Honeywell

SMV 3000

Laminar Flow Equation Reference Guide

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About This Publication

This manual is intended as a "how to" reference for configuring Honeywell's SMV 3000 Smart Multivariable Transmitter with the LF option. It is based on using the SCT 3000 Smartline® Configuration Toolkit software version 4.0 or greater as the operator interface.

This manual provides procedures to assist users in operating the SMV 3000 where the transmitter is used to provide dynamically compenstated flow measurement with Laminar flow elements.

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Tables and Figures

References

Publication Title	Publication Number	Binder Title	Binder Number
SMV 3000 Smart Multivariable Transmitter User's Manual	34-SM-25-02		
SCT 3000 Smartline Configuration Toolkit Start-up and Installation Manual	34-ST-10-08		

Technical Assistance

If you encounter a problem with your SMV 3000 Smart Multivariable Transmitter, check to see how your transmitter is currently configured to verify that all selections are consistent with your application.

If the problem persists, you can call our Solution Support Center between the hours of 8:00 am and 4:00 pm EST Monday through Friday for direct factory technical assistance.

1-800-423-9883 (U. S. only)
OR
1-215-641-3410

FAX: 1-215-641-3400

An engineer will discuss your problem with you. Please have your complete model number, serial number, and software revision number on hand for reference. You can find the model and serial numbers on the transmitter nameplates. You can also view the software version number using the SCT or SFC.

If it is determined that a hardware problem exists, a replacement transmitter or part will be shipped with instructions for returning the defective unit. Please do not return your transmitter without authorization from Honeywell's Solution Support Center or until the replacement has been received.

Laminar Flow Equation Reference

1. Introduction

Background

The SMV 3000 with Laminar Flow (LF) option provides three equations for use with Laminar Flow elements for standard volumetric flow rate, mass flow rate, and custom flow measurement. The equations allow for dynamic compensation of flow measurement due to process changes in temperature, density, viscosity and pressure.

LF Equation Set Up Process

Using the Smart Configuration Toolkit (SCT 3000) software program, you to enter selected equation parameters into a table (called a Generic Parameter Property Sheet). The property sheet allows you to enter parameter values for a particular flow application by index number, data type and value. Sample property sheets are provided in this document to aid in recording the values before you enter them into the SCT 3000. Configuration examples are also provided to aid in configuring the SMV 3000 database for the LF flow equations.

The equation parameters and values entered using the SCT 3000 comprise the SMV 3000 database files. These files can be created or edited off-line and then saved for future use. In the on-line mode, the file(s) can be edited and the changes downloaded to the SMV 3000 transmitter.

ATTENTION

Due to the advance capability of these new equations, the Smart Field Communicator, SFC cannot be used to set up the SMV 3000 for LF equations. The **SCT 3000 software version 3.12.3 or greater must be used** to configure the SMV because it contains the generic parameter interface necessary to enter the equation parameters.

SCT 3000 On-line User Manual and Help

Additional information and instructions about generic parameter sheets, on-line mode and off-line configuration is available in the SCT on-line User Manual and help topic windows.

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How to Configure the SMV 3000

Please refer to these sources for detailed information and procedures for SMV transmitter general configuration:

- *SMV 3000 User's Manual*, document 34-SM-25-02
- SCT 3000 on-line User Manual.

The procedures in this document outline additional steps to SMV configuration to set up the LF equations in the SMV 3000 database. These procedures are specific when using the SMV for flow applications using Laminar flow elements.

Reference Information

Consult the following references for data which is useful in setting up the flow equation:

- The flow element manufacturer's documentation.
- The process fluid manufacturer's documentation on density and viscosity characteristics.
- *Flow Measurement Engineering Handbook*, by Richard W. Miller, McGraw-Hill, Third Edition, 1996.
- Examples in this document for defining some of the equation terms used in LF equations. (See Section 9.)

2. Laminar Flow Equation Set Up Procedure

Using Generic Parameter Property Sheets

The property sheets included in Section 4 of this document contain the necessary parameters to configure the SMV transmitter for the LF equation. These property sheets provide a means to gather all the appropriate values before you enter them in the property sheets of the SCT 3000.

Use the generic parameter property sheets of the LF equation type for your flow application type. Fill in the appropriate spaces in the sheets, since the parameter values which you need may come from a variety of sources and some values may have to be calculated before entering them into the SCT 3000.

For example, values for the flow equation coefficients may be obtained from the flow element manufacturer. Also, density values for determining density correction coefficients may be obtained from process fluid vendor's data.

Follow the steps in Table 1 to fill-in the property sheets.

Procedure

Table 1 SMV 3000 Generic Parameter Property Sheets Procedure

Step	Action
1	Obtain application data sheet for the Laminar flow element from the manufacturer's documentation. This information includes flow equation values which you need to set up the configurable flow term in the LF equation for the SMV 3000.
2	Make a copy of the parameter property sheets provided in Section 4.
3	Select the flow equation type to be used by the SMV 3000 according to your process application requirements. Equation Type and output units selects the flow output type. See LF Equation Parameters, Section 5.

Continued on next page

Procedure, continued

Table 1 SMV 3000 Generic Parameter Property Sheets Procedure, Continued

Step	Action
4	Fill out the "Values" column of the property sheets. (The index number, data type and a brief description of the parameter are listed for each value needed to set up the equation.) **NOTE** — Make sure that all values have been converted to the appropriate units for the selected parameter before entering them on the property sheets. **IMPORTANT** — Consult the process fluid manufacturer's application data sheets (or tables) for the following values, if necessary, to fill in the property sheets: • Flow viscosity term equation for the process fluid. • Viscosity correction term equation for process fluid. • Density correction term equation for process fluid. **NOTE** — If you do not have values for some parameters, then you should use the best approximation for the value. For example: If you do not have an equation for the flow viscosity of your process fluid, enter the configurable Flow Viscosity term as a constant, i.e. the flowing viscosity.
5	Refer to the generic parameter property sheets when entering parameter values into the SCT 3000.

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SMV 3000 Database Files and Templates in the SCT

To configure the SMV 3000 for the LF equation, you must create database files using Honeywell templates or user-defined templates in the SCT 3000.

The Honeywell Templates provide a number of SMV 3000 templates in which you enter names and values for the transmitter general configuration. For example, you could choose the SMVRTD.hdt template to configure the SMV 3000's differential pressure (PV1), static pressure (PV2) and temperature (PV3) ranges.

Next, you choose a generic parameter property sheet to set up the flow equation. For example, choose the Blank Generic Template and enter the parameter values (from the property sheet) which are associated with the Laminar Flow equation.

NOTE: Procedures on the following pages outline the steps for creating SMV transmitter database files.

The result is that you will have two files that make up the complete database for the SMV 3000:

1. A file containing the SMV 3000 values for the transmitter (SMV 3000 Database). This file should be named with a *.sct file extension, and contains such information as the upper and lower range values of each Process Variable (PV).
2. A file containing the values used for executing the selected LF equation (Generic Database). This file should be named with a *.gdt file extension, and contains specific flow application data.

