Instruction Manual
P/N 20002315, Rev. A
February 2005

Micro Motion®
Enhanced Density Application

Theory, Configuration, and Use

Micro Motion®

EMERSON™
Process Management

Micro Motion®
Enhanced Density Application

Theory, Configuration, and Use

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Contents

Chapter 1
Before You Begin

1.1 Purpose of manual

This manual is designed to provide two types of information: how the enhanced density application works, and how to configure and use the enhanced density application.

1.2 Terminology

- Enhanced density curve – A three-dimensional surface that describes the relationship between temperature, concentration, and density.
- Standard curves – A set of curves that are supplied by Micro Motion as part of the enhanced density application, and are suitable for use in many processes. These curves are listed and described in Chapter 3.
- Custom curve – A curve that has been built by Micro Motion according to customer requirements.
- User-defined curve – A curve built by a customer, using the enhanced density application.

1.3 Transmitter interfaces

Depending on your transmitter, one or more of the following interfaces is available for the enhanced density application:

- ProLink II – available for all transmitters except the Series 3000 9-wire
- PocketProLink – available for all transmitters except the Series 3000 9-wire
- The display (PPI) on the Series 3000 9-wire (ALTUS) transmitter
- The display (PPI) on the Series 3000 4-wire (MVD) transmitter

This manual shows the ProLink II interface and the Series 3000 display interfaces. The PocketProLink interface is similar to the ProLink II interface.

1.4 Procedures described in this manual

There are two configuration procedures:

- If you purchased the standard curves or one or more custom curves, all you need to do is to load the curve(s) into a transmitter slot. Instructions for loading a curve into a slot are provided in Chapter 3.
- If you did not purchase standard or custom curves, you can configure your own curve(s), using your own process data. Instructions for configuring a user-defined curve are provided in Chapter 4.

After all curves have been loaded or defined, the active curve must be specified. Minor customization of the curve is possible. The enhanced density application is now available for use in transmitter configuration. Instructions for specifying the active curve, modifying a curve, and using a curve are provided in Chapter 5.

The optional density curve trim is described in Chapter 6.

Chapter 2
Enhanced Density Theory and Background

2.1 About this chapter

This chapter provides a conceptual overview of the relationship between density and concentration and how concentration can be calculated from density. Additionally, this chapter discusses how this calculation is implemented in the enhanced density application. Finally, this chapter provides an example of enhanced density used in a real-world application.

Note: This chapter does not provide configuration instructions. For assistance with loading a standard or custom curve provided by Micro Motion, see Chapter 3. For instructions on configuring a user-defined curve, see Chapter 4.

2.2 Enhanced density application overview

Micro Motion sensors provide direct measurements of density, but not of concentration. The enhanced density application calculates enhanced density variable,s such as concentration or density at reference temperature, from density process data, appropriately compensated for temperature.

The derived variable, specified during configuration, controls the type of concentration measurement that will be produced (see Section 2.3.1). Each derived variable allows the calculation of a subset of enhanced density process variables (see Table 2-1). The available enhanced density process variables can be used in process control, just as mass, volume, and other process variables are used. For example, an event can be defined on an enhanced density process variable.

2.3 Measuring density, specific gravity, and concentration

Density, specific gravity, and concentration are central concepts in the enhanced density application. This section defines these terms and describes the characteristics that are relevant to the enhanced density application.

2.3.1 Definition of density, specific gravity, and concentration

Density is a measure of mass per unit volume. Density measurements apply to both pure substances such as mercury or silver and compounds such as air and water. Typical density units include:

- kg/m^3
- g/cm^3
- lb (mass)/ft^3
- lb (mass)/gal^3

Specific gravity is the ratio of two densities:

$$\frac{\text{Density of Process Fluid at Reference Temperature T1}}{\text{Density of Reference Fluid at Reference Temperature T2}}$$

Water is typically used as the reference fluid. The T1 and T2 temperature values may be different. Specific gravity has no units. The following reference temperature combinations are frequently used to calculate specific gravity:

- SG20/4 – Process fluid at 20 °C, water at 4 °C (density = 1.0000 g/cm^3)
- SG20/20 – Process fluid at 20 °C, water at 20 °C (density = 0.9982 g/cm^3)
- SG60/60 – Process fluid at 60 °F, water at 60 °F (density = 0.9990 g/cm^3)

Concentration describes the quantity of one substance in a compound in relation to the whole, for example, the concentration of salt in salt water. Concentration is typically expressed as a percentage. Concentration can be based on mass or volume:

$$\frac{\text{Mass of Solute}}{\text{Total Mass of Solution}}$$

$$\frac{\text{Volume of Solute}}{\text{Total Volume of Solution}}$$

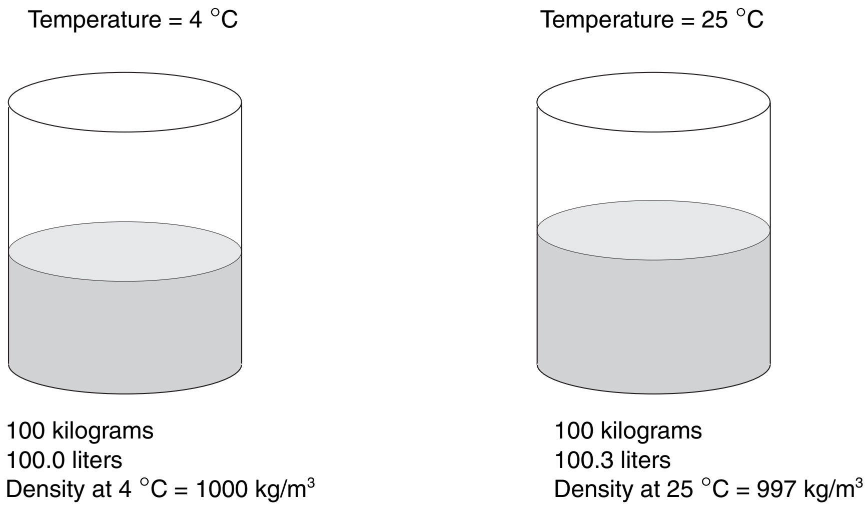
Typical concentration units include:

- Degrees Plato
- Degrees Balling
- Degrees Brix
- Degrees Baume (light or heavy)
- Degrees Twaddell
- %Solids/Mass
- %Solids/Volume
- Proof/Mass
- Proof/Volume

2.3.2 Effects of temperature on density, specific gravity, and concentration

Density always changes with temperature; as temperature increases, density decreases (for most substances). See Figure 2-1. The amount of change is different for different substances.

Figure 2-1 Density affected by temperature

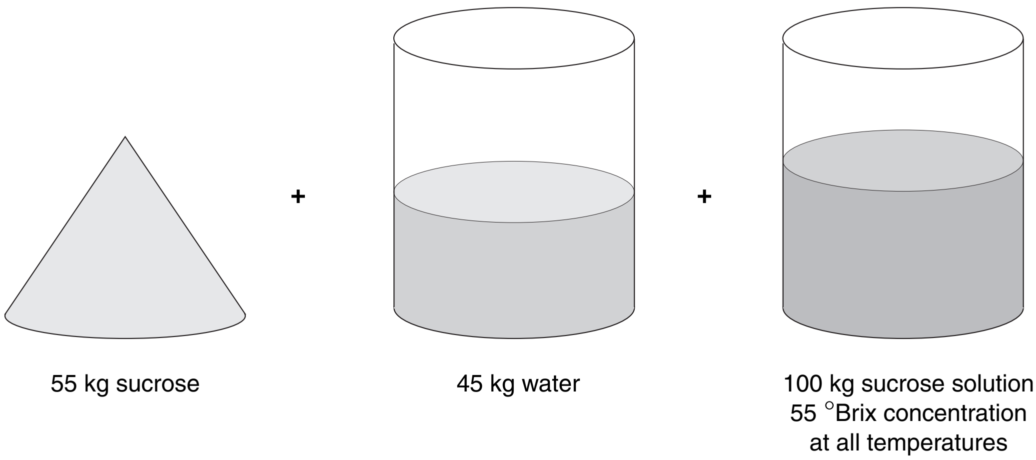


Specific gravity does not vary with changing temperature, because it is defined at reference temperatures.

When *concentration* is measured, the solute and the solvent typically have different responses to temperature, that is, one expands more than the other as temperature increases. Therefore:

- Concentration values based on mass are not affected by temperature. This is the most common type of concentration measurement. See Figure 2-2.
- Concentration values based on volume are affected by temperature. These concentration measurements are rarely used, with the exception of the distilled spirits industry (proof is a concentration measurement based on volume).

Figure 2-2 Concentration not affected by temperature



Because of these temperature effects, there is not a one-to-one relationship between density and concentration (see Figure 2-3). A three-dimensional surface – concentration, temperature, and density – is required. This three-dimensional surface is the enhanced density curve. Different process fluids have different enhanced density curves. A typical enhanced density curve is shown in Figure 2-4.

Figure 2-3 Relationship between density and concentration at two different temperatures

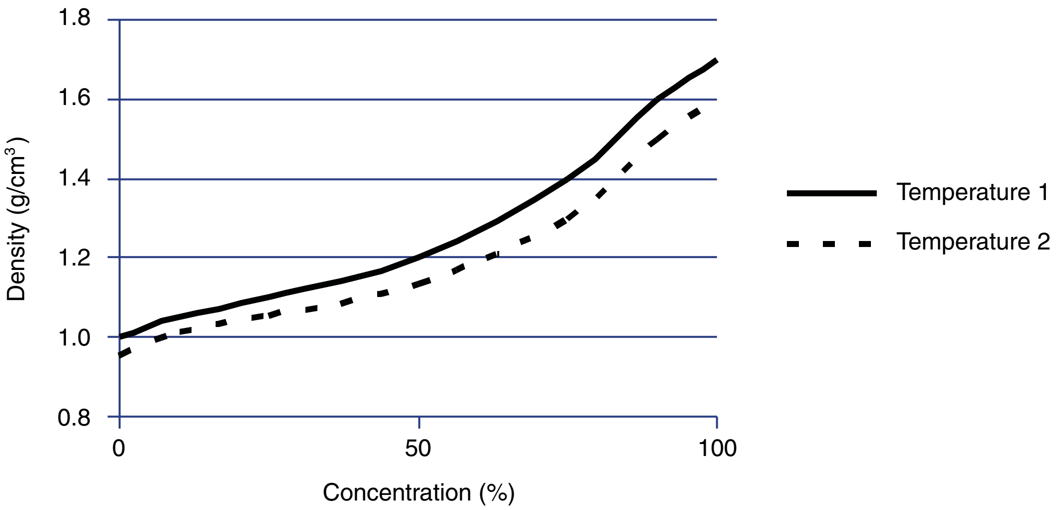
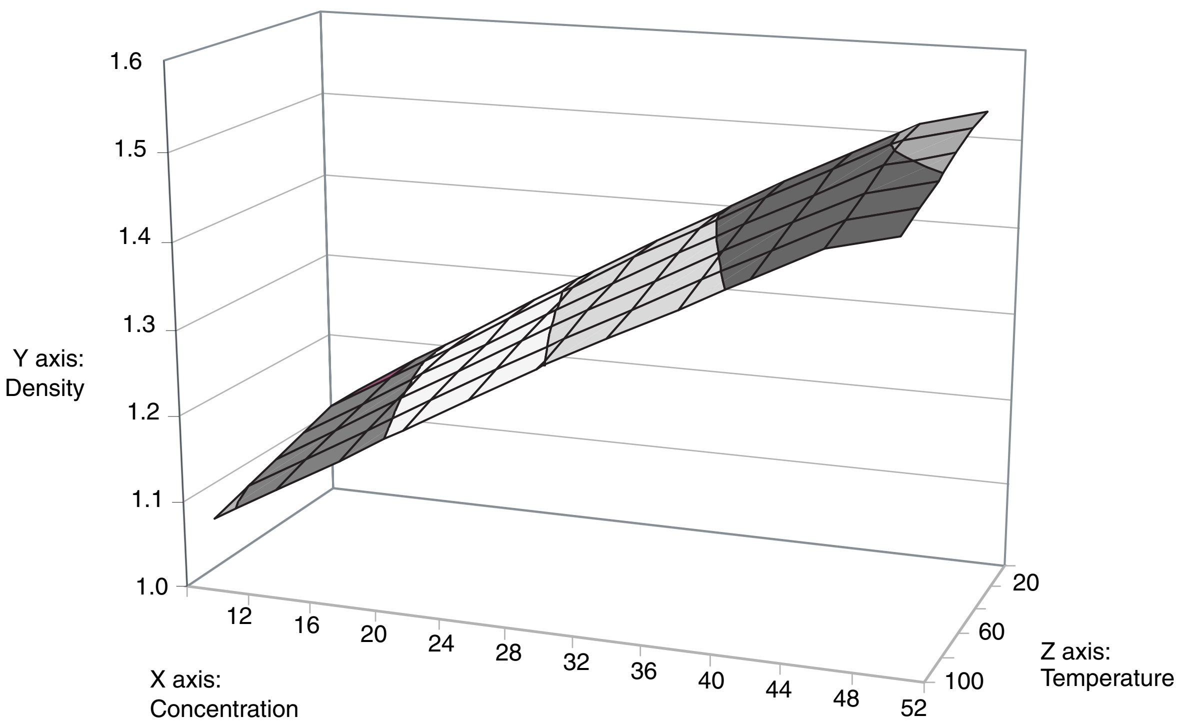


