<div align="center">

Errata Sheet or "Humility Features"
Chemical Process Safety, Fundamentals with Applications, 4th ed., 2019
D. A. Crowl and J. F. Louvar
First printing June 2019
January 13, 2023

</div>

Page 5	2nd paragraph from bottom, 3rd line from bottom. "or control or material or energy" should be "or control of material or energy."
Page 19	Equation (1-3) – right hand side. "workers" should be "people".
Page 26	Table 1-3. Change right column table heading from "Deaths per 100,000 people" to "Deaths per 100,000 people[b]" At bottom of table add "[b]See Equation 1-3."
Page 29	Table 1-14. Item 1 on top left side of table. "Read the Category…" should be "Read the Severity Category…"
Page 30	Last line in footnote at bottom. "…*Lagging Indicator*" should be "*Lagging Indicators*"
Page 37	Table 1-18. Items in table should be numbered consecutively from 1 to 20.
Page 45	Table 1-21. Use bold text for far-left column.
Page 70	Table 2-4. "%" in formula should be "%/100".
Page 72	Top of page. Probit equation should be (%/100) instead of (%).
Page 78	Problem 2-6. Problem is not very meaningful. Replace with:
	If 500 workers in a plant are exposed to the following concentrations of ammonia for an exposure time of 2 hours, estimate the number of deaths expected for each case."
	a. 150 ppm
	b. 300 ppm
	c. 1000 ppm
	d. 2000 ppm
	If the exposure time is now 4 hours, calculate the number of deaths for each case. Comment on the effect of increasing concentration and exposure time.
Page 87	Footnote 4 at bottom of page. "*A Guide to*" should be "A Guide to". Not italics.
Page 105	Equation (3-24). The subscript on C should be PPM, not PPm.
Page 124	Figure 4-4. "π = Liquid Density" should be ρ "= Liquid Density"
	Equation 4-3 should be $\dfrac{\Delta P}{\rho} + F = C_1^2\left(\dfrac{\Delta P}{\rho}\right)$
Page 125	Equation 4-7. The Greek μ on the left hand side should be a $\bar{u}$.
Page 131	Right hand side of Equation 4-28. m should be $\dot{m}$.
Page 133	Figure caption: Remove everything within the parenthesis. The figure was drawn using the Chen equation, Equation (4-37).
Page 137	Example 4-3. Just below Solution heading. Keep only 1st sentence and delete 2nd sentence and equation. Retain figure at bottom of page.
Page 138	Towards bottom after "and it follows that". Right hand side of equation $\bar{u}^2$ should be $\dfrac{\bar{u}^2}{g_c}$.
Page 141	Sentence below Equation (4-45). "T_o is the temperature" should be "T_o is the absolute temperature."
Page 141	Equation (4-48). Exponent on right hand term should be divided by γ not y.

