NUCLEAR SYSTEMS I: THERMAL HYDRAULIC FUNDAMENTALS

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ERRATA

- TEXT

PAGE (Line, Fig., Eq., Ex.)	ORIGINAL	CORRECTED
13, Table 1-3 (LMFBR column, Line 6)	Cylindrical pellet	Annular pellet
40 (Line 2)	... appears as kinetic energy of the fission fragments, ...	... appears as kinetic and decay energy of the fission fragments, ...
40 (Line 3)	... emitted γ-rays. ...	... emitted γ-rays and neutrinos. ...
42 (end of page)	... (neutrino energy).	... (neutrino energy). Accounting for capture energy, the fraction of recoverably energy, i.e., core power, deposited in the fuel becomes about 95%.
57 (Line 9)	thrermal	thermal
63 (Line 12)	$q_\gamma'''(x) = (10^{14})$ ...	$q_\gamma''' = (10^{14})$ ...
64 (Eq. 3-63)	$q_{e\ell}'''(\vec{r}) = \ldots$	$q_{e\ell}''' = \ldots$
64 (Eq. 3-64)	$q_{i\ell}'''(\vec{r}) = \ldots$ $\therefore q'''(\vec{r}) = q_\gamma'''(\vec{r}) + q_{e\ell}'''(\vec{r}) + q_{i\ell}'''(\vec{r})$	$q_{i\ell}''' = \ldots$ $\therefore q''' = q_\gamma''' + q_{e\ell}''' + q_{i\ell}'''$
85 (Eq. 4-22a)	$= - m \frac{D\psi}{dt} + m \frac{\partial \psi}{\partial t}$	$= - m \frac{D\psi}{Dt} + m \frac{\partial \psi}{\partial t}$
90 (Line 22)	$h_{in} - h_{out}$ $= u_{in}(T) - u_{out}(T) - (p/\rho)_{in} - (p/\rho)_{out}$ $= (p_{out} - p_{in})/\rho$	$h_{in} - h_{out}$ $= u_{in}(T) - u_{out}(T) + (p/\rho)_{in} - (p/\rho)$ $= (p_{in} - p_{out})/\rho$
94 (Line 2)	withn	within
141 (Line 22)	... Using Eq. 5-30, we can write ρ_m as:	... Using Eq. 5-30 and the area averaging analogy to Eq. 5-16, we can write ρ_m as:
143 (Line 2)	vapor fraction (β)	vapor fraction $\{\beta\}$
146 (Eq. 5-65, 1st term)	$\ldots\{\ldots + \rho_\ell(1-\alpha)v_{vz}\}\ldots$	$\ldots\{\ldots + \rho_\ell(1-\alpha)v_{\ell z}\}\ldots$
149 (Fig. 5-5, bottom)	$(\vec{A})_1$ $\vec{A}_s$	$(\vec{A}_\ell)_1$ $\vec{A}_{\ell s}$