Figure 2-4 Example density curve



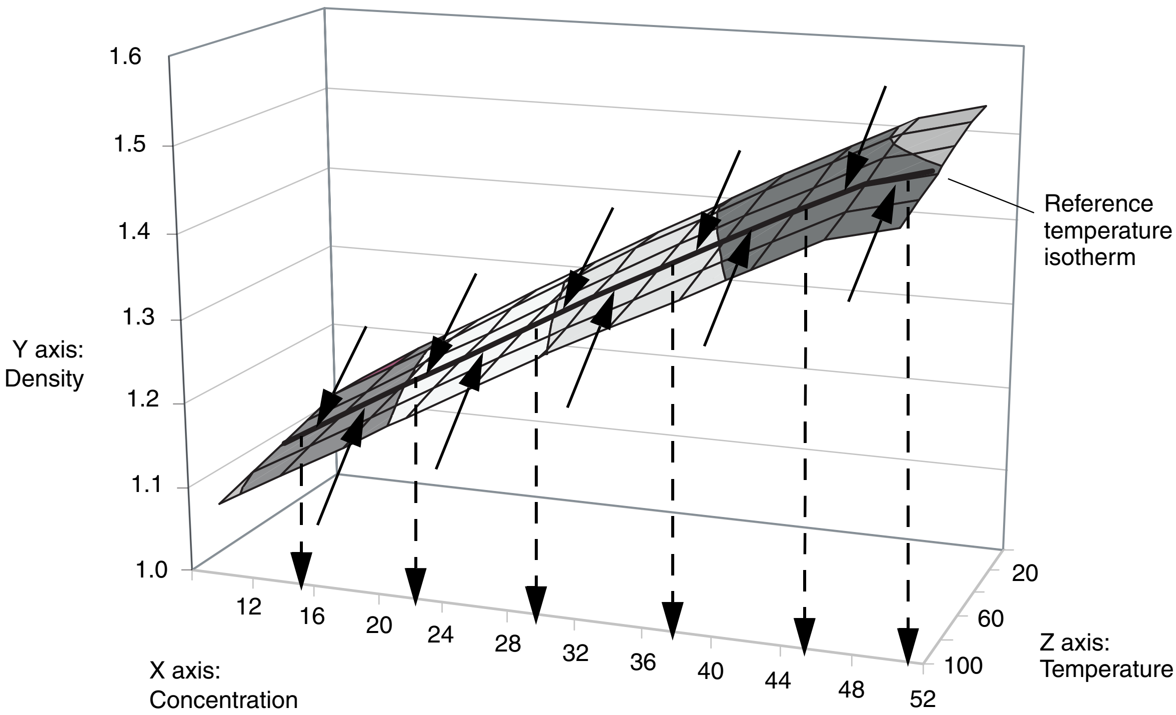
2.3.3 Calculating concentration from density

There are two main steps in calculating concentration (see Figure 2-5):

1. Applying temperature correction to density process data. This step maps the current point on the enhanced density surface to the equivalent point on the reference temperature isotherm, producing a density-at-reference-temperature value.
2. Converting the corrected density value to a concentration value. Because all density values have been corrected for temperature, any change in density must be a result of change in composition of the process fluid, and a one-to-one conversion can be applied.

The enhanced density curve data stored in the transmitter contains the coefficients required to collapse the surface to the density-at-reference-temperature curve, and to map that curve to the concentration axis.

Figure 2-5 Enhanced density calculations



2.4 Defining a Micro Motion enhanced density curve

This section provides a conceptual overview of the process of defining an enhanced density curve. Specific configuration instructions are provided for standard or custom curves in Chapter 3, and for user-defined curves in Chapter 4.

There are five steps involved in defining an enhanced density curve:

- Specifying the derived variable
- Specifying required reference values
- Defining the enhanced density surface
- Mapping density at reference temperature to concentration
- Curve fitting

Step 1 Specifying the derived variable

The enhanced density application can calculate concentration using any of several different methods, for example, mass concentration derived from reference density, or volume concentration derived from specific gravity. The method used, and therefore the concentration measurement in effect, is determined by the configured "derived variable."

Depending on the specified derived variable, different enhanced density process variables are available for use in process control. Table 2-1 lists the derived variables and the available process variables for each derived variable. Be sure that the derived variable you choose will provide the enhanced density process variables required by your application, and can be calculated from the data that you have.

Note: All "net" process variables assume that the concentration data is based on percent. This includes Net mass flow rate, Net volume flow rate, and the related totals and inventories. If you will be using a "net" process variable for process measurement, ensure that your concentration values are based on percent solids.

Table 2-1 Derived variables and available process variables

	Available process variables					
Derived variable – ProLink II label and definition	Density at reference temperature	Standard volume flow rate	Specific gravity	Concentration	Net mass flow rate	Net volume flow rate
Density @ Ref *Density at reference temperature* Mass/unit volume, corrected to a given reference temperature	✓	✓				
SG *Specific gravity* The ratio of the density of a process fluid at a given temperature to the density of water at a given temperature. The two given temperature conditions do not need to be the same	✓	✓	✓			
Mass Conc (Dens) *Mass concentration derived from reference density* The percent mass of solute or of material in suspension in the total solution, derived from reference density	✓	✓		✓	✓	
Mass Conc (SG) *Mass concentration derived from specific gravity* The percent mass of solute or of material in suspension in the total solution, derived from specific gravity	✓	✓	✓	✓	✓	
Volume Conc (Dens) *Volume concentration derived from reference density* The percent volume of solute or of material in suspension in the total solution, derived from reference density	✓	✓		✓		✓

Table 2-1 Derived variables and available process variables (continued)

Derived variable – ProLink II label and definition	Available process variables					
	Density at reference temperature	Standard volume flow rate	Specific gravity	Concentration	Net mass flow rate	Net volume flow rate
Volume Conc (SG) *Volume concentration derived from specific gravity* The percent volume of solute or of material in suspension in the total solution, derived from specific gravity	✓	✓	✓	✓		✓
Conc (Dens) *Concentration derived from reference density* The mass, volume, weight, or number of moles of solute or of material in suspension in proportion to the total solution, derived from reference density	✓	✓		✓		
Conc (SG) *Concentration derived from specific gravity* The mass, volume, weight, or number of moles of solute or of material in suspension in proportion to the total solution, derived from specific gravity	✓	✓	✓	✓		

Step 2 Specifying required reference values

Depending on the derived variable, different reference values are required for the enhanced density calculation. Table 2-2 lists and defines the reference values that may be required. Table 2-3 lists the derived variables and the reference values that each requires.

Table 2-2 Reference value definitions

Reference value	Definition
Reference temperature of process fluid	The temperature to which density values will be corrected
Reference temperature of water	The T2 temperature value to be used in calculating specific gravity
Reference density of water	The density of water at the T2 reference temperature

Table 2-3 Derived variables and required reference values

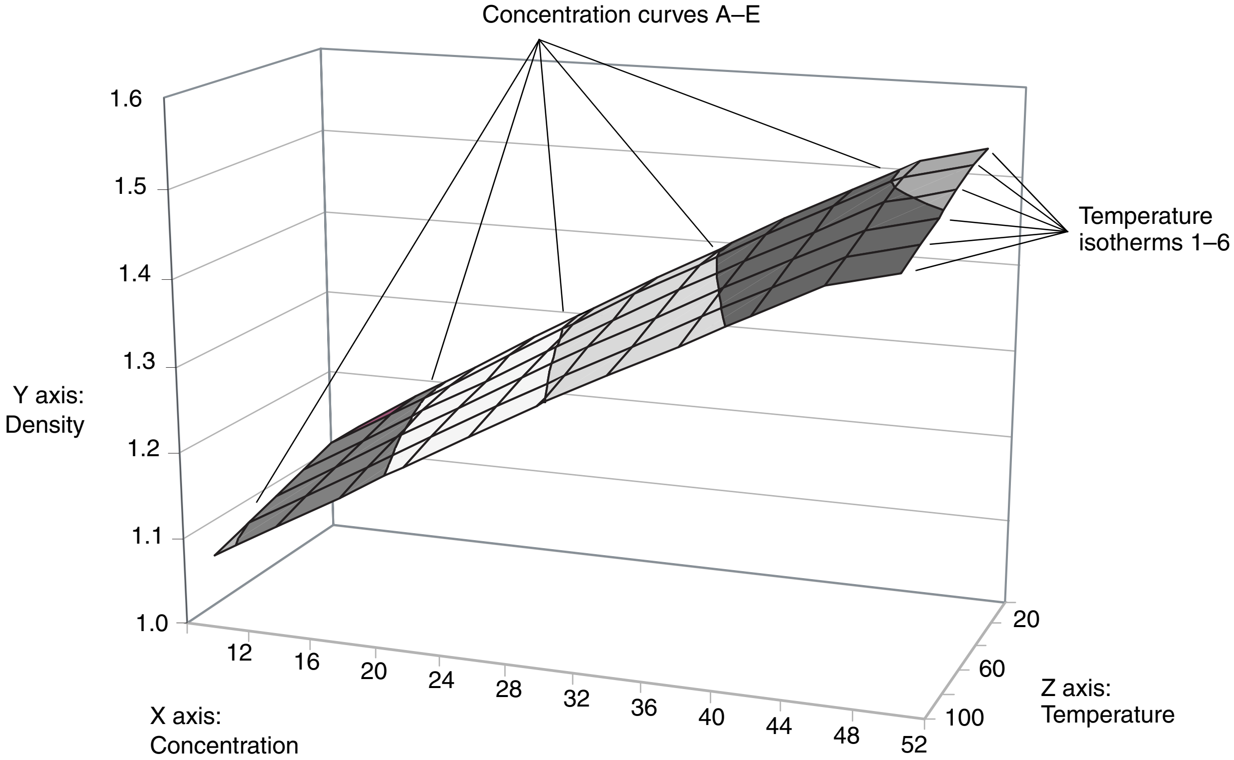
Derived variable	Reference values		
	Reference temperature of process fluid	Reference temperature of water	Reference density of water
Density @ Ref	✓		
SG	✓	✓	✓
Mass Conc (Dens)	✓		
Mass Conc (SG)	✓	✓	✓
Volume Conc (Dens)	✓		
Volume Conc (SG)	✓	✓	✓
Conc (Dens)	✓		
Conc (SG)	✓	✓	✓

Step 3 Defining the enhanced density surface

The enhanced density surface provides the information required to perform temperature correction on density process data, that is, to map process density values to density at reference temperature. To define the enhanced density surface:

1. Specify 2 to 6 temperature values that will define the temperature isotherms
2. Specify 2 to 5 concentration values that will define the concentration curves
3. For each data point (intersection of a temperature isotherm with a concentration curve), specify the density of the process fluid at the corresponding temperature and concentration. For example, to define the enhanced density surface shown in Figure 2-6, with 6 temperature isotherms and 5 concentration curves, you must specify the density of the process fluid at Concentration A and Temperature 1, at Concentration A and Temperature 2, and so on through Concentration E and Temperature 6.

