Errata

Fluid Flow and Heat Transfer in Wellbores

By A. Rashid Hasan and C. Shah Kabir

Throughout the book, "Blassius" should read "Blasius".

Chapter 1

Page 1, Column 1, 12 lines from the bottom:
"pA-(p+dp)-dF-A(dz)gρsinθ=" should read
"pA-(p+dp)A-dF-A(dz)gρsinθ="

Page 1, Column 2, Equation (1.4):
"-{dp/dz)+$(dp/dz)_F$-gsinθ-(w/A)dv/dz=0" should read
"-{dp/dz)+$(dp/dz)_F$-gρsinθ-(w/A)dv/dz=0"

Page 2, Column 2, 12 lines from the top:
"(R<2,100)" should read "(Re<2,100)"

Page 5, Nomenclature:
"d = pipe or well diameter, in." should read "d = pipe or well diameter, ft"
"d_c,d_t = pipe or well diameter, in." should read "d_c,d_t = pipe or well diameter, ft"
"F = force, lbm" should read "F = force, lbf"
"g_c = conversion factor, 32.17 lbm-ft/lbf-s^2" should read "g_c = conversion factor, 32.174 lbm-ft/(lbf-sec^2)"
T_D definition is not consistent with Equation (1.16) but is consistent with Chapter 5 definition
"v = fluid velocity, ft/hr" should read "v = fluid velocity, ft/sec"
"w = mass flow rate of fluid, lbm/hr" should read "w = mass flow rate of fluid, lbm/sec"
"η = parameter used in Eq. 1.21" should read "η_o = parameter used in Eq. 1.21"

Chapter 2

Page 8, Equation (2.5):"$G_m = \frac{w_L + w_g}{A} = \frac{\rho_L v_{sL} + \rho_g v_{sg}}{A}$" should read

"$G_m = \frac{w_L + w_g}{A} = \rho_L v_{sL} + \rho_g v_{sg}$"

Page 11, Equation (2.26):

"$-\left(\frac{dp}{dz}\right) = -\left(\frac{dp}{dz}\right)_{F}\Big|_L \quad \phi_L^2 ...$" should read

"$-\left(\frac{dp}{dz}\right) = -\left(\frac{dp}{dz}\right)_F\Big|_L \phi_L^2 \ldots$"

Page 11, Column 1, 5 lines from bottom:

"2.24, the term, $\rho_L v^2_{sL}$, can be…" should read "2.26, the term $\rho_L v^2_{sL}$ can be…"

Page 12, Equation (2.30):

"$f_L = 1 - f_g = 1 - (1 + X^{0.8})^2$" should read "$f_L = 1 - f_g = 1 - (1 + X^{0.8})^{-0.378}$"

Page 12, Column 1, 4th and 5th line from bottom:

"$N_s = S(\rho_L/g\sigma)^{1/4}$" should read

"$N_s = v_s(\rho_L/g\sigma)^{1/4}$"

Page 12, Table 2.1, Under Column titled "Parameters", for Region I:

"L_1 and L_2 are functions of pipe diameter number, $N_d = d(r_L g/S)^{1/2}$" should read

"L_1 and L_2 are functions of pipe diameter number, $N_d = d(\rho_L g/\sigma)^{1/2}$"

Page 12, Column 2, 4th line from top:

"$N_L = \mu_L(g/\rho_L S^3)^{1/4}$" should read

"$N_L = \mu_L(g/\rho_L \sigma^3)^{1/4}$"

Page 13, Figure 2.4, Horizontal axis label:

"$(v_{Ld}/v_{gd})N_L^{0.38}/N_d^{2.14})$" should read

"$v_{gd}N_L^{0.38}/N_d^{2.14}$"

Page 13, Equation (2.39):

"$\mu_m = \mu_L^{f_{l'}} \times \mu_L^{f_{g'}}$" should read

"$\mu_m = \mu_L^{f_L} \times \mu_L^{f_g}$"

Page 13, Column 2, 18th line from top:

"The Hagedorn and Brown[5] correlation for liquid holdup is shown in **Fig. 2.4** in terms of the correlating coefficients ψ, C, and various dimensionless numbers. Variation of ψ with the dimensionless number is shown in **Fig. 2.5** and that of C with N_L in **Fig. 2.6.**" should read

"The Hagedorn and Brown[5] correlation for liquid holdup is shown in **Fig. 2.6** in terms of the correlating coefficients ψ, C_{NL}, and various dimensionless numbers. Variation of ψ with the gas velocity number is shown in **Fig. 2.4** and that of C_{NL} with N_L in **Fig. 2.5.**"

Pages 13-15, Example 2.1:

<u>Hagedorn-Brown Method</u>

"$\mu_L = 13.09$ cp" should read

"$\mu_L = 13.693$ cp"

"C_{NL}=exp{-4.895-1.0775 ln(N_L)-0.80822[ln(N_L)^2]-0.1597 ln(N_L)^3-0.01019 ln(N_L)^4}= exp{-4.895-1.0775 ln(0.0594)-0.80822[ln(0.0594)]^2-0.1597 ln(0.0594)^3-0.01019 ln(0.0594)^4}=0.0048" should read
"C_{NL}=exp{-4.895-1.0775 ln(N_L)-0.80822[ln(N_L)]^2-0.1597 [ln(N_L)]^3-0.01019 [ln(N_L)]^4}= exp{-4.895-1.0775 ln(0.0594)-0.80822[ln(0.0594)]^2-0.1597 [ln(0.0594)]^3-0.01019 [ln(0.0594)]^4}=0.0048"

"$N_f = (v_{Ld}/v_{gd}^{0.575})(p/14.65)^{0.1}C_{NL}(10^6/N_d)$" should read
"$N_f \times 10^6 = (v_{Ld}/v_{gd}^{0.575})(p/14.65)^{0.1}C_{NL}(10^6/N_d)$"

The correlating equation for f_L on Page 14, Column 2:
"$f_L = \psi\{\exp(-3.6372)+0.8813(\ln N_f)-0.1335(\ln N_f)^2+0.018534(\ln N_f)^3-0.001066(\ln N_f)^4\}$" is not correct. Trials with N_f equal to 211.4 or 0.0002114 yielded incorrect results. Use of the calculated N_f in Fig. 2.6 yields the correct value of 0.46.

