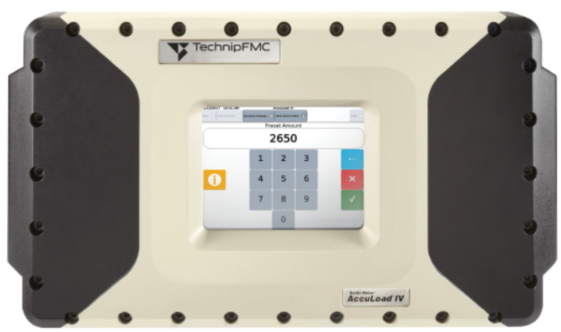
Smith Meter® AccuLoad®

Calculations

Bulletin TP06004 Issue/Rev. 0.5 (1/24)



Important

All information and technical specifications in this document have been carefully checked and compiled by the author; however, we cannot completely exclude the possibility of errors. TechnipFMC is always grateful to be informed of any errors; contact us at TechnipFMC.com.

Caution

The default or operating values used in this document and in the configuration parameters of the AccuLoad are for factory testing only and should not be construed as default or operating values for your metering system. Each metering system is unique and each configuration parameter must be reviewed and programmed for that specific metering system application.

Disclaimer

TechnipFMC hereby disclaims all responsibility for damages, including but not included to consequential damages arising out of or related to the inputting of incorrect or improper program or default values entered in connection with the AccuLoad.

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Literature Library
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Contents

1 Volume Calculations

- Volume calculations for indicated volume:

$$\text{Indicated Volume} = \frac{\text{Input Pulses}}{\text{K Factor}}$$

- Volume calculations for gross volume:

$$\text{Gross Volume} = \frac{\text{Meter Factor x Input Pulses}}{\text{K Factor}}$$

- Volume calculations for gross at standard temperature (GST) volume:

$$\text{GST Volume} = \frac{\text{CTL x Meter Factor x Input Pulses}}{\text{K Factor}}$$

- Volume calculations for gross standard volume (GSV) volume:

$$\text{GSV Volume} = \frac{\text{CTPL x Meter Factor x Input Pulses}}{\text{K Factor}}$$

1 Mass Calculations

A. Mass = Gross Volume x Observed Density

or

Mass = GST x Reference Density

Mass = GSV x Reference Density (if pressure is used)

B. Mass calculation using reference density

1. Program entry conditions

   a. A non-zero reference density entry

   b. Valid density units select entry

   c. Valid entries for GST compensation (GSV if pressure is used)

   d. Mass units

2. Hardware conditions

   a. A temperature probe installed

   > Note: Maintenance temperature may be used instead of a temperature probe.

3. Definition

   With this method the reference density and GST volume are used to calculate the mass. Therefore, the reference density program code must contain a non-zero entry, temperature must be installed, and GST compensation must be available. If pressure is used, GSV is used and must be available.

4. Calculation method

   Mass = GST Volume × Reference Density

   Mass = GSV Volume x Reference Density (if pressure is used)

C. Mass calculation using a densitometer

1. Program entry conditions
   a. Valid density units select entry
   b. Valid densitometer configuration entries
   c. Mass units
2. Hardware conditions
   a. A densitometer installed
3. Definition

   This method uses the densitometer input as the line density for calculating mass totals
4. Calculation method

$$\text{Mass} = \text{Gross Volume} \times \text{Observed Density}$$

1.1 Density Calculation

The density values derived from the API calculations are “in vacuo” values. If live density is used, the reference density calculated is “in vacuo.” Also, if a reference density for a fluid is entered into the AccuLoad (even tables), it should be an “in vacuo” value. If mass is calculated by the AccuLoad using the reference density and volume, the mass would also be “in vacuo.”

According to API ASTM D 1250-04, pure fluid densities used in the calibration of densitometers are based on “weight in vacuo” and the readings obtained from such calibrations are also “in vacuo” values. The standard also states that all densities used in the API standard are “in vacuo” values.

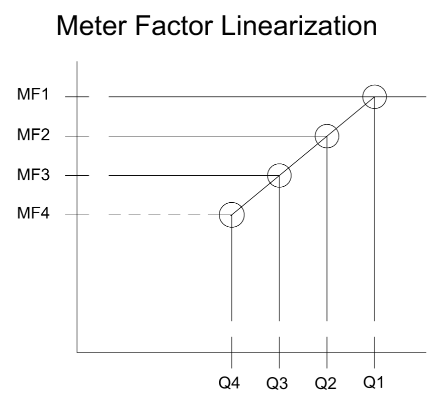
1 Meter Factor Linearization Calculations

The non-linearity of the meter calibration curve for each product can be approximated through use of a linearization method by entering meter factors at up to four different flow rates.