Figure 2-6 Example density curve



Micro Motion recommends:

- Specifying the reference temperature as one of the temperature isotherms
- Selecting a range of temperature values that includes and is slightly larger than the range of expected process temperatures
- Selecting a range of concentration values that includes and is slightly larger than the range of expected process concentrations

Data for many process fluids can be obtained from published tables. Data for sodium chloride is shown in Table 2-4.

Table 2-4 Density of sodium chloride (NaCl) in water (H_2O) at different temperatures and concentrations

Concentration %	0 °C	10 °C	25 °C	40 °C	60 °C	80 °C	100 °C
1	1.00747	1.00707	1.00409	0.99908	0.9900	0.9785	0.9651
2	1.01509	1.01442	1.01112	1.00593	0.9967	0.9852	0.9719
4	1.03038	1.02920	1.02530	1.01977	1.0103	0.9988	0.9855
8	1.06121	1.05907	1.05412	1.04798	1.0381	1.0264	1.0134
12	1.09244	1.08946	1.08365	1.07699	1.0667	1.0549	1.0420
16	1.12419	1.12056	1.11401	1.10688	1.0962	1.0842	1.0713
20	1.15663	1.15254	1.14533	1.13774	1.1268	1.1146	1.1017
24	1.18999	1.18557	1.17776	1.16971	1.1584	1.1463	1.1331
26	1.20709	1.20254	1.19443	1.18614	1.1747	1.1626	1.1492

Step 4 Mapping density at reference temperature to concentration

Note: If density at reference temperature or specific gravity was specified as the derived variable, conversion to concentration is not required because these two variables are not measures of concentration. Therefore, this step is omitted.

The enhanced density application must be able to map the density-at-reference-temperature curve to concentration. This is accomplished by:

- Specifying 2 to 6 concentration values. Micro Motion recommends using the same values that were used in Step 3.
- For each concentration value, specifying the corresponding density of the process fluid at reference temperature.

Again, data for many process fluids can be obtained from published tables. For example, if the process fluid is sodium chloride in water, and the specified reference temperature is 25 °C, the third column of data in Table 2-4 provides the required values.

Step 5 Curve fitting

When data entry is complete, the transmitter automatically generates the enhanced density curve. There are two measures of the goodness of a density curve:

- The outcome of the curve-fitting algorithm. Concentration will be calculated from the input data only if the curve fit results are **Good**. If the curve fit results are **Poor** or **Fail,** you must repeat the process with modified data. Options include:
  - Correcting inaccurately entered data
  - Reconfiguring the curve using fewer temperature isotherms or concentration curves

  If the curve fit results are **Empty**, the curve-fitting calculation has not completed or has failed. Wait for another minute, or reenter your data.
- The curve fit error. This value is based on the average error of the curve fit and does not include any error values used to define the density curve, or any error in the density or temperature measurements.

Note: Determination of the overall accuracy of the concentration calculation is complex and can be laborious. If this information is required, contact Micro Motion customer service.

The curve fit error is reported in the concentration unit that is currently active. It may be represented as a value like the following:

8.4337E-5

In this example, if the concentration unit for the density curve is % solids, the average curve fit error is 0.000084337 % solids.

2.5 Enhanced density application example

A plant uses a caustic cleaning solution (NaOH in H_2O) and discharges it into the city water system. To meet emission standards, the total concentration of NaOH in the wastewater cannot exceed 5%. The concentration standard is defined on mass (rather than volume).

Without the enhanced density application

Based on testing, the cleaning solution is assumed to flow into the discharge tank at a concentration of 50%. Therefore, to comply with emission standards, one unit of the cleaning solution should be diluted with 19 units of water. Periodically, samples are tested in the lab to monitor compliance.

This approach has the following drawbacks:

- The concentration of the cleaning solution may be different from the original sample.
- The concentration of the cleaning solution may vary beyond tolerances.
- Laboratory testing is slow and expensive, and may not catch serious variance: some batches may be in violation of standards, while other batches contain more water than required, which is unnecessary expense.
- Processing waste one batch at a time is inefficient.
- There is no provision for handling bad batches.

With the enhanced density application

A continuous blending process is implemented. A downstream flowmeter with the enhanced density application is configured to measure concentration (mass). Through a PLC, the flowmeter controls an upstream valve that controls the flow of water into the static mixer.

Using this technology:

- Any variation in the concentration of the cleaning solution flowing into the discharge tank is compensated for, immediately and automatically.
- No laboratory testing is required.
- Batching is eliminated, along with bad batches.

Chapter 3
Loading a Standard or Custom Curve

3.1 About this chapter

This chapter defines standard and custom curves, and provides instructions for loading them.

Note: If the standard curves are not appropriate for your application, you did not purchase custom curves, and you require transmitter output based on enhanced density, you must configure one or more curves to meet your application requirements. See Chapter 4 for instructions.

Note: For information on using and modifying an existing curve, see Chapter 5.

3.2 Standard and custom curves

When the enhanced density application is purchased, a set of six standard curves is supplied. These curves, with the measurement units they are based on, are described in Table 3-1.

These curves are supplied in several different ways:

- For Series 3000 transmitters, if the Food and Beverage Option is purchased, the curves are preloaded into transmitter memory. (The Food and Beverage Option is not available for Series 2000 transmitters.)
- For Series 2000 transmitters purchased with the enhanced density application, the curves are supplied on the enhanced density CD.
- If ProLink II is purchased, the curves are supplied on the ProLink II installation CD.

In addition, custom curves may be purchased. These curves are defined at the factory using customer-supplied data. Custom curves can be preloaded onto the transmitter at the factory, or the customer can load the curve file(s) into the transmitter.

Table 3-1 Standard curves and associated measurement units

Name	Description	Density unit	Temperature unit
Deg Balling	Curve represents percent extract, by mass, in solution, based on °Balling. For example, if a wort is 10 °Balling and the extract in solution is 100% sucrose, the extract is 10% of the total mass.	g/cm^3	°F
Deg Brix	Curve represents a hydrometer scale for sucrose solutions that indicates the percent by mass of sucrose in solution at a given temperature. For example, 40 kg of sucrose mixed with 60 kg of water results in a 40 °Brix solution.	g/cm^3	°C
Deg Plato	Curve represents percent extract, by mass, in solution, based on °Plato. For example, if a wort is 10 °Plato and the extract in solution is 100% sucrose, the extract is 10% of the total mass.	g/cm^3	°F

Table 3-1 Standard curves and associated measurement units (continued)

Name	Description	Density unit	Temperature unit
HFCS 42	Curve represents a hydrometer scale for HFCS 42 (high fructose corn syrup) solutions that indicates the percent by mass of HFCS in solution.	g/cm^3	°C
HFCS 55	Curve represents a hydrometer scale for HFCS 55 (high fructose corn syrup) solutions that indicates the percent by mass of HFCS in solution.	g/cm^3	°C
HFCS 90	Curve represents a hydrometer scale for HFCS 90 (high fructose corn syrup) solutions that indicates the percent by mass of HFCS in solution.	g/cm^3	°C

3.3 Loading procedures

If a curve has been provided as a file, it must be loaded into a transmitter slot using ProLink II. See Section 3.3.1. This procedure can be used with any transmitter that can be accessed by ProLink II. It can also be used for any user-defined curve that has been saved to a file.

If a curve has been preloaded into transmitter memory on a Series 3000 transmitter, it must be loaded into a slot using the transmitter display.

- To load a preloaded curve into a slot on the Series 3000 4-wire transmitter, see Section 3.3.2.
- To load a preloaded curve into a slot on the Series 3000 9-wire transmitter, see Section 3.3.3.

If a curve has been preloaded into transmitter memory on a Series 2000 transmitter, it has already been loaded into a slot.

3.3.1 Using ProLink II

Note: This method cannot be used with preloaded curves. The curve must be available as a file.

To load a curve file into a slot using ProLink II:

1. Set the transmitter measurement units for temperature and density to the units used to create the curve you are loading.
   - For standard curves, see Table 3-1 for the units to use.
   - For custom curves supplied by Micro Motion, see the information provided with the curve.

   For information on configuring the measurement units, see your transmitter documentation.
2. Click **ProLink > Configuration** > **ED Setup**. A window similar to Figure 3-1 is displayed.
3. If necessary, change the derived variable. If you are loading a standard curve, set the derived variable to Mass Conc (Dens). If you are loading a custom curve, set the derived variable to the derived variable used by the custom curve. The list of available process variables is updated to match the derived variable.

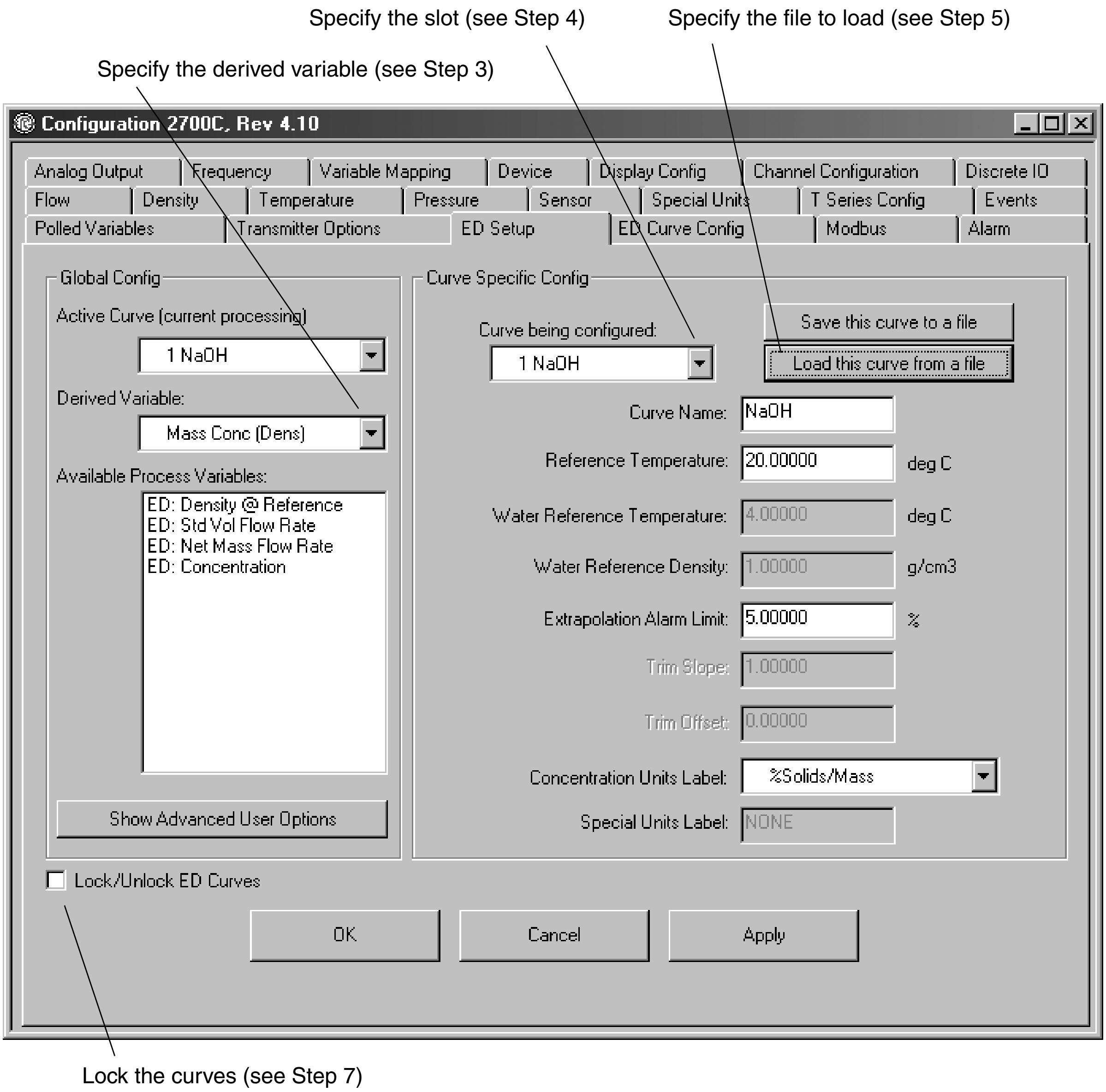
Warning: Changing the derived variable will erase all existing curve data.

4. Use the **Curve being configured** dropdown list to specify the slot into which the curve will be loaded (Density Curve 1–6), and click **Apply**.
5. Click the **Load this curve from a file** button and specify the curve file to be loaded.
6. Repeat Steps 4 and 5 to load as many curves as required. Make sure that all loaded curves use the same derived variable.