"$\mu_m = (\mu_L)^{fL} \times \mu_g^{fg}$" should read
"$\mu_m = \mu_L^{f_L} \times \mu_g^{f_g}$"

Page 14, Fig. 2.5, Horizontal axis: "N" should read "N_L"

Page 14, Fig. 2.6, Label for figure: "Hagedorn-Brown correlation for $f/_L/\psi$" should read "Hagedorn-Brown correlation for f'_L/ψ"

Page 15, Column 1: "Re = $\rho_n v_m d/\mu_m$=1,488(28.07)(3.43)(0.25)/(0.388) = 90,024" should read
"Re = 1,488$\rho_n v_m d/\mu_m$ = 1,488(21.3)(4.425)(0.25)/(0.388) = 90,366"

Page 15, Column 1: "f = 0.184(Re)$^{-0.2}$=0.184(90,024)0.25=0.019" should read
"f = 0.184(Re)$^{-0.2}$=0.184(90,024)$^{-0.2}$=0.019"

The Lockhart-Martinelli Correlation

Page 15, Column 1: "$\rho_m = \rho_g f_g + f_L \rho_L$" should read "$\rho_m = \rho_g f_g + \rho_L f_L$"

Page 15, Column 1: "Re_L=($dv_{sL}\rho_L/\mu_L$) = 1,488(0.25x55.04x1.605/13.09)= 2,385" should read
"Re_L=1,488$dv_{sL}\rho_L/\mu_L$ =1,488(0.25x55.042x1.601/13.693)= 2,385"

Page 15, Column 1: "$-(dp/dz)_F=f_L(\rho_g f_g G_m)^2(1-x)^2\phi_L^2/(2\rho_L g_c d)$=2.364 psf/ft = 0.0164 psi/ft" should read "$-(dp/dz)_F = f_L\rho_L v_{sL}^2\phi_L^2/(2g_c d)$ = 2.321psf/ft = 0.0161 psi/ft"

Page 15, Column 1: "-dp/dz = 0.0164 + 0.1677 = 0.1840 psi/ft" should read
"-dp/dz = 0.0161 + 0.1677 = 0.1838 psi/ft"

The Homogeneous Model

Page 15, Column 1: "$Re_m = G_m d/\mu_m$ = 94.32(0.25)/(12.6 x 0.000672) = 2,732" should read "$Re_m = G_m d/\mu_m$ = 94.32(0.25)/(12.8 x 0.000672) = 2,741"

Page 16, Nomenclature:

"d = pipe or well diameter, in." should read "d = pipe or well diameter, ft"
"g_c = conversion factor, 32.17 (lbm-ft)/lbf/sec^2" should read "g_c = conversion factor, 32.174 (lbm-ft)/(lbf-sec^2)"
"G = mass flux, mass flow rate per unit area, ρv, lbm/(hr-ft^2)" should read "G = mass flux, mass flow rate per unit area, ρv, lbm/(sec-ft^2)"
"G_m = mixture mass flux, $\rho_m v_m$, lbm/(hr-ft^2)" should read "G_m = mixture mass flux, $\rho_m v_m$, lbm/(sec-ft^2)"
"N_f = inverse viscosity number [$=gd^3\rho_L(\rho_L - \rho_g)]^2/\mu_L$], dimensionless" should read "N_f = friction factor correlating number in Hagedorn-Brown correlation, dimensionless"
"N_L = liquid viscosity number [$=\mu_L(g/\rho_L\sigma^3$], dimensionless" should read "N_L = liquid viscosity number [$=\mu_L(g/\rho_L\sigma^3)^{1/4}$], dimensionless"
"N_s = Duns and Ros slip velocity [$=S(\rho_L/g\sigma]^{1/4}$, dimensionless" should read "N_s = Duns and Ros slip velocity [$=v_s(\rho_L/g\sigma)^{1/4}$], dimensionless"
"v_s = [=S]" should read "v_s = slip velocity, ft/sec [=S]"
"μ = oil viscosity, cp" should read "μ_L = oil viscosity, cp"

Chapter 3

Page 20, Fig. 3.4: Froth-Annular mist flow transition equation shown on figure is "$y=1/100(x/70)^{-062}$". Equation (3.2) shows this equation to be "$Yv_{sL} = 0.01(Xv_{sg}/70)^{-6.17}$". The graph line would indicate that the exponent in the equation is correct.