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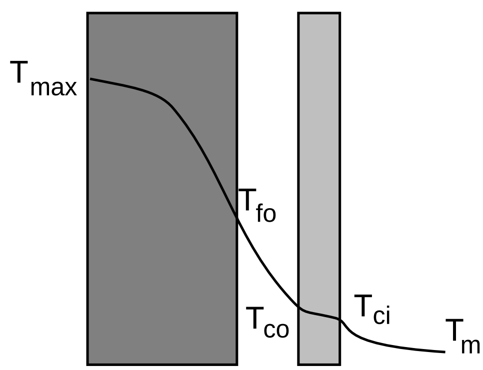
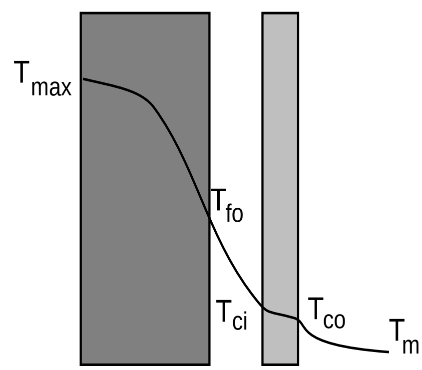
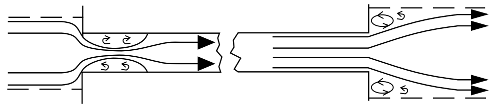
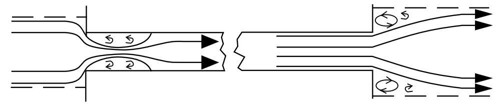
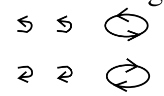
167 (Eq. 5-158)	first term $\frac{\partial}{\partial t}\rho_m\left(v_m^2/2\right)A_z$	$\frac{\partial}{\partial t}\rho_m\left[\left(v^2\right)_m/2\right]A_z$
	second term $\frac{\partial}{\partial z}G_m\left(v_m^2/2\right)A_z$	$\frac{\partial}{\partial z}G_m\left[\left(v^2\right)_m^+/2\right]A_z$
172 (Table 6-1, Line 8, Eq. 6-1)	$U_2 - U_1 = Q_{1+2} - W_{1+2}$	$U_2 - U_1 = Q_{1\rightarrow 2} - W_{1\rightarrow 2}$
176 (renumber Eqs.)	(6-2)	(6-3a)
	(6-3)	(6-3b)
188 (Eq. 6-32)	$\dot{W}_{u,max} = \left[\frac{\partial(U - T_oS)}{\partial t}\right]$	$\dot{W}_{u,max} = -\left[\frac{\partial(U - T_oS)}{\partial t}\right]$
219 (Eq. 6-97)	$r_p = \frac{p_2}{p_1} \equiv \frac{p_3}{p_4}$	$r_p \equiv \frac{p_2}{p_1} = \frac{p_3}{p_4}$
221 (Ex. 6-7, solution)	$\zeta = \frac{\left(\dot{W}_T - \dot{W}_{CP}\right)/\dot{m}}{\dot{W}_{u,max/\dot{m}}} = \ldots$	$\zeta = \frac{\left(\dot{W}_T - \dot{W}_{CP}\right)/\dot{m}}{\dot{W}_{u,max}/\dot{m}} = \ldots$
227 (Ex. 6-10, solution)	$\dot{W}_{C_p} = \dot{m}c_p(T_2 - T_1) = \dot{m}c_p\,T \ldots$	$\dot{W}_{C_p} = \dot{m}c_p(T_2 - T_1) = \dot{m}c_p\,T_1 \ldots$
231 (Fig. 6-29)	Graph drawn as $T_{1'} \neq T_{2'}$ and $T_{3'} \neq T_{4'}$	Graph redrawn so that $T_{1'} = T_{2'}$ and $T_{3'} = T_{4'}$
232 (after 2nd eq.)	where $T_2' = T_1''\,(r_p)^{\frac{\gamma - 1}{\gamma}} \ldots$	where $T_2' = T_1''\,(r_p')^{\frac{\gamma - 1}{\gamma}} \ldots$
241 (Line 1)	... m_{wc_1}, m_{wpd}, and m_{wpr})	... m_{wc_1} and m_{wp})
241 (Eq. 7-2c)	For m_{wpd}: $\frac{d\,(m_{wpd}u_{wpd})}{dt} = \dot{Q}_{wpr\text{ - }wpd} - \ldots$	For m_{wp}: $\frac{d\,(m_{wpd}u_{wpd} + m_{wpr}u_{wpr})}{dt} = \dot{Q}_{n\text{ - }wpr} - \ldots$
242 (Eq. 7-2d)	$\frac{d\,(m_{wpr}u_{wpr})}{dt} = \ldots$	delete
243 (Lines 3 & 4)	... 7-2c and 7-2d ...	... and 7-2c ...
245 (last Line)	... coolant in the primary or secondary system, ...	... coolant in the primary system, ...
246 (Fig. 7-4)		Changed to differentiate primary and secondary coolant in steam generator.
250 (Ex. 7-1)	... saturated water in equilibrium ...	... saturated water mixture in equilibrium ...
251 (Table 7-2)	Example 7-1: saturated water in ...	Example 7-1: saturated water mixture in ...
	Example 7-2: superheated water in ...	Example 7-2: superheated steam in ...