Both of these files then can be downloaded to the transmitter to provide flow measurement for laminar flow applications.

IMPORTANT: The .sct file **must** be downloaded before the .gdt file.

ATTENTION

It is suggested that you create the database files with the SCT 3000 in the off-line mode. This allows you to enter and verify the values before downloading the files to the transmitter.

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Database Set Up Procedure

Table 2 outlines the steps for creating a SMV 3000 database file.

Table 2 SMV 3000 Database Set Up Procedure (Off-line)

Step	Action
1	Open the SCT 3000 application program and enter user name
2	Select **File** and **New**...to select a Honeywell or user template for the SMV 3000 database. For example, choose the SMVRTD.hdt.
3	Fill-in the fields of the various tab cards with appropriate names and values. For example, configure the URVs for DP and Temperature. **NOTE** — Do not use the FlowAlg or K(user) tab cards, except for configuring the low flow cutoff. Due to the advanced capability of the LF equation, the parameters for flow equation type and K_{LF} values are not entered on these cards.
4	Save the file as .sct. (Use **Save As** and give the file a new name).

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Equation Set Up Procedure

Table 3 lists the steps for creating a generic database file for the LF equation parameters.

Table 3 Generic Database Set Up Procedure (Off-line)

Step	Action
1	Open the SCT 3000 application program and enter user name
2	Select **File** and **New**...
3	Select a **Generic Template** Window and choose Blank Generic Template (Blank.gdt).
4	For each parameter on the property sheet in which you have values: - enter the appropriate index number in the Index column - select the appropriate Data Type from the drop down window, and - enter the Value for each parameter from the property sheet. **NOTE** — Make sure that all values have been converted to the appropriate units for the selected parameter before entering them into the generic parameter property sheet. Some parameters may not be needed based on the application. If so, do not enter a value for that parameter. **IMPORTANT** — The equation Type parameter (index 94) must always be the first entry in the generic parameter property sheet. You must either accept or reject the changes for the current page of parameters before moving to the next page. • Select OK at the bottom of the window to accept the changes. • Select Cancel to reject all changes for the current page.
To Access On-line Help ⇒	• Select **Help** and **Contents** from the drop down menu. • Select **How to . . .** *"Configure a Generic Tab."* (The topics explain the tasks for creating a generic database for a SMV 3000.)
5	Once all parameters have been entered, save the file to disk for future use. (Use **Save As** and give the file a new name). Save a generic database with the .gdt extension, and a tab card database with the .sct extension.

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Transmitter Database Download

The two files that contain the transmitter and equation parameter values can be downloaded to the SMV 3000. Follow the steps in Table 4 for the download procedure.

IMPORTANT: **The SMV database file (.sct file) must be downloaded before the SMV generic database file (.gdt file).**

Table 4 SMV 3000 Database Download Procedure (On-line)

Step	Action
1	Connect SCT to SMV and establish communications. (See Subsection 5.2 in the *SMV User Manual* for procedure, if necessary.)
2	Be sure any switches that may trip alarms or interlocks associated with analog loops are secured or turned off.
3	Select **Open...** from the **File** menu to open the saved SMV 3000 database file.
4	Select **Device** and **Download** from the drop down menu (or click the Download to Device toolbar button) to initiate a SMV 3000 database download to the transmitter.
5	A Communications Status dialog box displays during the downloading process.
6	When the download is completed, repeat steps 3 and 4 to select and download the generic database file to the transmitter. See NOTE.
7	After successful download, perform an upload of the database and check status of the SMV 3000.
8	Perform the procedure in the SMV User Manual in Section 7.4 *Using Transmitter to Simulate PV Input* to substitute values for inputs PV1, PV2, PV3 and check transmitter output (PV4) for accuracy across the full range of input values valid for your application and configuration.

NOTE: SMV database configurations containing several higher order polynomials may take a considerable amount of time to download the database to the transmitter.

3. Editing SMV 3000 Configuration

On-line Database Editing

Changing values in the transmitter while in the on-line mode is useful when debugging the device configuration. To edit the generic database file in the on-line mode follow the steps in Table 5.

Table 5 Generic Database On-Line Edit Procedure

Step	Action
1	Connect SCT to SMV and establish communications. (See Subsection 5.2 in the *SMV User Manual* for procedure, if necessary.)
2	Be sure any switches that may trip alarms or interlocks associated with analog loops are secured or turned off.
3	Select **Help** and **Contents** from the drop down menu.
4	Select **How To . . .** in the Help window and choose: *Configure a Generic Tab.*
5	Select **Online Configuration** and click on *"Editing the Generic Parameter Property Sheet Tab".*
6	If operating the SCT 3000 in the off-line mode: • Perform steps 3 and 4 above, and then • Select **Offline Configuration** and click on *"Editing a Generic Parameter Property Sheet Tab".*

4. Generic Parameter Property Sheets

SMV 3000 Generic Parameter Property Sheets

The following pages contain property sheets that list the parameters necessary for setting up the Laminar Flow equation in the SMV 3000 transmitter.

ATTENTION

Refer to Sections 5 through 11, for more detailed information on the descriptions and meaning of the parameters and descriptions of valid values used to set up the LF equation.

Using the Property Sheets

Make a copy of the property sheets and then follow the steps in Tables 1, 2, 3 and 4 to fill in the parameter values and configure the SMV 3000 with the laminar flow equation for your process application.

- The first three columns of the parameter property sheet (Index Number, Data Type and Value) must be entered when creating the generic database file with the SCT 3000.
- Please be aware of the units column and enter the value in the units specified.
- Also be sure to enter the parameters in the order as listed on the property sheets.

Continued on next page

Generic Parameter Property Sheets

LF Equation Basic Parameters:				
Index Number	**Data Type**	**Value**	**Description**	**Units**
94	1 byte		Equation Type (Section 5)	-
95	1 byte		Flow Failsafe Selection (Section 5)	-
224	Uint8		PV4 Flow Units Mode (00=volume, 01=mass, 02=custom) (Section 5)	-
97	HW Float		K_{LF}, Constant for LF Equation	-
98	HW Float		Temperature at Standard (base) conds.	degrees F
99	HW Float		Pressure at Standard (base) conds.	psia
100	HW Float	*not used*	Relative Humidity	0 - 100%
101	HW Float		Density at standard (base) conditions	lb/ft^3
Flow Term Parameters:				
65	UInt8		Flow term, Formula code selection *(See Table 7)*	-
66	UInt8		Flow term, Qualifier 1 *(See Table 7)*	-
67	UInt8	0	Flow term, Qualifier 2 (Must enter zero) *(See Table 7)*	-
68	UInt8		Flow term, Variable index selection *(See Table 8)*	-
102	HW Float		Flow term coefficients, A_0	
103	HW Float		" " " , A_1	
104	HW Float		" " " , A_2	
105	HW Float		" " " , A_3	
106	HW Float		" " " , A_4	
107	HW Float		" " " , A_5	
108	HW Float		" " " , A_6	
109	HW Float		" " " , A_7	
110	HW Float		" " " , A_8	
111	HW Float		" " " , A_9	
112	HW Float		" " " , A_{10}	
113	HW Float		" " " , A_{11}	