Page 143	Variable list below Equation (4-50). "T_o is the temperature" should be "T_o is the absolute temperature."
Page 149	Equation (4-65). P_{choked} should be ρ_{choked}
	2nd paragraph below Equation (4-67). "and temperature" should be "and absolute temperature"
Page 151	Figure 4-13. Y-axis title. $\left(P_1 - P_2\right)P_1$ should be $\left(P_1 - P_2\right)/P_1$
Page 153	1/3 of the way down. $\delta W_{s=0}$ should be $\delta W_s = 0$.
Page 155	Table 4-5. *Pressure Drop Ratio* should not be italicized.
Page 156	Figure 4-17. Y-axis title. $\left(P_1 - P_2\right)P_1$ should be $\left(P_1 - P_2\right)/P_1$
Page 160	Towards the end of the part b solution for Example 4-5. The number "8.56" in the equation should be "8.52" to be consistent with the number computed at the top of the page.
Page 161	Sentence after Q_m calculation: "Figure 4-15" should be "Figure 4-17.
	Sentence after pressure drop calculation. "Figure 4-16" should be "Figure 4-18."
	Table at end of Example 4-5. Under item b, for "Simplified" case, 113.4 should be 49.4.
Page 165	Bottom of page. "A mass velocity" should be "A mass flux".
Page 168	Variable list below Equation (4-106). "T_L is the temperature" should be "T_L is the absolute temperature"
Page 170	Table 4-6. Under "Vessels" Last sentence under "Guideline" should be "Use the Process Pipes criteria above."
Page 173	Problem 4-3. 2nd line. "20-m^2" should be "20-m square"
Page 176	Equation with problem 4-17. $-u$ should be u without minus sign.
Page 194	Equation 5-31. Delete "u" in denominator.
Page 196	Part b solution to Example 5-1.
	Table 5-3 should be Table 5-2.
	100 kg/s in solution using Equation 5-21 should be 10.0 kg/s
	Calculated concentration is then 5.17×10^{-3} kg/m^3 $= 5.17$ mg/m^3
	Last line in part b should be 37.8 ppm.
Page 227	Equations (6.2) and (6.3) should be (6-2) and (6-3)
Page 254	Table 6-6. 4th column from left. "Senecalz" should be "Senecal". Also "beaulieu" should be "Bealieu" in two places.
Page 272	Variable list under Equation (6-36). "T_1 is the ambient temperature" should be "T_1 is the absolute temperature".
Page 275	Example 6-13. Problem statement. "15 m" should be "150 m"
Page 283	2nd line from bottom. "Acceptable" should be "Accepted".
Page 309	Example 7-4. The data listed should include "Tank volume: 300 gal"
Page 311	2nd line of text: Equation 7-26 should be Equation 7-27.
	3rd line of text below **Method 2**: Equation 7-28 should be Equation 7-29.
	5th line of text below **Method 2**:
	"Substitution into Equation 7-28" should be "Substitution into Equation 7-29"
	Further on down page: "determined using Equation 7-20" should be "determined using Equation 7-21"
Page 312	Method 2 calculation. First equation answer should be 120 s.
	For the next line replace 160 s with 120 s. Answer is 6.78×10^{-5} coulombs.

For the 3rd line replace 9 by 6.78. Answer should be 23 J.

Page 314	Last line in Example 7-5: "Table 7-5" should be "Table 7-6"

Page 314   Last line in Example 7-5: "Table 7-5" should be "Table 7-6"

Page 360   Figure 8-7. X-axis. The variable B should be italicized, B.

Page 363   The lettering "**c.**" should be on first line at top of page.
            Present "**c.**" should be "**d.**"
            Present "**d.**" should be "**e.**:

Page 367   Change x-axis title to: $Bx/(1+Bx)=(T-T_o)/T$

            On y-axis. T_o should be just T.

Page 371   Item 2 towards bottom of page. Last two sentences should be "If the peaks occur at the same time then the system is hybrid. If the peaks do not occur at the same time then the system is gassy."

Page 377   Problem 8-7, last line of text. $x_m = 5\ 0$ should be $x_m = 0$

Page 405   Arrange Table 9-7 from highest to lowest heat intensity.
            Left hand column should be, from top to bottom: 5300, 3000 – 4000, 2000, 350.
            Rearrange right hand side accordingly.

Page 413   3rd line below heading for section 10-1. "In the table, the accumulated pressure …" should be "In the table, the maximum accumulated pressure…"

Page 416   Equation (10-5).

Page 417   Item 2 on list. Replace last sentence with "For balanced bellows valves consult the manufacturer, otherwise, use Figure 10-2 as an estimate."

Page 418   Replace 1st sentence in caption on Figure 10-2 with "Backpressure correction K_b for balanced bellows reliefs in liquid service with backpressures up to 50% of set pressure."

Page 421   Replace first sentence in last paragraph at bottom. "Manufacturers do not provide relief devices to the nearest 0.01 in." should be "Relief devices are provided by the manufacturer in standard, fixed sizes."