PAGE (Line, Fig., Eq., Ex.)	ORIGINAL	CORRECTED
254 (Ex. 7-2)	... superheated water in equilibrium ...	... superheated steam in equilibrium ...
254 (Line 20)	If the water is superheated ...	If the steam is superheated ...
254 (Line 25)	... treats the superheated water ...	... treats the superheated steam ...
263 (Line 2)	computer	compute
267 (Line 9)	discontinuous phases	continuous phases
267 (Fig. 7-16B)	$(\dot{m}_v)_{s'U}$ $(\dot{m}_\ell)_{s'L}$	$(\dot{m}_v)_{s''U}$ $(\dot{m}_\ell)_{s''L}$
278 (Fig. 7-20)	vapor at h_g liquid at h_ℓ	liquid at h_ℓ vapor at h_g
280 (Fig. 7-21)		Redrawn with lighter shading so arrows show.
281 (Fig. 7-22)		Redrawn with lighter shading so arrows show.
283 (Fig. 7-23)		Redrawn with lighter shading so arrows show.
301 (Eq. 8-16c, last term)	- 1797017	- 1.797017
317 (Line 3)	Hence:	Hence, Eq. 8-57 becomes:
319 (Fig 8-13, y-axis label)	Void Factor, F_v (α/β)	Void Factor, F_v (α, β)
338 (Eq. 8-23, top)		
359 (Solution, 1st Eq.)	$\dot{m}(t) = \frac{1}{C}\left[\frac{e^{2C\,\Delta p\left(\frac{A}{\ell}\right)_T^t} - 1}{e^{2C\,\Delta p\left(\frac{A}{\ell}\right)_r^t} + 1}\right]$	$\dot{m}(t) = \frac{1}{C}\left[\frac{exp\left[2C\,\Delta p\left(\frac{A}{\ell}\right)_T t\right] - 1}{exp\left[2C\,\Delta p\left(\frac{A}{\ell}\right)_T t\right] + 1}\right]$
376 (Eq. 9-62)	$(\tau_{zr})_{eff} = \tau_{zr} - \rho\overline{v'_z v'_r}$	$(\tau_{rz})_{eff} = \tau_{rz} - \rho\overline{v'_z v'_r}$
384 (Eq. 9-84)	$\frac{D'_{el}}{D'_{eb}}$	$\frac{D'_{ei}}{D'_{eb}}$
397 (Line 9)	$\therefore C_s = 1.75$ (by extrapolation ...	$\therefore C_s = 1.7$ (by extrapolation ...
397 (Line 12)	$...\frac{(1.75)(8.678\text{ m/s})^2(0.417)}{2} = 0.153\text{ MPa}$	$...\frac{(1.7)(8.678\text{ m/s})^2(0.417)}{2} = 0.149\text{ MPa}$