Continued on next page

Generic Parameter Property Sheets, continued

Standard Viscosity (μ_{std}) Parameters:				
Index Number	**Data Type**	**Value**	**Description**	**Units**
69	UInt8		Standard viscosity term, Formula code selection *(See Table 7)*	-
70	UInt8		Standard viscosity term, Qualifier 1 *(See Table 7)*	-
71	UInt8	0	Standard viscosity term, Qualifier 2 (Must enter zero) *(See Table 7)*	-
72	UInt8		Standard viscosity term, Variable index selection *(See Table 8)*	-
114	HW Float		Standard viscosity coefficients, A_0	
115	HW Float		" " " , A_1	
116	HW Float		" " " , A_2	
117	HW Float		" " " , A_3	
118	HW Float		" " " , A_4	
119	HW Float		" " " , A_5	
120	HW Float		" " " , A_6	
121	HW Float		" " " , A_7	
122	HW Float		" " " , A_8	
123	HW Float		" " " , A_9	
124	HW Float		" " " , A_{10}	
125	HW Float		" " " , A_{11}	

Continued on next page

Generic Parameter Property Sheets, continued

Flow Viscosity (μ_{flow}) Parameters:				
Index Number	**Data Type**	**Value**	**Description**	**Units**
73	UInt8		Flow viscosity term, Formula code selection *(See Table 7)*	-
74	UInt8		Flow viscosity term, Qualifier 1 *(See Table 7)*	-
75	UInt8	0	Flow viscosity term, Qualifier 2 (Must enter zero) *(See Table 7)*	-
76	UInt8		Flow viscosity term, Variable index selection *(See Table 8)*	-
126	HW Float		Flow viscosity coefficients, A_0	
127	HW Float		" " " , A_1	
128	HW Float		" " " , A_2	
129	HW Float		" " " , A_3	
130	HW Float		" " " , A_4	
131	HW Float		" " " , A_5	
132	HW Float		" " " , A_6	
133	HW Float		" " " , A_7	
134	HW Float		" " " , A_8	
135	HW Float		" " " , A_9	
136	HW Float		" " " , A_{10}	
137	HW Float		" " " , A_{11}	

Continued on next page

Generic Parameter Property Sheets, continued

Viscosity Correction Factor (μ_{adjust}) Parameters:				
Index Number	**Data Type**	**Value**	**Description**	**Units**
77	UInt8		Viscosity correction term, Formula code selection *(See Table 7)*	-
78	UInt8		Viscosity correction term, Qualifier 1 *(See Table 7)*	-
79	UInt8	0	Viscosity correction term, Qualifier 2 (Must enter zero) *(See Table 7)*	-
80	UInt8		Viscosity correction term, Variable index selection *(See Table 8)*	-
138	HW Float		Viscosity correction coefficients, A_0	
139	HW Float		" " " , A_1	
140	HW Float		" " " , A_2	
141	HW Float		" " " , A_3	
142	HW Float		" " " , A_4	
143	HW Float		" " " , A_5	
144	HW Float		" " " , A_6	
145	HW Float		" " " , A_7	
146	HW Float		" " " , A_8	
147	HW Float		" " " , A_9	
148	HW Float		" " " , A_{10}	
149	HW Float		" " " , A_{11}	

Continued on next page

Generic Parameter Property Sheets, continued

Density Correction Factor (ρ_{adjust}) Parameters:				
Index Number	**Data Type**	**Value**	**Description**	**Units**
81	UInt8		Density correction term, Formula code selection *(See Table 7)*	-
82	UInt8		Density correction term, Qualifier 1 *(See Table 7)*	-
83	UInt8	0	Density correction term, Qualifier 2 (Must enter zero) *(See Table 7))*	-
84	UInt8		Density correction term, Variable index selection *(See Table 8)*	-
150	HW Float		Density correction coefficients, A_0	
151	HW Float		" " " , A_1	
152	HW Float		" " " , A_2	
153	HW Float		" " " , A_3	
154	HW Float		" " " , A_4	
155	HW Float		" " " , A_5	
156	HW Float		" " " , A_6	
157	HW Float		" " " , A_7	
158	HW Float		" " " , A_8	
159	HW Float		" " " , A_9	
160	HW Float		" " " , A_{10}	
161	HW Float		" " " , A_{11}	

5. LF Equation Parameters

LF Flow Equation, Parameter Index 94

For LF measurement, the SMV 3000 flow output can be configured in three forms:

1. Volumetric Flow at **Standard** Conditions. (equation type 05)
2. Mass Flow Rate (equation type 25)
3. Custom Flow Equation (equation type 15)

Index Number 94 of the generic database contains the flow equation type parameter which determines the flow measurement output. The equations are listed below along with the output units, the units mode selection and the equation form of the equation.

Volumetric Flow at Standard Conditions

Flow Equation (index 94): 05
Output Units: CFM
PV4 Units Mode (index 224): 00

Equation Form —

$$StdFlow = K_{LF} \bullet Flow \bullet \left(\frac{\mu_{std}}{\mu_{flow} \bullet \mu_{adjust}} \right) \bullet \left(\frac{T_{std}}{T_{flow}} \right) \bullet \left(\frac{P_{flow}}{P_{std}} \right) \bullet \rho_{adjust}$$

$$= K_{LF} \bullet Flow \bullet \mu_{ratio} \bullet T_{norm} \bullet P_{norm} \bullet \rho_{adjust}$$

Equation Terms —

Constant Terms: K_{LF}
Fixed Equation Terms: T_{norm}, P_{norm}
Configurable Equation Terms: Flow, μ_{std}, μ_{flow}, μ_{adjust}, ρ_{adjust}

Mass Flow Rate

Flow Equation (index 94): 25
Output Units: lbs/hr
PV4 Units Mode (index 224): 01

Equation Form —

$$MassFlow = StdFlow \bullet Density \bullet \left(60 \frac{\min}{hr} \right)$$

Equation Terms —

Constant Terms: K_{LF}, Density
Fixed Equation Terms: T_{norm}, P_{norm}
Configurable Equation Terms: Flow, μ_{std}, μ_{flow}, μ_{adjust}, ρ_{adjust}

Continued on next page

Custom Flow Equation

Flow Equation (index 94): 15
Output Units: user-defined
PV4 Units Mode (index 224): 02

Equation Form —

$$CustomFlow = K_{LF} \bullet Flow \bullet \left(\frac{\mu_{std}}{\mu_{flow} \bullet \mu_{adjust}} \right) \bullet \rho_{adjust}$$

Equation Terms —

Constant Terms: K_{LF}
Fixed Equation Terms: none
Configurable Equation Terms: Flow, μ_{std}, μ_{flow}, μ_{adjust}, ρ_{adjust}

NOTE: For actual volumetric flow rate output, set the ρ_{adjust} term to a constant value of one. If the units of Flow are CFM, K_{LF} is unitless, and the result of the viscosity ratio is unitless, then the actual volumetric flow rate will be in CFM.