The meter factors used will be determined from a straight line interpolation of the meter factor and its associated flow rate.

Graphically, the linearization method used can be represented as a point slope function between points as shown below:

Figure 1: Meter Factor versus Flow Rate:



where:

- MF1, MF2, MF3, MF4 = meter factors 1, 2, 3, and 4
- Q1, Q2, Q3, Q4 = associated flow rates 1, 2, 3, and 4

The number of factors used is determined by the programming. Up to four factors are available at corresponding flow rates. See the meter factors and flow rate program codes.

The input meter pulses may also be monitored by the unit to verify the integrity of the meters and transmitters. This is accomplished through pulse comparator circuitry. The pulse comparator verifies the integrity of the meter and the voltage sense verifies the integrity of the transmitter. The type and resolution of the pulse input stream to the unit is also programmable.

The input resolution, pulse and transmitter integrity, meter factors and their controls and adjustments can be defined through use of program parameters.

A. Calculations for meter factors between the flow points:

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

where:

m = slope (to be calculated)

y_2 = meter factor at the lower flow rate

y_1 = meter factor at the higher flow rate

x_1 = flow rate for the meter factor of y1

x_2 = flow rate for the meter factor of y2

B. After calculating m, calculate the straight line equation:

$$y - y_1 = m\,(x - x_1)$$

so

$$y = m\,(x - x_1) + y_1$$

where:

- x = the present flow rate
- y = the unknown meter factor

C. Meter factor calculating methods

1. The four-point linearization method uses four sets of the flow rate and associated meter factor program codes.

   Method:

   a. From zero to factor 4 flow, factor 4 will be used

   b. Linearize from factor 4 flow to factor 3 flow

   c. Linearize from factor 3 flow to factor 2 flow

   d. Linearize from factor 2 flow to factor 1 flow

   e. From factor 1 flow up, factor 1 will be used

2. The three-point linearization method uses three sets of the flow rate and associated meter factor program codes.

   Method:

   a. From zero to factor 3 flow, factor 3 will be used
   b. Linearize from factor 3 flow to factor 2 flow
   c. Linearize from factor 2 flow to factor 1 flow
   d. From factor 1 flow up, factor 1 will be used

3. The two-point linearization method uses two sets of the flow rate and associated meter factor program codes.

   Method:

   a. From zero to factor 2 flow, factor 2 will be used
   b. Linearize from factor 2 flow to factor 1 flow
   c. From factor 1 flow up, factor 1 will be used

4. The single-point method uses one meter factor program code.

   Method:

   a. Factor 1 will be used at all flow rates

1 Temperature Calculations

1.2 Measurement Standards Applied in AccuLoad Firmware Revision

AccuLoad Revision	Tables 5, 6, 23, 24, 53, 54 (A, B, C, D)	Tables 59, 60 (A, B, C, D)
AccuLoad IIIX 0.0 – 10.13	API Chapter 11.1 – 1980	–
AccuLoad IIIX 10.09 – 10.13	API Chapter 11.1 – 1980	ISO 91 – 2
AccuLoad IIIX 10.14 – 10.21	API Chapter 11.1 – 2004	ISO 91 – 2
AccuLoad IIIX 10.22 and up	API Chapter 11.1 – 2004/2007	
AccuLoad III.net 11.00 – 11.01	API Chapter 11.1 – 2004	ISO 91 – 2
AccuLoad III.net 11.02 and up	API Chapter 11.1 – 2004/2007	
AccuLoad IV	API Chapter 11.1 – 2004/2007	

> Actual calculations cannot be included since the API standard requires "no reproduction permitted without license." The standards should be procured from API.

1.3 Volume Correction for Temperature (CTL) Calculation

1. Volume correction factor terms, formulas, and constants:

   a. Definition of terms

      Δt = actual temperature - reference temperature

      k_0, k_1, and k_2 = API product range constants

      ρ_t = density at actual temperature

      ρ_{60} = density at reference temperature

      α = coefficient of expansion

   b. Formulas used (simplified, see API chapter 11.1:2004 for complete formulas)

1. α calculation

   a. Using k_0, k_1, and k_2 constants

$$\alpha = \frac{k_0}{\rho_{60}{}^2} + \frac{k_1}{\rho_{60}} + k_2$$

2. CTL calculation

$$\frac{\rho^t}{\rho^{60}} = e^{(-\alpha \times \Delta t\,(1+0.8\alpha \times \Delta t))}$$