Page 22, Equation (3.9): "$1.53[g(\rho_L - \rho_g)\,\sigma/\rho_L^2]^{1/4}$" should read "$1.53[g(\rho_L - \rho_g)\,\sigma_L/\rho_L^2]^{1/4}$"

Page 23, Equation (3.11):

"$\frac{v_{sg}}{v_{sg}+v_{sg}} > 0.52$" should read

"$\frac{v_{sg}}{v_{sL}+v_{sg}} > 0.52$"

Page 28, Equation (3.34):

"$(v_{TB}-v_{gTB})(1-f_{LTB}) = (1.2v_m + v_{\infty T} - v_{gLS})(1-f_{LLS})$" should read

"$(v_{TB}-v_{gTB})(1-f_{LTB}) = (v_{TB} - v_{gLS})(1-f_{LLS})$"

Page 28, Equation 3.45: "m = 10, for $N_f > 250$
= $69N_f^{-0.35}$, for $18 < N_f < 250$
= 25, for $18 < N_f$"

should read "m = 10, for $N_f > 250$
= $69N_f^{-0.35}$, for $18 < N_f < 250$
= 25, for $N_f < 18$"

Page 28, Column 2, 15th line from the bottom: "as shown in Eq. 2.15" should read "as shown in Eq. 1.5"

Page 29, Column 1, 8th and 9th lines from top: "frictional component estimated with Eq. 3.48 is not very different from that given by Eq. 2.15." should read "frictional component estimated with Eq. 3.49 is not very different from that given by Eq. 2.14."

Page 30, Column 2, 8th and 9th lines from bottom: "approach used by Hasan and Kabir[8] (Eqs. 3.23, 3.26, and 3.57)" should read "approach used by Hasan and Kabir[8] (Eqs. 3.24, 3.26, and 3.57)"

Page 31, Table 3.1: In annotation at bottom of table, 5th line from bottom: "VS=Vertical Well Cases with 100 Slug Flow" should read "VS=Vertical Well Cases with 100% Slug Flow"

Page 31, Table 3.1: In annotation at bottom of table, 2nd line from bottom: "Orkis=Orkiszewski" should read "Orkis=Orkiszewski correlation"

Pages 32-33, Example 3.4.1:

- Data: "μ_L = 13.09 cp" should read "μ_L = 13.693 cp"
- Solution-Flow Pattern. Transition Criteria:
    i. Eq. 3.8: Constant 0.345 shown is 0.35 in text. Which is correct?
    ii. Page 32, Column 2, 20th line from top: ", while the actual v_{sg} is 2.19 ft/sec." should read ", while the actual v_{sg} is 2.824 ft/sec."
- Solution-Gas-Volume Fraction and Pressure Gradient. The Hasan-Kabir Model:
    i. Page 32, Column 2, 22nd line from bottom: "$x=v_{sg}/(v_{sg}\rho_g + v_{sl}\rho_l)$" should read "$x=v_{sg}/(v_{sg}\rho_g + v_{sL}\rho_L)$"

ii. Page 32, Column 2, 12th line from bottom:
"μ_m=0.934(13.09)+0.066(0.019)=12.296 cp." should read
"μ_m=0.934(13.693)+0.066(0.019)=12.79 cp."

iii. Page 32, Column 2, 10th and 11th lines from bottom:
"Re_m=(0.25)(4.425)(30.84)/(12.296x0.000672)=3,973" should read
"Re_m=(0.25)(4.425)(30.84)/(12.79x0.000672)=3,967"

iv. Page 32, Column 2, 9th line from bottom:
"$f_m = 0.032(3,973)^{-0.25}$=0.04" should read
"$f_m = 0.32(3,967)^{-0.25}$=0.04"

v. Page 32, Column 2, 7th and 8th lines from bottom:
"$(dp/dz)_F$=(0.04)$(4.425)^2$(30.84)/[2(32.2)(0.25)]=1.516 psf/ft=0.0105 psi/ft" should read
"$(dp/dz)_F$=(0.04)$(4.425)^2$(30.82)/[2(32.2)(0.25)]=1.511 psf/ft=0.0105 psi/ft"

- Solution-Gas-Volume Fraction and Pressure Gradient. The Ansari et. al. Model:

  i. Page 33, Column 1, 25th and 26th line from bottom:
  "v_{TB}=1.2(4.425)+0.958=6.28 ft/sec." should read
  "v_{TB}=1.2(4.425)+0.958=6.268 ft/sec."

  ii. Replace all instances of 6.28 with 6.268 in all calculations for the rest of the example; negligible difference in the answers result.

  iii. Page 33, Column 1, 5th line from the bottom:
  "$Re_{LS}=dv_m\rho_{LS}/\mu_{LS}$=6,664; f_{LS}=0.0316" should read
  "$Re_{LS}=dv_m\rho_{LS}/\mu_{LS}$=6,692; f_{LS}=0.0354"

  iv. Page 33, Column 1, 3rd and 4th lines from the bottom: "Eq. 3.49: $(dp/dz)_F$=(0.0316)$(4.425)^2$(43.7)(1-0.37)/[2(32.2)(0.25)]=1.06 psf/ft=0.00737 psi/ft." should read
  "Eq. 3.49: $(dp/dz)_F$=(0.0354)$(4.425)^2$(43.7)(1-0.37)/[2(32.2)(0.25)]=1.19 psf/ft=0.00824 psi/ft."

  v. The total pressure gradient is negligibly different from that calculated in the book.