Equation Terms

See Sections 6 through 8 for descriptions of the equation terms used in the flow equations.

Continued on next page

Flow Failsafe, Parameter Index 95

LF equations use PV1 (DP), PV2 (AP or GP) and PV3 (Temp.) and calculated values based on these measurements to produce a compensated flow output - PV4. The transmitter performs checks to see if these input values are valid before computing flow. When one or more of the values are invalid, transmitter action is determined by the user's failsafe selection. Index 95 of the generic parameter property sheet contains the flow failsafe parameter and defines the failsafe selections for the LF equations.

NOTE: Both pressure and temperature compensation is used in the LF equation.

Flow Failsafe Selection

The choices for (Index Number 95) flow failsafes are as follows:

Index 95 = 00	PV2 or PV3 failure **does not cause** PV4 (flow) failsafe.
Index 95 = 10	PV4 failsafe due to PV2 (AP) failure.
Index 95 = 20	PV4 failsafe due to PV3 (Temp) failure.
Index 95 = 30	PV2 or PV3 failure **causes** PV4 (flow) failsafe.

NOTE: If PV2 or PV3 measurements fail and PV4 failsafe is not enabled (index 95 = 00), any calculated value which is a function of PV2 or PV3 such as P_{norm}, T_{norm} ,ρ_{adjust} or μ_{ratio} will be set equal to 1 and flow will continue to be calculated.

Continued on next page

Failsafe Status Messages

When PV4 is in failsafe, the SCT 3000 will display CRITICAL status. Other status messages may also be displayed at the SCT 3000, depending on the cause of the failsafe. Status messages are visible by selecting the Status tab from an SCT 3000 on-line window.

The PV4 flow output goes to failsafe when one of these conditions occurs:

	IF . . .	Then SCT 3000 will show Detailed Status Display . . .
1.	P_f (PV2) sensor fails *AND* Flow Failsafe is enabled - Index 95 = 10 or 30	"PV4 in Failsafe" "PV4 (AP) Bad Compensation" "Suspect Input" *or* "PV2 (AP) Input Suspect"
2.	T_f (PV3) fails *AND* Flow Failsafe is enabled - Index 95 = 20 or 30	"PV4 in Failsafe" "PV4 (Flow) Bad PT Compensation" "PV3 (Temp) Open Input"
3.	h_w (PV1) sensor fails	"PV4 in Failsafe" "Suspect Input"
4.	A division by zero occurs in the LF equation	None specifically for this condition.
5.	Invalid or incomplete PV4 database	"Invalid Equation Parameters" "PV4 in Failsafe"

Note: PV4 flow failsafe action depends upon the LF equation configuration and the selected output form. For example, when the custom flow output is selected and none of the PV4 configurable equation terms are a function of PV2, a failure of PV2 will not place PV4 into failsafe.

6. LF Equation Constants

LF Equation Constants, Parameter Indexes 97, 98, 99, 101

There are constants used in the various output forms of the LF equation. Table 6 lists the constants, the index number associated with each constant, and where they are required in the generic parameter property sheets.

Table 6 Equation Term Constants

Equation Term		Index Number	Use
K_{LF} =	Constant for LF Equation	97	Always required.
T_{std} =	Temperature at Standard (base) conditions, in °F	98	Required for Standard Volumetric and Mass flow rate output forms.
P_{std} =	Pressure at Standard (base) conditions, in psia	99	Required for Standard Volumetric and Mass flow rate outputs.
ρ_{std} =	Density at Standard conditions, in lbs/ft^3	101	Required for Mass flow rate output.

7. LF Fixed Equation Terms

Fixed Equation Terms

There are two fixed ratios that can be used in the LF equation and are defined as follows:

1. $T_{norm} = T_{std} / T_{flow}$
2. $P_{norm} = P_{flow} / P_{std}$

where: T_{std} = Temperature at standard (base) conditions, in Kelvin. user entered, at index 98, in °F. (SMV 3000 converts to Kelvin for use in T_{norm} ratio.)

T_{flow} = Measured process flow temperature (PV3), in Kelvin.

P_{std} = Absolute pressure at standard (base) conditions, in psia. user entered, at index 99, in psia.

P_{flow} = Measured absolute pressure (PV2), in psia.

Each ratio is fixed in format, and is expressed in absolute units (Kelvin and psia). The T_{norm} ratio is recalculated when T_{flow} is updated, or when the T_{std} parameter is changed. The P_{norm} ratio is recalculated when P_{flow} is updated, or when the P_{std} parameter is changed.

8. LF Configurable Equation Terms

Configurable Equation Terms

There are five configurable equation terms that can be used in the LF equation and are defined as follows:

1. Flow = Calculated as a function of DP only
2. μ_{std} = Standard Viscosity
3. μ_{flow} = Flow viscosity
4. μ_{adjust} = Viscosity correction factor
5. ρ_{adjust} = Density correction factor

Each term is a single variable function, Y = f(X) and can be configured in any of the four different equation forms listed below. For example, the flow equation can be configured as a function of differential pressure, whether it is polynomial function or piecewise linear fit function.

All five equation terms are used in the LF equations, and must be configured in the SMV 3000. Any unused term may be configured as a constant value equal to one.

Equation Forms

Any one of four equation forms can be selected for use in a configurable term:

1. Constant
2. Polynomial
3. Piece-wise linear fit
4. Generic Equation 1

Independent Variable Parameter

The SMV 3000 process variables and a user-selected standard temperature can be selected as an independent variable, X, to be used in each term, $Y=f(X)$. The selections are:

1. DP (PV1), in inches H_2O @39 °F
2. P_{flow} (PV2), in psia
3. T_{flow} (PV3), in Kelvin
4. T_{flow} (PV3), in °F
5. T_{std}, in Kelvin
6. T_{std}, in °F

The variable is used in the units selected in the configurable term equation. See Table 9 for a description of the 6 variables.
The T_{std} parameter is entered by the user. It is offered for the user's convenience, as the configurable term can also be entered as a constant.

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Parameters Used in Equation Types

Table 7 shows the four integer parameters and the floating point parameters (DATA TYPE = Hfloat) that make up an equation term for each equation type. These parameters are used by the SMV 3000 in executing the LF equations.

