-critical region.

3.3.1 Prediction of entry region effect on SC heat transfer coefficient

The correlations of Bishop et al. (1965), Gupta et al. (2010) and Mokry et al. (2008) were applied to 5668 data points (of which 1314 points have $L/D < 50$) in the three SCHT regions. Table 7 compares percentages of error predicted by the best two correlations in the three SCHT regions.

3.3.2 Error analysis for each dataset

An error analysis has been performed on each dataset in the three supercritical regions. The average, rms and percentage errors for the four error bands were calculated for each dataset. Note that datasets having fewer than 20 data points were ignored in this analysis. Tables 8–10 list these calculations for the near-critical, gas-like and liquid-like regions.

4. Summary and concluding remarks

A detailed error analysis has been performed on the 2010 version of the UO combined data bank.

In the supercritical region, the correlation of Mokry et al. (2008) showed the best agreement with the data for all three sub-regions.

Correlations that account for the *L/D* effect were applied to part of the compiled data; these correlations are compared to the Mokry et al. (2008) correlation. This correlation showed better agreement than other correlations, even though it does not include an *L/D* effect factor.

Nomenclature

D	tube inside diameter	(mm, m)
G	mass flux	(kg m^{-2} s^{-1})
H	enthalpy	(kJ kg^{-1})
P	pressure	(kPa)
q	heat flux	(kW m^{-2})
T	temperature	(˚C or K)
e	error	(%)

Subscripts

b	bulk
c	critical
pc	pseudo-critical
w	wall
A, S	average error, root mean square

Dimensionless numbers

Re	Reynolds number	$(= G\,D\,\mu^{-1})$
Gr^*	modified Grashof number based on q	$(= g\beta q D_{hy}{}^4 / k\upsilon^2)$
q^+	non-dimensional heat flux number	$(= (q/G)\,(\beta/Cp))$
Pr	Prandtl number	$(=\mu C_p/k)$
Pr_{avg}, $\overline{Pr}$	averaged or modified Prandtl number	$(= (H_w-H_b)\mu_b/\,(k_b\times(T_w-T_b)))$

Abbreviations

CP	critical point
SCW	supercritical water
SCHT	supercritical heat transfer
HTC	heat transfer coefficient

5. References

Bishop, A.A., Sandberg, R.O., and Tong, L.S., "Forced convection heat transfer to water at near-critical temperatures and supercritical pressures", *A.I.Ch.E.-I.Chem.E Symposium Series No*. 2, 1965, pp. 77−85

Bourke, P.J., and Denton, W.H., "An unusual phenomenon of heat transfer near the critical point", Memorandum AERE-M 1946, Chemical Engineering and Process Technology Division, U.K.A.E.A. Research Group, Atomic Energy Research Establishment, Harwell, Berkshire, August, 1967, 9 pages

Chalfant, A.I., “Heat transfer and fluid friction experiments for the supercritical water reactor”, Report PWAC-109, 1954

Cheng, X., 2009, Private communication

Cheng, X., Yang, Y.H., and Huang, S.F., “A simple heat transfer correlation for SC fluid flow in circular tubes”, NURETH-13, Kanazawa City, Ishikawa Prefecture, Japan, September 27-October 2, 2009

Cheng, X., and Schulenberg, T., “Heat transfer at supercritical pressures–literature review and application to an HPLWR”, Wissenschaftliche Berichte (Tech. Report) FZKA6609, Forschungszentrum Karlsruhe, Mai, 2001

Dittus, F.W., and Boelter, L.M.K., University of California, Berkeley, Publications on Engineering, Vol. 2, 1930, pp. 443–461

Gnielinski, V., “New equation for heat and mass transfer in turbulent pipe and channel flow”, *Intern. Chem. Eng.*, Vol. 16, No. 2, 1976, pp. 359–366

Griem, H., A new procedure for the at near-and supercritical prediction pressure of forced convection heat transfer, *Heat Mass Trans.*, Vol. 3, 1996, pp. 301–305

Groeneveld, D.C., and Zahlan, H.Z., SCWR data compilation and LUT, Progress Report to AECL, December 31, 2009

Gupta, S., Mokry, S., Farah, A., King, K., Peiman, W., and Pioro, I., “Developing a heat-transfer correlation for supercritical-water flow in bare vertical tubes and its application”, 2010 UOIT unpublished report

Hadaller, G., and Banerjee, S., “Heat transfer to superheated steam in round tubes”, AECL Report, 1969

Hall, W.B., Jackson, J.D. and Watson, A., “A review of forced convection heat transfer to fluids at supercritical pressures”, *Proc. I. Mech. E.*, Vol. 182, Part 31, Bristol Symposium, HTFS 3907, 1968

Harrison, G.S., and Watson, A., “A experimental investigation of forced convection to supercritical pressure water in heated small bore tubes”, Proceedings of the Institute of Mechanical Engineers, 190 (40/76), 1976b, pp. 429–435

Herkenrath, H., Mörk-Mörkenstein, P., Jung, U., and Weckermann, F. J., “Wärmeubergung an wasser bei erzwungener strömung in drückbereich von 140 bis 250 Bar”, EUR-3658d, 1967

Jackson, J. D., “Consideration of the heat transfer properties of supercritical pressure water in connection with the cooling of advanced nuclear reactors”, Proc. of the 13th Pacific Basin Nuclear Conference Shenzhen City, China, 2002

Jackson, J. D., Cotton, M. A., and Axcell, B. P., "Studies of mixed convection in vertical tubes", *Int. J. Heat Fluid Flow*, Vol.10, No. 1, 1989

Jackson, J.D. and Hall, W.B., "Forced convection heat transfer to fluids at supercritical pressure", in "Turbulent forced convection in channels and bundles, S. Kakaç and D.B. Spalding (editors), Hemisphere Publishing Corp., Washington, USA, Vol. 2, 1979a, pp. 563−611

Jackson, J.D., and Hall, W.B., "Influences of buoyancy on heat transfer to fluids flowing in vertical tubes under turbulent conditions, in "Turbulent forced convection in channels and bundles", S. Kakaç and D.B. Spalding (editors), Hemisphere Publishing Corp., Washington, USA, Vol. 2, 1979b, pp. 613−641

