Changes to
FE Reference Handbook 10.2
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Errata posted June 10, 2022

Errata below has been corrected in *FE Reference Handbook* 10.2.
The exam will be administered using the updated version of the handbook.

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UNITS AND CONVERSION FACTORS

p. 3

Added revolution (rev) and RPM (revolution per minute) to table.

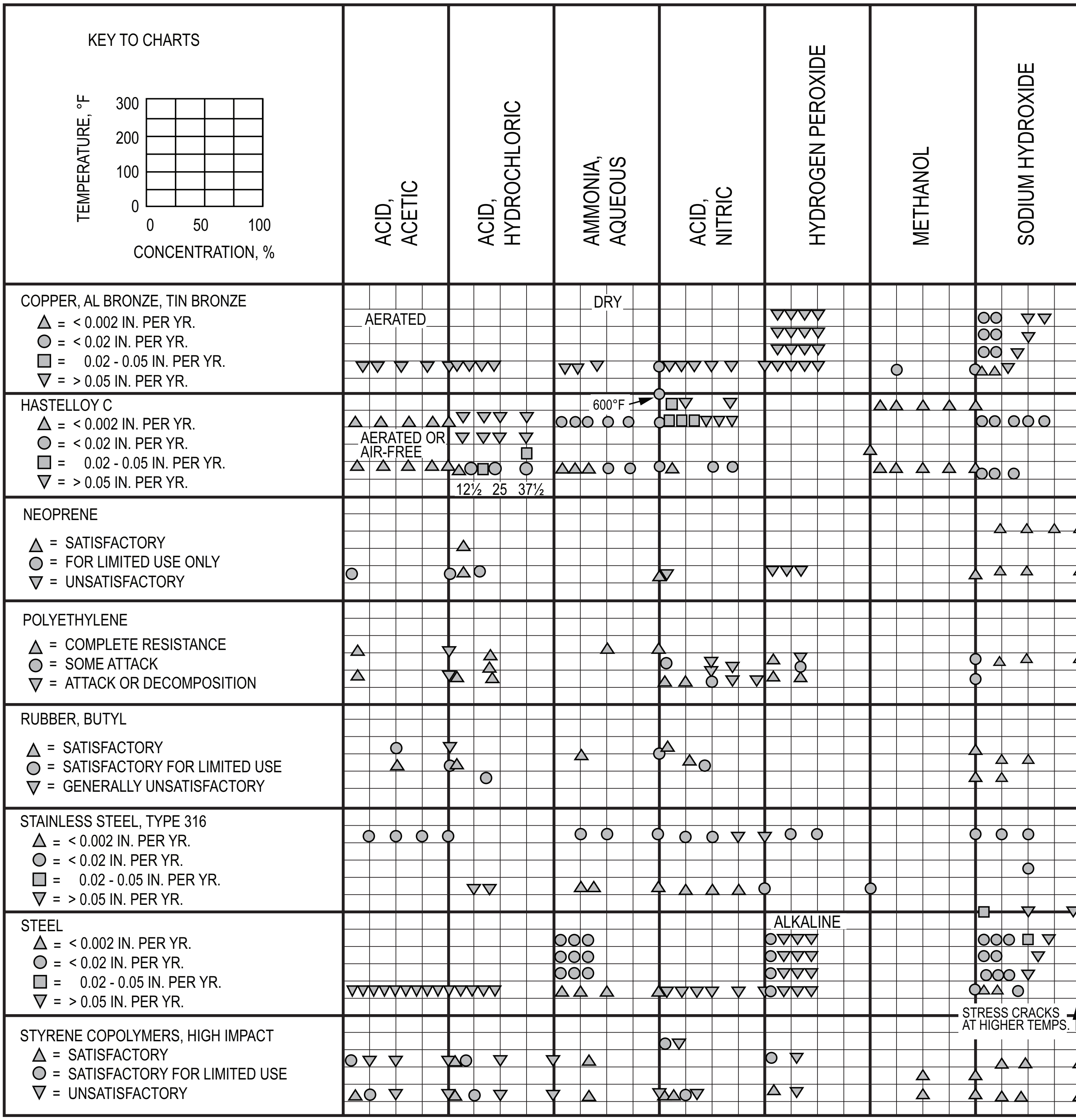
Multiply	By	To Obtain
radian (rad)	$180/\pi$	degree
revolution (rev)	$2 \times \pi$	radian
rpm (revolutions per minute)	$2 \times \pi/60$	radian/second

SAFETY

p. 26

Updated table and added a note.