Pages 34 and 35, Nomenclature

- "d = pipe or well diameter, in." should read "d = pipe or well diameter, ft"
- Between 17th and 18th lines from bottom, add: "f_{LS}=friction factor for liquid slug, dimensionless"
- "g_c = conversion factor, 32.17 lbm-ft/lbf-sec^2" should read "g_c = conversion factor, 32.174 (lbm-ft)/(lbf-sec^2)"
- "G = mass flux = mass flow rate per unit area, lbm/ft^2" should read "G = mass flux = mass flow rate per unit area, lbm/(ft^2-sec)"
- "L_{sB}=length of liquid slug" should read "L_{sB}=length of liquid slug, ft"
- "L_{TB}=length of a Taylor bubble" should read "L_{sB}=length of a Taylor bubble, ft"
- "N_f=inverse viscosity number $[=gd^3\rho_L(\rho_l - \rho_g)]^2/\mu_l]$, dimensionless" should read "N_f=inverse viscosity number $[=\{gd^3\rho_L(\rho_L - \rho_g)/\mu_L{}^2\}^{1/2}]$, dimensionless"
- All velocity terms are shown with units of ft/hr. The correct units are ft/sec.

- v_{sgc} is shown with no units; correct units are ft/sec.
- "Y_M=ratio of gravitational to gas-phase frictional gradient, dimensionless" should read "Y_M=ratio of gravitational to gas-core frictional gradient, dimensionless"
- Under Superscripts, "N=exponent used in Eq. 3.20, dimensionless" should read "n=exponent used in Eq. 3.20, dimensionless"

Chapter 4

Page 37, Column 1, 13th line from top: "already complex flow phenomena, generally observed…" should read "already complex flow phenomena generally observed…"

Page 38, Column 2, 5th line from bottom: "$(1 – 0.65 \cos\alpha)^2$…" should read "$(1 – 0.65 \cos \alpha)^2$…"

Page 39, Table 4.1: $\Delta\rho$ is not defined. Assume it is $\rho_o - \rho_g$.

Page 39, Table 4.1, Entry for Vertical and Inclined Flow Orientation, Bubbly Transition, Definition of ϕ_1: "$(d/d_s)(1 – 0.65cosa)$" should read ""$(d/d_s)(1 – 0.65\cos \alpha)$"
Page 39, Table 4.1, Entry for Vertical and Inclined Flow Orientation, Intermittent Transition, Definition of ϕ_1: "$n = {}_{0.26e}{}^{-0.17}{}_{vsL/vssL}$" should read "$n = 0.26e^{-0.17v_{sL}/v_{ssL}}$" (my assumption – I do not have the reference.)
Page 39, Table 4.1, notation at bottom of table: "s denotes standard condtions, d_s=1.0 inc., r_{sg}=0.0013 kg/L, r_{sL}=1 kg/L,…" should read "s denotes standard conditions, d_s=1.0 inc., ρ_{sg}=0.0013 kg/L, ρ_{sL}=1 kg/L,…"
Page 39, Column 2, 14th line from top: "$A\sin\alpha$" should read "$A\sin \alpha$"
Page 39, Column 2, Eq. 4.6: f_{gL} is not in the nomenclature at the end of the chapter.
Page 39, Column 2, Eq. 4.7: "v_{sg}" should read "v_t"
Page 40, Column 2, 23rd line from top: "exception of bubbly slug flow transition,…" should read "exception of bubbly-slug flow transition,…"
Page 40, Column 2, 12th line from bottom: "by Beggs,[10]" should read "by Beggs[10]".
Page 41, Column 1, Eq. 4.12, 2nd Line: "$L_3 = 0.1\ C_L^{-1.4516}$, and $L_2 = 0.5\ C_L^{-6.738}$" should read "$L_3 = 0.1\ C_L^{-1.4516}$, and $L_4 = 0.5\ C_L^{-6.738}$"
Page 41, Column 1, 18th Line from top: "Transition: $C_L < 0.01$ and $L_2 < Fr < L_{3;}$" should read "Transition: $C_L > 0.01$ and $L_2 < Fr < L_{3;}$"
Page 41, Column 1, 19th Line from top: "Intermittent: $0.01 < C_L > 0.4$ and $L_3 < Fr < L_{3;}$" should read "Intermittent: $0.01 < C_L < 0.4$ and $L_3 < Fr < L_{3;}$"
Page 41, Column 1, 26th Line from top: "f_g), for horizontal…" should read "f_g) for horizontal…"
Page 41, Figure 4.3: Graph Region I is not labeled on graph below L_1 and to left of L_2.
Page 42, Eq. 4.21: "$F(\alpha) = 1 + Z[\sin(1.8\alpha) – \sin^3(1.8\alpha)]$" should read "$F(\alpha) = 1 + Z[\sin(1.8\alpha) – \sin^3(1.8\alpha)/3]$"
Page 42, Eq. 4.22: "$Z = (1 – C_L)\ln[dC_L^e v_{dL}^f Fr_g]$" should read "$Z = (1 – C_L)\ln[dC_L^e v_{Ld}^f Fr^g]$"
Page 42, Column 1, 2nd Line from bottom: f_{gT} is not defined in the nomenclature and does not match nomenclature in referenced Eq. 4.14.