Kirillov, P., Pometko, R., Smirnov, A. et al., "Experimental study on heat transfer to supercritical water flowing in 1- and 4-m-Long Vertical Tubes", Proc. GLOBAL'05, Tsukuba, Japan, Oct. 9–13, Paper No. 518, 2005

Koshizuka, S., and Oka, Yo., "Computational analysis of deterioration phenomena and thermal-hydraulic design of SCR, Proceedings of the 1st International Symposium on Supercritical Water-Cooled Reactor Design and Technology (SCR-2000), Paper No. 302, 2000

Krasnoshchekov, E. A., and Protopopov, V. S., "Experimental study of heat exchange in carbon dioxide in the supercritical range at high temperature drops", *Teplofizika Vysokikh Tempraturi* (High Temp.), Vol. 4, No. 3, 1966

Kuang, B., Zhang, Y., and Cheng, X., "A new, wide-ranged heat transfer correlation of water at supercritical pressures in vertical upward ducts, NUTHOS-7, Seoul, Korea, 2008

Löwenberg, M., Starflinger, J., Laurien, E., and Schulenberg, T., "A look-up table for heat transfer of supercritical water", Proc. GLOBAL 2005, Paper No. 037, 2005, pp. 1–6

Löwenberg, M., Starflinger, J., Laurien, E., Class, A., and Schulenberg, T., "Supercritical heat transfer in vertical tubes": A Look-up table, *Progress in Nuclear Energy*, Vol. 50, 2008, pp. 532−538

McEligot, D. M., and Jackson, J. D., "Deterioration criteria for convective heat transfer in gas flow through non-circular ducts", *Nucl. Eng. Des.,* 2004, pp. 327−333

Mokry, S., Gospodinov, Ye., Pioro, I., and Kirillov, P., "Supercritical water heat-transfer correlation for vertical bare tubes", Proceedings of the 17th International Conference on Nuclear Engineering ICONE-17, Brussels, Belgium, July 12-16, Paper # 76010, 2009a, 8 pages

Petukhov, B.S., and Polyakov, A.F., "Heat transfer in turbulent mixed convection", Hemisphere Publishing Corp., New York, NY, USA, Chapter 7.1, Heat Transfer at Supercritical Pressures, 1988, pp. 183–201

Pioro, I.L., and Duffey, R.B., "Experimental heat transfer in supercritical water flowing inside channels (survey)", *Nucl. Eng. Des.,* Vol. 235, 2005, pp. 2407−2430

Pioro, I.L., Khartabil, H.F., and Duffey, R.B., Heat transfer to supercritical fluids flowing in channels – empirical correlations (survey), *Nucl. Eng. Des.*, Vol. 230, No. 1–3, 2004, pp. 69–91

Pioro, I.L. 2010, Private communication

Pis'mennyy, E.N., Razumovskiy, V.G., Maevskiy E.M. et al., "Experimental study on temperature regimes to supercritical water flowing in vertical tubes at low mass fluxes, Proceedings of the International Conference GLOBAL-2005, Tsukuba, Japan, October 9–13, Paper No. 519, 2005, 9 pages

Polyakov, A.F., "Mechanism and limits on the formation of conditions for impaired heat transfer at a supercritical coolant pressure", High Temperatures (Теплофизика Высоких Температур, стр. 1210–1219), 13 (6), 1975, pp. 1119–1126

Randall, D.G., "Some heat transfer and fluid friction experiments with supercritical water", Report NDA 2051, November (also TID-7529, Part 3, November, 1957

Seider, N. M., and Tate, G. E., "Heat transfer and pressure drop of liquids in tubes", *Ind. Eng. Chem.* 28 (12), 1936, pp. 1429–1435

Shiralkar, B.S. and Griffith, P., "Deterioration in heat transfer to fluids at supercritical pressures and high heat fluxes", *Journal of Heat Transfer*, Transactions of the ASME, 91(1), February, 1969, pp. 27–36

Shiralkar, B. and Griffith, P., "The deterioration in heat transfer to fluids at SCP and high heat fluxes, Report, Engineering Projects Laboratory, MIT, Cambridge, MA, USA, June, 1968, 185 pages

Swenson, H.S., Carver, J.R., and Kakarala, C.R., Heat transfer to supercritical water in smooth-bore tubes, *J. of Heat Transfer*, *Trans. ASME Series C*, 87 (4), 1965, pp. 477–484

Thompson, W.R. and Geery, E.L., 1960, "Heat transfer to cryogenic hydrogen at supercritical pressures", Cryogenic Engineering Conference (US), 1960, pp. 391–40

Watts, M. J., and Chou, C-T., "Mixed convection heat transfer to supercritical pressure water", Proc. 7th, IHTC, Munich, Germany, 1982, pp. 495–500

Yamagata, K., Nishikawa, K., Hasegawa, S., Fujii, T., and Yoshida, S., "Forced convective heat transfer to supercritical water flowing in tubes", *Int. J. Heat Mass Transfer*, Vol. 15 (12), 1972, pp. 2575–2593

Zahlan, H., Groeneveld, D.C., Tavoularis, S., "Look-up table for trans-critical heat transfer", the 2nd Canada-China Joint Workshop on Supercritical Water-Cooled Reactors (CCSC-2010), Toronto, Canada, April 25-28, 2010, 18 pages

Table 1 SCHT water data compilation

Database source	Number of references	Number of data after screening	Data availability
UO	28	6024	Tables and graphs
SJTU	11	7168	Tables and graphs
Stuttgart U	15	2936	Tables and graphs
UOIT	20	8125	Tables and graphs
Combined compilation for all databases			
Number of data before screening	36030	Number of data after screening	24253