PAGE (Line, Fig., Eq., Ex.)	ORIGINAL	CORRECTED
399 (Fig. 9-35, top)		 Note: The arrows change to – 
399 (Fig. 9-35, bottom)	$K_e \rho \frac{V_2^2}{2}$	$K_c \rho \frac{V_2^2}{2}$
406 (Ref. 18)	Zerke, J.E.	Zerbe, J.E.
437 (Line 9)	... sublayer. numerical results for the ...	... sublayer. Kays and Leung (1963) used various refinements for their approach and obtained numerical results for the ...
451 (Line 11)	...P/D > 1.1 the equivalent diameter...	...P/D > 1.1 the equivalent annulus...
467 (Line 4)	... depend on the channel exit conditions.	... depend on the design of the channel ends.
467 (Line 14)	Pushkina	Pushkin
490 (Eq. 11-82)	$\phi_{\ell o}^2 =$	$\phi_{fo}^2 = ...$
490 (Eq. 11-83)	$\phi_{\ell o}^2 = \frac{\rho_\ell\, f_{TP}}{\rho_m\, f_{\ell o}} =$	$\phi_{fo}^2 = \frac{\rho_f\, f_{TP}}{\rho_m\, f_{fo}} = ...$
510 (Eq. 11-126b)	$\left(\frac{p_b}{p_o}\right)_{cr} = \left(\frac{2}{\gamma + 1}\right) \frac{\gamma}{\gamma - 1}$	$\left(\frac{p_b}{p_o}\right)_{cr} = \left(\frac{2}{\gamma + 1}\right)^{\frac{\gamma}{\gamma - 1}}$
535 (Eq. 12-17c)	$T_w - T_{sat} = 0.00135 \frac{q''}{k_\ell} \left(Re_\ell\right)^{1/2}$	$T_{sat} - T_{bulk} = 0.00135 \frac{q''}{h_{\ell o}} \left(Re_\ell\right)^{1/2}$
559 (Line 5)	p = 800 to 2000 psia	p = 800 to 2300 psia
559 (Eq. 12-62)	[(2.022 - ... exp (18.177 - ...)x_e] [(0.1484 ... 0.869x_e] [0.2664 + 0.837 exp...]	{(2.022 - ... exp [(18.177 - ...)x_e]} [(0.1484 ... 0.869x_e] [0.2664 + 0.8357 exp...]
567 (Line 7)	... needed for x, which ...	... needed for x = x_{cr}, which ...
571 (Line 10)	83:3	83:351
581 (Ex. 13-1)	Linear heat ... = 17.8	31.1
582 (Ex. 13-1)	C_p = 6.143 μ = 917	5.60 μ = 91.7
585 (Eq. 13-22)	$\sin\left(\frac{\pi Z}{L_e}\right)$	$\sin\left(\frac{\pi z}{L_e}\right)$

PAGE (Line, Fig., Eq., Ex.)	ORIGINAL	CORRECTED
587-588 (Ex. 13-2)	Change every 17.8 (q') to	31.1
	Change every 6.143 (c_p) to	5.60
	$T_m(z) = 295.9 + 9.9 \sin ...$	$305.0 + 19.0 \sin ...$
	$z_c = 0.6$	0.65
	$T_c(z_c) = 286 + 17.8(0.83 + 0.858) = 316.0^\circ C$	$286 + 31.1(0.851 + 0.836) = 341.0^\circ C$
	$z_f = 0.014$	0.015
	$T_{℄}(z_f) = 286 + 17.8 \left[0.556 \left(\sin \frac{\pi(0.014)}{3.66} + 1\right) + 45.99 \left(\cos \frac{\pi(0.014)}{3.66}\right)\right] = 1114.7^\circ C$	$286 + 31.1 \left[0.610 \left(\sin \frac{\pi(0.015)}{3.66} + 1\right) + 45.99 \left(\cos \frac{\pi(0.015)}{3.66}\right)\right] = 1735.3^\circ C$
597 (Eq. 13-45b)	$... - \left(\frac{G_m^2}{p_m^+}\right)_{in}$	$... - \left(\frac{G_m^2}{\rho_m^+}\right)_{in}$
599 (Eq. 13-53)	$\frac{1}{\left(x'^2 - x''^2\right)^{1/2}}$	$\frac{2}{\left(x'^2 - x''^2\right)^{1/2}}$
603 (Line 12)	$\frac{1}{\left(x' - x''^2\right)^{1/2}}$	$\frac{2}{\left(x'^2 - x''^2\right)^{1/2}}$
603 (Line 17)	$(0.1036^2 - 0.0862^2)^{-1/2}$	$\frac{2}{\left(0.1036^2 - 0.0862^2\right)^{1/2}}$
604 (Line 7)	$-\pi(0.794)$	$-\pi(0.793)$
604 (Line 8)	1.1362(1.277 - 0.7260)	2.276(1.277 - 0.7265)
604 (Line 9)	12.3 kPa	16.6 kPa
604 (Line 14)	$q = \dot{m}(h_{out} - h_{in})$	$\dot{q} = \dot{m}(h_{out} - h_{in})$
604 (Table 13-3)	$\Delta p_{gravity}$: 6.47, 9.07, 12.58, 15.14, 17.20, 20.51, 23.34; Δp_{total}: 16.90, 28.61, 49.61, 69.43, 88.89, 128.30, 170.10	8.81, 12.21, 16.63, 19.62, 21.83, 24.85, 26.64; 19.24, 31.71, 53.68, 73.91, 93.52, 132.7, 173.4
605 (Fig. 13-11)	Graph based on original Table 13-3 values.	Change graph according to Table 13-3 changes.
605 (Line 4)	h_{out} - 1224.1)	(h_{out} - 1224.1)
610 (Eq. 13-70)	ρ_{Z_b}	ρ_{ZB}
611 (Eq. 11-104)	x	x_e
623 (App. A-4, Δp^+)	$\frac{\Delta p}{\rho^*} gL - 1$	$\frac{\Delta p}{\rho^* gL} - 1$
625 (App. A-4)	x_{cr} Vol. II	P12-557