Table 7 Parameters Needed for Configurable Term Equation Types

Parameters ⇓	Equation Term Formula Types			
	Polynomial †	**Linear Fit ‡**	**Constant**	**Generic Equation 1**
Formula Code	3	4	2	5
Qualifier 1	order n	number of points n	0	0
Qualifier 2	0	0	0	0
Independent Variable	*(See Table 8)*	*(See Table 8)*	0	*(See Table 8)*
A_0	A_0	X_1	C = constant	A_0
A_1	A_1	Y_1	*unused*	A_1
A_2	A_2	X_2	*unused*	A_2
A_3	A_3	Y_2	*unused*	A_3
A_4	A_4	X_3	*unused*	*unused*
A_5	A_5	Y_3	*unused*	*unused*
A_6	A_6	X_4	*unused*	*unused*
A_7	*unused*	Y_4	*unused*	*unused*
A_8	*unused*	X_5	*unused*	*unused*
A_9	*unused*	Y_5	*unused*	*unused*
A_{10}	X_{min}	X_6	*unused*	X_{min}
A_{11}	X_{max}	Y_6	*unused*	X_{max}

† *For the polynomial equation type*- the order of the polynomial has a maximum of 6, and the number of coefficients needed is n+1 ($A_0..A_n$). Unused coefficients $A_{n+1}..A_9$ are ignored by the SMV 3000.

‡ *For the linear fit equation type* - the number of points (n) has a minimum of 2 and a maximum of 6. The number of coefficients needed is 2n. Points must be entered in pairs, (X, Y) and in ascending order of X. All unused coefficients ($A_{2n}..A_{11}$) are ignored by the SMV 3000.

NOTE: SMV database configurations containing several higher order polynomials may take a considerable amount of time to download the database to the transmitter.

Continued on next page

Table 8 Description of Independent Variables

Value	Meaning
1	DP , inches. H_2O @ 39 degrees F
2	P_{flow}, Absolute Pressure, psia
3	T_{flow}, Process Temperature, in Kelvin
4	T_{flow}, Process Temperature, degrees F
5	T_{std}, Temperature at Standard (base) conditions., in Kelvin
6	T_{std}, Temperature at Standard (base) conditions., degrees F

9. LF Configurable Term Examples

Equation Term Configuration Examples

Four examples are given below for defining some of the equation terms used in the LF equations. Two examples are given for configuring the Flow term and two examples for configuring Viscosity terms (μ_{std} and μ_{flow}).

- The Flow term in the LF equation is typically a function of DP - differential pressure, so PV1 will be the selected as the independent variable in examples 1 and 2. In example 1, the flow term is configured so that the SMV 3000 calculates flow using a 2^{nd}-order polynomial.
- Example 2 shows configuration of the flow term so that flow is calculated using a 3-segment linear fit.
- Example 3 shows the standard viscosity term being configured as a constant.
- The exact Generic Equation 1 is used for the flow viscosity term in Example 4. The flow viscosity is typically a function of the process temperature, therefore, T_{flow} in units of Kelvin will be used for the independent variable in Example 4.

General SMV Configuration

First, use the SCT 3000 tab cards to enter the general SMV 3000 configuration.

NOTE: Do not use the FlowAlg or K(user) tab cards, except for configuring the low flow cutoff. Due to the advanced capability of the LF equation, the parameters for flow equation type and K_{LF} values are not entered on these cards.

A typical general configuration might be as follows:

SCT 3000 Tab Card	Entries
General	Communication Mode = DE mode PV1 - PV4 output
DPConf:	URV = 10 inches H_2O LRV = 0 inches H_2O
AP/GPConf	URV = 100 psi LRV = 0 psi
TempConf	URV = 150 °F LRV = 50 °F
FlowConf	URL = 300 CFM URV = 200 CFM LRV = 0 CFM

Note: These values are used as part of the equation configuration examples below.

LF Equation Configuration

All parameters needed to configure the LF equations are entered in the generic parameter property sheet.

Example 1: Flow Term Calculated with 2nd-order Polynomial

Three coefficients of the equation (A_0, A_1 and A_2) are used along with two limits (X_{min}, X_{max}) and must be entered in the generic parameter property sheet as coefficients of the flow term.
The polynomial formula for order n = 2 is:

$$Y = A_0 + A_1 \bullet X + A_2 \bullet X^2$$

where: Y = Flow, in CFM
X = DP, in inches H_2O @ 39 °F
Polynomial coefficients $A_0..A_2$ are in units to produce
Flow in CFM: A_0 in CFM
A_1 in CFM/inH_2O
A_2 in CFM/inH_2O^2
Polynomial limits are X_{min} (A_{10}) and X_{max} (A_{11})

Polynomial Limits (X_{MIN} and X_{MAX})

In the LF equation, all polynomial terms must have limits. The minimum (X_{min}) and maximum (X_{max}) limits are entered for the independent variable X, in this case DP. The SMV 3000 responds to a differential pressure - DP out of range in the following manner:

- The Flow equation output will be clamped at the value calculated using the limit values. For example, if the measured differential pressure X = DP is less than the minimum limit ($X < X_{min}$) then the Flow output will be clamped at value $Y_{min} = f(X_{min})$. The same procedure holds true if the measured DP is greater than the maximum limit. If either occurs, a non-critical system status flag will be raised on the SCT 3000 status tabcard and will read "Independent Variable Out Of Range". The flag will remain until the DP returns within the designated limits.

NOTE: The selected limits must be within the configured URV and LRV for the differential pressure measurement.

CAUTION

A polynomial equation can produce unexpected results outside of the range in which it was defined. Care must be given to the selection of the limit values, so that all Y values (flow results) are within the defined range of operation. A spreadsheet may aid in this evaluation.

Continued on next page

Entering Coefficients

Any required coefficient MUST be entered, that is, all polynomial coefficients designated in the Flow term (A_0, A_1 and A_2 in Example 1) must be entered with a value, or at least zero. All unused coefficients are ignored by the SMV 3000 (A_3..A_9 in Example 1). Polynomial limit values (X_{min}, X_{max}) must also be entered.

NOTE: To produce zero flow at zero differential pressure, the first coefficient (A_0) entered must be a zero.

SMV 3000 Parameter Index Values for Example 1

In example 1, the following parameter indexes are used to configure the Flow term for a 2nd-order polynomial. Values for these indexes must be entered as part of SMV 3000 configuration in the generic parameter property sheet:

Index	Data Type	Value
65	UInt8	3 (selects polynomial equation)
66	UInt8	2 (selects order of polynomial n = 2)
67	UInt8	0 (unused - must be zero)
68	UInt8	1 (select independent variable as DP)
102	Hfloat	A_0 (first coefficient, in CFM)
103	Hfloat	A_1 (2nd coefficient, in CFM/inH_2O)
104	Hfloat	A_2 (3nd coefficient, in CFM/inH_2O^2)
112	Hfloat	A_{10} (X_{min} = the minimum limit for DP)
113	Hfloat	A_{11} (X_{max} = the maximum limit for DP)

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Configuration Example 1

Figure 1 shows a graphical representation of Example 1.