Detailed Corrosion Data on Construction Materials



Note: Symbols on vertical heavy lines represent 100% concentration. Symbols on horizontal heavy lines represent 300°F temperature.

Adapted from Perry, Robert H., and Don Green, *Perry's Chemical Engineers' Handbook*, 6 ed, New York: McGraw-Hill, 1963, pp 23-13-23-30.

ENGINEERING PROBABILITY AND STATISTICS p. 69

Updated the variable definitions for the least squares equation.

Linear Regression and Goodness of Fit

Least Squares

$$\hat{y} = \hat{a} + \hat{b}x$$

where

$$\hat{b} = S_{xy}/S_{xx}$$

$$\hat{a} = \bar{y} - \hat{b}\bar{x}$$

$$S_{xy} = \sum_{i=1}^{n} x_i y_i - (1/n)\left(\sum_{i=1}^{n} x_i\right)\left(\sum_{i=1}^{n} y_i\right)$$

$$S_{xx} = \sum_{i=1}^{n} x_i^2 - (1/n)\left(\sum_{i=1}^{n} x_i\right)^2$$

$$\bar{y} = (1/n)\left(\sum_{i=1}^{n} y_i\right)$$

$$\bar{x} = (1/n)\left(\sum_{i=1}^{n} x_i\right)$$

where

n = sample size

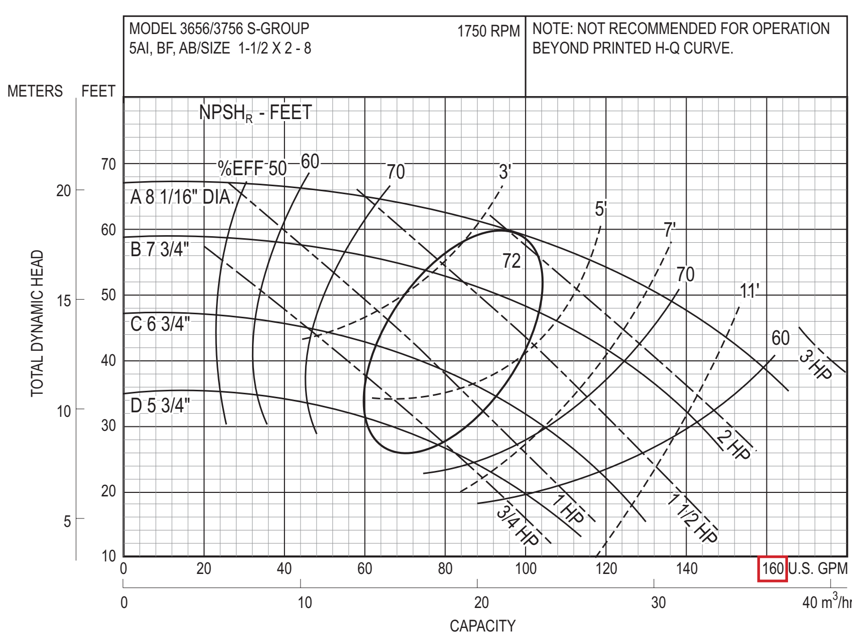
FLUID MECHANICS

p. 191

Updated the y axis on the graph, changing 100 to 160.

Fluid Flow Machinery

Centrifugal Pump Characteristics



CENTRIFUGAL PUMP CURVE FOR A GOULD MODEL 3656/3756 PUMP

Aerodynamics

Airfoil Theory

pp. 198–199

Updated the equation and variables for the aspect ratio AR.

$$AR = \frac{b^2}{A_p}$$

where

b = span length

A_p = plan area

CIVIL ENGINEERING

p. 276

Moved table from Unified Design Provisions to just under Beams—Shear.

Beams—Shear

<table>
<tr><th></th><th>$\frac{\phi V_c}{2} < V_u \le \phi V_c$</th><th>$V_u > \phi V_c$</th></tr>
<tr><td>Required spacing</td><td>Smaller of:
$s = \frac{A_v f_y}{50 b_w}$
$s = \frac{A_v f_y}{0.75 b_w \sqrt{f_c'}}$</td><td>$V_s = \frac{V_u}{\phi} - V_c$
$s = \frac{A_v f_y d}{V_s}$</td></tr>
<tr><td rowspan="2">Maximum permitted spacing</td><td rowspan="2">Smaller of:
$s = \frac{d}{2}$
OR
$s = 24"$</td><td>$V_s \le 4\, b_w\, d \sqrt{f_c'}$
Smaller of:
$s = \frac{d}{2}$ OR
$s = 24"$</td></tr>
<tr><td>$V_s > 4\, b_w\, d \sqrt{f_c'}$
Smaller of:
$s = \frac{d}{4}$
$s = 12"$</td></tr>
</table>

pp. 303–304

Basic Freeway Segment Highway Capacity

Reorganized this section and replaced tables.

