Table 1.1 Comparison of some properties for traditional and new refrigerants

Group	Refrigerant	Chemical Formula	Composition (% of mass)	Glide Temperature(℃)	ODP (R-11=1)	GWP (CO_2=1)	Replacing
CFCs	R-11	CCl_3F		0	1	3800	
	R-12	CCl_2F_2		0	1	8100	
HCFCs	R-22	$CHClF_2$		0	0.055	1500	
HFCs	R-134a	CH_2FCF_3		0	0	1300	R-12, R-22
	R-407C	CH_2F_2/ CHF_2CF_3/ CH_2FCF_3	R32/125/134a (23/25/52)	7.2	0	1600	R-22
	R-410A	CH_2F_2/ CHF_2CF_3	R32/R125 (50/50)	< 0.1	0	1900	R-22
	R-410B	CH_2F_2/ CHF_2CF_3	R32/125 (45/55)	< 0.1	0	2000	R-22
	R-507	CHF_2CF_3/ CH_2FCF_3	R125/143a (50/50)	0	0	3800	R-22

Table 1.2 Comparison of Properties of three HFCs refrigerants for air conditioning and refrigeration applications

Refrigerant	R-134a	R-410A	R-407C
Component	HFC-134a	HFC-32/125	HFC-32/125/134a
Wt %	100 %	50/50%	23/25/52%
Comparison with R-22	1. the lower working pressure. 2. the frication pressure drop is larger in the same capability of freezing.	1. near-azeotropic refrigerant. 2. the working pressure is five times than R-22. 3. the frication pressure drop is smaller.	1. zeotropic refrigerant, and the components charge easy. 2. the working pressure is same with R-22.
The energy efficiency ratio relative to R-22	72~90	94~100	90~97
Molecule quality	102.3	72.6	85.62
Remark	1. the volume of operating system becomes larger. 2. the air-out volume of compress is larger.	1. the design of system must to consider the strong and optimum elements.	1. the solutions of variation of R-407C components.
Green-house effect (100 years)	1300	1725	1526
Toxicity limit (kg/m^3)	0.25	0.44	0.31
Boiling point (℃)	-26.2	-52.7 R32 (-51.8℃) / R125 (-48.5℃)	-43.6 R32 (-51.8℃) / R125 (-48.5℃) / R134a (-26.2℃)
Temperature glides	—	＜1 °F	10 °F

Table 1.3 Heat transfer correlations for two-phase flow boiling in conventional channels

Reference	Heat Transfer Correlations
Chen [56]	$h_{tp} = h_{mac} + h_{mic}$ $h_{mac} = h_l \cdot E, \quad h_{mic} = h_{pool} \cdot S$ $E, S = f(Re_l, X_{tt})$
Gaungor and Winterton [58]	$h_{tp} = h_l \cdot E + h_{pool} \cdot S$ $h_l = 0.023 \cdot Re_l^{0.8} \cdot Pr_l^{0.4} (k_l / D)$ $h_{pool} = 55 \cdot Pr^{0.12} \cdot (-\log_{10}^{Pr})^{-0.55} \cdot M^{-0.5} \cdot q^{0.67}$ $E = 1 + 24000 \cdot Bo^{1.16} + 1.34 \cdot (1 / X_{tt})^{0.86}$ $S = (1 + 1.15 \times 10^{-6} \cdot E^2 \cdot Re_l^{1.17})^{-1}$
Shah [59]	$\psi = \frac{h_{tp}}{h_l}$ $\psi = Max(\psi_{nb}, \psi_{cb}), \quad \psi_{nb}, \psi_{cb} = f(Co, Bo, Fr)$
Kandikar [60]	$\frac{h_{tp}}{h_l} = [C_1 \cdot Co^{C_2} \cdot (25 \cdot Fr)^{c_5} + C_3 \cdot Bo^{C_4} \cdot F_f]$
Lin and Winterton [61]	$h_{tp} = [(S \cdot h_{pool})^2 + (E \cdot h_l)^2]^{1/2}$ $E = [1 + (x) \cdot (Pr_l) \cdot (\frac{\rho_l}{\rho_v} - 1)]^{0.35}$ $S = [1 + 0.055 \cdot E^{0.1} \cdot (Re_l)^{0.16}]^{-1}$

Table 1.4 Heat transfer correlations for two-phase flow boiling in small channels