7. If desired, check the **Lock/Unlock ED curves** checkbox to lock the curves. When curves are locked, no curve parameters can be changed. You can specify a different active curve. You can also specify a different curve to configure, so that you can view the curve parameters, but you cannot change any of those parameters.

Note: The Lock/Unlock ED Curves option is available only on Series 2000 transmitters v4.1 and higher, Series 2000 FOUNDATION™ fieldbus transmitters v3.0 and higher, or Series 3000 transmitters v6.1 and higher.

Figure 3-1 ED Setup window – Loading a curve



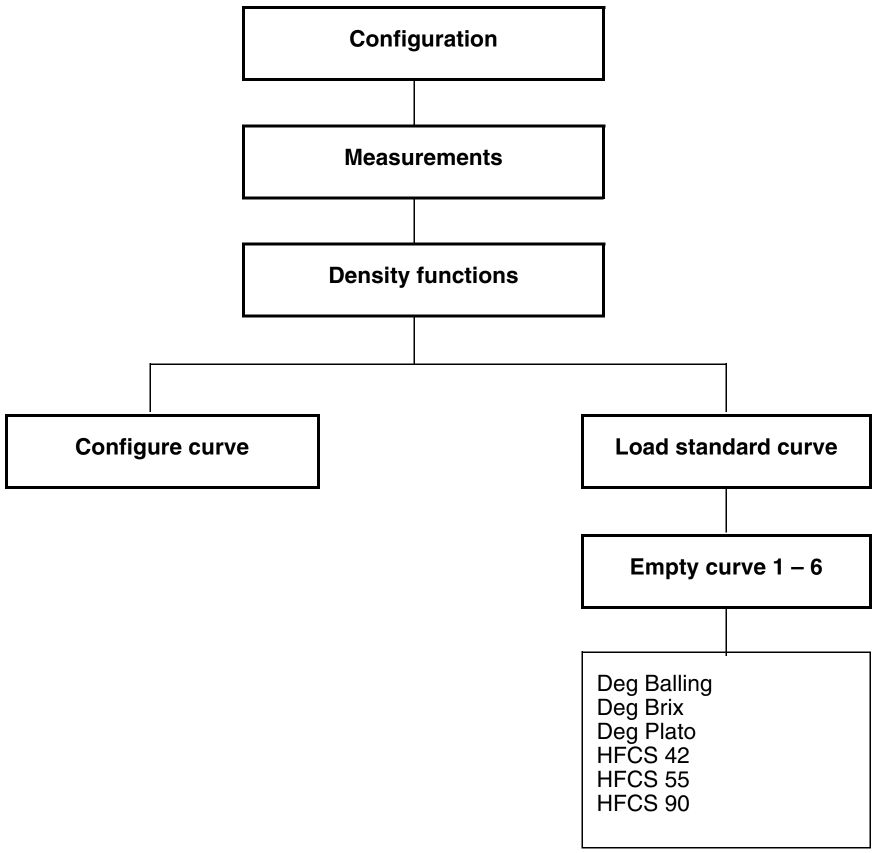
3.3.2 Using the display on Series 3000 4-wire transmitters

If the Food and Beverage option was purchased, the display can be used to load a standard curve into any slot. To load a standard curve using the display:

1. Open the **Density functions** menu (see Figure 3-2). If the derived variable is not Mass conc (Dens), it will be automatically set to Mass conc (Dens). Changing the derived variable will automatically erase all enhanced density curves in the transmitter. A warning is displayed, allowing you to cancel the action if desired.
2. Select **Load standard curve**.
3. Select the slot (Empty curve 1 – 6).
4. Select the curve to be loaded. Any existing data in the selected slot is overwritten.

When loading curves, ensure that the transmitter is connected to the core processor. Curve data is stored in the core processor.

Figure 3-2 Series 3000 4-wire transmitter menu



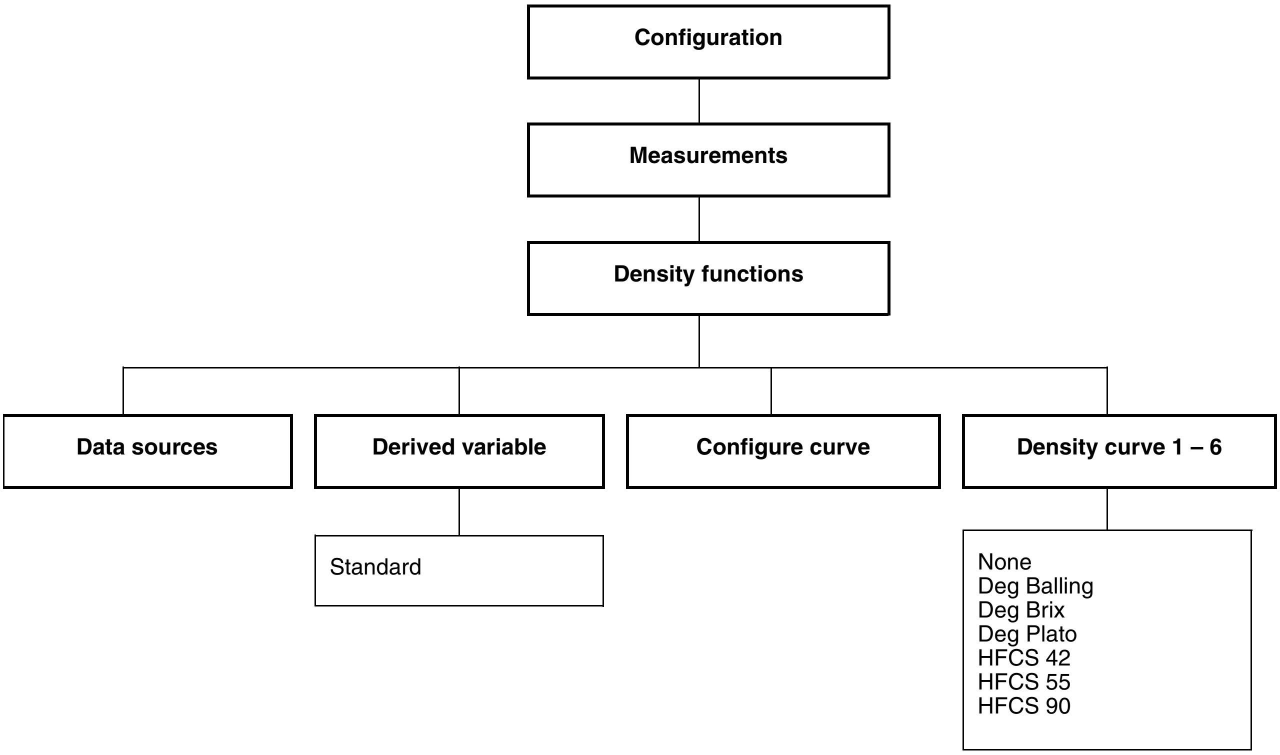
3.3.3 Using the display on Series 3000 9-wire transmitters

The display on the Series 3000 9-wire transmitter can be used to load a standard curve into any slot. All curves must be standard or all curves must be custom; you cannot mix standard, custom, and user-defined curves.

To load a standard curve using the display:

1. Using the **Density functions** menu (see Figure 3-3), configure the data source from which the derived variable will be calculated.
2. If the frequency input will be used as the flow source for the enhanced density application, configure the frequency input to represent mass flow. For information on configuring the frequency input, see your transmitter documentation.
3. Using the **Density functions** menu:
    a. Set the derived variable to Standard.
    b. Select the slot (Density curve 1 – 6).
    c. Select the curve to be loaded. Any existing data in the selected slot is overwritten.

Figure 3-3 Series 3000 9-wire transmitter menu



Chapter 4
Configuring a User-Defined Curve

4.1 About this chapter

This chapter provides information on configuring a user-defined enhanced density curve. Micro Motion recommends that you review Section 2.4 before starting this procedure.

Note: If you are loading a pre-defined curve (a standard or custom curve, or a curve that has been saved to a file), follow the instuctions in Chapter 3.

Note: For information on using and modifying an existing curve, and saving a curve to a file, see Chapter 5.

4.2 Measurement units

When a density curve is configured, the measurement units used to enter temperature and density in the curve data must match the measurement units configured for transmitter processing. If you subsequently change the transmitter's temperature or density unit, all configured curves will be automatically updated to use the new unit. For information on configuring measurement units, see the transmitter documentation.

4.3 Configuration steps

To configure a user-defined curve using ProLink II, see Section 4.3.1.

To configure a user-defined curve using the Series 3000 display, see Section 4.3.2.

4.3.1 Using ProLink II

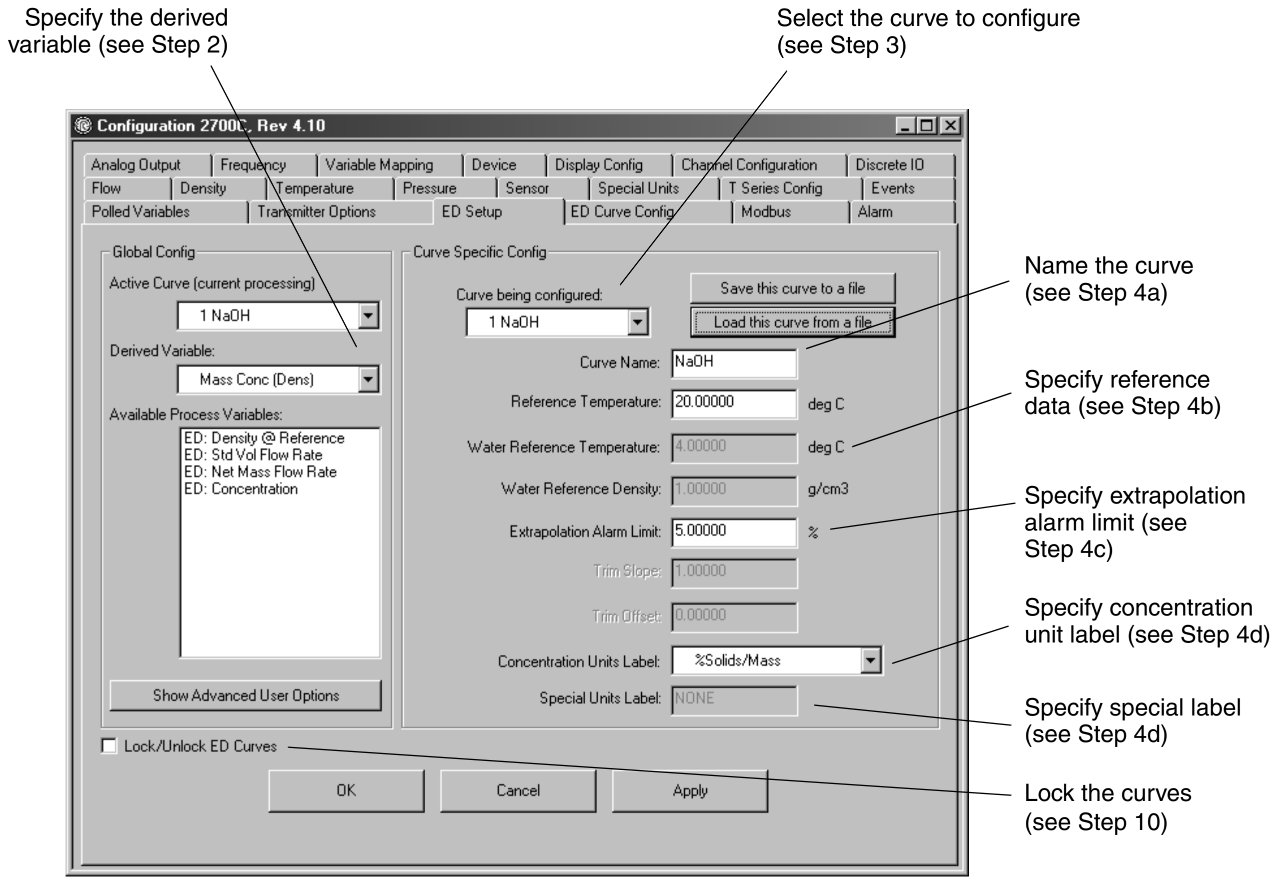
Follow the steps in this section to configure a user-defined curve.