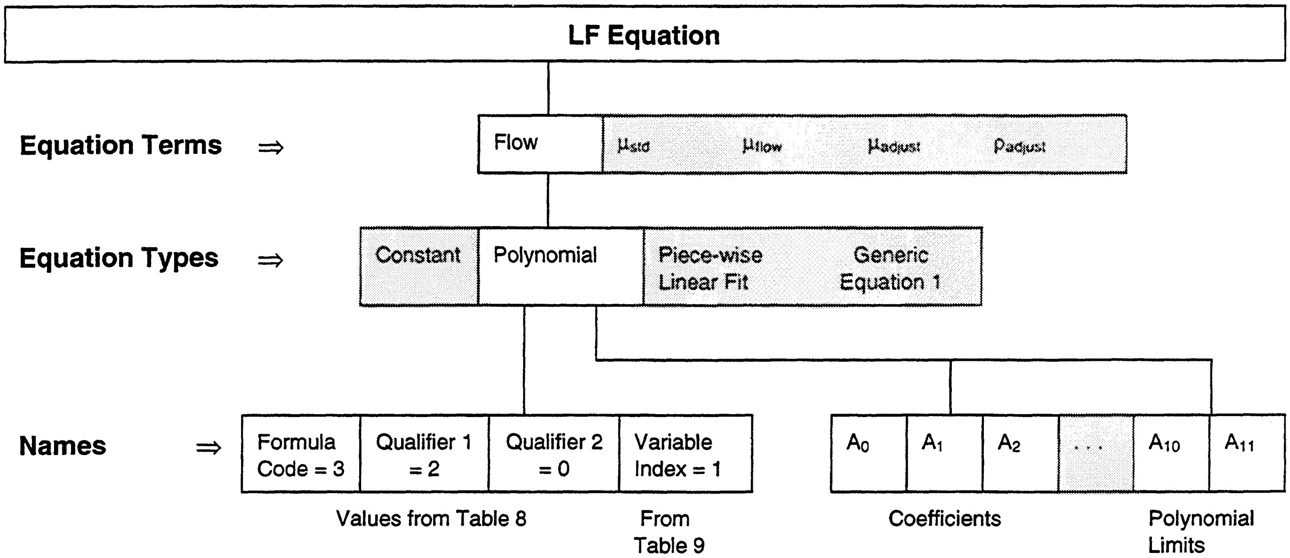

Figure 1 Flow Equation Term Configuration (as described in Example 1)

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Example 2: Flow Term Calculated with 3-Segment Linear Fit

In this example, the Flow term is configured so that the SMV 3000 calculates flow using a 3-segment piece-wise linear fit.

Between two points, $Point_m$ and $Point_{m+1}$, the flow output Y is calculated using:

$$Y = m \bullet X + b$$

where: Y = Flow, in CFM

X = DP in inches H_2O @ 39 °F

$$m = slope = \frac{Y_{m+1} - Y_m}{X_{m+1} - X_m}$$

$$b = \text{int}ercept = Y_m - m \bullet X_m$$

Four points (consisting of flow and differntial pressure values) are used as coefficients of the Flow equation.

where: $Point_1$ is A_0, $A_1 = (X_1, Y_1)$

$Point_2$ is A_2, $A_3 = (X_2, Y_2)$

$Point_3$ is A_4, $A_5 = (X_3, Y_3)$

$Point_4$ is A_6, $A_7 = (X_4, Y_4)$

Note that the points are entered in the SMV 3000 generic parameter property sheet in ascending order of X; from X_{min} to X_{max}.

Linear Fit Limits (X_{MIN} and X_{MAX})

Limit checking and error handling for the linear fit exists in a similar manner as for the polynomial equation. The limits for this equation are automatically set to X_{min} = lowest value of X and X_{max} = highest value of X.

For Example 2:

The minimum limit of differential pressure X_{min} is X_1 and the maximum limit of differential pressure X_{max} is X_4 (the last point). The action taken by the SMV 3000 when the differential pressure is not within the given range is the same as described in Example 1 above: The flow output will be clamped at the appropriate limit - $Y_{min} = Y_1$ or $Y_{max} = Y_4$.

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SMV 3000 Parameter Index Values for Example 2

In Example 2, the following parameter indexes are used to configure the Flow term for a 3-segment piece-wise linear fit. Values for these indexes must be entered as part of SMV 3000 configuration in the generic parameter property sheet:

Index	Data Type	Value
65	UInt8	4 (selects linear fit)
66	UInt8	4 (selects number of points n = 4)
67	UInt8	0 (unused - must be zero)
68	UInt8	1 (select independent variable as DP)
102	HFloat	A_0 ($POINT_1$ X_1 in inH_2O) - also the minimum limit X_{min}
103	HFloat	A_1 ($POINT_1$ Y_1 in CFM)
104	Hfloat	A_2 ($POINT_2$ X_2 in inH_2O)
105	Hfloat	A_3 ($POINT_2$ Y_2 in CFM)
106	Hfloat	A_4 ($POINT_3$ X_3 in inH_2O)
107	Hfloat	A_5 ($POINT_3$ Y_3 in CFM)
108	Hfloat	A_6 ($POINT_4$ X_4 in inH_2O) - also the maximum limit X_{max}
109	HFloat	A_7 ($POINT_4$ Y_4 in CFM)

Configuration Example 2

Figure 2 shows a graphical representation of Example 2.

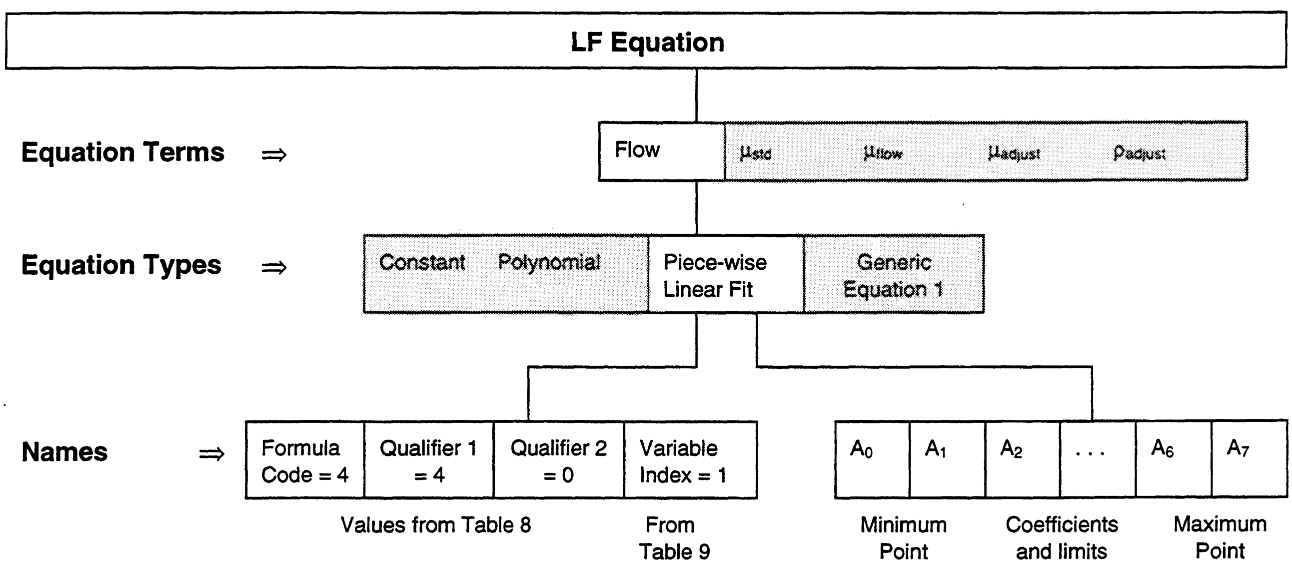

Figure 2 Flow Equation Term Configuration (as described in Example 2)

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Example 3: Standard Viscosity Term (μ_{std}) Configured as a Constant

This example shows the Standard Viscosity (μ_{std}) term of the LF equation equation configured as a constant. The only coefficient needed is the constant of the viscosity entered as parameter A_0.