Reference	Fluid	Heat Transfer Coefficient Correlations	Application Range
Y. Fujita et al. [23]	R-123	$h_{tp} = 0.884G^{0.143}q^{0.714}$	$D: 1.12mm$ $G: 50-400\,kg/m^2s$ $q: 5-20\,kW/m^2$ $\mathrm{Re}: 135-1070$ $P: 1.1-1.2bar$ $x: -0.2-0.9$ $Bo: 3\times10^{-4}-8.9\times10^{-4}$
Lazarek and Black [24]	R-113	$h_{tp} = 30\,\mathrm{Re}_l^{0.857}\,Bo^{0.714}(k_l/D)$	$D: 3.1mm$ $G: 125-750\,kg/m^2s$ $q: 14-380\,kW/m^2$ $\mathrm{Re}: 860-5500$ $Bo: 2.3\times10^{-4}-76\times10^{-4}$ $P: 1.3-4.1bar$
T. N. Tran et al. [27]	R-12, R113	$h = (8.4\times10^{-5})(Bo^2We_l)^{0.3}(\frac{\rho_l}{\rho_g})^{-0.4}\ for\ \ \Delta T > 2.75\,^{\circ}C$	$D: 2.46mm, 2.92mm; D_h = 2.4mm$ $G: 44-832\,kg/m^2s$ $q: 7.5-129\,kW/m^2$ $P_r: 0.045-0.2$ $Bo: 2\times10^{-4}-23\times10^{-4}$ $\Delta T_{sat}: 2.8-18.2^{\circ}C$
Z. Y. Bao et al. [28]	R-11, R-123	$h_{tp}/h_l = 1+3000Bo^{0.86}+1.12(x/(1-x))^{0.75}(\rho_l/\rho_g)^{0.41}$	$D: 1.95mm$ $G: 50-1800\,kg/m^2s$ $q: 50-200\,kW/m^2$ $\mathrm{Re}: 860-5500$ $P: 2-5bar$ $x: -0.3-0.9$ $\Delta T_{sat}: 5-15^{\circ}C$
G. R. Warrier et al. [29]	FC-84	$\frac{h_{tp}}{h_l} = 1+6Bo^{1/16}+f_2(Bo)(x)^{0.65}$ $f_2(Bo) = -5.3\cdot[1-855Bo]$	$D: 0.75mm$ $G: 557-1600\,kg/m^2s$ $q: 0-59.9\,kW/m^2$ $\mathrm{Re}: 418-2015$

Table 1.4 Continued

<table>
<tr><th>Reference</th><th>Fluid</th><th>Heat Transfer Correlations</th><th>Application Range</th></tr>
<tr><td>S. G. Kandlikar [60]</td><td></td><td>$\frac{h_{tp}}{h_l} = [C_1 \cdot Co^{C_2} \cdot (25 \cdot Fr_l)^{c_5} + C_3 \cdot Bo^{C_4} \cdot F_f]$
<table>
<tr><td>Constant</td><td>Convection</td><td>Nucleate</td></tr>
<tr><td>C1</td><td>1.136</td><td>0.6683</td></tr>
<tr><td>C2</td><td>-0.9</td><td>-0.2</td></tr>
<tr><td>C3</td><td>667.2</td><td>1058</td></tr>
<tr><td>C4</td><td>0.7</td><td>0.7</td></tr>
<tr><td>C5</td><td>0.3</td><td>0.3</td></tr>
</table></td><td>$D: 4-32mm$ $G: 13-8179\,kg/m^2s$
$q: 0.03-228\,kW/m^2$ $P: 0.4-64.2bar$
$x: 0.001-0.987$ $Bo: 0.03\times10^{-4}-46.5\times10^{-4}$
C5=0, for vertical tube and for horizontal tube with
Frl>0.04</td></tr>
<tr><td>S. G. Kandlikar [63]</td><td></td><td>$h_{tp}/h_l = \text{maximun of} \begin{matrix}[h_{tp}/h_l]_{NBD} \\ [h_{tp}/h_l]_{CBD}\end{matrix}$
Nucleate boiling dominant region
$[h_{tp}/h_l]_{NBD} = 0.6683(\rho_l/\rho_g)^{0.1} x^{0.16}(1-x)^{0.64} f(Fr_l)$
$+1058Bo^{0.7}F_f(1-x)^{0.8}$
Convection boiling dominant region
$[h_{tp}/h_l]_{CBD} = 1.1360(\rho_l/\rho_g)^{0.45} x^{0.72}(1-x)^{0.08} f_2(Fr_l)$
$+667.2Bo^{0.7}F_f(1-x)^{0.8}$
$f(Fr_l) = \begin{matrix}(25Fr_l)^{0.3}\ for\ \ Fr_l < 0.04\ forH.-tube \\ 1\ for\ \ Fr_l > 0.04\ forH.\&V.-tube\end{matrix}$</td><td>$D: 8.1-20mm$ $G: 123-1523\,kg/m^2s$
$q: 0.8-82.1kW/m^2$ $P: 1.6-14.8bar$
$x: 0-0.868$ $Bo: 0.035\times10^{-4}-24.02\times10^{-4}$</td></tr>
</table>