1. Click **ProLink > Configuration** > **ED Setup**. A window similar to Figure 4-1 is displayed.
2. Specify the derived variable by selecting it from the dropdown list. Derived variables are listed and defined in Table 2-1.

Note: Changing the derived variable will erase all existing curve data in the transmitter. All curves in the transmitter m ust use the same derived variable. Be sure that any existing curves have been saved to a file before changing the derived variable. See Section 5.5 for information on saving an enhanced density curve to a file.

3. Up to six curves can be configured. Specify the curve to be configured by selecting it from the dropdown list.

Figure 4-1 ED Setup window – Configuring a curve



4. Specify curve setup data:
   a. Name the curve as desired. The name can contain a maximum of 8 characters.
   b. Specify reference data. Different derived variables require different reference data. ProLink II enables and disables reference data textboxes as appropriate to your derived variable. Enter data in all textboxes that are enabled, which will include some or all of the following:
      - Reference temperature (for the process fluid). Enter the temperature to which the density will be corrected. Enter the temperature value in the temperature units that are currently configured on the transmitter.
      - Water reference temperature. Specify the water reference temperature to be used in calculating the specific gravity. Enter a value between 32 °F and 212 °F (0 °C and 100 °C), using the temperature units that are currently configured on the transmitter.
      - Water reference density. This value represents the water density as calculated by the transmitter. Modify as required. Enter the value in the density units that are currently configured on the transmitter.
   c. Specify the extrapolation alarm limit. This specifies how much the process temperature and process density can vary above and below the density curve's defined range before an extrapolation alarm will be posted. For example, if the highest temperature isotherm is 100 °C, and the extrapolation alarm limit is set to 5%, an alarm will be posted if the actual process temperature exceeds 105 °C.

Note: As the value for extrapolation alarm limit is increased, the probability of inaccurate enhanced density calculations also increases. Micro Motion recommends using the default value for extrapolation alarm limit.

d. Specify the label to be used for the concentration unit. Pre-defined labels are listed in Table 4-1. Table 4-1 also describes the typical use of each label. If none of the pre-defined labels is appropriate, select **Special**, then enter the text to be used for the label.

Note: The label specified here is used for display purposes, and has no effect on transmitter processing. However, for consistency and ease of use, select a label that appropriately represents the values you will enter in Steps 6 and 7.

e. Click **Apply**.

Table 4-1 Concentration unit labels and definitions

Label	Typical density curve represents
% Plato	Percent extract, by mass, in solution, based on °Plato. For example, if a wort is 10 °Plato and the extract in solution is 100% sucrose, the extract is 10% of the total mass
% Solids/Mass	Percent mass of solute or of material in suspension in the total solution
% Solids/Volume	Percent volume of solute or of material in suspension in the total solution, calculated at reference temperature
degBalling	Percent extract, by mass, in solution, based on °Balling. For example, if a wort is 10 °Balling and the extract in solution is 100% sucrose, the extract is 10% of the total mass
degBaume (H)	The conversion for °Baume heavy. The fluid reference temperature is 60 °F and the water reference temperature is 60 °F. (°Baume is calculated when fluid reference temperature and water reference temperature are both set to 60 °F.) $degBaume = 145 - \left(\frac{145}{SpecificGravity}\right)$ This label should be used for fluids heavier than water.
degBaume (L)	The conversion for °Baume light. The fluid reference temperature is 60 °F and the water reference temperature is 60 °F. (°Baume is calculated when fluid reference temperature and water reference temperature are both set to 60 °F.) $degBaume = \left(\frac{140}{SpecificGravity}\right) - 130$ This label should be used for fluids lighter than water.
degBrix	A hydrometer scale for sucrose solutions that indicates the percent by mass of sucrose in solution at a given temperature. For example, 40 kg of sucrose mixed with 60 kg of water results in a 40 °Brix solution.
degTwaddell	A value from which the specific gravity of liquids can be calculated, using the following formula: $Tx = 200 \times (d - 1)$ where *Tx* is the reading in degrees Twaddell, and *d* is the required specific gravity
Proof/Mass	The proof of the solution, based on mass, and calculated at reference temperature. A value of 50 here is equivalent to a value of 25 using % Solids/Mass.
Proof/Volume	The proof of the solution, based on volume, and calculated at reference temperature. A value of 50 here is equivalent to a value of 25 using % Solids/Volume.
Special	Select this option if none of the labels in this table describes your density curve. You will be allowed to enter a label of your choice.

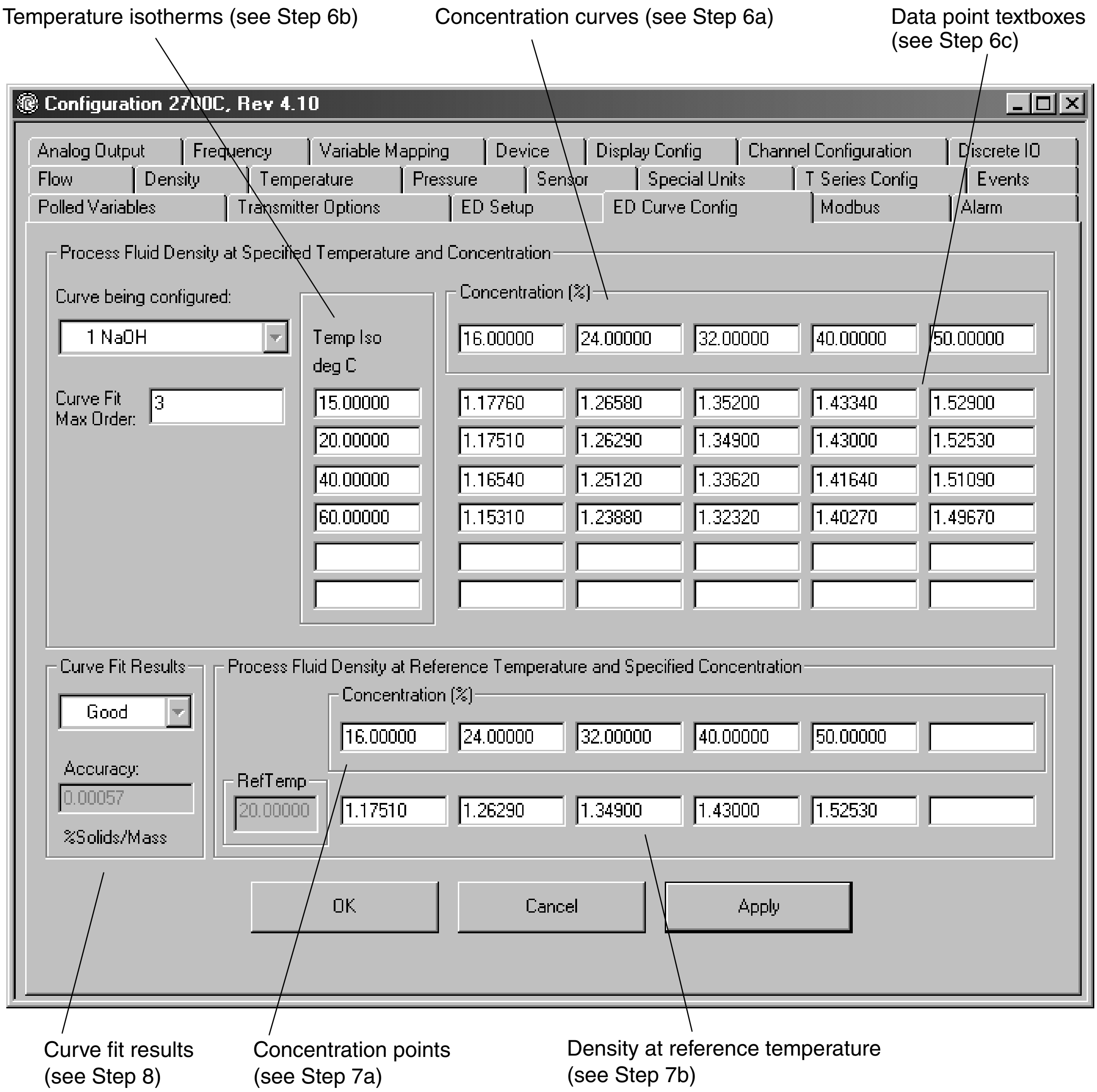
5. Click **ProLink > Configuration** > **ED Curve Config**. A window similar to Figure 4-2 is displayed, showing data for the curve that is currently being configured.

This window has two main work areas:

- *Process Fluid Density at Specified Temperature and Concentration* is used to define the three-dimensional surface described in Section 2.3.2. During the curve-fitting procedure, the enhanced density application will calculate coefficients that will be used to map all points on this surface to their equivalent values at reference temperature.
- *Process Fluid Density at Reference Temperature and Specified Concentration* is used to enter data that will be used to map density values at reference temperature to the equivalent concentration values.

If you specified Density @ Ref or SG as the derived variable, the *Process Fluid Density at Reference Temperature and Specified Concentration* work area is disabled, because the derived variable is not a concentration value and therefore this conversion is not required.

Figure 4-2 ED Curve Config window



6. In the *Process Fluid Density at Specified Temperature and Concentration* work area:
   a. In the **Concentration %** textboxes, enter the concentration values that identify the concentration curves (see Figure 2-6). Enter the values as percentages, in the concentration unit that you want to be used for calculating the derived variable and enhanced density process variables. Minimum number of concentration curves is two; maximum number is five.

Note: If you specified Density @ Ref as the derived variable, enter two to five density values at reference temperature.

   b. In the **Temp Iso** textboxes, enter the temperature values that define the temperature isotherms (see Figure 2-6). Minimum number of temperature isotherms is two; maximum number is six.
   c. For each data point (intersection of concentration curve and temperature isotherm), enter the density of the process fluid at the corresponding concentration curve and temperature isotherm. For example, for Point A1, enter the density of the process fluid at concentration A and temperature 1.

Note: You must enter a value for each data point. If any data points are undefined, the curve fitting results will be Empty or Fail.

7. If you specified Density @ Ref or SG as the derived variable, the *Process Fluid Density at Reference Temperature at Specified Concentration* work area is disabled. Continue with Step 8.

   If you specified any other derived variable, enter the following in the *Process Fluid Density at Reference Temperature at Specified Concentration* work area:
   a. In the **Concentration %** textboxes, enter the concentration points that will define the curve used to convert density values at reference temperature to concentration values. Enter the values as percentages, in the concentration unit that you want to be used for calculating the derived variable and enhanced density process variables. Minimum number of concentration points is two; maximum number is six. These values may or may not match the concentration curves that you defined in Step 6a.
   b. For each concentration point, enter the corresponding density or specific gravity value of the process fluid at the displayed reference temperature. This is the temperature that you configured in Step 4b.
8. Click **Apply**. The transmitter will attempt to fit a density curve to the configured values. The results of the curve fit algorithm are shown in the **Curve Fit Results** textbox. See Section 4.4 for a discussion of curve fitting.
9. Repeat Steps 3 through 8 for as many density curves as required. Note that all density curves must use the same derived variable.
10. If desired, check the **Lock/Unlock ED curves** checkbox on the **ED Setup** window (see Figure 4-1) to lock the curves. When curves are locked, no curve parameters can be changed. You can specify a different active curve. You can also specify a different curve to configure, so that you can view the curve parameters, but you cannot change any of those parameters.