Table 2: All combined SCHT water data sets

Reference	P (MPa)	T_b (°C)	q (kW/m^2)	G (kg/m^{2}s)	Tube ID (mm)	Number of data
Ackerman (1970)	22.75−31.03	90.7−405	158− 1260	407−1221	9.4−24.4	409
Alekseev et al. (1976)	24.5	101−341	270−580	380	10.4	99
Alferov et al. (1969)	24.5−30.4	55-261	473−521	342	20	179
Alferov et al. (1975)	26.5	76−248	480	447	20	63
Barulin et al. (1971)	24.5	320−381	480−490	467	3	45
Bishop et al. (1965)	22.47−27.8	271−524	309−3526	663−3607	2.5−5.1	809
Belyakov data of Cheng (xx)*	25	115−489	174−1161	300−2000	20	85
Bourke and Denton (1967)	23−25..4	310−348	1230−2240	1207−2713	4	52
Chalfant (1954)	34.5	96−223	3533−5457	2034, 2712	1.4, 1.6	93
Dickenson and Welch (1958)	24.2−31.1	102−536	748−1844	2170−3418	7.6	123
Domin (xx)*	22.7−25	338−398	1254−2264	1210−2720	4	43
Dyadyakin and Koblyakov (1971)	22.5	391−418	3910	5000	3 mm	10
Glushchenko et al. (1972)	22.54	19−402	1050−1770	750, 1000	4, 6, 8	104
Goldmann (1961)	34.5	222−363	3533−3659	2034	1.6	26
Griem (1996)	22.08−25	332−424	300−600	500−2500	14	666
Harrison and Watson (1976b)	22.5, 24.5	86−370	490−2323	467−2250	1.64−20	174
Herkenrath et al. (1967)	22.5−25	302−446	200−2000	700−3500	10, 20	4580
Ishigai et al. (1976)	25.3	207−531	151−698	500	3.92	169
Jackson (2002)	22.8−26.5	54−348	221−820	407−686	2−20.4	334
Jacopo (xx)*	24.5	104−360	329, 698	376, 1180	10, 16	151
Kirillov et al. (2005)	23.9−25	299−516	72 −1308	201−1506	10	7871
Koshizuka and Oka (2000)	31	351−356	473	540	9.4	11
Krasyakova et al. (1977)	24.5	202−393	81−900	90−1000	20	216
Lee et al. (1974)	24.1	243−382	252−1577	542−2441	38.	1330

Continued

Table 2: All combined SCHT water data sets

Reference	P (MPa)	T_b (˚C)	q (kW/m^2)	G (kg/m^{2}s)	Tube ID (mm)	Number of data
Ornatsky et al. (1971)	25.5	24−384	395−1810	850−1530	3	116
Petukhov and Polyakov (1988)	22.6−29.4	186−380	379−2400	424−2000	3, 5, 8	115
Pis'Menny et al. (2005)	23.5	18−304	76−496	248−509	6.3, 9.5	395
Polyakov (1975)	24.5−29.4	124−319	490−1810	424−1500	3, 8	90
Randall (1956)	24.5	201−218.6	570	595	8	17
Razumovskiy (2005)	23.5	17−325	76−496	248,249	6.28, 9.5	380
Schmidt (1959)	22.3−30.4	192−564	291– 815	700	5	369
Shiralkar and Griffith (1969)	22.8	312.5−375	252−426	461	10	165
Shitsman (1963)	23−25.3	202−434	190−1083	323−1500	6, 8, 10	1211
Shitsman (1968)	24.5−34.3	74−403	238−700	103−608	8, 16	580
Swenson et al. (1965)	22.75−31	127−516	787−1741	2150	9.4	439
Thompson and Geery (1960)	23	333−368	280−340	430	8	47
Vikhrev et al. (1967)	24.6, 26.5	60−407	362−1160	493−1400	7.8−20.4	668
Watts and Chou (1982)	25	149−177	250	493	32.2	20
Yamagata et al. (1972)	24.5	294−488	233−930	1200−1830	7.5, 10	1472
Yin et al. (2006)	26	286−434	200	600	29	34
Yoshida and Mori (2000)	24.5, 25.3	78−466	230−698	376−1180	10, 16, 18	493

* These datasets have unknown full reference.

Table 3 Number of SCW data for each dataset before and after screening (all databases)

Reference	Before	After	Reference	Before	After
Ackerman (1970)	1038	409	Shitsman (1968)	732	580
Alekseev et al. (1976)	99	99	Styrikovich et al. (1967)	119	0
Alferov et al. (1969)	211	179	*Swenson et al. (1965)*	647	439
Alferov et al. (1975)	63	63	Vikhrev et al. (1967)	1069	668
Barulin et al. (1971)	45	45	Watts and Chou (1982)	20	20
Bishop et al. (1965)	1218	809	*Yamagata et al. (1972)*	1899	1472
Belyakov (xx)	85	85	Yin et al. (2006)	34	34
Dickenson and Welch (1958)	123	123	*Yoshida and Mori (2000)*	494	493
Dyadyakin & Koblyakov (1971)	10	10	Zhu (xx)*	87	0
Domin (xx)	43	43	*Bourke and Denton (1967)*	52	52
Glushchenko et al. (1972)	132	104	*Chalfant (1954)*	93	93
Goldmann (1961)	26	26	*Harrison and Watson (1976b)*	174	174
Griem (1996)	1201	666	*Jacopo (xx)*	151	151
Herkenrath et al. (1967)	8745	4580	*Jackson (2002)*	334	334
Ishigai et al. (1976)	169	169	*Koshizuka and Oka (2000)*	11	11
Kirillov et al. (2005)	11421	7871	*Petukhov and Polyakov (1988)*	187	115
Krasyakova et al. (1977)	216	216	*Pis'Menny et al. (2005)*	411	395
Lee et al. (1974)	2062	1330	*Polyakov (1975)*	90	90
Ornatsky et al. (1971)	210	116	*Randall (1956)*	17	17
Razumovskiy (2005)	380	380	*Shiralkar and Griffith (1969)*	165	165
Schmidt (1959)	369	369	*Thompson and Geery (1960)*	47	47
Shitsman (1963)	1331	1211	**Total**	**36030**	**24253**

References in italics were updated recently by UOIT database.
* This dataset has an unknown full reference.