Parameters for Speed-Flow Curves for Basic Freeway Segments

Parameter	Definition and Units	Basic Freeway Segments
FFS	Base segment free-flow speed (mph)	Measured *or* predicted with equation
FFS_{adj}	Adjusted free-flow speed (mph)	$FFS_{adj} = FFS \times SAF$
SAF	Speed adjustment factor (decimal)	$SAF = 1.00$ for base conditions
c	Base segment capacity (pc/h/ln)	$c = 2{,}200 + 10(FFS - 50)$ $c \leq 2{,}400$ $55 \leq FFS \leq 75$
c_{adj}	Adjusted segment capacity (pc/h/ln)	$c_{adj} = c \times CAF$
CAF	Capacity adjustment factor (decimal)	$CAF = 1.00$ for base conditions
D_c	Density at capacity (pc/mi/ln)	45
BP	Breakpoint (pc/h/ln)	$BP_{adj} = [1{,}000 + 40 \times (75 - FFS_{adj})] \times CAF^2$
a	Exponent calibration parameter (decimal)	2.00

Adapted from *HCM: Highway Capacity Manual, 6th ed., A Guide for Multimodal Mobility Analysis*, Transportation Research Board of the National Academies, Washington, DC, 2016.

where
pc/h/ln = passenger cars per hour per lane

$$S = FFS_{adj} \qquad v_p \leq BP$$

$$S = FFS_{adj} - \frac{\left(FFS_{adj} - \frac{c_{adj}}{D_c}\right)\left(v_p - BP\right)^a}{\left(c_{adj} - BP\right)^a} \qquad BP < v_p \leq c$$

$$FFS = \text{BFFS} - f_{LW} - f_{RLC} - 3.22\ TRD^{0.84}$$

where

FFS = free flow speed of basic freeway segment (mph)
BFFS = base free flow speed of basic freeway segment (mph); default is 75.4 mph
f_{LW} = adjustment for lane width (mph)
f_{RLC} = adjustment for right-side lateral clearance (mph)
TRD = total ramp density (ramps/mi)

Adjustment to FFS for Average Lane Width for Basic Freeway and Multilane Highway Segments

Average Lane Width (ft)	Reduction in FFS, f_{LW} (mph)
≥12	0.0
≥11 – 12	1.9
≥10 – 11	6.6

HCM: Highway Capacity Manual, 6th ed., A Guide for Multimodal Mobility Analysis, Transportation Research Board of the National Academies, Washington, DC, 2016, Exhibit 12-20, p. 12-29.

Adjustment to FFS for Right-Side Lateral Clearance, f_{RLC} (mph), for Basic Freeway Segments

Right-Side Lateral Clearance (ft)	Lanes in One Direction			
	2	3	4	≥5
≥6	0.0	0.0	0.0	0.0
5	0.6	0.4	0.2	0.1
4	1.2	0.8	0.4	0.2
3	1.8	1.2	0.6	0.3
2	2.4	1.6	0.8	0.4
1	3.0	2.0	1.0	0.5
0	3.6	2.4	1.2	0.6

HCM: Highway Capacity Manual, 6th ed., A Guide for Multimodal Mobility Analysis, Transportation Research Board of the National Academies, Washington, DC, 2016, Exhibit 12-21, p. 12-29.

$$v_p = \frac{V}{PHF \times N \times f_{HV}}$$

where

v_p = demand flow rate under equivalent base conditions (pc/h/ln)
V = demand volume under prevailing conditions (veh/h)
PHF = peak-hour factor
N = number of lanes in analysis direction
f_{HV} = adjustment factor for presence of heavy vehicles in traffic stream, calculated with

$$f_{HV} = \frac{1}{1 + P_T\left(E_T - 1\right)}$$

where

f_{HV} = heavy-vehicle adjustment factor
P_T = proportion of single unit trucks and tractor trailers in traffic stream
E_T = passenger-car equivalent (PCE) of single unit truck or tractor trailer in traffic stream

Vehicle	PCE by Type of Terrain	
	Level	Rolling
E_T	2.0	3.0

$$D = \frac{v_p}{S}$$

where

D = density(pc/mi/ln)
v_p = demand flow rate (pc/h/ln)
S = mean speed of traffic stream under base conditions (mph)

Level of Service (LOS)	Density (pc/mi/ln)
A	≤11
B	>11 – 18
C	>18 – 26
D	>26 – 35
E	>35 – 45
F	Demand exceeds capacity >45

p. 308

Earthwork formulas

Inserted the Mass Haul Diagram.