Page 423   In the nomenclature definitions under Equation (10-12). Change "P is the upstream relieving pressure, equal to the set pressure plus the allowable overpressure" to "P is the maximum relieving pressure, equal to the set pressure plus the allowable overpressure (see Example 10-1)"

Page 424   First line below "Steam Flow Relief Sizing". "steam a well known" should be "steam are well known"

Page 425   Example 10-4: Change the first paragraph of the solution to: "From Table 10-1, the maximum set pressure is equal to the vessel MAWP at 3.0 barg. The maximum relieving pressure is 1.10 x 3.0 barg = 3.3 barg = 4.3 bara (see Example 10-1).

Page 426   Second paragraph from top of page.   "The maximum accumulated pressure .." should be "The maximum relieving pressure …"
            6th text line from bottom of page. Figure 10-6 should be Figure 10-5.
            Last sentence on bottom of page should be replaced by: "The pressure, P is the upstream relieving pressure, which is the maximum accumulated pressure. From Table 10-1 this is 3.0 barg × 1.10 = 3.3 barg = 4.31 bara."

Page 427   4.51 bara in computation should be 4.31 bara. The computed vent area is then $2.06 \times 10^{-2}\ m^2$. Replace 1.97 in final calculation with 2.06. Answer is still the same.
            Example 10-5 at bottom of page. Replace 1.97 from previous example with 2.06. The area is then $3.24 \times 10^{-2}\ m^2$. Replace 3.05 in final calculation with 3.24. Answer is 0.0203 m =

	20.3 cm.
Page 431	3rd text line from top: Equation 4-103: should be Equation 10-17:
Page 432	Example 10-6. Physical Property Data table. "Bar" should be "bar" in 2 places.
Page 433	Middle of page. "0.084m²" should be "0.084 m²"
	Equation under "The required relief diameter is". 314 should be 3.14.
Page 449	Replace Problem 10-1 with the problem below to make the problem more meaningful.

10-1. Fill in the blanks in the table. The numbers are gauge pressure units, either psig or barg.

	Relief Configuration	Vessel MAWP	Set Pressure	Maximum Set Pressure	Maximum Accumulated Pressure	Allowable Overpressure
a.	Single relief, nonfire	100	100	**100**	**110**	**10**
b.	Single relief, nonfire	100	90	**100**	**110**	**20**
c.	Primary relief, nonfire	100	100	**100**	**116**	**16**
	Secondary relief, nonfire	-	-	**105**	**116**	**11**
d.	Single relief, fire	100	100	**100**	**121**	**21**
e.	Single relief, fire	100	90	**100**	**121**	**31**
f.	Primary relief, fire	100	100	**100**	**121**	**21**
	Secondary relief, fire	-	-	**105**	**121**	**16**
g.	Primary relief, fire	100	100	**100**	**121**	**21**
	Supplemental relief, fire	-	-	**110**	**121**	**11**

Page 450	Example 10-2. The pump capacities for parts c and d are much too large. For part c use 0.5 m³/hr and for part d use 0.7 m³/hr.
	Example 10-4. The liquid flows for parts c and d are much too large. For part c use 0.5 m³/hr and for part d 1.0 m³/hr.
Page 451	The table for problem 10-6 has units missing for the liquid-specific volume. The English \ units for parts a and b are ft³/lb$_m$ while the metric units for parts c and d are m³/kg.

Professor Ron Willey of Northeastern has suggested the following improvements in this problem to make the problem more realistic. The changes are shown below.