Table 4 Overall average and rms errors in the three supercritical sub-regions

Correlation	**Liquid-like region**		**Gas-like region**		**Close to CP or PC point**	
	e_A, %	e_S, %	e_A, %	e_S, %	e_A, %	e_S, %
Bishop et al. (1965)	5	28	5	20	23	31
Swenson et al. (1965)	1	31	-16	21	4	23
Krasnochekov et al. (1967)	18	40	-30	32	24	65
Watts and Chou (1982), Normal	6	30	-6	21	11	28
Watts and Chou (1982), Deter.	2	26	9	24	17	30
Griem (1996)	2	28	11	28	9	35
Jackson (2002)	15	36	15	32	30	49
Mokry et al. (2008)	-5	26	-9	18	-1	17
Kuang et al. (2008)	-6	27	10	24	-3	26
Cheng et al. (2009)	4	30	2	28	21	85
Gupta et al. (2010)	-26	33	-12	20	-1	18
Koshizuka and Oka (2000)	26	47	27	54	39	83
Hadaller and Banerjee (1969)	34	53	14	24	-	-
Sieder and Tate (1936)	46	65	97	132	-	-
Dittus-Boelter (1930)	24	44	90	127	-	-
Gnielinski (1976)	10	36	99	139	-	-

Table 5 Single-phase and supercritical prediction methods used for the application of the compiled water data

Reference	Prediction method
Dittus-Boelter (1930)†	$\mathrm{Nu_b} = 0.0243\,\mathrm{Re_b^{0.8}}\,\mathrm{Pr_b^{0.4}}$
Sieder and Tate (1936)†	$\mathrm{Nu_b} = 0.027\,\mathrm{Re_b^{0.8}}\,\mathrm{Pr_b^{1/3}}(\mu/\mu_w)^{0.14}$
Hadaller and Banerjee (1969)†	$\mathrm{Nu_f} = 0.0101\,\mathrm{Re}_f^{0.8774}\,\mathrm{Pr}_f^{0.6112}(L/D)^{0.0328}$
Gnielinski (1976)†	$\mathrm{Nu} = \frac{(f/8)(\mathrm{Re_b}-1000)\mathrm{Pr_b}}{1+12.7(f/8)^{1/2}(\mathrm{Pr}^{2/3}-1)}\left(\frac{\mathrm{Pr_b}}{\mathrm{Pr_w}}\right)^{0.11}(1+(D/L)^{2/3})$ where $f = 1/(1.82\,log_{10}(\mathrm{Re})-1.64)^2$ $(T_b/T_w)^{0.45}$ replaces $(\mathrm{Pr_b}/\mathrm{Pr_w})^{0.11}$ when $T_b > T_{pc}$
Bishop et al. (1965)	$\mathrm{Nu_b} = 0.0069\,\mathrm{Re}_b^{0.9}\,\overline{\mathrm{Pr}}_b^{0.66}\left(\frac{\rho_w}{\rho_b}\right)^{0.43}\left(1+2.4\frac{D}{L}\right)$
Swenson et al. (1965)	$\mathrm{Nu_w} = 0.00459\,\mathrm{Re_w^{0.923}}\,\overline{\mathrm{Pr}}_\mathrm{w}^{0.613}(\rho_w/\rho_b)^{0.231}$
Krasnoscheckov et al. (1967)	$\mathrm{Nu_b} = \mathrm{Nu_0}(\rho_w/\rho_b)^{0.3}(C_p/C_{pb})^n$, $\mathrm{Nu_0} = \frac{(\xi/8)\mathrm{Re_b}\overline{\mathrm{Pr}}}{12.7(\xi/8)^{0.5}(\overline{\mathrm{Pr}}^{2/3}-1)+1.07}$ and $\xi = 1/(1.82 Log_{10}\mathrm{Re}_b - 1.64)^2$, $n = 0.4$ for $(T_w/T_{pc}) \le 1$ or $(T_b/T_{pc}) \ge 1.2$, $n = n_1 = 0.22 + 0.18(T_w/T_{pc})$ for $1 \le (T_w/T_{pc}) < 2.5$ and $n = n_1 + (5n_1-2)(1-(T_b/T_{pc}))$ for $1 \le (T_b/T_{pc}) \le 1.2$, T in K
Yamagata et al. (1972)	$\mathrm{Nu_b} = 0.0135\,\mathrm{Re_b^{0.85}}\,\mathrm{Pr_b^{0.8}}\,\mathrm{F_c}$, $F_c = 1$ *for* $\mathrm{E} \succ 1$, $Fc = 0.67\overline{\mathrm{Pr}}_{pc}^{(0.05)}(\overline{Cp}/Cp_b)^{n1}$ *for* $0 < \mathrm{E} < 1$ and $Fc = (\overline{Cp}/Cp_b)^{n2}$ for $\mathrm{E} \prec 0$, $\mathrm{E} = (T_{pc} - T_b)/(T_w - T_b)$ $n_1 = 0.77(1+1/\mathrm{Pr_{pc}}) + 1.49$ and $n_2 = 1.44(1+1/\mathrm{Pr_{pc}}) - 0.53$
Koshizuka and Oka (2000)	$\mathrm{Nu_b} = 0.015\,\mathrm{Re_b}^{0.85}\,\mathrm{Pr_b}^{(0.69-81000/CHF+1000 f_c q)}$, $q(\mathrm{W/m^2})$, $fc = 2.9\times10^{-8} + 0.11/CHF$, for $H < 1.5$ MJ/kg $fc = -8.7\times10^{-8} - 0.65/CHF$, for $1.5 \le H \le 3.3$ MJ/kg and $fc = -9.7\times10^{-7} + 1.3/CHF$, for $3.3 < H \le 4$ MJ/kg, $CHF = 200G^{1.2}$

Continued, † single-phase correlation

Table 5 Single-phase and supercritical prediction methods used for the application of the compiled water data