SMV 3000 Parameter Index Values for Example 3

In Example 3, the following parameter indexes are used to configure μ_{std} as a constant. Values for these indexes must be entered as part of SMV 3000 configuration in the generic parameter property sheet:

Index	Data Type	Value
69	UInt8	2 (selects linear fit)
70	UInt8	0 (unused)
71	UInt8	0 (unused - must be zero)
72	UInt8	0 (unused)
114	Hfloat	$A_0 = \mu_{std}$ (enter the viscosity in micropoise)

Configuration Example 3

Figure 3 shows a graphical representation of Example 3.

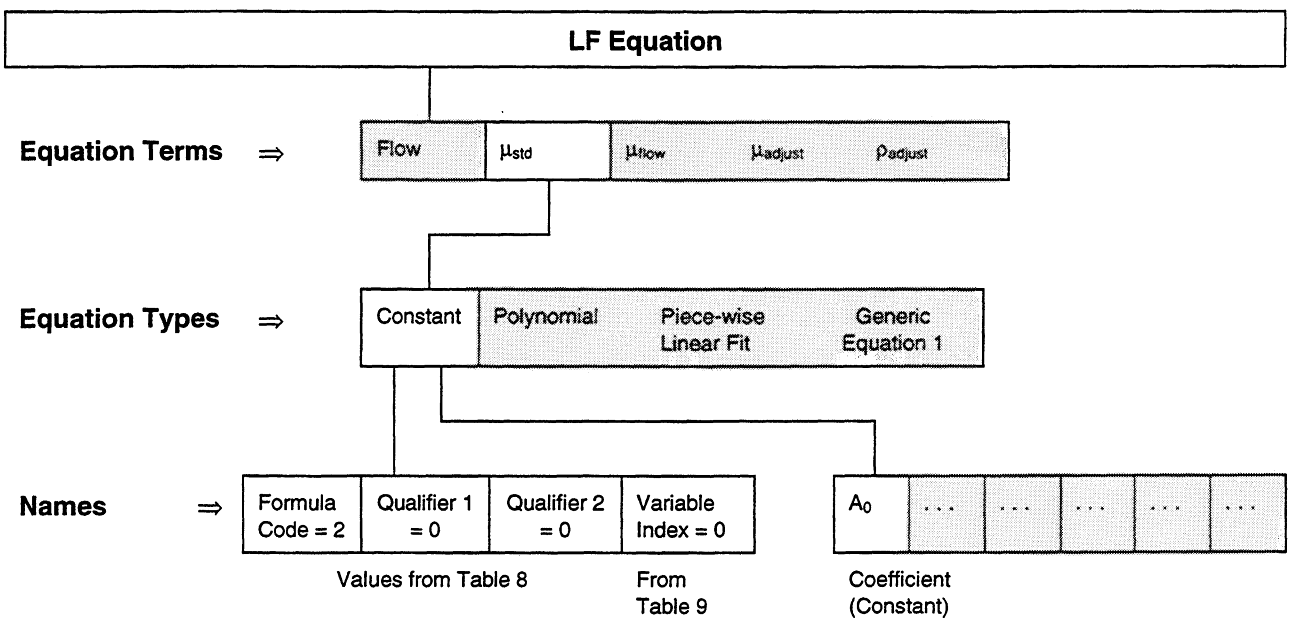

Figure 3 μ_{std} Equation Term Configuration (as described in Example 3)

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Example 4: Flow Viscosity Term (μ_{flow}) Calculated with "Equation 1"

Example 4 shows the Flowing Viscosity term configured so that the SMV 3000 calculates flowing viscosity as a function of temperature using the Generic Equation 1. This is the exact formula for the viscosity of Nitrogen and Air, as a function of temperature in Kelvin.

Generic Equation 1 is:

$$Y = \left[\frac{A_0 \bullet X^{3/2}}{X + A_1} \right] \bullet \left[\frac{X + A_2}{X + A_3} \right]$$

where: Y is μ_{flow}, in micropoise
X is the T_{flow} (PV3) in Kelvin
Coefficients $A_0..A_3$ are in units to produce viscosity in micropoise

Generic Equation 1 Limits (X_{min} and X_{max})

Limit checking and error handling for Generic Equation 1 is the same as for the polynomial and linear fit equation selections. The limit values must be entered by the user. The actions taken by the SMV 3000 in response to a detected limit error are as described in Example 1 for the polynomial.

SMV 3000 Parameter Index Values for Example 4

In Example 4, the following parameter indexes are used to configure μ_{flow} using the Generic Equation 1. Values for these indexes must be entered as part of SMV 3000 configuration in the generic parameter property sheet:

Index	Data Type	Value
73	UInt8	5 (selects "Generic Equation 1")
74	UInt8	0 (unused)
75	UInt8	0 (unused - must be zero)
76	UInt8	3 (select independent variable as $T_{f;pw}$ in Kelvin)
114	Hfloat	A_0
115	Hfloat	A_1
116	Hfloat	A_2
117	Hfloat	A_3
136	Hfloat	A_{10} (X_{min} = the minimum boundary point)
137	Hfloat	A_{11} (X_{max} = the maximum boundary point)

Continued on next page

Entering Coefficients

Any designated coefficient MUST be entered, that is, all coefficients designated in the viscosity term ($A_0..A_3$ in Example 4) must be entered with a value, or at least zero. In addition, the two limit values (X_{min}, X_{max}) must be entered. All unused coefficients are ignored by the SMV 3000 ($A_4..A_9$ in Example 4). For instance, when the Generic Equation 1 is used to calculate the viscosity of air, coefficients A_2 and A_3 are not used, and should be entered as zero.

Configuration Example 4

Figure 4 shows a graphical representation of Example 4.