Page 42, Column 2, 6th line from top: "tion, with its counterpart for vertical systems, indicates…" should read "tion with its counterpart for vertical systems indicates…"
Page 42, Column 2, 21st Line from bottom: "and Kabir,[6] as well as Kaya *et al.*[9]" should read "and Kabir,[6] as well as Kaya *et al*.,[9]"
Pages 44-46, Field Example 4.1:

- **Solution**. Flow Pattern and Transition Criteria:
    i. Page 45, Column 1, 20th from top: "=[(0.429)(6.211)+(0.357)(0.769)](0.9537)" should read "=[(0.429)(6.153)+(0.357)(0.675)](0.9537)". The answer "2.747 ft/sec" should read "2.753 ft/sec".
    ii. Page 45, Column 2, 3rd line from top: "Using Eq. 3.11 (v_{sg}=1.08v_{sL})…" should read "Using Eq. 3.11 (v_{sg}>1.08v_{sL})…"
    iii. Page 45, Column 2, 10th line from top: "In Eq. 3.12, v_{sg}=3.1[(32.2)(0.064)(52.33)/1.03^2]$^{1/4}$…" should read "In Eq. 3.12, v_{sg}>3.1[(32.2)(0.064)(52.33)/1.03^2]$^{1/4}$…"
    iv. Page 45, Column 2, 11th line from bottom: "Eq. 3.28: v_∞=0.675[1-$e^{-2.747x14.8}$]+1.169 $e^{-2.747x14.8}$" should read "Eq. 3.28: v_∞=0.675[1-$e^{-2.747/14.8}$]+1.169 $e^{-2.747/14.8}$"
    v. Page 45, Column 2, 5th line from bottom: "= 22.71 lbm/ft^3" should read "= 22.60 lbm/ft^3".
    vi. Page 45, Column 2, last line: "Re_m = (0.20)(20.89)(22.71)/(2.15 X 0.000672) = 66,792" should read "Re_m = (0.20)(20.95)(22.60)/(2.15 X 0.000672) = 66,183".
    vii. Page 46, Column 1, 1st line: "f = 0.32(66,792)$^{-0.25}$ = 0.02" should read "f = 0.32(66,183)$^{-0.25}$ = 0.0199".
    viii. Page 46, Column 1, 2nd and 3rd lines from top: "Eq. 2.14: $(dp/dz)_F$=(0.0199)(20.95)^2(22.71)/[2(32.2)(0.2)]=15.21 psf/ft=0.1057 psi/ft." should read "Eq. 3.49: $(dp/dz)_F$=(0.0354)(4.425)^2(43.7)(1-0.37)/[2(32.2)(0.25)]=1.19 psf/ft=0.00824 psi/ft."
- Solution-Gas-Volume Fraction and Pressure Gradient. The Ansari et. al. Model:
    ix. Page 33, Column 1, 25th and 26th line from bottom: "v_{TB}=1.2(4.425)+0.958=6.28 ft/sec." should read "v_{TB}=1.2(4.425)+0.958=6.268 ft/sec."
    x. Replace all instances of 6.28 with 6.268 in all calculations for the rest of the example; negligible difference in the answers result.
    xi. Page 33, Column 1, 5th line from the bottom: "$Re_{LS}=dv_m\rho_{LS}/\mu_{LS}$=6,664; f_{LS}=0.0316" should read "$Re_{LS}=dv_m\rho_{LS}/\mu_{LS}$=6,692; f_{LS}=0.0354"
    xii. Page 33, Column 1, 3rd and 4th lines from the bottom: "Eq. 3.49: $(dp/dz)_F$=(0.0316)(4.425)^2(43.7)(1-0.37)/[2(32.2)(0.25)]=1.06 psf/ft=0.00737 psi/ft." should read "Eq. 3.49: $(dp/dz)_F$=(0.0354)(4.425)^2(43.7)(1-0.37)/[2(32.2)(0.25)]=1.19 psf/ft=0.00824 psi/ft."
    xiii. The total pressure gradient is negligibly different from that calculated in the book.

- The Beggs and Brill Correlation:
    i. Page 46, Column 1, 11th line from bottom: "and Fr = v_m^2/gd = 67.2" should read "and Fr = v_m^2/gd = 67.5".
    ii. Page 46, Column 2, 7th line from top: "Eq. 4.21: F(α) = 1 + Z[sin(1.8α) – $\sin^3$(1.8α)] = 0.982" should read "Eq. 4.21: F(α) = 1 + Z[sin(1.8α) – $\sin^3$(1.8α)/3] = 0.977".
    iii. Page 46, Column 2, 10th line from top: "Eq. 2.18: ρ_m = 53.33(0.40) + 1.03(0.60)=21.99 lbm/ft^3" should read : "Eq. 2.18: ρ_m = 53.36(0.40) + 1.03(0.60)=21.96 lbm/ft^3."
    iv. Page 46, Column 2, 11th line from top: "Eq. 2.15: $(dp/dz)_H$ = $\rho_m g \sin\alpha/g_c$ = 22.14 psf/ft=0.1467" should read "Eq. 2.15: $(dp/dz)_H$ = $\rho_m g \sin\alpha/g_c$ = 20.95 psf/ft=0.1457"
    v. Page 46, Column 2, 14th line from top: "(1-C_L)=16.58 lbm/ft^3," should read "(1-C_L)=16.40 lbm/ft^3,"
    vi. Page 46, Column 2, 15th line from top: "=(0.20)(20.89)(16.58)/ (0.674x0.00672)=153,944." should read "=(0.202)(20.953) (16.40)/ (0.674x0.00672)=153,944."
    vii. Page 46, Column 2, 16th line from op:"Eq.1.11:f_n= 0.184$(153,944)^{-0.2}$=0.167." should read :"Eq.1.11:f_n= 0.184$(153,944)^{-0.2}$=0.0169."
    viii. Page 46, Column 2, 19th line from top: "+0.01853$(\ln y)^3$]= 0.3894." should read "+0.01853$(\ln y)^3$]= 0.3887."
    ix. Page 46, Column 2, 23rd line from top: "Eq. 2.17: dp/dz=0.1467 + 0.096=0.2426 psi/ft=total pres-" should read "Eq. 2.17: dp/dz=0.1467 + 0.096=0.2427 psi/ft=total pres-"