Reference	Prediction method
Watts and Chou (1982)	$Nu_b = 0.021Re_b^{0.8}Pr_b^{0.55}(\frac{\rho_w}{\rho_b})^{0.35} f(\frac{Gr_b}{Re_b^{2.7}Pr_b^{0.5}})$, where for normal heat transfer: $f(\frac{Gr_b}{Re_b^{2.7}Pr_b^{-0.5}}) = (1-3000\frac{Gr_b}{Re_b^{2.7}Pr_b^{0.5}})^{0.295}$ if $\frac{Gr_b}{Re_b^{2.7}Pr_b^{0.5}} \le 10^{-4}$, or $f(\frac{Gr_b}{Re_b^{2.7}Pr_b^{-0.5}}) = (7000\frac{Gr_b}{Re_b^{2.7}Pr_b^{0.5}})^{0.295}$ if $\frac{Gr_b}{Re_b^{2.7}Pr_b^{0.5}} \succ 10^{-4}$ where $Gr_b = (\rho_b - \rho_{avg})D_{hy}{}^3 g/\rho_b \nu_b{}^2$
Griem (1996)	$Nu_b = 0.0169Re_b^{0.8356}Pr_{sel}^{0.432}\omega,\ \bar{k} = 0.5(k_b + k_w), \mu = \mu_b, Pr_{sel} = Cp_{sel}\ \mu_b/\bar{k}$ and $\omega = \min(1.0, \max(0.82; 0.82 + 9.7\times10^{-7}(H_b - 1.54\times10^6)))$, H_b in kJ/kg
Jackson (2002)	$Nu_b = 0.0183Re_b^{0.82}Pr_b^{0.5}(\frac{\rho_w}{\rho_b})^{0.3}(\frac{\bar{Cp}}{Cp_b})^n$
Kuang et al. (2008)	$Nu = 0.0239Re_b^{0.759}\ \bar{Pr}^{0.833}(\frac{k_w}{k_b})^{0.0863}(\frac{\mu_w}{\mu_b})^{0.832}(\frac{\rho_w}{\rho_b})^{0.31}(\overset{*}{Gr})^{0.014}(\overset{+}{q})^{-0.021}$ This correlation is valid for: P = 22.75–31.03 MPa, G = 380–3600 kg/m^2 s, q = 233–3474 kW/m2, ID = 7.5–26 mm. *P* = 22.75–31.03 MPa, *G* = 380–3600 kg/m^2 s, *q* = 233–3474 kW/m^2, ID = 7.5–26 mm
Mokry et al. (2008)	$Nu = 0.0061Re_b^{0.904}\ \bar{Pr}_b^{0.684}(\frac{\rho_w}{\rho_b})^{0.564}$
Cheng, Xu et al. (2009)	$F = Nu/Nu_0 = Nu/0.023Re_b^{0.8}Pr_b^{1/3} = \min(F_1, F_2),\ F_1 = 0.85 + 0.776(\pi_A \times 10^3)^{2.4}$ and $F_2 = 0.48/(\pi_{A,pc}\times 10^3)^{1.55} + 1.21(1 - \pi_A/\pi_{A,pc})$
Gupta et al. (2010)	$Nu_w = 0.0033Re_w^{0.941}Pr_{avg,w}^{0.764}(\frac{\rho_w}{\rho_b})^{0.156}(\frac{\mu_w}{\mu_b})^{0.398}$; $Nu_{w,entrance} = Nu_w(1 + exp(-\frac{L}{24D}))^{0.3}$

Table 6 Error bands for the best correlations for the combined databases at the three SCHT regions

Error band for 15283 data points	Percentage of data predicted by a correlation, %		
	Mokry et al. (2008)	Gupta et al. (2010)	Swenson et al. (1965)
Near CP region			
e_{10}	46	50	44
e_{20}	79	78	71
e_{30}	92	91	86
e_{50}	99	98	95
Error band for 4386 data points	**Mokry et al. (2008)**	**Watts & Chou (1982), DHT**	**Kuang et al. (2008)**
High density state region (liquid-like region)			
e_{10}	41	28	33
e_{20}	64	57	59
e_{30}	79	79	79
e_{50}	94	95	94
Error band for 4584 data points	**Mokry et al. (2008)**	**Gupta et al. (2010)**	**Bishop et al. (1965)**
Low density state region (gas-like region)			
e_{10}	47	35	45
e_{20}	79	71	75
e_{30}	92	88	89
e_{50}	99	98	97

DHT deteriorated heat transfer

Table 7 Error bands for the best correlations including the entry region effect for the three SCHT regions

Error band for 3441 data points	Percentage of data predicted by a correlation, %	
	Mokry et al. (2008)	Gupta et al. (2010)
	Near CP region:	
e_{10}	54	54
e_{20}	80	77
e_{30}	90	89
e_{50}	99	98
Error band for 1674 data points	**High density state region (liquid-like region)**	
e_{10}	33	15
e_{20}	56	36
e_{30}	69	61
e_{50}	89	88
Error band for 553 data points	**Low density state region (gas-like region)**	
e_{10}	38	27
e_{20}	71	63
e_{30}	84	79
e_{50}	97	95

Table 8 Average error, rms error and error band percentage for the best correlations by dataset (close to critical point region)