Average End Area Formula

$V = L(A_1 + A_2)/2$

Prismoidal Formula

$V = L\ (A_1 + 4A_m + A_2)/6$

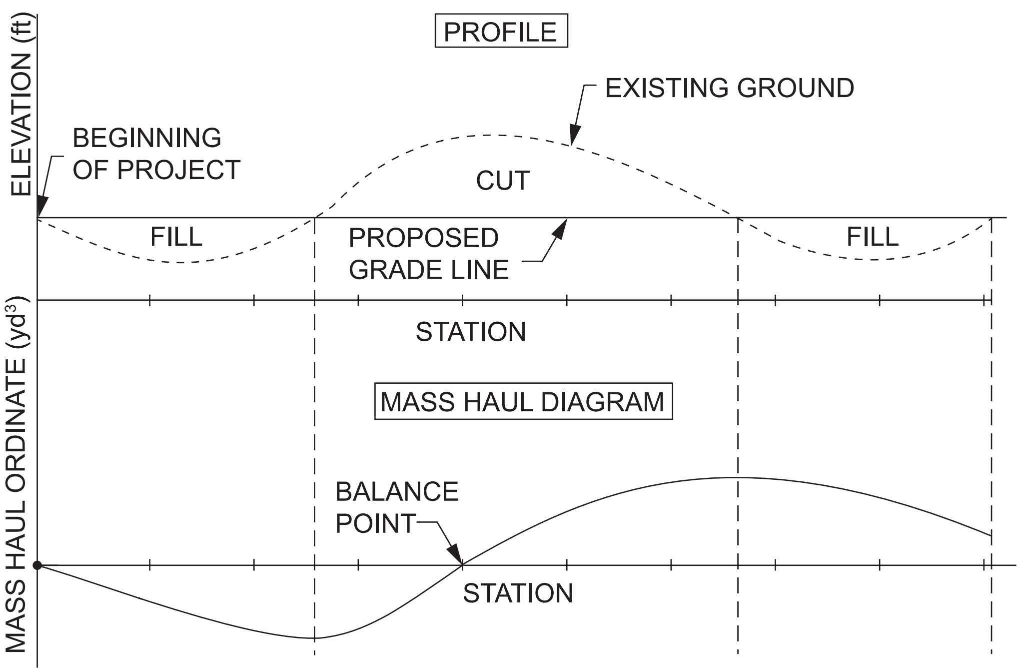
where

A_m = area of mid-section

L = distance between A_1 and A_2

Pyramid or Cone

$V = h$ (area of base)/3



Mass haul ordinate is the cumulative total of excavation and embankment at a given station.

Earthwork may be adjusted to account for shrinkage by increasing fill at each station by the shrinkage factor.

ELECTRICAL AND COMPUTER ENGINEERING

p. 366

Reworded the AC Machines section.

AC Machines

The synchronous speed n_s for ac motors is given by

$$n_s = 120f/p$$

where

f = the line voltage frequency (Hz)

p = the number of poles

MECHANICAL ENGINEERING

p. 442

Updated the ASME standard as shown.

Geometric Dimensioning and Tolerancing (GD&T)

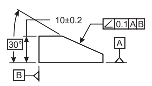
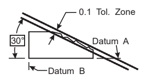
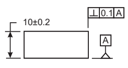
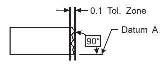
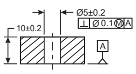
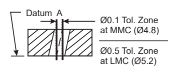
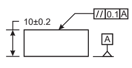
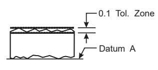
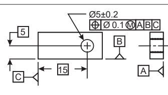
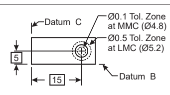
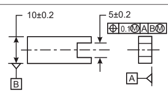
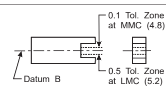
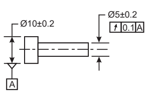
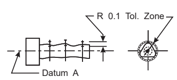
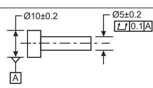
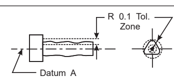
Feature Control Frame

From the ASME Y14.5 standard: "A feature control frame is a rectangle divided into compartments containing the geometric characteristic symbol followed by the tolerance value or description, modifiers, and any applicable datum reference features."

p. 445

Removed Concentricity and Symmetry from the table in the Location section.