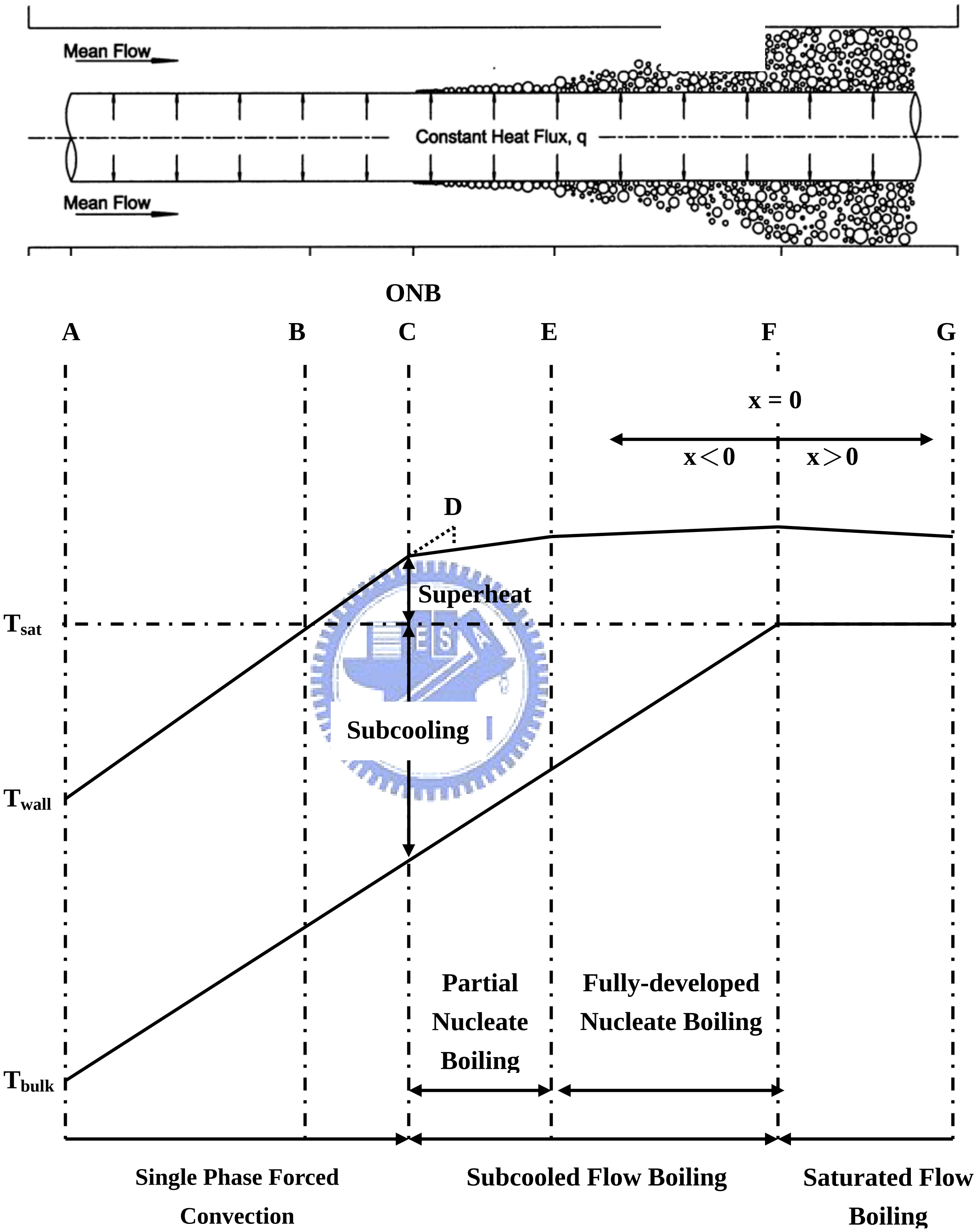

Fig. 1.1 Schematic diagram of boiling regimes for a subcooled liquid refrigerant entering an annular duct with constant heat flux.