3. ρt calculation

$$\rho_t = \rho_{60} \times e^{(-\alpha \times \Delta t\,(1+0.8\alpha \times \Delta t))}$$

4. API to density calculation

$$\rho_{60} = \frac{141.5 \text{ x weight of water at ref conditions}}{131.5 + \text{API}}$$

5. Relative density to density calculation

$$\rho_{60} = \text{relative density} \times \text{weight of water at reference conditions}$$

c. Constants used

1. Weight of water at reference conditions

Table 1: Weights of Water at Reference Conditions

Weight	Temperature
999.102 kg/m^3	15 °C
62.367 lb/ft^3	60 °F

2. k_0 and k_1 constants for different API products (API Chapter 11.1:2004)

Table 2: k_0 and k_1 Constants for Different API Products

API Table	Range at 60 °F	k_0 at 60 °F	k_1 at 60 °F
5A, 6A, 23A, 24A, 53A, 54A, 59A, and 60A Crude Oils	API -10 to 100 RD 0.6112 to 1.1646 DEN 38.12 to 72.63 lb/ft^3 DEN 610.6 to 1163.5 kg/m^3	341.0957	0.0
5B, 6B, 23B, 24B, 53B, 54B, 59B, and 60B Diesel, Heating and Fuel Oils	API -10 to 37.1 RD 0.8391 to 1.1646 DEN 52.33 to 72.63 lb/ft^3 DEN 838.3 to 1163.5 kg/m^3	103.8720	0.2701

API Table	Range at 60 °F	k_0 at 60 °F	k_1 at 60 °F
5B, 6B, 23B, 24B, 53B, 54B, 59B, and 60B jet fuels and kerosene	API 37.1 to 48.0 RD 0.7883 to 0.8391 DEN 49.16 to 52.33 lb/ft^3 DEN 787.5 to 838.3 kg/m^3	330.3010	0.0
5B, 6B, 23B, 24B, 53B, 54B, 59B, and 60B gasolines and napthanes	API 52.0 TO 100 RD 0.6112 to 0.7711 DEN 38.12 to 48.09 lb/ft^3 DEN 610.6 to 770.3 kg/m^3	192.4571	0.2438
5D, 6D, 23D, 24D, 53D, 54D, 59D, and 60D lube oils	API -10 to 45 RD 0.80168 to 1.1646 DEN 50.00 TO 72.63 lb/ft^3 DEN 800.9 TO 1163.5 kg/m^3	0.0	0.34878
BR1P and BR2P (API tables for Brazil)	RD 0.498 to 0.9693 at 20 °C	N/A	N/A

3. k coefficients, refined products, transition zone

Table 3: k Coefficients, Refined Products, Transition Zone

API Table	Range	k_2 at 60 °F	k_0 at 60 °F
5B, 6B, 23B, 24B, 53B, 54B, 59B, and 60B transition zone	API 48 to 52 RD 0.7711 to 0.7883 DEN 48.09 to 49.16 lb/ft^3 DEN 770.3 to 787.5 kg/m^3	-0.00186840	1489.0670

4. Old Tables 6, 23, 24, 53, and 54

> The American Petroleum Institute recommends that Tables 6, 24, and 54 may be used for asphalt in place of ASTM D4311.

Table 4: Old Tables 6, 23, 24, 53, and 54

API Table	Range
6	API -3 to 104 RD 0.6000 to 1.1000 DEN 37.42 to 68.60 lb/ft^3
23	API 89 to 205 RD 0.42 to 0.64 DEN 26.22 to 39.95 lb/ft^3
24	API -3 to 151 RD 0.5000 to 1.1000 DEN 31.18 to 68.60 lb/ft^3
53	API 89 to 205 RD 0.42 to 0.64 DEN 420.0 to 640.0 kg/m^3
54	API -3 to 151 RD 0.5005 to 1.1011 DEN 500.0 to 1100.0 kg/m^3

5. Tables 23E, 24E, 53E, 54E, 59E. and 60E provide temperature correction for the volume of natural gas liquid (NGL) and liquefied petroleum gas (LPG) products. Calculations are performed per API Manual of Petroleum Measurement Standards Chapter 11.2.4 or GPA Technical Publication TP-

27. The standard provides correction for temperature on a liquid (CTLs) calculated to five decimal digits (for example, 0.xxxxx or 1.xxxxx).

Example liquids include ethane, propane, hexane, heptanes, ethylene, and propane mixtures.