PAGE (Line, Fig., Eq., Ex.)	ORIGINAL		CORRECTED
628 (37)	FS	Fuel pellet ...	Delete the entire line
633 (App. B)	Electron charge	1.60210×10^{-20} emu	1.60210×10^{-19} Coulomb
637 (App. C, Table C-1)			
Col. 5, Row 1	6.214×10^{-4}		6.214×10^{-6}
Col. 5, Row 2	6.214×10^{-6}		6.214×10^{-4}
637 (App. C, Table C-2)			
Col. 6, Row 1	2.4711×10^{-3}		2.4711×10^{-8}
638 (App. C, Table C-4)			
Col. 2, Row 5	1.016		1016
Col. 2, Row 6	1.000		1000
640 (App. C, Table C-7)			
Col. 3, Row 5	1.440		1440
641 (App. C, Table C-9)			
Col. 1, Row 6	1.0133×10^{3}		1.0133×10^{6}
641 (App. C, Table C-9) Col. 2, heading	Pascal $kgm^{-1}s^{-3}$*		Pascal $kgm^{-1}s^{-2}$*
641 (App. C, Table C-10)			
Col. 4, Row 7	1.9500×10^{6}		1.9800×10^{6}
644 (App. C, Table C-14)			
Col. 6, Row 4	1.1583×10^{3}		1.1583×10^{5}
646 (App. C, Table C-18)			
Col. 1, Row 3	14.618		14.594
Col. 2, Row 3	1.4168×10^{4}		1.4594×10^{4}
Col. 3, Row 1	6.841×10^{-2}		6.852×10^{-2}
Col. 3, Row 2	6.841×10^{-5}		6.852×10^{-5}
662 (Table E-4, Col. 1 @ 2700	(1.052×10^{2})		(1.5052×10^{2})
663 (App. E, Table E-5)	All *v*		v
670 (Fig. F-2)	He graphed inproperly.		He specific heat level corrected.
672 (Line 5)	$p \left(\frac{kg}{m^3}\right)$		$\rho \left(\frac{kg}{m^3}\right)$
690 (Index)	Cladding thermal properties of, 295t ...		Cladding thermal properties of 296t, ...

- <u>PROBLEMS</u> (Answers and Statements)