Case:	a	b	c	d
Reaction mass	10,000 lb$_m$	10,000 lb$_m$	4000 kg	4000 kg
Volume	200 ft³	500 ft³	15 m³	500 m³
Set pressure	100 psia	100 psia	3.7 bara	3.7 bara
Set temperature	500°F	500°F	452 K	452 K
$(dT/dt)_s$	0.5°F/s	0.5°F/s	0.38 K/s	0.38 K/s
Maximum pressure	120 psia	120 psia	3.83 bara	3.94 bara
Maximum temperature	520°F	520°F	456.25 K	460.5 K
$(dT/dt)_m$	0.66°F/s	0.66°F/s	0.422 K/s	0.5 K/s
Liquid-specific volume	0.02 ft³/lb$_m$	0.02 ft³/lb$_m$	0.0014 m³/kg	0.0014 m³/kg
Vapor-specific volume	1.4 ft³/lb$_m$	1.4 ft³/lb$_m$	0.0975 m³/kg	0.0975 m³/kg

	Heat capacity	1.1 Btu/lb$_m$°F	1.1 Btu/lb$_m$°F	2.5 kJ/kg K	2.5 kJ/kg K
	Heat of vaporization	130 Btu/lb$_m$	130 Btu/lb$_m$	300 kJ/kg	300 kJ/kg

Professor Willey also provides the following solutions.

The computations are similar to the part c and d solutions in the solutions manual.

	Prob10-6a	Prob10-6b	Units	revised 10-6c	revised 10-6d	Units
Phi, figure 10-7, page 430, use 1	1	1		1	1	
ΔH_v, J/kg, or BTU/lb	130	130	BTU/lb	300000	300000	J/kg
v_{fg}, m^3/kg or ft^3/lbm	1.38	1.38	ft^3/lb	0.0961	0.0961	m^3/kg
g_c, 1 SI, 25036 lb$_m$ ft^2/BTU s^2	25036	25036		1	1	
T_s, Temperature at Set Pressure, K or °R	960	960	°R	452	452	K
C_p, J/kg K or BTU/lb$_m$ °R	1.1	1.1	BTU/lb$_m$ F	2500	2500	J/kg/C
G_T, mass velocity, kg/s m^2 or lb/s ft^2	412.8167	412.8167	lb/ft^2 s	2643.024	2643.024	kg s m^2
dT/dt at set point, K/s or °R/s	0.5	0.5	°R/s	0.38	0.38	
dT/dt at max press, K/s or °R/s	0.66	0.66	°R/s	0.422	0.5	
q, J/kg s or BTU/lb$_m$ hr	0.638	0.638	BTU/lb s	1002.5	1100	J/kg/s
Mass in vessel, kg or lb$_m$	10000	10000	lb$_m$	4000	4000	kg
Volume of vessel, m^3 or ft^3	200	500	ft^3	15	500	m^3
ΔT, temperature difference between set and max	20	20	°R	4.25	8.5	
Energy removed by vaporization (V ΔH/m v_{fg})	1.884058	4.710145	BTU/lb	11706.56	390218.5	J/kg
Energy removed by sensible heat (Cv ΔT)	22	22	BTU/lb	10625	21250	J/kg
Area m^2 or ft^2	0.420421	0.328342	ft^2	0.03399	0.002805	m^2
Diameter, m or inch	8.779678	7.758887	inches	0.208032	0.059757	m

Problem 10-7 should be the following:

10-7. Determine the deflagration vent size for the following structures.

Vapors	**a**	**b**	**c**	**d**
Internal area of structure:	1000 ft^2	1000 ft^2	300 m^2	300 m^2
Turbulent augmentation factor, λ :	1.0	1.5	1.0	1.5
Max. internal pressure, P_{red} :	0.05 bar	0.10 bar	0.05 bar	0.10 bar
Gas:	Methane	Hydrogen	Methane	Hydrogen

Dusts	**e**	**f**	**g**	**h**
Volume of structure:	1000 ft^3	1000 ft^3	30 m^3	30 m^3
Deflagration index, K_{St}, bar m/s:	200	300	200	300
Opening pressure of vent, P_{stat}:	3 psig	6 psig	0.2 barg	0.4 barg
Max. pressure of unvented, P_{max}:	150 psig	200 psig	10 barg	15 barg
Max internal pressure, P_{red}:	6 psig	8 psig	0.4 barg	0.6 barg

Page 476   4th line from top. Replace the sentence beginning with "The final column lists …" with "The final column lists the recommendations / actions required. Recommendations are to add new barriers. Actions address information needs for completing the HAZOP."