Geometric Dimensioning and Tolerancing (GD&T) (continued)

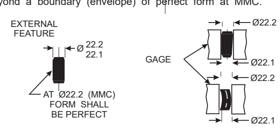
Tolerance Types	ASME Symbol	Drawing Callout Example	Drawing Callout Meaning	Tolerance Zone Definition (for Example)	Zone Modifiers Allowed	Datums Used	Additional Comments
Orientation	∠ Angularity			Parallel planes, at a specified basic angle from a datum plane(s) within which all surface elements must lie	No (Surface)	Yes	☐ Also controls surface flatness. ☐ A basic angle must be used from the toleranced feature to the datum referenced. ☐ MMC can be used when angularity is applied to an axis or centerplane of a feature.
	⊥ Perpendicularity			Parallel planes, at 90 degrees basic (perpendicular) to a datum plane(s) within which the elements of a surface must lie	No (Surface)	Yes	☐ A refinement of size. ☐ Also controls surface flatness.
				Cylindrical boundary, at 90 degrees basic (perpendicular) to a datum plane within which the axis of the feature must lie	Yes (Axis)	Yes	☐ Not a refinement of size. ☐ Hole must also be within size limits. ☐ Calculation
	// Parallelism			Parallel planes, parallel to a datum plane (or axis) within which the elements of a surface must lie	No (Surface)	Yes	☐ Refinement of size. ☐ Also controls surface flatness. ☐ Can be applied to an axis of a feature in which the zone could be parallel planes or a cylindrical tolerance zone. ☐ MMC can be used when parallelism is applied to an axis or centerplane of a feature.
Location	⌖ Position			Cylindrical boundary, within which the center axis of a cylindrical feature of size is permitted to vary from the true (theoretically exact) position	Yes	Yes	☐ Primary control for features of size. ☐ Tolerance zone also defines the limits of variation in attitude (perpendicularity) of the axis of a cylinder or slot in relationship to a datum(s). ☐ Where feature control frames contain the same datums in the same order of precedence with the same modifying symbols, they are considered a single composite pattern. If not required, it must state 'SEPARATE REQUIREMENT.'
				Parallel planes, within which the center plane of a slot is permitted to vary from the true (theoretically exact) position	Yes	Yes	
Runout	↗ Circular Runout			Two concentric circles, within which each circular element must lie in relationship to the datum axis	No	Yes	☐ An axis to surface control. ☐ A composite control which includes roundness and axis offset. ☐ Applies to each circular element independently. ☐ Datum applied on an RFS basis only.
	⌰ Total Runout			Two concentric cylinders, within which all circular elements must lie (simultaneously) in relationship to the datum axis	No	Yes	☐ An axis to surface control. ☐ Provides composite control of all surface elements. Used to control cumulative variations of circularity, straightness, taper, and axis offset. ☐ Datum applied on an RFS basis only.

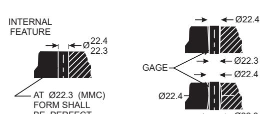
Rule #1

Individual Feature of Size

Where only a tolerance of size is specified, the limits of size of an individual feature prescribe the extent to which variations in its geometric form, as well as size, are allowed.

Variations of Form (Envelope Principle) A feature shall not extend beyond a boundary (envelope) of perfect form at MMC.





Variations of Size

The actual local size of an individual feature at each cross section shall be within the specified tolerance of size.

Perfect Form at MMC Not Required

Where it is desired to permit a surface or surfaces of a feature to exceed the boundary of perfect form at MMC, a note such as PERFECT FORM AT MMC NOT REQUIRED is specifiied.

Rule #2

All Applicable Geometric Tolerances

RFS applies, with respect to the individual tolerance, datum reference, or both, where no modifying symbol is specified. MMC and LMC must be specified on the drawing where it is required.

Courtesy of Dr. Greg Hetland, International Institute of Geometric Dimensioning & Tolerancing, www.iigdt.com.