Data set	# Points	Kuang et al. (2008)						Gupta et al. (2010)						Mokry et al. (2008)					
		e_A	e_S	e_{10}	e_{20}	e_{30}	e_{50}	e_A	e_S	e_{10}	e_{20}	e_{30}	e_{50}	e_A	e_S	e_{10}	e_{20}	e_{30}	e_{50}
Ackerman (1970)	245	-4	17	42	76	96	100	2	15	59	82	97	99	2	14	61	81	96	100
Alekseev et al. (1976)	41	-32	34	2	7	37	93	-20	22	10	39	90	100	-16	18	22	61	100	100
Barulin et al. (1971)	44	0	18	30	68	91	100	-12	19	18	55	100	100	-11	15	41	84	100	100
Bishop et al. (1965)	429	-20	25	18	43	76	100	-15	17	31	73	100	100	-15	17	24	69	99	100
Belyakov data of Cheng	22	-25	29	5	23	50	100	-22	27	32	50	59	96	-23	28	14	46	68	91
Bourke and Denton (1967)	46	12	39	30	41	63	78	21	40	11	33	54	80	14	32	17	41	65	87
Chalfant (1954)	50	-46	46	0	0	2	68	-39	39	0	0	16	94	-31	32	0	2	36	100
Domin	34	8	40	21	38	59	85	14	39	9	38	59	82	9	33	18	47	62	88
Glushchenko et al. (1972)	47	-40	46	2	17	21	51	-35	37	9	13	30	96	-34	37	6	11	23	98
Griem (1996)	511	14	18	32	67	95	100	20	28	37	54	70	92	17	22	34	63	81	98
Harrison and Watson (1976b)	143	-12	23	29	60	80	99	-6	15	46	88	94	100	-6	15	59	80	95	100
Herkenrath et al. (1967)	3687	-14	21	29	59	84	100	-2	14	55	86	95	100	-3	14	48	86	97	100
Ishigai et al. (1976)	61	7	23	36	66	79	95	-5	19	53	67	82	100	-7	14	57	85	97	100
Jacopo (xx)	82	-11	17	35	62	100	100	-2	15	56	78	94	100	-3	13	68	83	100	100
Jackson (2002)	151	-11	23	36	62	80	97	-13	24	24	54	74	99	-12	21	38	62	76	100
Kirillov et al. (2005)	5678	9	28	37	61	78	91	0	14	60	86	96	100	2	15	55	84	94	100
Krasyakova et al. (1977)	111	-31	34	9	23	33	100	-24	25	6	23	87	100	-24	25	7	27	74	100
Lee et al. (1974)	1093	-26	30	11	32	59	98	-4	18	43	77	92	99	-10	17	34	75	95	100
Ornatsky et al. (1971)	27	2	47	22	41	59	89	15	43	33	56	74	89	7	28	33	74	85	89
Petukhov and Polyakov (1988)	71	-4	26	20	44	76	96	-12	20	28	63	87	100	-11	18	47	70	87	100
Pis'Menny et al. (2005)	35	-26	40	9	23	40	71	-22	38	9	26	34	94	-18	30	20	37	51	100
Polyakov (1975)	52	1	31	15	33	46	96	-3	15	40	85	100	100	0	10	62	96	100	100
Razumovskiy (2005)	25	-42	43	0	8	20	68	-36	37	0	8	20	100	-27	30	20	28	52	100
Schmidt (1959)	139	3	25	32	60	77	95	-1	24	24	56	84	97	-2	21	33	68	90	97
Shiralkar and Griffith (1969)	131	7	22	55	70	79	96	1	25	26	53	80	95	0	16	47	79	92	100
Shitsman (1963)	777	3	23	38	67	85	96	-2	23	38	72	89	95	-2	19	40	75	92	98
Shitsman (1968)	206	-11	29	20	49	70	89	-7	21	41	68	87	98	-5	19	45	74	88	99
Swenson et al. (1965)	99	-8	16	64	77	86	100	0	15	62	85	94	100	1	12	66	90	98	100
Thompson and Geery (1960)	42	2	18	36	74	95	98	0	16	43	86	93	98	-2	12	48	95	98	100
Vikhrev et al. (1967)	279	-24	28	18	36	53	100	-6	13	46	89	100	100	-8	13	47	88	100	100
Yamagata et al. (1972)	645	11	33	34	64	75	88	5	24	38	68	85	93	4	22	41	74	86	95
Yoshida and Mori (2000)	223	1	25	33	60	87	93	18	35	19	31	47	87	21	38	17	26	41	83

Table 9 Average error, rms error and error band percentage for the leading correlations by dataset (gas-like region)

Data set	# Points	Bishop et al. (1965)						Mokry et al. (2008)						Gupta et al. (2010)					
		e_A	e_S	e_{10}	e_{20}	e_{30}	e_{50}	e_A	e_S	e_{10}	e_{20}	e_{30}	e_{50}	e_A	e_S	e_{10}	e_{20}	e_{30}	e_{50}
Bishop et al. (1965)	335	4	12	60	92	97	100	-11	14	50	88	97	100	-12	15	42	82	97	100
Belyakov data of Cheng	25	-7	22	20	56	80	100	-18	25	20	48	80	100	-19	26	28	48	72	96
Dickenson and Welch (1958)	66	-4	21	88	94	97	97	-13	22	29	96	97	99	-16	24	11	82	97	99
Griem (1996)	143	8	11	58	97	100	100	-4	8	78	99	100	100	-9	11	62	94	100	100
Herkenrath et al. (1967)	811	3	15	51	82	96	100	-11	15	42	77	97	100	-12	17	40	71	94	100
Ishigai et al. (1976)	60	-11	19	27	73	90	98	-22	25	12	37	83	98	-26	30	13	32	58	97
Jackson (2002)	21	-33	33	0	0	29	100	-42	42	0	0	0	100	-47	47	0	0	0	95
Kirillov et al. (2005)	1799	13	21	44	75	87	96	-4	13	57	87	98	100	-7	17	36	80	94	100
Krasyakova et al. (1977)	34	3	11	62	94	100	100	-14	16	27	79	100	100	-16	20	29	53	91	100
Polyakov (1975)	32	-24	34	41	53	56	78	-33	39	6	38	53	72	-34	42	19	41	53	66
Schmidt (1959)	159	-25	28	11	25	62	99	-33	35	2	11	28	98	-38	39	1	3	13	97
Shiralkar and Griffith (1969)	29	-6	15	66	79	93	100	-18	21	38	66	83	100	-25	27	0	41	69	100
Shitsman (1963)	131	1	22	37	65	82	97	-13	22	30	64	86	99	-18	25	24	49	81	96
Shitsman (1968)	25	39	42	0	20	32	64	14	18	32	60	100	100	14	21	44	64	72	100
Swenson et al. (1965)	166	-2	21	21	73	87	96	-12	22	51	70	86	95	-14	23	50	63	81	93
Vikhrev et al. (1967)	49	15	19	37	69	94	100	-3	7	86	100	100	100	-1	10	67	98	100	100
Yamagata et al. (1972)	527	7	14	58	83	96	100	-4	12	53	95	99	100	-10	15	39	81	98	100
Yoshida and Mori (2000)	99	-36	41	0	14	55	80	-41	44	0	5	27	76	-45	48	0	0	8	70

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Table 10 Average error, rms error and error band percentage for the leading correlations by dataset (liquid-like region)