27. Page 48, Column 1, Fig. 4.10: Third drawing from top, "Elongated Bubble Flow" should read "Elongated Bubble Flow (Plug Flow)"
28. Page 48, Column 1, 18th line from top: "of gravity in horizontal flow." should read "of gravity effects in horizontal flow."
29. Pages 48 – 49, Section on Discussion of ***Transition Between Stratified and Intermittent or Annular Flow***. The equations in the discussion of this section use nomenclature that does not match Fig. 4.12. One of the two should be changed to be consistent with the other.
30. Page 50, Fig. 4.13: The parameter label in the interior of the graph "Y=1,000" is too close to the data points, and the Y is almost hidden.
31. Page 51, Column 1, 15th line from the top: ", which can be evaluated form the" should read ", which can be evaluated from the"
32. Page 52, Column 1, 28th and 29th lines from top: "A_l/S_l" should read "A_L/S_L"
33. Page 53, Column 1, 13th line from bottom and Page 59, Column 2, 14th and 16th lines from bottom: "f_{fm}" should read "f_m"
34. Page 53, Column 2, 10th line from bottom: "hole diameter presents further complications." should read "hole diameter present further complications."
35. Page 54, Column 1, 3rd line from top: "α′ = 0 0.25" should read "α′ = 0.25"
36. Page 55, Column 2, 6th and 7th lines from bottom: "**Figs. 4.16** through **4.18**   provide the model's validation." has too many spaces between 4.18 and provide.

37. Page 59, Column 1, 5th line from bottom and Column 2, 3rd line from top: "ations (<70°)," should read "ations <70°,"

38. **Nomenclature Corrections**
    - E_o, Eotvos number, should be Eo.
    - f_{gT} is mentioned on page 42, where Eq. 4.14 is referenced. This term is not defined in either the equation or the nomenclature.
    - G_m, G_g, and G_L = mixture, gas, and liquid mass fluxes, ρv, lbm/(hr-ft^2) should have units of lbm/(sec-ft^2)
    - v_{tr} = superficial gas at the bubbly-slug transition zone, ft/sec should read superficial gas <u>velocity</u> at the bubbly-slug transition zone.
    - $v_{\infty T\alpha}$ = terminal rise velocity of a Taylor bubble in a horizontal well inclined by α degrees, ft/sec is terminal rise velocity of a Taylor bubble in a <u>deviated</u> well inclined by α degrees, ft/sec.
    - μ = oil viscosity, cp should read μ = viscosity, cp.
    - Add n = no-slip to subscript nomenclature.

<u>Chapter 5</u>

1. Page 66, Column 2, Eq. 5.12:

$$wH\big|_{z+dz} + \frac{(z+dz)wg\sin\alpha}{Jg_c} + \frac{wv^2\big|_{z+dz}}{2Jg_c} + Qdz = wH\big|_z + \frac{zwg\sin\alpha}{Jg_c} + \frac{wv^2\big|_z}{2Jg_c}$$

should read

$$wH\big|_{z+dz} - \frac{(z+dz)wg\sin\alpha}{Jg_c} + \frac{wv^2\big|_{z+dz}}{2Jg_c} + Qdz = wH\big|_z - \frac{zwg\sin\alpha}{Jg_c} + \frac{wv^2\big|_z}{2Jg_c}$$

2. Page 66, Column 2, Eq. 5.13: $\frac{dH}{dz} + \frac{g\sin\alpha}{Jg_c} + \frac{v}{Jg_c}\frac{dv}{dz} = \mp\frac{Q}{w}$

should read $\frac{dH}{dz} - \frac{g\sin\alpha}{Jg_c} + \frac{v}{Jg_c}\frac{dv}{dz} = \mp\frac{Q}{w}$

3. Page 67, Column 1, Eq. 5.14: $dH = \left(\frac{\partial H}{\partial T_P}\right)dT + \left(\frac{\partial H}{\partial p}\right)_T dp = c_p dT - C_J c_p dp$

should read $dH = \left(\frac{\partial H}{\partial T}\right)_p dT + \left(\frac{\partial H}{\partial p}\right)_T dp = c_p dT - C_J c_p dp$

4. Page 68, Column 2, Eq. 5.29: $\frac{dT_f}{dz} = \pm L_R\left(T_f - T_{ei}\right) - \frac{g\sin\alpha}{c_p Jg_c} + \phi$

should read $\frac{dT_f}{dz} = \pm L_R\left(T_f - T_{ei}\right) + \frac{g \sin\alpha}{c_p J g_c} - \phi$

5. Page 69, Column 1, Eq. 5.30: $\phi = -\frac{v}{c_p J g_c}\frac{dv}{dz} + C_J \frac{dp}{dz}$

should read $\phi = +\frac{v}{c_p J g_c}\frac{dv}{dz} - C_J \frac{dp}{dz}$

6. Page 69, Column 1, Eq. 5.33: $\phi \equiv -\frac{v}{c_p J g_c}\frac{dv}{dz} + C_J \frac{dp}{dz} = \frac{1}{c_p \rho}\frac{dp}{dz}$

should read $-\phi \equiv -\frac{v}{c_p J g_c}\frac{dv}{dz} + C_J \frac{dp}{dz} = \frac{1}{c_p \rho}\frac{dp}{dz}$

7. Page 69, Column 1, 19th and 20th lines from top: "nearly equals the total pressure gradient. In other words, dp/dz~$\rho(g/g_c)\sin\alpha$." should read "nearly equals the total pressure gradient. In other words,

$\frac{dp}{dz} \approx -\rho\left(\frac{g}{g_c}\right)\sin\alpha$" (Set the equation off from the text)