The standard covers a temperature range of -50.8 to 199.4 °F (-46 to 93 °C). The allowable density ranges are shown below:

Table 5: Allowable Density Ranges

Reference Temperature	Reference Density Range
60 °F	0.3500 to 0.6880 relative density
15 °C	351.7 to 687.8 kg/m^3
20 °C	331.7 to 683.6 kg/m^3

The API tables should be used as shown below:

Table 6: API Tables

API Table	Reference Temperature	Density Input
23E	60 °F	Observed
24E	60 °F	Reference
53E	15 °C	Observed
54E	15 °C	Reference
59E	All other temperatures	Observed
60E	All other temperatures	Reference

> 1. Observed density input—density at line temperature (live density available)
> 2. Reference density input—density at reference density is programmed into AccuLoad
> 3. 59E and 60E are typically used with reference temperatures of 20 °C and 30 °C but can be used for any desired reference temperature

Rounding of input values are performed as follows:

Table 7: Rounding of Input Values

Temperature in F	0.1
Temperature in C	0.05
Relative Density	0.0001
Density	0.1 kg/m^3

6. API Table Conversion Guide for AccuLoad IV

The following table shows how to relate API tables in the AccuLoad IV to the old-style AccuLoad III API table selections:

Table 8: Relating API Tables in ALIV to ALIII

AccuLoad III	AccuLoad IV		
API Table	API Table	Reference Density Units	Densitometer Type
6A	API 2004 crude oils	API	No densitometer
24A	API 2004 crude oils	Relative density	No densitometer
54A	API 2004 crude oils	kg/m^3	No densitometer
60A	API 2004 crude oils	kg/m^3	No densitometer
6B	API 2004 refined	API	No densitometer
24B	API 2004 refined	Relative Density	No densitometer
54B	API 2004 refined	kg/m^3	No densitometer
60B	API 2004 refined	kg/m^3	No densitometer
6D	API 2004 lube oils	API	No densitometer
24D	API 2004 lube oils	Relative density	No densitometer
54D	API 2004 lube oils	kg/m^3	No densitometer
60D	API 2004 lube oils	kg/m^3	No densitometer
24E	API 2004 LPG, NGL	Relative density	No densitometer
54E	API 2004 LPG, NGL	kg/m^3	No densitometer
60E	API 2004 LPG, NGL	kg/m^3	No densitometer
5A	API 2004 crude oils	NA	Observed density
23A	API 2004 crude oils	NA	Observed density
53A	API 2004 crude oils	NA	Observed density
59A	API 2004 crude oils	NA	Observed density
5B	API 2004 refined	NA	Observed density
23B	API 2004 refined	NA	Observed density
53B	API 2004 refined	NA	Observed density
59B	API 2004 refined	NA	Observed density
5D	API 2004 lube oils	NA	Observed density
23D	API 2004 lube oils	NA	Observed density
53D	API 2004 lube oils	NA	Observed density
59D	API 2004 lube oils	NA	Observed density
23E	API 2004 LPG, NGL	NA	Observed density
53E	API 2004 LPG, NGL	NA	Observed density
59E	API 2004 LPG, NGL	NA	Observed density
6C	API 2004 C special	see below	No densitometer
54C	API 2004 C special	see below	No densitometer
6	API 1952	API	No densitometer

AccuLoad III	AccuLoad IV		
23	API 1952	NA	Observed density
24	API 1952	Relative density	No densitometer
53	API 1952	NA	Observed density
54	API 1952	kg/m^3	No densitometer

If AccuLoad III API table is 6C or 54C:

- Save the ALIII reference density in ALIV coefficient of expansion (not in ALIV reference density).
- If ALIII reference density for C tables is not zero:
  - Save this value in ALIV reference density.
  - Set reference density units equal to System Directory -> Density Units.

1.4 Volume Correction Factor Calculation Options

A. Coefficient of expansion used (table 6C or 54C)

1. Program entry conditions
   a. Correct entry in API table and product (Product Parameter 411)
   b. Valid entry in reference density (Product Parameter 412)
2. Hardware conditions
   a. A temperature probe installed

> Maintenance temperature may be used instead of a temperature probe.

3. Calculation method
   a. Input temperature units
   b. Calculate delta t (Δt)
   c. Coefficient of expansion entry (Product Parameter 412) will be used as alpha

d. Calculate the CTL

$$CTL = e^{(-\alpha \times \Delta t\,(1+0.8\alpha \times \Delta t)}$$

B. API tables with API product range A, B, or D (with reference density)

1. Program entry conditions:

   a. A valid API table and product entry (Product Parameter 411)

   b. A valid reference density entry (Product Parameter 412)

   c. A valid density units entry (System Parameter 411)

   d. A valid temperature units entry (System Parameter 401)

   e. A valid reference temperature entry (System Parameter 402)

2. Hardware conditions:

   a. A temperature probe installed.