Data set	# Points	Watts & Chou (1982), DHT						Mokry et al. (2008)						Kuang et al. (2008)					
		e_A	e_S	e_{10}	e_{20}	e_{30}	e_{50}	e_A	e_S	e_{10}	e_{20}	e_{30}	e_{50}	e_A	e_S	e_{10}	e_{20}	e_{30}	e_{50}
Ackerman (1970)	160	6	18	28	61	98	100	-3	12	60	92	99	100	-1	16	44	74	97	100
Alekseev et al. (1976)	58	-10	23	29	50	81	100	4	30	28	52	72	90	-9	19	36	66	90	100
Alferov et al. (1969)	174	-27	28	2	11	69	99	-5	8	75	98	99	100	-23	24	0	40	87	99
Alferov et al. (1975)	63	-10	14	46	86	100	100	-7	23	16	46	91	98	-21	24	27	43	76	100
Bishop et al. (1965)	45	15	17	29	80	93	100	-10	12	49	96	100	100	-14	17	20	73	100	100
Belyakov data of Cheng	38	-21	32	11	21	40	97	-19	31	24	42	58	90	-15	28	16	45	63	100
Chalfant (1954)	43	7	14	49	77	100	100	-27	29	0	23	72	100	-38	38	0	0	14	95
Dickenson and Welch (1958)	50	23	25	4	38	84	98	4	10	82	98	98	100	-3	10	68	98	98	100
Glushchenko et al. (1972)	52	9	16	33	75	96	100	-17	21	29	65	77	100	-40	42	0	0	25	79
Harrison and Watson (1976b)	24	-18	20	21	54	96	100	-44	44	0	0	0	79	-42	43	0	0	0	96
Herkenrath et al. (1967)	82	22	26	11	37	74	99	5	16	51	84	94	100	3	11	74	94	98	100
Ishigai et al. (1976)	48	3	27	46	67	81	88	-26	33	8	17	63	94	-8	28	25	54	75	92
Jacopo (xx)	54	-11	20	20	61	91	100	3	25	28	70	80	94	-2	16	43	80	91	100
Jackson (2002)	162	-12	20	44	74	89	96	-10	27	56	72	75	88	-19	24	27	61	78	96
Kirillov et al. (2005)	394	-1	29	21	47	72	90	-7	23	41	70	83	95	6	27	39	66	80	90
Krasyakova et al. (1977)	71	-4	12	62	87	99	100	-26	31	18	34	65	90	-28	29	0	10	73	97
Lee et al. (1974)	237	5	12	51	93	99	100	2	11	65	94	99	100	-6	13	68	88	95	100
Ornatsky et al. (1971)	89	9	20	44	70	87	98	-9	19	37	74	90	100	-8	20	27	60	92	100
Pis'Menny et al. (2005)	360	-5	29	24	50	71	91	0	32	25	50	68	89	0	34	24	46	65	86
Polyakov (1975)	34	17	24	18	44	74	100	-8	15	62	82	91	100	-7	15	74	82	91	100
Razumovskiy (2005)	355	2	28	22	54	73	92	3	38	17	36	52	86	3	44	18	36	56	83
Schmidt (1959)	71	13	18	24	75	94	100	-18	20	14	69	92	100	-8	14	42	87	100	100
Shitsman (1963)	303	-10	26	33	59	78	94	-27	33	18	36	60	90	-21	27	24	50	78	94
Shitsman (1968)	349	-11	23	35	62	81	97	-12	27	31	51	77	93	-16	24	30	60	83	95
Swenson et al. (1965)	174	19	20	9	60	99	100	1	5	95	100	100	100	-4	8	86	95	99	100
Vikhrev et al. (1967)	340	14	21	36	66	84	98	3	13	73	92	97	99	-10	17	29	75	96	100
Watts, M.J., and Chou (1982)	20	3	10	55	95	100	100	-5	11	75	90	95	100	-3	9	80	95	100	100
Yamagata et al. (1972)	300	31	39	16	31	50	82	13	21	44	69	80	99	22	30	32	50	67	91
Yoshida and Mori (2000)	171	4	37	32	52	71	90	-3	40	14	37	55	77	-4	26	29	52	74	98

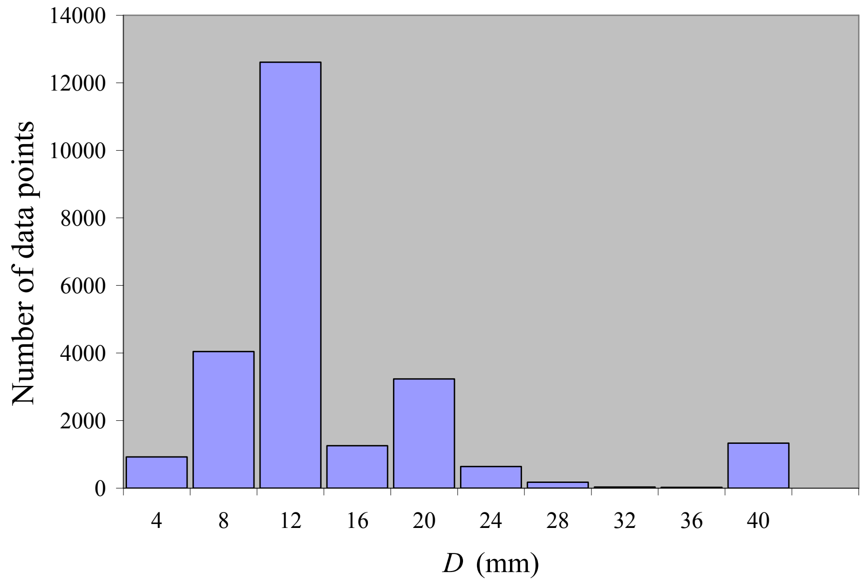

Figure 1 Numbers of data points for different *D* ranges for the combined SCW database.