8. Page 70, Column 2, Field Example 5.1 Data: $\hat{\alpha} = 0.04 ft/\sec^2$ should read

$\hat{\alpha} = 0.04 ft^2/hr$

9. **Nomenclature Corrections**
   - h_a, h_t, and h_c = convective heat transfer coefficients, Btu/(°F-hr-ft) should have units of Btu/(°F-hr-ft^2)
   - Insert h_r=radiative heat-transfer coefficient, Btu/(°F-hr-ft^2)
   - Insert J=mechanical equivalent of heat, 778 (ft-lbf)/Btu
   - "N_f=inverse viscosity number [=$gd^3\rho_L(\rho_l - \rho_g)]^2/\mu_L$], dimensionless" should read "N_f=inverse viscosity number [=$\{gd^3\rho_L(\rho_L - \rho_g)/\mu_L^2\}^{1/2}$], dimensionless"
   - "t_D=dimensionless time, $ket/\rho_e c_e r_{wb}^2$" should read "t_D=dimensionless time, $k_e t/\rho_e c_e r_{wb}^2$"
   - U = overall-heat-transfer coefficient, Btu/(hr-ft^2-°F) should have units of Btu/(sec-ft^2-°F)
   - w = mass flow rate of fluid, lbm/hr should have units of lbm/sec.

Chapter 6

1. Page 77, Column 2, Fig. 6.5 and Fig. 6.6 are numbered in reverse. The well schematic should be Fig. 6.5, and the synthetic case temperature profiles should be Fig. 6.6.

2. **Nomenclature Corrections**
   - B_a=parameter defined by Eq. 6.2, ft/lbm should have units of ft-hr/lbm.
   - "c_p=heat capacity of fluids, Btu/(lbm-^{o}F)" should read "c_p=heat capacity of fluids at constant pressure, Btu/(lbm-^{o}F)"
   - "J=ft-lbf to Btu conversion factor, dimensionless" should read "J=mechanical equivalent of heat, 778 ft-lbf/Btu"

Chapter 7

1. Page 79, Column 2, Eq. 7.2: $\frac{\partial v}{\partial t}+v\frac{\partial v}{\partial z}=-\frac{1}{\rho}\frac{\partial p}{\partial z}-g-\frac{2fv^2}{d}$ should read

   $$\frac{\partial v}{\partial t}+v\frac{\partial v}{\partial z}=-\frac{1}{\rho}\frac{\partial p}{\partial z}-g\sin\alpha-\frac{2fv^2}{d}$$

2. Page 80, Column 1, Eq. 7.3: $Q=\frac{d(mE)_{cv}}{dt}+\frac{d(m'E)}{dt}\frac{d}{dz}\left[w\left(H+\frac{1}{2}v^2+gz\sin\theta\right)\right]$

   should read $Q=\frac{d(mE)_{cv}}{dt}+\frac{d(m'E)}{dt}\frac{d}{dz}\left[w\left(H+\frac{1}{2}v^2+gz\sin\alpha\right)\right]$
3. Page 80, Column 1, 12th line from top: "given by[10] (Eq. 5.20)" should read "given by[10] (Eq. 5.19)".
4. Page 80, Column 1, Eq. 7.4: $Q=\rho vc_p(T_{ei}-T_f)L_R$ should read $Q=A\rho vc_p(T_{ei}-T_f)L_R$
5. Page 80, Column 2, Eq. 7.9:

   $$Q=A\rho\frac{\partial H}{\partial t}+\frac{\partial(m'cT_f)}{\partial t}-A\rho R\frac{\partial(ZT_f)}{\partial t}+A\left(H-\frac{ZRT_f}{M}\right)\frac{\partial\rho}{\partial t}+\frac{d}{dz}\left[(A\rho v)\left(H+\frac{v2}{2}+gz\sin\theta\right)\right]$$

   should read

   $$Q=A\rho\frac{\partial H}{\partial t}+\frac{\partial(m'cT_f)}{\partial t}-A\rho R\frac{\partial(ZT_f)}{\partial t}+A\left(H-\frac{ZRT_f}{M}\right)\frac{\partial\rho}{\partial t}+\frac{d}{dz}\left[(A\rho v)\left(H+\frac{v^2}{2}+gz\sin\alpha\right)\right]$$

6. Page 84, Column 1, Table 7.1: Data for pipe roughness shows 1.8x10 – (with an overstrike of the 1 by the x). It should read 1.8 x 10^{-5}.
7. Page 86, Column 1, Last line: "analogous to the gas and oil model described earlier in this-" should read "analogous to the gas and oil model described earlier in this-"
8. Page 87, Column 1, 11th line from bottom: "from both depth- and time depended mixture" should read "from both depth- and time dependent mixture"
9. Page 87, Column 1, 6th line from bottom: "depended fluid density," should read "dependent fluid density,"
10. **Nomenclature Corrections**

- "R= universal gas-law constant, psia-ft^3/lbmole-^{o}R" should read "R= universal gas-law constant, 10.732 psia-ft^3/lbmole-^{o}R"
- "t_D=dimensionless time [=2.64 x 10^{-4}kt/$\phi\mu c_t r_w^2$]" should read "t_D=dimensionless time [=$k_e t/\rho_e c_e r_w^2$]"