Page 477   Table 11-10.
             At top of table. Both Project Name and Process should reference Example 11-2, not 11-4.
             At top of table. Section should refer to Figure 11-6, not "example 11-6."
             Replace final column name "Action required" with "Recommendations / Actions"

Page 493   Example 12-2. Change "This system is activated at a pressure somewhat higher than the alarm system and consists of a pressure switch connected to a solenoid valve in the reactor feed line" to "This system is activated at a pressure somewhat higher than the alarm system and consists of a pressure controller connected to a solenoid valve in the reactor feed line"

Page 494   Table with solution to Example 12-2. Change "1. Pressure switch 1" to "Pressure switch". Change "3. Pressure switch 2" to "3. Pressure controller".

Page 509   Example 12-5. Bottom paragraph in example. Change "The alarm indicator can fail by a failure of either pressure switch 1 or the alarm indicator light. These must be connected by an OR gate. The emergency shutdown system can fail by a failure of either the pressure switch 2 or the solenoid valve." to "The alarm indicator can fail by a failure of either the pressure switch or the alarm indicator light. These must be connected by an OR gate. The emergency shutdown system can fail by a failure of either the pressure controller or the solenoid valve."

Page 510   Figure 12-14. Change at bottom on left hand side "Pressure Switch 1 Failure" to "Pressure Switch Failure". Change at bottom on 2nd circle from right hand side "Pressure Switch 2 Failure" to "Pressure Controller Failure".

Page 520   Table 12-4. Bottom line. Middle column text should extend completely over to the right hand side to imply that these standards must be consulted for PFD values.

Page 523   Item 4 in list at top of the page. Replace with:
             4. Safety Instrumented System (SIS): The SIS is separate from the BPCS and consists of multiple Safety Instrumented Functions (SIF), designed to achieve a specific SIL. The SIS consists of the SIFs and all associated field sensors, logic solver, final control elements, etc. The purpose of the SIF is to isolate the threat and put the **unit** in a safe state - this may or may not include shutting down the process.

Page 524   Item 7 on list. "as low as reasonably possible" should be "as low as reasonably practicable".

Page 536   Last line on bulleted list. Change "Are often very dirty" to "Are often *dirty* since they *soil* everything they touch meaning they have a widespread effect"

Page 530   Homework problem 12-1 is identical to combined examples 12-2 and 12-5. Example 12-2 does the numerical calcs and Example 12-5 draws the fault tree which is shown in Figure 12-14. So this homework problem is meaningless.

Page 601   Change table to the following, maintaining format in book. Add J for power.

	First Letter		Succeeding Letters		
	Measured or Initiating Variable	Modifier	Readout Function	Output Function	Modifier
A	Analysis		Alarm		
C				Control	Closed
D	Density	Differential			
F	Flow	Ratio			
H	Hand				High
I	Current		Indicate		
J	Power	Scan			
L	Level		Light		Low
P	Pressure, vacuum				
Q	Quantity	Totalize			
R	Radiation		Record		
S	Speed	Safety		Switch	
T	Temperature			Transmit	
V	Vibration			Valve, damper	
Z	Position			Actuator	

Also, please place a light horizontal line between every third element in table to improve readability.

Add the following to the list below the table:

PV: Pressure valve
PSV: Pressure safety valve
PAL: Pressure alarm low
PAH: Pressure alarm high
HV: Hand valve or manual valve

Page 621   RAGAGEP near bottom of right hand column should be:
     "Recognized and Generally Accepted Good Engineering Practices"

Page 626   Index. Middle of page in right hand column. "Texas Refinery explosion" should be "Texas fertilizer plant explosion."