   > Maintenance temperature may be used instead of a temperature probe.

3. Definition:

   In this mode of operation, the AccuLoad software will calculate the CTL using the k_0 and k_1 constants of the API product range selected. (If API product range B is selected, it will use the k_0 and k_1 constants for the product range it is measuring.) All related entries shown above must correspond. If table 53 or 54 is used, the temperature units must be in Celsius.

4. Calculation method for reference density at 60 °F

   a. Input temperature units.

   b. Calculate delta t (Δt).

   c. Calculate the alpha and the CTL using the reference density entered

      1. Calculate alpha with the proper k_0 and k_1 constants for API product range selected.

      2. Calculate CTL.

   d. Calculate the CPL.

e. Calculate the CTPL.

$$CTPL = CTL \times CPL$$

5. Calculation method for reference density at 15 °C or 20 °C

> For the following calculation methods, the asterisk (*) indicates an intermediate CTL value used for the CTL calculation per API Chapter 11.1.)

a. Calculate the correction factors (CTL60) for the density at 60 °F (p60) corresponding to the metric base density at the metric base temperature (15 °C or 20 °C) using the procedure defined in step C.4.

b. Using the calculated base density at 60 °F (p60), calculate the CTL* to correct the live density using the procedure defined in step B.4.

c. Calculate the CTL to correct the volume to the metric base temperature.

$$CTL = CTL^* / CTL_{60}$$

$$CTPL = CTL \times CPL$$

C. API tables with API product range A, B, or D (live density)

1. Program entry conditions:

   a. A valid API table and product entry (must be an odd-numbered table) (Product Parameter 411)

   b. A valid density units entry (System Parameter 411)

   c. A valid temperature units entry (System Parameter 401)

   d. A valid reference temperature entry (System Parameter 402)

2. Hardware conditions

   a. A temperature probe installed

   > Maintenance temperature may be used instead of a temperature probe.

   b. A densitometer installed

3. Definition:

   In this mode of operation, the AccuLoad software will calculate the CTL using the k_0 and k_1 constants of the API product range selected. (If API product range B is selected, it will use the k_0 and k_1 constants for the product range it is measuring.) All related entries shown above must correspond. If table 53 or 54 is used, the temperature units must be in Celsius. Density units selected must match the densitometer output.

4. Calculation method for live density at 60 °F

   a. Input temperature units.

   b. Calculate delta t (Δt).

   c. Input density units.

   d. Calculate the density corrected to reference temperature using Newton's method, which will in turn calculate the required CTL and CTPL.

      1. Calculate alpha selecting proper k_0 and k_1 constants for API product range selected (Parameter 411).

      2. Calculate the CTL, CPL and CTPL.

      3. Calculate the corrected density.

      4. Check for convergence of the solution. (A converged solution is reached when a change in density is less than 0.05 kg/m^3 in two successive passes).

      5. For API product range B only, check to see that the k_0 and k_1 constants used are in the range of the corrected density calculated. If not, repeat steps 1 through 4 with the correct constants.

5. Calculation method for live density at 15 °C or 20 °C

   > For the following calculation methods, the asterisk (*) indicates an intermediate CTL value used for the CTL calculation per API Chapter 11.1.)

   a. Calculate the correction factors (CTL*) for the density at 60 °F (p60) corresponding to the observed density at observed temperature and pressure using the procedure defined in step C.4

   b. Using the corresponding density at 60 °F (p60), calculate the associated metric base density. Call the CTL associated with this step CTL60 using the procedure defined in step B.4.

   c. Calculate the CTL to correct the volume to the metric base temperature.

$$CTL = CTL^* / CTL60$$

$$CTPL = CTL \times CPL$$

D. API (old) tables 24 and 54 with API range 100 to 150

1. Program entry conditions:

   a. A valid API table and product entry (Product Parameter 411)

   b. A valid reference density entry (Product Parameter 412)

   c. A valid density units entry (System Parameter 411)

   d. A valid temperature units entry (System Parameter 401)

   e. A valid reference temperature entry (System Parameter 402)

2. Hardware conditions:

   a. A temperature probe is installed

   > Maintenance temperature may be used instead of the temperature probe.

3. Definition:

   In this mode of operation, the AccuLoad software will use the reference density and the current temperature to retrieve the CTL from the selected table. (If table 24 is selected, temperature units must be Fahrenheit. If table 54 is selected, temperature units must be Celsius.)

4. Calculation method

   a. Input temperature units.

   b. Using the temperature and reference density, go to the proper table (24 or 54) and select the proper CTL.