PAGE (PROB. #)	ORIGINAL	CORRECTED
37 (2-3, Lines 9, 10 & 12)	$q'(z) = q'_{max}$ ... where α = 1.96. *Answer:* MCPR = 3.43	$q'(z) = q'_{ref}$ ... where α = 1.96. Determine q'_{ref} such that $q''(z)_{max}$ = 44 kW/m. *Answer:* MCPR = 1.54
72 (3.3)	Assume uniform axial power profile. 1. $\dot{Q}$ = 23.85 MW 2. $\dot{Q}$ = 24.37 MW	Assume uniform axial power prof and the slab approximation. 1. $\dot{Q}$ = 23.79 MW 2. $\dot{Q}$ = 24.39 MW
123 (4.7)	1. F_x = 1875 N, F_y = 3247.6 N 2. F_x = 833.3 N, F_y = 1443.4 N	F_x = 5625 N, F_y = -3248 N F_x = 2500 N, F_y = -1443 N
169 (5.3)	2. 4.89 m/sec 3. 1.636 m/sec	2.83 0.74
233 (6-2, Question 3)	... in the legs 3→4 ...	... in the legs 3'→4 ...
236 (6.5)	36.7% to 37.8%	36.9% to 37.7%
236 (6-6)	1. A perfect gas.	1. A perfect gas of c_p = 1.30.
287 (7.2)	Heat of fusion for water = 3.33(10^5) J	3.33(10^5) J/kg
289 (7.4)	p = 93.15	87.9
289 (7.5)	34.7˚C (94.4˚F)	35.3˚C (95.5˚F)
290 (Table 7.8)	Specified cool-down rate = 38˚C/hr (100˚F/hr) s_f = 3.1211 s_g = 2.6922 Suppression pool initial pressure = 0.1 MPa (15 psia)	(68.4˚F/hr) 3.1211 kJ/kg K 2.6922 kJ/kg K 0.1 MPa (14.5 psia)
293 (7.8)	230.2 seconds 22.16 m^3 28.81 m^3	227 22.14 28.83
339 (8.2)	0.7 T_{ci} + 0.3 T_{co} 1.73	0.7 T_{cl} + 0.3 T_f 1.67
340 (8.4)	2. T_{ave} (˚C) 1395.9 1213.9	1388 1213
409 (9.5)	$\Delta p_{friction}$ = 29.29 Δp_T = 92.71	31.17 94.59
519 (11.3)	Slug to Churn: $\{j_\ell\} + \{j_v\}$ = 0.5344	0.527
519 (11.4)	... tubes longer than about ...	... tubes with a diameter largerthan about ...

PAGE (PROB. #)	ORIGINAL	CORRECTED
521 (11.6)	$D = 3.5$ ft	2.4 ft
521 (11.7)	*Answer*: Level =	*Answer*: Level swell =
573 (12.1)	$(T_v - T_{sat})_{sodium} = 25.2$	26.1
	$(T_v - T_{sat})_{water} = 3.25$	3.15
573 (12.2)	... boiler operates at 3.34 MPa, ...	3.35 MPa
574 (12.2)	$h_{fg} = 1803$	1766
	$\rho_v = 17.3$	16.8
	$\sigma = 0.0204$	0.0286
	$k = 0.606$	0.628
	Answers: 1. N = 6	N = 6 (based on $C_1 = 0.18$ in Eq. 12-10)
	2. $q_i'' = 3.04$	4.19
574 (12.3)	H_2O at 0.1 MPa: $T_B^M - T_{sat} = 176$	156
	$T_H^M - T_{sat} = 406$	368
	H_2O at 7.0 MPa: $T_B^M - T_{sat} = 194$	1907 (too high in physical sense)
	$T_H^M - T_{sat} = 374$	2629 (too high in physical sense)
	Na at 0.1 MPa: $T_B^M - T_{sat} = 206$	87 (too low in physical sense)
	$T_H^M - T_{sat} = 1071$	771
574 (12.5)	$q''_{cr} = 1.37 \times 10^6$	1.41×10^6
615 (13.1)	1. $\dot{Q} = 6170$	5760
	2. $\dot{Q} = 4070$	3960
617 (13.4)	$\Delta p_{fric} = 13.9$	14.4
	$\Delta p_{grav} = 16.1$	15.8
	$\Delta p_{total} = 42.7$	42.9
	Martinelli-Nelson $\Delta p_{fric} = 18.0$	20.4

- SUPPLEMENT

PROBLEMS	SUPPLEMENTARY ANSWERS	REMARKS
9.6	answers for interior channels: 1. $f_{laminar} = 0.12$ 2. $f_{turbulent} = 0.02$ 3. Yes for Turbulent flow ($f \approx 0.018$ from Moody's chart) 4. Cannot compute entrance length for laminar flow in this case. 5. $Z = 11.7$ to 18.6 cm	No available equations