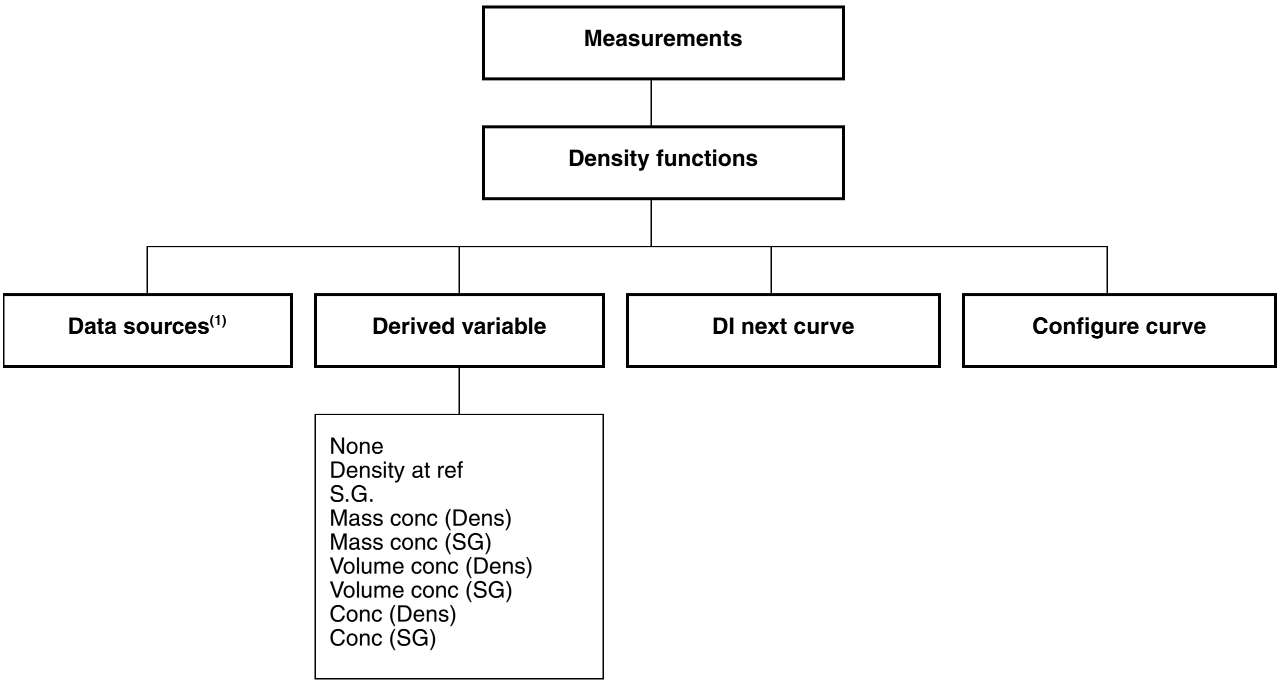
Note: The Lock/Unlock ED Curves option is available only on Series 2000 transmitters v4.1 and higher, Series 2000 FOUNDATION™ fieldbus transmitters v3.0 and higher, or Series 3000 transmitters v6.1 and higher.

4.3.2 Using the display on Series 3000 transmitters

Note: The instructions in this section apply to both 4-wire and 9-wire transmitters.

1. From the **Measurement** menu, select **Density functions**. See Figure 4-3.
2. Specify the derived variable.
3. If you are using a Series 3000 9-wire transmitter:
   a. Configure the data source from which the derived variable will be calculated. See Figure 4-3.
   b. If the frequency input will be used as the flow source for the enhanced density application, configure the frequency input to represent mass flow. For information on configuring the frequency input, see your transmitter documentation.
4. Select **Configure curve**.
5. Specify the slot (Density curve 1–6).
6. Use the appropriate flowchart to enter data for your curve.
   - For *Density at reference temperature* and *Specific gravity*, see Figure 4-4.
   - For all other derived variables, see Figure 4-5.
7. When all values are entered, the transmitter will attempt to fit a density curve to the configured values. The results of the curve fit algorithm are shown in the **Curve Fit Results** screen. See Section 4.4 for a discussion of curve fitting.

Figure 4-3 Density functions menu



(1) Series 3000 9-wire transmitters only.

Figure 4-4 Density functions menu – Density at Ref and S.G.

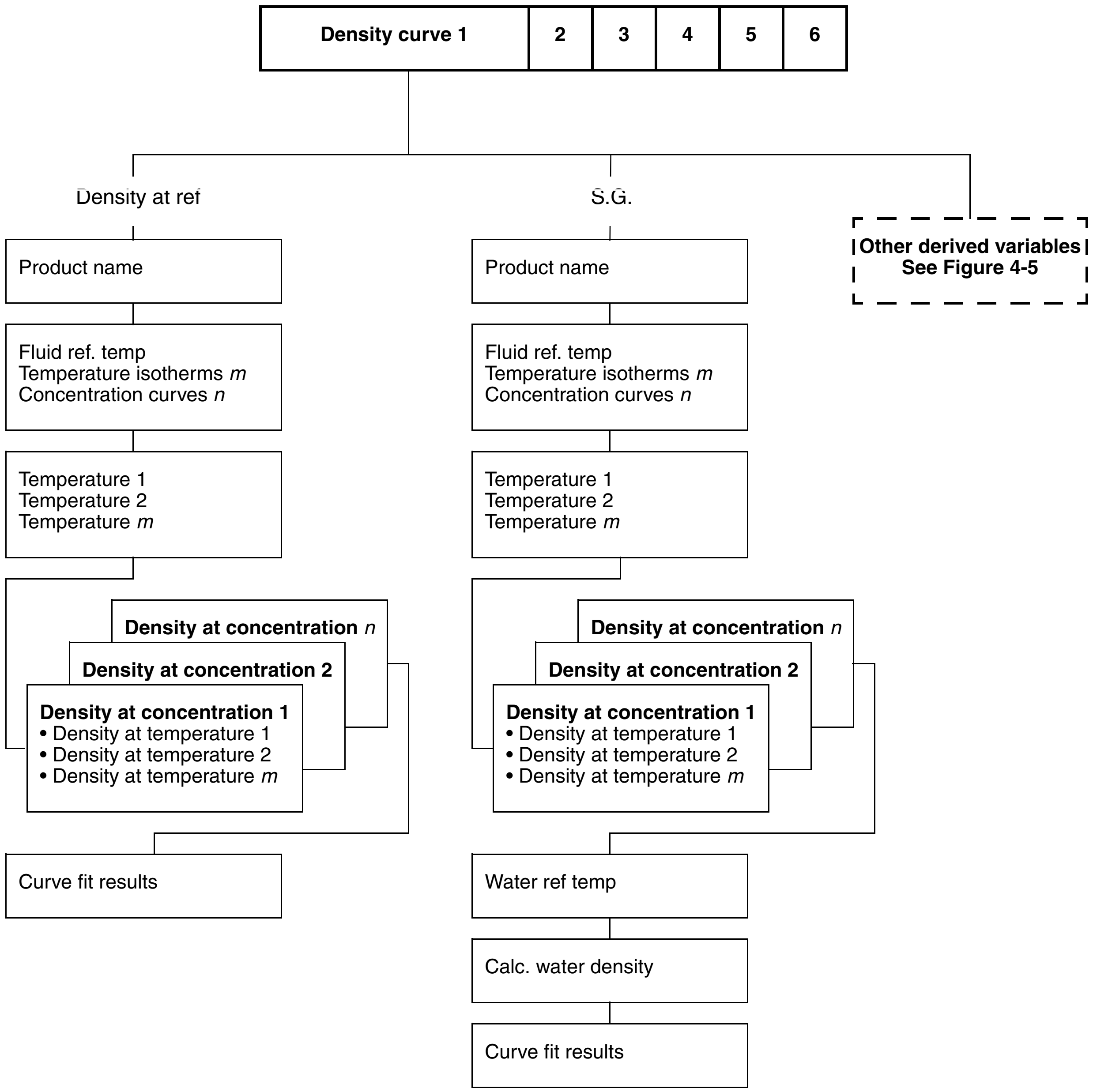
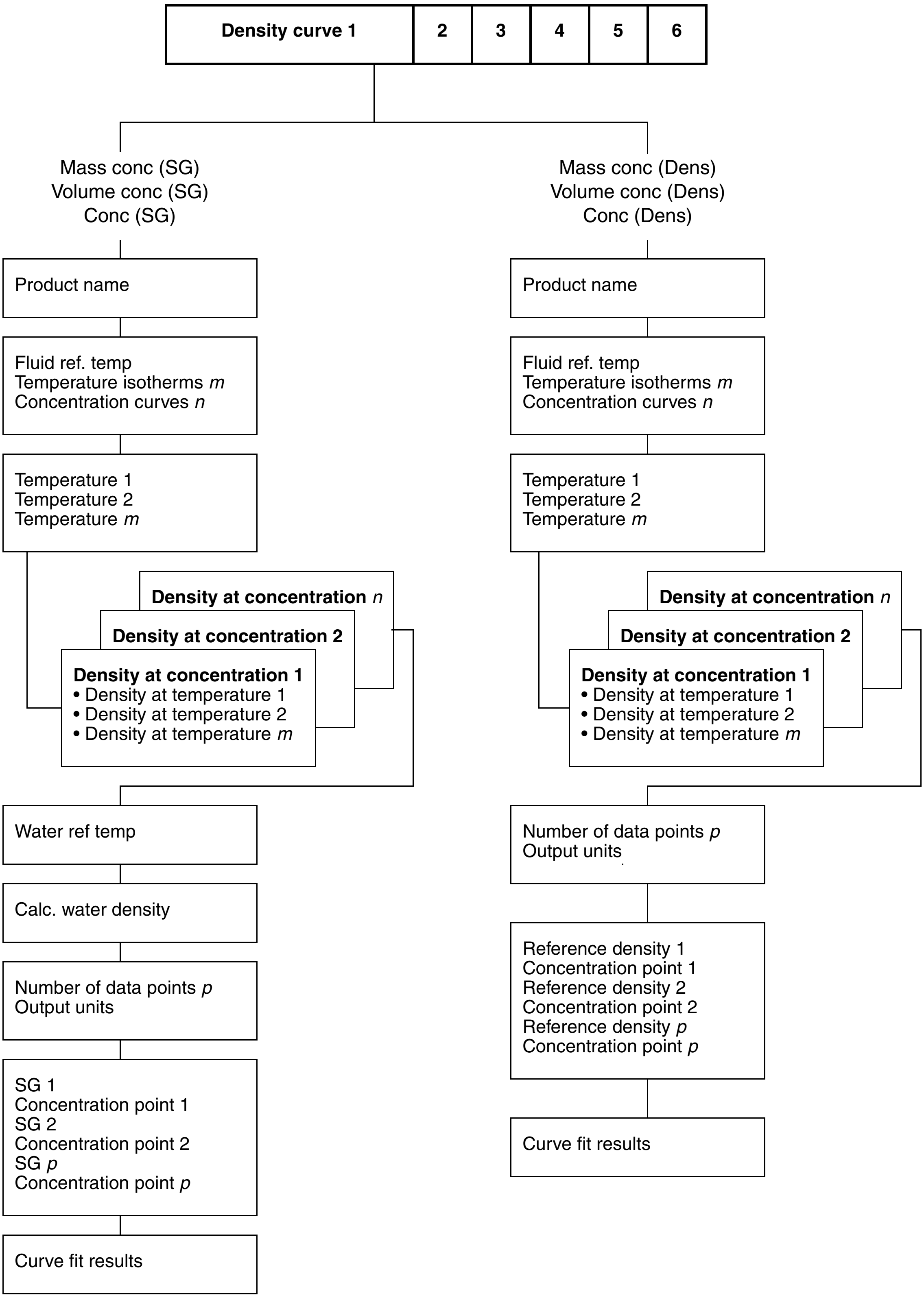


Figure 4-5 Density functions menu – Mass conc (SG), Volume conc (SG), Conc (SG), Mass conc (Dens), Volume conc (Dens), Conc (Dens)



4.4 Curve fitting

There are two measures of the goodness of a density curve:

- The outcome of the curve-fitting algorithm. The concentration will be calculated from the input data only if the curve fit results are **Good**. If the curve fit results are **Poor** or **Fail,** you must repeat the process with modified data. Options include:
  - Correcting inaccurately entered data
  - Reconfiguring the curve using fewer temperature isotherms or concentration curves

  If the curve fit results are **Empty**, the curve-fitting calculation has not completed or has failed. Wait for another minute, or reenter your data.
- The curve fit error. This value is based on the average error in the curve fit, and does not include any error in the entered data or any error in the density or temperature measurements.

Note: Determination of the overall accuracy of the concentration calculation is complex and can be laborious. If this information is required, contact Micro Motion customer service.

The curve fit error is reported in the concentration unit that is currently active. It may be represented as a value like the following:

8.4337E-5

In this example, if the concentration unit for the density curve is % solids, the expected curve fit error is 0.000084337 % solids.

Before You Begin
Theory and Background
Standard or Custom Curves
User-Defined Curves

Chapter 5
Using an Enhanced Density Curve

5.1 About this chapter

This chapter discusses the following topics:

- Specifying the active curve
- Using enhanced density process variables in transmitter configuration
- Modifying a curve
- Saving a curve to a file

5.2 Specifying the active curve

Only one curve can be active (in use by the transmitter) at a time. Specify the active curve using either ProLink II or the display on a Series 3000 transmitter.