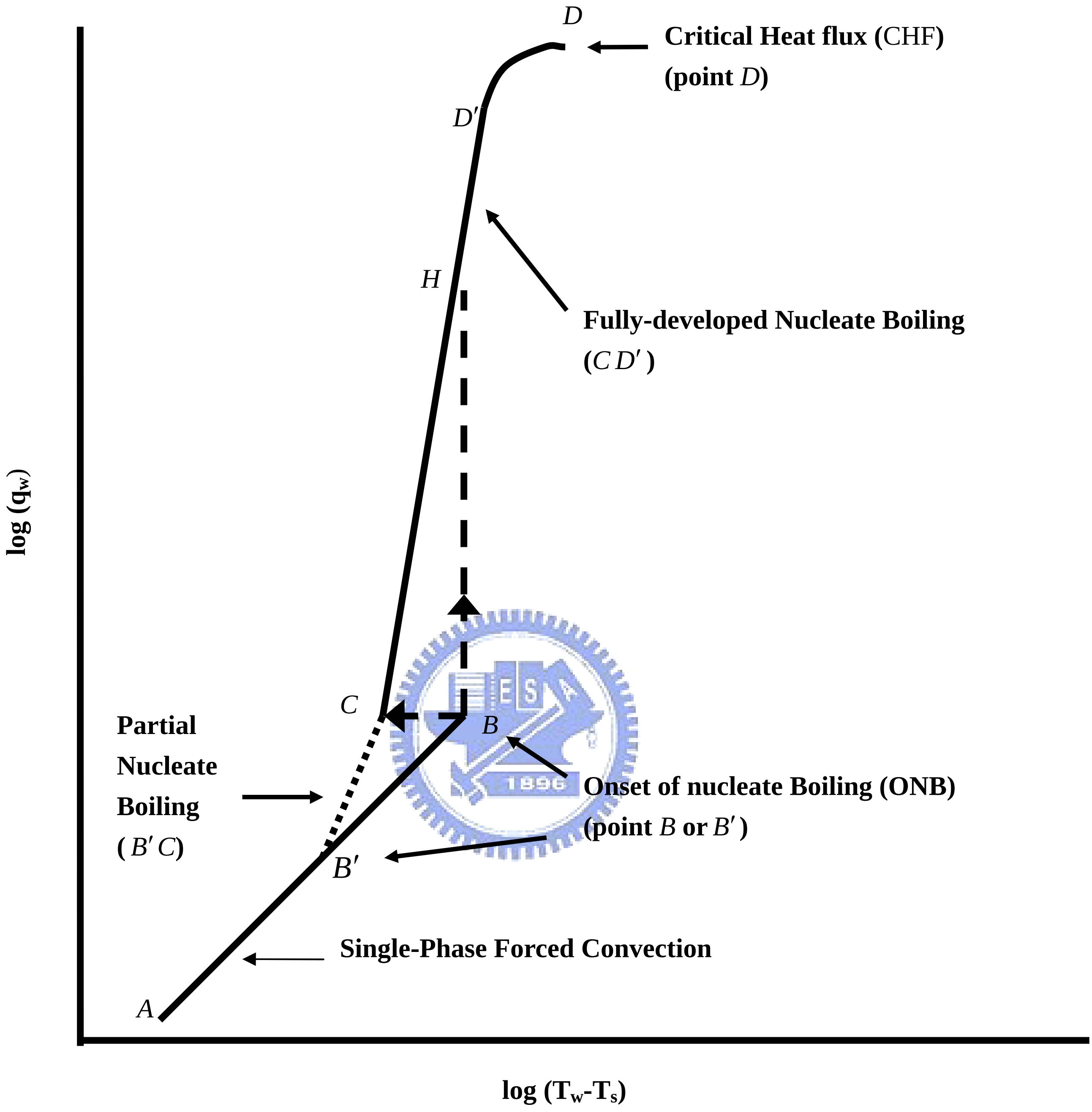

Fig. 1.2 Schematic diagram of a forced-convection boiling curve.