1.5 Eth/Bio (PTB-1) Calculation – Method 1

Table 9: Eth/Bio (PTB-1) Calculation – Method 1 Definition of Terms

Definition of Terms	
V_T	Volume measurement observed [L]
V_0	Volume at base conditions [L]
k_{0E}	Average change in the relative density factor [1/K]
T	Temperature measurement observed
RME	Rapeseed oil methyl ester
SME	Soybean oil methyl ester
PME	Palm oil methyl ester
CME	Coconut oil methyl ester

Formula:

$$V_0 = V_T \bullet (1 - k_{0E} \bullet \Delta T)$$

where: $\Delta T = T - T$ at base condition

Table 10: Eth/Bio (PTB-1) Calculation – Method 1 Coefficients

Coefficients		
Liquid and their mixtures	**Mixing Ratio**	**k_{0E}**
Diesel, Heating Oil EL, RME, SME, PME	B0 to B100	$0.84 \bullet 10^{-3}$ 1/K
Diesel, Heating Oil EL, CME	B0 to B40	$0.84 \bullet 10^{-3}$ 1/K
Gasoline, Ethanol	E0 to E40	$1.27 \bullet 10^{-3}$ 1/K
Gasoline, Ethanol	E60 to E100	$1.14 \bullet 10^{-3}$ 1/K

1.6 Eth/Bio (PTB-3) Calculation – Method 3

1. Definition of terms:

Table 11: Eth/Bio (PTB-3) Calculation – Method 3 Definition of Terms

Definition of Terms	
ρ_0	Density at base temperature
$\rho(T)$	Density at observed temperature
T_0	Base Temperature (15 °C)
T	Observed Temperature
A_1, A_2, A_3	Biofuel coefficients

2. Formula used:

$$\rho(T) = \rho_0 *\{1 + [A_1 *(T - T_0) + A_2 *(T - T_0)^2 + A_3 *(T - T_0)^3]\}$$

3. CTL calculation:

$$\frac{\rho(T)}{\rho_0} = \{1 + [A_1 *(T - T_0) + A_2 *(T - T_0)^2 + A_3 *(T - T_0)^3]\}$$

The Biofuel coefficients are required only with the Eth/Gas (PTB) API table selection, which is a calculation method required for use when metering pre-blended ethanol/gasoline and biodiesel mixtures in some markets. The entry is dependent on the percentage of ethanol or biodiesel in the product. PTB specifies certain coefficients be used for specific ratios of gasoline/ethanol and diesel/biodiesel. Currently only the following coefficients for commonly used ethanol and biodiesel blend percentages are defined:

Table 12: Commonly Used Ethanol and Biodiesel Blend Percentages

Ratio	A1	A2	A3	Reference Density
E5	-1.2422×10^{-3}	-9.1811×10^{-7}	-5.3906×10^{-9}	738.858
E10	-1.2415×10^{-3}	-9.8712×10^{-7}	-6.6333×10^{-9}	741.447
E80	-1.1129×10^{-3}	-6.5049×10^{-7}	-8.8556×10^{-9}	781.410
E85	-1.1023×10^{-3}	-6.0110×10^{-7}	-8.7249×10^{-9}	784.549
E100	-1.0720×10^{-3}	-4.5474×10^{-7}	-8.3383×10^{-9}	793.949
Benzin/Petrol	-1.2361×10^{-3}	-6.7788×10^{-7}	-3.8516×10^{-9}	733.919
Diesel	-8.2239×10^{-4}	5.1745×10^{-8}	-1.3703×10^{-9}	844.615
B100 Rapeseed Oil Methyl Ester (RME)	-8.2330×10^{-4}	1.4698×10^{-7}	-1.6545×10^{-9}	883.314
B5 (RME)	-8.2261×10^{-4}	5.5270×10^{-8}	-1.3289×10^{-9}	846.439
B7 (RME)	-8.2258×10^{-4}	5.4729×10^{-8}	-1.3921×10^{-9}	847.171
B100 Soybean Oil Methyl Ester (SME)	-8.2132×10^{-4}	1.0329×10^{-7}	-1.0793×10^{-9}	885.229
B5 (SME)	-8.1922×10^{-4}	2.9212×10^{-8}	-1.0385×10^{-9}	846.486
B7 (SME)	-8.1925×10^{-4}	3.1305×10^{-8}	-1.0918×10^{-9}	847.253

> Reference Density (kg/m^3) of mixture at 15 °C. This value should be entered in parameter Product 412. Reference Density at 15 °C in units of kg/m^3 should be entered regardless of programmed density units or reference temperature.