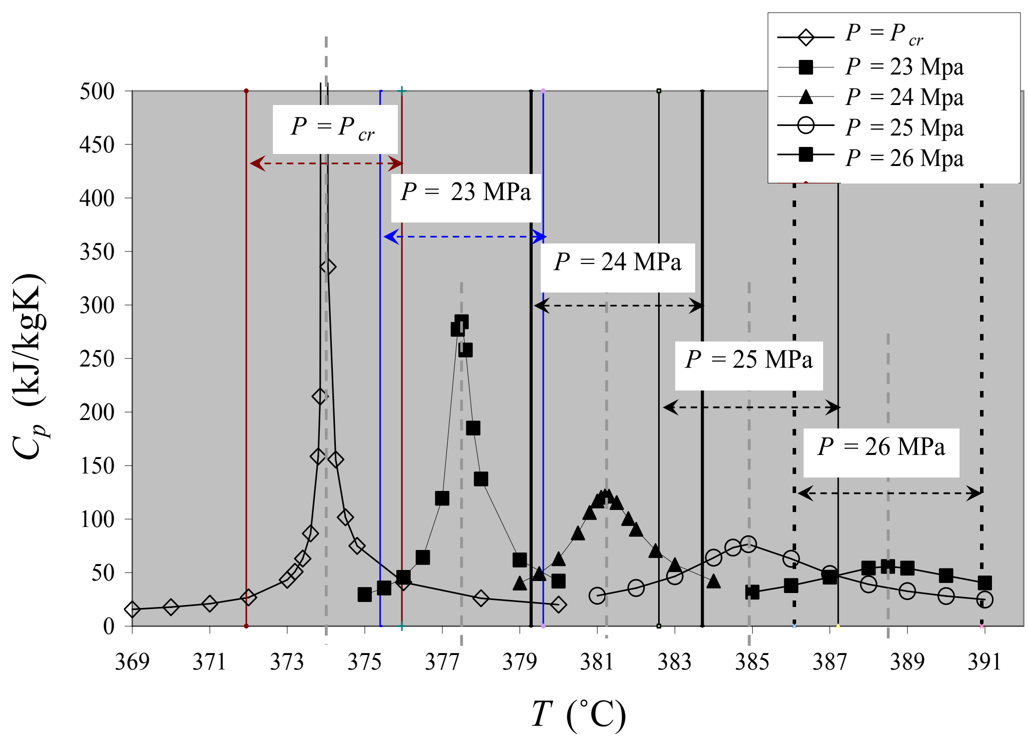

Figure 2 Variation of C_p for different pressures; horizontal lines mark the near-critical/ pseudo-critical ranges, each having a width of $2\Delta T$.

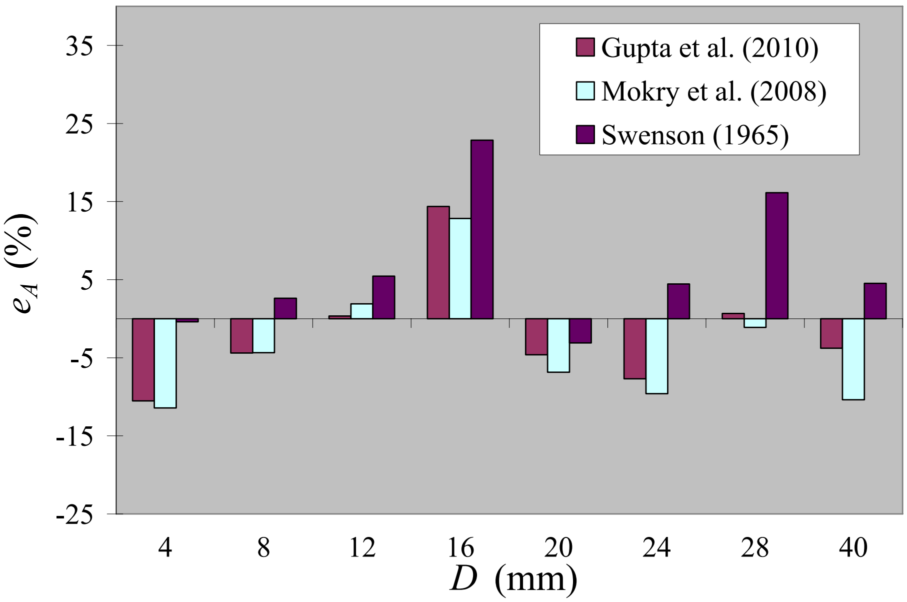

Figure 3 Distribution of e_A vs. D for the leading correlations in the near-critical/pseudo-critical sub-region.

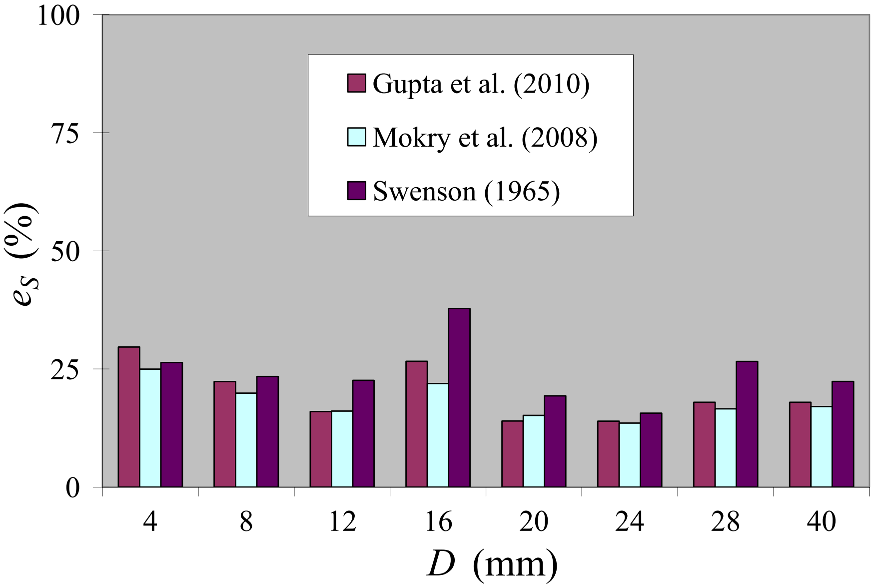

Figure 4 Distribution of e_S vs. D for the leading correlations in the near-critical/pseudo-critical sub-region.