5.2.1 Using ProLink II

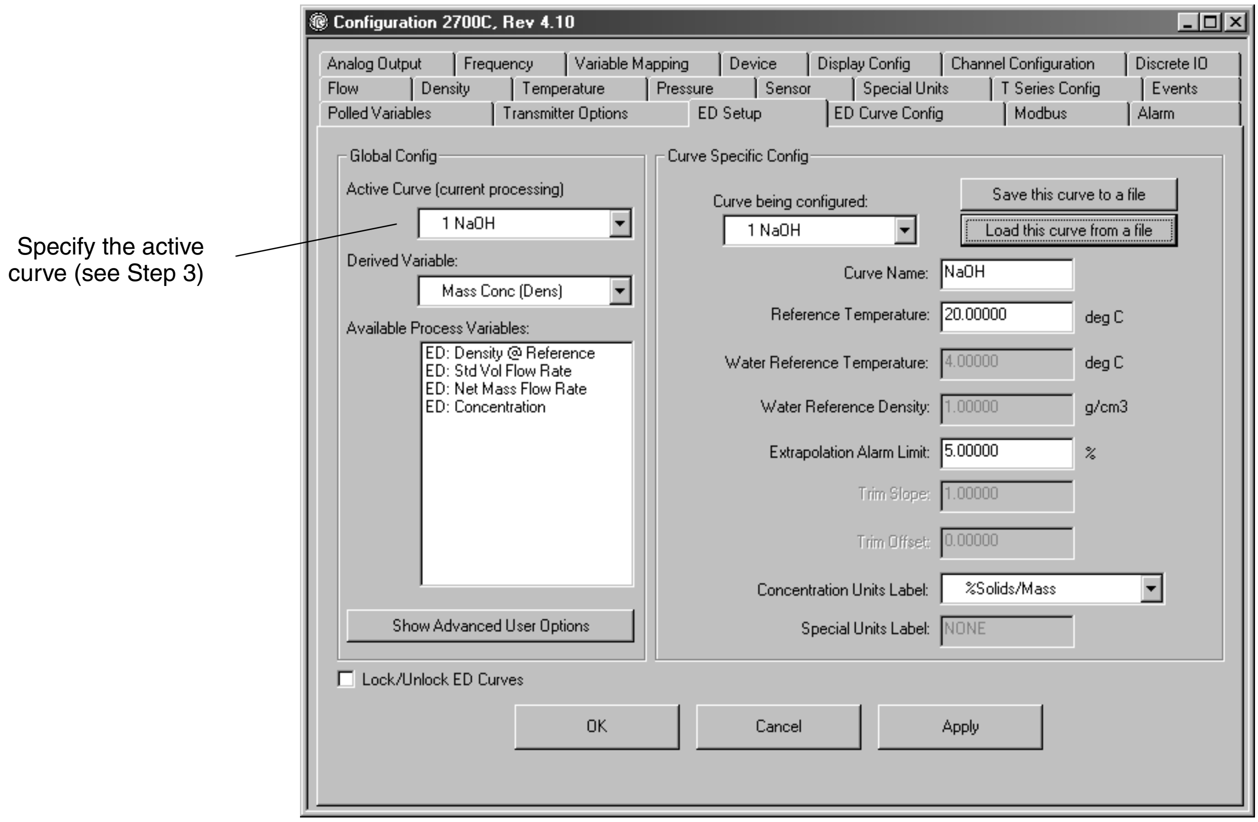
To specify the active curve using ProLink II:

1. If the **ED Process Variables** window is open, close it.
2. Click **ProLink > Configuration** > **ED Setup**. The window shown in Figure 5-1 is displayed.
3. Click on **Active Curve**. All curves that have been loaded into slots are listed. Select the desired curve from the list.

Note: If you are using a Series 3000 transmitter, curves that were loaded through the display are marked with an asterisk (*). This mark does not affect processing in any way.

4. Click **Apply**.

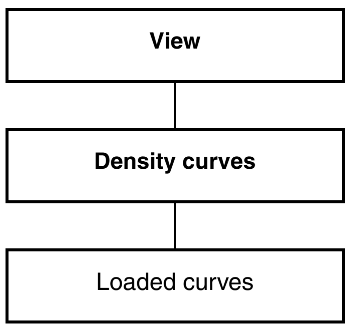
Figure 5-1 ED Setup window – Specifying the active curve



5.2.2 Using the display on Series 3000 transmitters

To specify the curve to use for enhanced density calculations using the display on a Series 3000 transmitter, use the **Density curves** option in the **View** menu. See Figure 5-2.

Figure 5-2 View menu – Specifying the active curve



5.3 Using enhanced density process variables

When the enhanced density application is enabled and an active curve has been specified, any of the available enhanced density process variables can be used like any other process variable. For example:

- Transmitter outputs can be configured to report enhanced density process variables.
- Events can be defined on enhanced density process variables.
- A discrete input can be configured to reset an enhanced density total.

Enhanced density process variables are automatically included in transmitter configuration options.

Note: All "net" process variables assume that the concentration data is based on percent. This includes "net" totals and inventories.

5.4 Modifying the curve

An existing density curve may be modified. The following parameters can be modified without affecting the enhanced density calculations:

- Curve name
- Concentration unit label and optional text string
- Extrapolation alarm limit

Note: As the value for extrapolation alarm limit is increased, the probability of inaccurate enhanced density calculations also increases if the measured density varies beyond the defined density curve. Micro Motion recommends using the default value for extrapolation alarm limit.

Note: Information on performing a density curve trim is provided in Chapter 6.

Do not change any other parameters. In particular, if you change the derived variable, all data is erased for all existing curves.

If you are using ProLink II and the **ED Process Variables** window is open, you will be allowed to view configuration information for the active curve, but you will not be allowed to make any changes. To make changes, you must first close the **ED Process Variables** window.

If the density curves have been locked, you will be allowed to change the active curve and to view configuration information for any curve, but you will not be allowed to change any curve parameters.

5.5 Saving a density curve

Micro Motion recommends that all modified or user-defined curves be saved to a file.

Note: This feature requires ProLink II and is not available with Series 3000 9-wire transmitters.

To save a curve to a file:

1. Click **ProLink > Configuration** > **ED Setup**.
2. Use the **Curve being configured** dropdown list to specify the curve to save, and click **Apply**.
3. Click the **Save this curve to a file** button and specify the file name and location.
4. Repeat these steps for all density curves on your transmitter.

The following are saved to the file:

- Extrapolation alarm limit
- Concentration units label
- Curve trim values

The following are not saved to the file:

- Derived variable
- Density and temperature measurement units

Note: Micro Motion recommends keeping a configuration record on paper as well as saving the curve electronically. Configuration record forms are provided in Appendix B.

Chapter 6
Advanced Options

6.1 About this chapter

This chapter provides information on the following advanced options:

- Curve fit maximum order
- Density curve trim

6.2 Maximum order during curve fit

Curve Fit Max Order defines the maximum order of polynomial to use for the curve fit. The curve fitting algorithm will always use one fewer than the number of concentration curves used to define the density curve, up to the configured maximum value.

For example, if **Max Order** is set to 3:

- If you enter 3 concentration points, the algorithm will use a second-order polynomial.
- If you enter 4 concentration points, the algorithm will use a third-order polynomial.
- If you enter 5 concentration points, the algorithm will still use a third-order polynomial.

Micro Motion recommends leaving **Max Order** set to 3.

6.3 Density curve trim

Before beginning the density curve trim, click the **Show Advanced User Options** button on the **ED Setup** window (see Figure 3-1). This enables the **Trim Slope** and **Trim Offset** textboxes.

The density curve trim is a field adjustment used to bring the transmitter's concentration output values closer to reference values over a restricted density and temperature range.

Two modifications can be made to the enhanced density curve: offset only or slope and offset. For most applications, adjusting the offset is sufficient.

6.3.1 Offset trim

To perform an offset trim:

1. Obtain a good reference value for the concentration of the process fluid. Use the same concentration unit that the enhanced density application is configured to produce (e.g., mass concentration derived from density).
2. Obtain the concentration value calculated by the Micro Motion enhanced density application at the equivalent density and temperature (the measured value).
3. Subtract the reference value from the measured value.
4. (Series 3000 9-wire transmitters only) Divide the value from Step 3 by 100.
5. Enter the result as the trim offset value.

Note: Ensure that you use the correct sign: If the reference value is higher than the measured value, enter a positive Trim Offset value; if the reference value is lower than the measured value, enter a negative Trim Offset value.

6. Obtain a new measured value and compare it to the reference value. If it is acceptably close to the reference value, the offset trim is complete. If it is not acceptably close, repeat the trim.

Example

Reference concentration, measured in °Brix: 64.21

Transmitter concentration reading, in °Brix: 64.93

Series 3000 9-wire transmitters:

$$64.21 - 64.93 = -0.72$$

$$\frac{-0.72}{100} = -0.0072$$

Enter a value of –0.0072 for trim offset.

All other transmitters:

$$64.21 - 64.93 = -0.72$$

Enter a value of –0.72 for trim offset.

6.3.2 Slope and offset trim

To perform a slope and offset trim:

1. Compare transmitter output to reference values at two points. You will have two reference concentration values and two measured concentration values.
2. Enter both sets of values into the following equation:

$$\text{ReferenceConcentration} = (\text{A} \times \text{MeasuredConcentration}) + \text{B}$$

3. Solve for A (slope).
4. Solve for B (offset), using the calculaled slope and one set of values.
5. Enter the results as the trim slope and the trim offset values.

Example

First comparison point:

- Reference concentration: 50.00%
- Measured concentration: 49.98%

Second comparison point:

- Reference concentration: 16.00%
- Measured concentration: 15.99%

Populate equations:

$$50.00 = (\text{A} \times 49.98) + \text{B}$$

$$16.00 = (\text{A} \times 15.99) + \text{B}$$

Solve for A:

$$50.00 - 16.00 = 34.00$$

$$49.98 - 15.99 = 33.99$$

$$34.00 = A \times 33.99$$

$$A = 1.00029$$

Solve for B:

$$50.00 = (1.00029 \times 49.98) + B$$

$$50.00 = 49.99449 + B$$

$$B = 0.00551$$

Enter a value of 1.00029 for trim slope.

Enter a value of 0.00551 for trim offset.

Appendix A
Isotherm and Concentration Curve Ranges

A.1 About this appendix

This appendix discusses good practices in selecting temperature isotherms and concentration curve values and ranges when defining enhanced density surfaces.

A.2 Fewer versus more points

Sodium hydroxide (NaOH caustic soda) concentration is being measured.

- Under normal operating conditions, the concentration is 20% ± 3%.
- The process is stable at approximately 30°C ± 10 °C.