1.7 RTD Temperature Input Conversion

The resistance temperature detector (RTD) supplies resistance from which temperature may be calculated. The Callendar-Van Dusen equation is used to approximate the RTD curve.

$$T = \frac{-A + \sqrt{A^2 - 4B\left(1 - \frac{R}{R(0)}\right)}}{2B}$$

where:

T = Temperature in degrees Celcius

R = Resistance at temperature T

R(0) = Resistance at zero degrees Celcius

A = 3.9083 e-3

B = -5.775 e-7

1 Pressure Calculations

1.8 Volume Correction for Pressure (CPL) Calculation

1. Definition of terms
   - P = Pressure
   - P_e = equilibrium pressure (vapor pressure at temperature)
   - F = compressibility factor (API Chapters 11.2.1 or 11.2.2)
   - CPL = correction for pressure on a liquid
2. Formula used

a.

$$CPL = \frac{1}{1-(P-P_e \times F)}$$

b.

$$°API = \frac{141.5 \times \rho_{60}\, H_2O}{\rho_{60}\, \text{Product}} - 131.5$$

c. For -10 to 90 °API (-10 to 100 per API Chapter 11.1)

$$F = e^{A + (B \times T) + \frac{C}{\rho^2} + (D \times \frac{T}{\rho^2})}$$

> This calculation is used for densities from -10 to 100 degrees API for products included in API Chapter 11.1 (5A, 5B, 5D, 6A, 6B, 6C, 6D, 23A, 23B, 23D, 24A, 24B, 24D, 53A, 53B, 53D, 54A, 54B, 54C, 54D). Otherwise this calculation is used for densities from -10 to 90 degrees API.

where:

- A, B, C and D = Constant
- T = Temperature (°F or °C dependent)
- ρ = grams (g)/cm^3 at 60 °F or g/cm^3 at 15 °C

	A	B	C	D
°F	-1.99470	0.00013427	0.79392	0.0023260
°C	-1.62080	0.00021592	0.87096	0.0042092

> Note that F is scaled before usage in the CPL formula above. If temperature is in degrees Fahrenheit, F is multiplied by 0.00001. If temperature is in degrees Celsius, F is multiplied by 0.000001.

d. For 91 to 220 °API (101 to 220 per API Chapter 11.1)

$$F = \frac{1}{A + (D_p \times B)}$$

where:

- A and B = Calculated variables based on temperature and density
- D_p = Pressure above equilibrium in (PSI or Kpa dependent) (for example, Pressure – Vapor Pressure)

$$A*10^{-5} = A_1 * TR^2 + A_2 * G^2 + A_3 * TR^2 * G^4 + A_4 * TR^3 * G^6 + A_5$$
$$+ A_6 * TR^3 * G^2 + A_7 * TR^3 * G^4 + A_8 * TR * G^2$$
$$+ A_9 * TR * G + A_{10} * TR + A_{11} * G^6$$

If temperature units are degrees Celsius, then A = A * 6.894757E0

$$B*10^{-5} = B_1 * TR^2 + B_2 * TR * G^2 + B_3 * G + B_4 * G^2$$

where:

- TR = Temperature, in degrees Rankine
- G = Relative density
- A_1 = -2.1465891E-6
- A_2 = +1.5774390E-5
- A_3 = -1.0502139E-5
- A_4 = +2.8324481E-7

- A_5 = -0.95495939E0
- A_6 = +7.2900662E-8
- A_7 = -2.7769343E-7
- A_8 = +0.036458380
- A_9 = -0.05110158E0
- A_{10} = +0.00795529E0
- A_{11} = +9.13114910E0
- B_1 = -6.0357667E-10
- B_2 = +2.2112678E-6
- B_3 = +0.00088384E0
- B_4 = -0.00204016E0

1.9 Vapor Pressure Calculations

A. Linearization method: Calculate the slope of a line between two points:

1. Calculate m

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

A. where:

- m = Slope (to be calculated)
- y_2 = Vapor pressure at x_2 in PSI, Bars or kg/cm^2
- y_1 = Vapor pressure at x_1 in PSI, Bars or kg/cm^2
- x_1 = Temperature for vapor pressure of y_1
- x_2 = Temperature for vapor pressure of y_2

> Note: Temperature may be in degrees C or F.