Chapter 8

1. Page 94, Column 2, Fig. 8.8: Labels T_{ti} and T_{ae} are reversed on each set of curves.
2. Page 97, Column 2, 5th line from bottom: "D, Sec. D.2." should read "D, Sec. D.3."
3. Page 98, Column 1, 3rd line from bottom: "Eqs. D-21, D-22, and D-27, respectively," should read "Eqs. D-28, D-29, and D-36, respectively,"
4. Page 98, Column 2, Discussion of ***Method Two: Exponential Approach***: This entire discussion is unclear because there is no parameter A' in Eq. D-14 (that equation refers to parameter α), and the reference to integrating Eq. D-13 is not reasonable (Eq. D-13 is a definition of a parameter ω_2). Most likely this refers to Eq. D-20, but I am not sure of this.
5. Page 98, Column 2, Discussion of ***Method Three: Log-Linear Approximation***: References to Eq. D-16 should probably be Eq. D-22 or Eq. D-23. I am not sure which.
6. Page 99, Column 1, Discussion of ***Method Four: Square-Root Time Approximation***: References to Eq. D-15 are probably incorrect. This should probably be Eq. D-22 or Eq. D-23; again, I am not sure of this reference.
7. Page 100, Column 1, 2nd line from bottom: Reference to Eq. D-15 appears incorrect; this should probably be Eq. D-22. Once again, I am not sure.
8. Page 101, Column 1, 2nd line from top: "and a thermal diffusivity of 0.04 hr-ft^{-2}" should read "and a thermal diffusivity of 0.04 ft^2-hr"
9. **Nomenclature Corrections**
   - In the equation for T_D, q_F is referenced but is not included in the nomenclature. The subscript F is also not included in the nomenclature. This term is replaced in Appendix D with the term Q. This should be made consistent in both places.

Chapter 9

1. Page 120, Column 1, 4th line from bottom: "rate results in an increase in both T_a and T_t." should read "rate results in a decrease in both T_a and T_t."
2. Page 122, Column 2, 11th line from top: "volume-fraction occurs at 2,500 ft," should read "volume-fraction occurs at 2,400 ft,". This assumes that the data in Table 9.3 is correct.
3. Page 126, Column 1, 13th line from top: "omputed values of pressure and temperature" should read "computed values of pressure and temperature"
4. Page 127, Column 1, 16th line from top: "in Eq. 9.26, has not been very successful" should read "in Eq. 9.26, have not been very successful"
5. Page 127, Column 2, Eq. 9.30: $H_c = xH_L + (1-x)H_L$ should read $H_c = xH_g + (1-x)H_L$

6. Page 128, Column 1, 10th line from top: "Chisholm[44] suggested" should read "Chisholm[46] suggested"
7. Page 128, Column 1, 19th line from top: "Chisholm[15] for various fittings" should read "Chisholm[46] for various fittings"
8. Page 128, Column 1, Eq. 9.36: $(\Delta p)_{fit} = d(L_e)_{fit}\left(\frac{fG_2(1-x)}{2\rho_L d}\right)\left(1+\frac{C}{X}+\frac{1}{X_2}\right)$

   should read $(\Delta p)_{fit} = d(L_e)_{fit}\left(\frac{fG_2(1-x)}{2\rho_L d}\right)\left(1+\frac{C}{X}+\frac{1}{X^2}\right)$
9. Page 128, Column 2, 2nd line from top: "Chisholm[15] also suggested" should read "Chisholm[46] also suggested"
10. Page 128, Column 2, 12th line from bottom: "and H_L = 1057.7." should read "and H_m = 1057.7."
11. Page 129, Column 1, 1st line: 0.0965 should be 0.0840.
12. Page 129, Column 1, 2nd and 3rd lines from top and 13th and 14th lines from top: Equations for C carry over to second line and should have a multiplication sign at the end of each first line.
13. Page 130, Column 2, 3rd and 4th lines from top: "Ref. 50 presents a com-i prehensive review" should read "Ref. 50 presents a comprehensive review"
14. Page 132, Column 1, 21st line from top: "occurrence of oil to the left side of he" should read "occurrence of oil to the left side of the"
15. Page 135, Column 1, 6th and 7th lines from top: "or a suitable solvent into thep-roduction string" should read "or a suitable solvent into the production string"
16. **Nomenclature Corrections**
    - Units for D_a, constant defined by Eq. 9.11, should be Btu/(lbm-ft) (add parentheses in denominator)
    - Units for G and G^*, mass fluxes, should be lbm/(sec-ft^2)
    - Units for J_p, productivity index, should be STB/(D-psi) (add parentheses in denominator)
    - Units for r_{co}, r_{jo}, r_{ti}, and r_{to}, all radii in the wellbore, should be ft.
    - Definition of T_D includes a factor of q_F, which is not defined in the text anywhere. See Chapter 8 nomenclature corrections (above) for further discussion.
    - Units for U_1, U_{tc}, and U_{to}, overall-heat-transfer coefficients, should be Btu/(sec-ft^2-^{o}F)

Chapter 10

1. Page 147, Column 2, last line: "We used this depth-depended correction factor to" should read "We used this depth-dependent correction factor to"
2. Page 150, Column 1, 2nd line from top: "and Flores *et. al.*,[13] allow understanding of" should read "and Flores *et. al.*,[13] allows understanding of"

Appendix A

1. **Nomenclature Corrections**
    - Add: h_r = radiative heat-transfer coefficient, Btu/(hr-ft^2-^{o}F)

- "T_{ai},T_{ti} = inlet-temperature of annular or tubing fluid, ^{o}F" should read "T_{ai},T_{ti} = inside temperature of annular or tubing fluid, ^{o}F"

Appendix B

1. **Nomenclature Corrections**
   - Add: θ=inclination from vertical, degrees