Table A-1 shows the minimum number of values that must be entered to enable measurement:

Table A-1 Two isotherms and two concentration curves

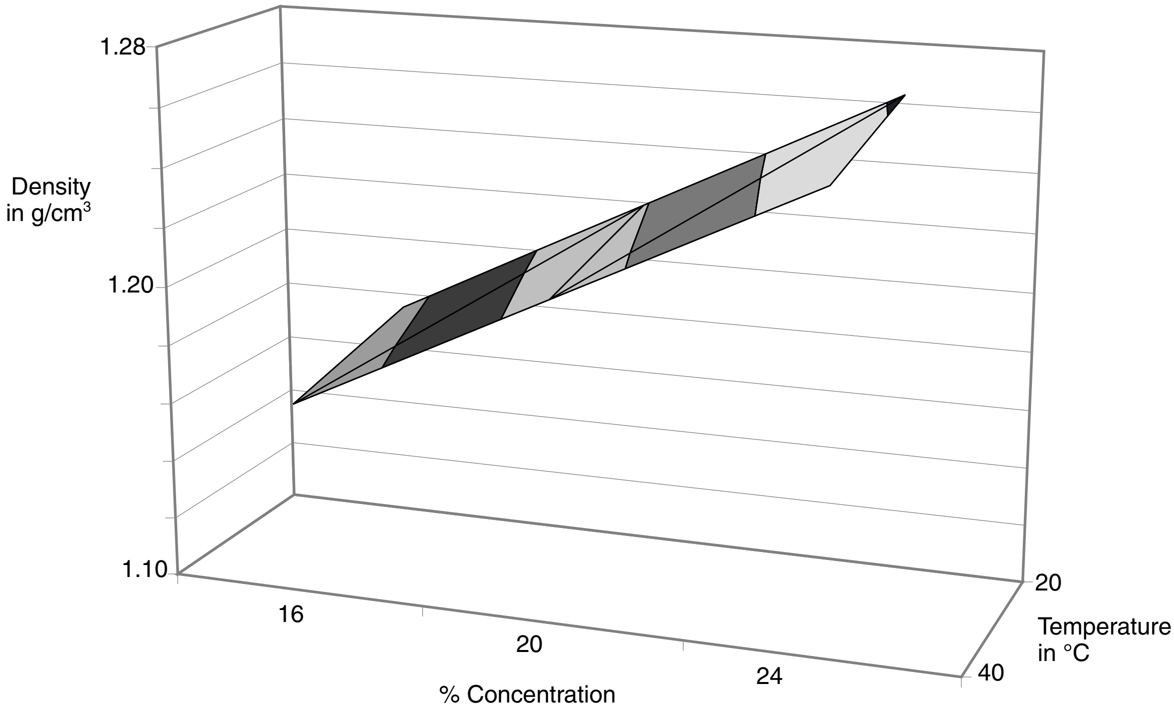
Isotherms	16% concentration	24% concentration
20.00 °C	1.1751 g/cm^3	1.2629 g/cm^3
40.00 °C	1.1645 g/cm^3	1.2512 g/cm^3

This defines the simplest possible surface. For most process fluids, measurement accuracy is improved by adding more concentration and/or temperature values. Table A-2 and Figure A-1 illustrate a density curve that contains density values at two temperature isotherms and three concentration curves.

Table A-2 Two isotherms and three concentration curves

Isotherms	16% concentration	20% concentration	24% concentration
20.00 °C	1.1751 g/cm^3	1.2191 g/cm^3	1.2629 g/cm^3
40.00 °C	1.1645 g/cm^3	1.2079 g/cm^3	1.2512 g/cm^3

Figure A-1 Enhanced density surface derived from Table A-2



A.3 Fewer versus more points, and required ranges

Sodium hydroxide (NaOH caustic soda) concentration is being measured.

- The concentration varies from 16% to 50%.
- The temperature varies from 15 °C to 60 °C.

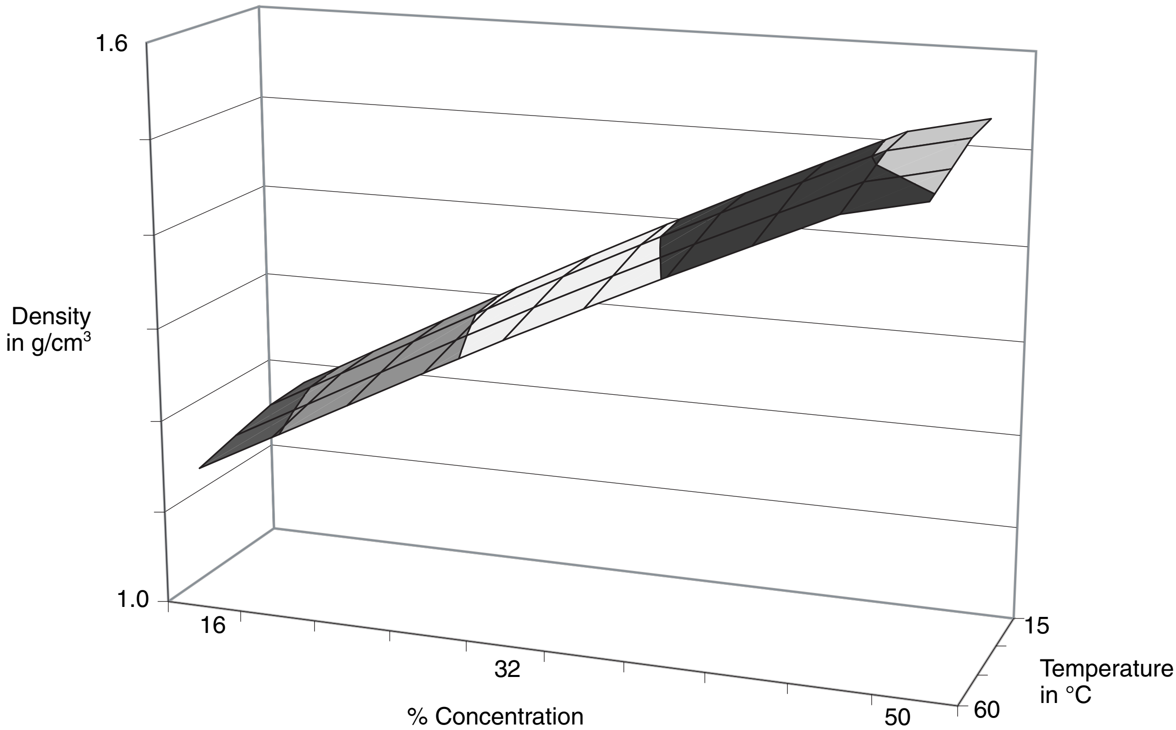
The set of data points used in the previous example are not sufficient here because, for a significant amount of time, the measured density would be outside the defined surface and past the extrapolation alarm limit. Table A-3 shows a set of data points that are chosen to include all expected temperature and concentration values. The resulting enhanced density surface is shown in Figure A-2.

Table A-3 Four isotherms and five concentration curves

Isotherms	16% concentration	24% concentration	32% concentration	40% concentration	50% concentration
15.00 °C	1.1776 g/cm^3	1.2658 g/cm^3	1.3520 g/cm^3	1.4334 g/cm^3	1.5290 g/cm^3
20.00 °C	1.1751 g/cm^3	1.2629 g/cm^3	1.3490 g/cm^3	1.4300 g/cm^3	1.5253 g/cm^3
40.00 °C	1.1645 g/cm^3	1.2512 g/cm^3	1.3362 g/cm^3	1.4164 g/cm^3	1.5109 g/cm^3
60.00 °C	1.1531 g/cm^3	1.2388 g/cm^3	1.3232 g/cm^3	1.4027 g/cm^3	1.4967 g/cm^3

Micro Motion recommends selecting a range of temperature and concentration curves that extend past the expected process variation. For example, given the variation described above, you might specify two additional temperature isotherms, one at 10.00 °C and one at 65 °C, and change the concentration curves so that they range from 12% to 55%.

Figure A-2 Enhanced density surface derived from Table A-3



Appendix B
Configuration Records

B.1 About this appendix

This appendix provides worksheets or configuration records for each type of enhanced density curve. Make copies as required.

B.2 Electronic versus paper configuration records

Using ProLink II, you can save each enhanced density curve to a file, for backup or copying to other transmitters. Instructions are provided in Chapter 5.

However, the derived variable and the density and temperature units are not saved to the file. Micro Motion recommends using both methods: keeping paper configuration records as well as saving the curve to a file.

B.3 Derived variable: Density at reference temperature

Curve number: ______________________________
Curve name: ______________________________
Density unit: ______________________________
Process fluid reference temperature: ______________________________
Extrapolation alarm limit: ______________________________
Trim slope: ______________________________
Trim offset: ______________________________
Concentration units label: ______________________________

Temperature isotherms			Reference density values at concentrations A–E				
#	Value	☐ °F ☐ °C	A ______ %	B ______ %	C ______ %	D ______ %	E ______ %
1							
2							
3							
4							
5							
6							

B.4 Derived variable: Specific gravity

Curve number: ______________________________
Curve name: ______________________________
Density unit: ______________________________
Process fluid reference temperature: ______________________________
Water reference temperature: ______________________________
Water reference density: ______________________________
Extrapolation alarm limit: ______________________________
Trim slope: ______________________________
Trim offset: ______________________________
Concentration units label: ______________________________

Temperature isotherms		Reference density values at concentrations A–E				
#	Value ☐ °F ☐ °C	A ______ %	B ______ %	C ______ %	D ______ %	E ______ %
1						
2						
3						
4						
5						
6						

B.5 Derived variable: Mass Conc (Dens)

Curve number: ______________________
Curve name: ______________________
Density unit: ______________________
Process fluid reference temperature: ______________________
Extrapolation alarm limit: ______________________
Trim slope: ______________________
Trim offset: ______________________
Concentration units label: ______________________

Temperature isotherms		Reference density values at concentrations A–E				
#	Value ☐ °F ☐ °C	A ______ %	B ______ %	C ______ %	D ______ %	E ______ %
1						
2						
3						
4						
5						
6						

Reference density values at concentrations A–F					
A ______ %	B ______ %	C ______ %	D ______ %	E ______ %	F ______ %

B.6 Derived variable: Mass Conc (SG)

Curve number: ______________________________
Curve name: ______________________________
Density unit: ______________________________
Process fluid reference temperature: ______________________________
Water reference temperature: ______________________________
Water reference density: ______________________________
Extrapolation alarm limit: ______________________________
Trim slope: ______________________________
Trim offset: ______________________________
Concentration units label: ______________________________

Temperature isotherms		Reference density values at concentrations A–E				
#	**Value** ☐ °F ☐ °C	**A ______ %**	**B ______ %**	**C ______ %**	**D ______ %**	**E ______ %**
1						
2						
3						
4						
5						
6						

Specific gravity values at concentrations A–F					
A ______ %	**B ______ %**	**C ______ %**	**D ______ %**	**E ______ %**	**F ______ %**

B.7 Derived variable: Volume Conc (Dens)

Curve number: ______________________
Curve name: ______________________
Density unit: ______________________
Process fluid reference temperature: ______________________
Extrapolation alarm limit: ______________________
Trim slope: ______________________
Trim offset: ______________________
Concentration units label: ______________________

Temperature isotherms		Reference density values at concentrations A–E				
#	Value ☐ °F ☐ °C	A ______ %	B ______ %	C ______ %	D ______ %	E ______ %
1						
2						
3						
4						
5						
6						

Reference density values at concentrations A–F					
A ______ %	B ______ %	C ______ %	D ______ %	E ______ %	F ______ %

B.8 Derived variable: Volume Conc (SG)

Curve number: ______________________________
Curve name: ______________________________
Density unit: ______________________________
Process fluid reference temperature: ______________________________
Water reference temperature: ______________________________
Water reference density: ______________________________
Extrapolation alarm limit: ______________________________
Trim slope: ______________________________
Trim offset: ______________________________
Concentration units label: ______________________________

Temperature isotherms		Reference density values at concentrations A–E				
#	Value ☐ °F ☐ °C	A ______ %	B ______ %	C ______ %	D ______ %	E ______ %
1						
2						
3						
4						
5						
6						

Specific gravity values at concentrations A–F					
A ______ %	B ______ %	C ______ %	D ______ %	E ______ %	F ______ %

B.9 Derived variable: Conc (Density)

Curve number: ______________________
Curve name: ______________________
Density unit: ______________________
Process fluid reference temperature: ______________________
Extrapolation alarm limit: ______________________
Trim slope: ______________________
Trim offset: ______________________
Concentration units label: ______________________

Temperature isotherms		**Reference density values at concentrations A–E**				
#	**Value** ☐ °**F** ☐ °**C**	**A ______ %**	**B ______ %**	**C ______ %**	**D ______ %**	**E ______ %**
1						
2						
3						
4						
5						
6						

Reference density values at concentrations A–F					
A ______ %	**B ______ %**	**C ______ %**	**D ______ %**	**E ______ %**	**F ______ %**

B.10 Derived variable: Conc (SG)

Curve number:	______________________
Curve name:	______________________
Density unit:	______________________
Process fluid reference temperature:	______________________
Water reference temperature:	______________________
Water reference density:	______________________
Extrapolation alarm limit:	______________________
Trim slope:	______________________
Trim offset:	______________________
Concentration units label:	______________________

Temperature isotherms		**Reference density values at concentrations A–E**				
#	**Value** ☐ °F ☐ °C	**A ______ %**	**B ______ %**	**C ______ %**	**D ______ %**	**E ______ %**
1						
2						
3						
4						
5						
6						

Specific gravity values at concentrations A–F					
A ______ %	**B ______ %**	**C ______ %**	**D ______ %**	**E ______ %**	**F ______ %**

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