2. After calculating m, calculate the straight line equation:

$$y - y_1 = m\,(x - x_1)$$

so

$$y = m\,(x - x_1) + y_1$$

where:

- x = the present temperature
- y = the unknown vapor pressure

B. GPA TP-15 Method: Calculate vapor pressure using the following formula as outlined in the GPA TP 15:

$$\text{Vapor Pressure} = e^{\,A_0 + A_1 \text{ relative density} + \frac{B_0 + B_1 \text{ relative density}}{\text{temperature °F} = 443}}$$

where A_0, A_1, B_0, and B_1 are constants dependent on the range of the density.

> Note that this method requires GST compensation installed as the relative density is used in the calculation.

1 Load Average Calculations

The load average temperature, pressure, density, and meter factor will be accumulated in a volume-weighted method. See below. At the start of any batch, a reading of each load average parameter installed will be taken. This will be the value used for the initial average. Thereafter, another sample will be taken along with the accumulated volume to determine the load average value. Samples will be taken only when flow is in progress. The following formula will be used to calculate the load average value:

Load average value (LAV) formula:

$$\text{LAV} = \frac{\Sigma\ (\Delta\text{Volume} \times \text{Current parameter reading})}{\text{Total Volume}}$$

Load average temperature, pressure, and density values will only be calculated when correct entries have been made in the temperature, pressure, or density program codes. If a probe or transducer alarm occurs, the corresponding current reading will stop being used in the calculation of the load average value. The current load average value for the failed probe or transducer stands until flow goes to zero. At this point the alarm must be cleared and the problem corrected for normal load average calculations to resume.

1 Auto Prove Meter Factor Calculations

The following equations are used by the AccuLoad III to calculate the new meter factor:

1.10 CTSP (Correction for Temperature on Steel of a Prover)

$$CTSP = 1 + ((T-t_{ref}) * y)$$

where

- T = temperature of the prover
- y = coefficient of cubical expansion, a constant, 0.0000186 for mild steel
- t ref = reference temperature (System Parameter 402)

1.11 CTLP (Correction for Temperature on Liquid in a Prover)

$$CTLP = e^{(\alpha \cdot \Delta t\ (1 + 0.8\ \alpha \cdot \Delta t))}$$

where

- e = the exponential constant
- Δt = Δ temperature = actual temperature of the prover - reference temperature(System Parameter 402)
- $\alpha = k_0/(\rho_{60})^2 + (k_1/\rho_{60})$

  where

  - k_0 and k_1 are constants determined based on the product group
  - ρ_{60} = (141.5 * weight of H_2O)/(131.5 + API)

or

- $\alpha = A + (B/(\rho_{60})^2)$

where

- A and B are constants for a special range of API gravities
- ρ_{60} = (141.5 * weight of H_2O)/(131.5 + API)

1.12 Combined Correction Factor (CCF) For a Prover

CCFP = CTSP * CTLP

where

CTSP and CTLP are as shown above

1.13 Corrected Prover Volume

Corrected Prover Volume = Base Prover Volume * CCFP

where

- Base Prover Volume is as determined by a water draw
- CCFP is as shown above

1.14 Corrected Meter Volume

Corrected Meter Volume = CTPLM * Raw Meter Volume

where

- CTPLM is as shown earlier

1.15 Meter Factor

Meter Factor = Corrected Prover Volume/Corrected Meter Volume

where

- Corrected Prover Volume and Corrected Meter Volume are as shown above.

1.16 Average Meter Factor

Average Meter Factor = Sum of Meter Factors/Number of Meter Factors

> Note that the buffer of meter factors saved for calculating an average meter factor is cleared whenever a meter factor is saved or a new flow rate is selected for proving.

1 Downstream Injector Calculations

The AccuLoad supports injection of additive both upstream and downstream of the main meter. When the additive is injected upstream of the main meter, the additive flows through the main meter therefore the total reported by the main meter represents both the main product volume and the additive volume. When the additive is injected downstream of the main meter, the additive volume does not flow through the main meter. Therefore, the additive volume must be added to the main meter volume to accurately report the total delivered volume.

When the AccuLoad is delivering a single main product with downstream injection, the total delivered volume will be the sum of the volume reported by the main meter plus the additive volume. In the case that multiple products are blended, the additive volume is added to the main products in proportion to the blend ratio(s). Provided the AccuLoad configuration matches the metering system plumbing, the total delivery volume reported by the AccuLoad will accurately reflect the combined product and additive volume.

1.17 Total Downstream Injected Volume Formula

$$\text{TDIV} = \text{Preset x PIVCCF x} \sum \frac{\text{PIVC}}{\text{RPIR}}$$

Where:

- TDIV = Total Downstream Injected Volume
- RPIP = Recipe Programmed Injection Rate
- PIVC = Programmed Injector Volume per Cycle
- PIVCCF = Programmed Injector Volume per Cycle Conversion Factor

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