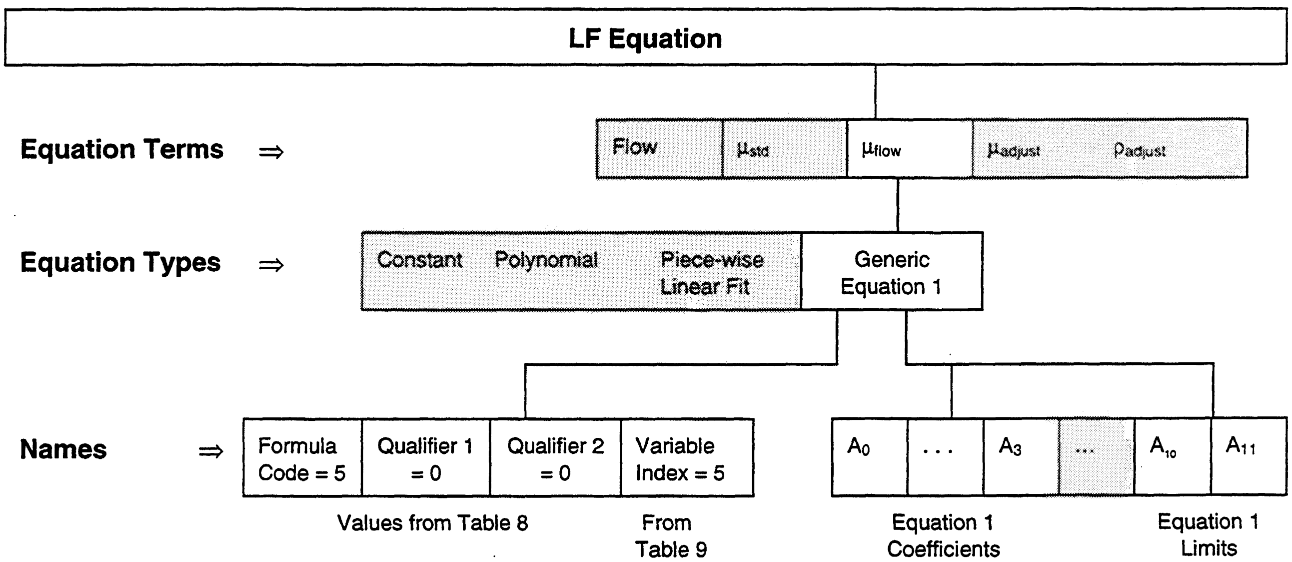

Figure 4 μ_f Equation Term Configuration (as described in Example 4)

10. Bi-directional Flow

Bi-directional Flow

The SMV 3000 with LF Option supports bi-directional flow as long as the configurable Flow term is defined to produce a negative flow rate for a negative value of Differential Pressure - DP.

The standard characterization provided by one manufacturer of Laminar Flow Elements (LFE) is for one (positive direction based on flow arrow) direction only. The calibration result consists of a set of test points and a polynomial equation that expresses the base flow rate as a function of DP, valid over the range of the test points. The LFE has clear markings for the direction of the calibration. Reverse flow through this element using the unidirectional characterization could result in an incorrect flow rate. Therefore, the user must enter the limits required in the Flow term configuration to clamp the flow rate output (section 11). A negative DP will then result in the clamped flow rate of the lower limit (usually zero), along with an "Independent Variable out of Range" status message.

A compound characterization is available from the noted LFE manufacturer*, providing two unidirectional characterizations. The user must then use the combined set of calibration points for both directions, and either fit a polynomial to this data or use the linear fit equation for the Flow term. The upper limit is the last (largest DP) point in the forward flow direction, and the lower limit is the last point in the reverse flow direction.

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NOTE: In the case of reverse flow, the Lower Range Value (LRV) in the FlowConf tab of the SCT 3000 should be configured as a value less than zero.

11. LF Equation Reference

Reference Information

The following tables provide more information about the SMV 3000 parameters and the LF equations. Although some information is listed in more than one table, it is provided for easier referencing.

Flow Measurement Symbols

Table 9 describes the terms used in the LF equation for flow measurement. The symbols are listed with a brief description, the units of measure and the formula used to calculate the value.

Table 9 LF Measurement Terms

Symbol	Description	Units	Calcluated using the Formula:
A_0, A_1, $A_2 \ldots A_n$	Equation Term Coefficients	Coefficients must be in the proper units to produce the desired units of the configurable term. For example: The coefficients for the flow term must produce flow in CFM.	If equation term selected is — ***Constant:*** Only coefficient A_0 is used to produce $Y = A_0$ ***Polynomial of order n:*** Coefficients $A_0 \ldots A_n$ used to calculate $Y = A_0 + A_1 \bullet X + A_2 \bullet X^2 + \ldots + A_n \bullet X^n$ Coefficients A_{10} and A_{11} are the minimum and maximum limits. ***Piecewise Linear fit between n points:*** Coefficients are: For Point 1 - $A_0 = X_1$, $A_1 = Y_1$ For Point 2 - $A_2 = X_2$, $A_3 = Y_2$: : For Point n - $A_{2n-2} = X_n$, $A_{2n-1} = Y_n$ Note: Points must be in ascending order of X. ***Generic Equation 1:*** Coefficients $A_0 \ldots A_3$ used to calculate $Y = \left[\frac{A_0 \bullet X^{3/2}}{X + A_1}\right] \bullet \left[\frac{X + A_2}{X + A_3}\right]$ Coefficients A_{10} and A_{11} are the minimum and maximum limits.

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Table 9 LF Measurement Terms, Continued

Symbol	Description	Units	Calculated using the Formula:
ρ_{adjust}	Density Correction Factor	-	$\rho_{adjust} = f(T_{flow})$ ρ_{adjust} = Calculated using selected equation type *(See Table 10)*
ρ_{std}	Density at Standard (base) Conditions	lb/ft^3	*Entered by user*
DP	Differential Pressure	inH_2O @ 39 °F	DP = PV1 as measured by SMV 3000
PV4	Calculated Flow Rate	CFM or lb/h	Flow = f(DP) Flow = Calculated using selected equation type *(See Table 10)*
K_{LF}	Constant for LF Equation	-	$K_{LF} = 1$ (Unless using non-standard or custom units)
μ_{adjust}	Viscosity Correction Factor	-	$\mu_{adjust} = f(T_{flow})$ μ_{adjust} = Calculated using selected equation type *(See Table 10)*
μ_{flow}	Flowing Viscosity	micropoise	$\mu_{flow} = f(T_{flow})$ μ_{flow} = Calculated using selected equation type *(See Table 10)*
μ_{ratio}	Viscostiy Ratio	-	$\mu_{ratio} = \mu_{std} / \mu_{f} \bullet \mu_{adjust}$
μ_{std}	Standard Viscosity	micropoise	$\mu_{std} = f(T_{std})$ μ_{std} = Calculated using selected equation type *(See Table 10)*

Continued on next page

Table 9 LF Flow Measurement Terms, Continued

Term	Description	Units	Calculated using the Formula:
P_{flow}	Flowing Absolute Pressure	psia	P_{flow} = PV2 as measured by SMV 3000
P_{norm}	Pressure Compensation Term	-	$P_{norm} = P_f / P_b$
P_{std}	Pressure at Standard (base) Conditions	psia	P_{std} = constant, *Entered by user*
T_{flow}	Flowing Process Temperature	°F	T_{flow} = PV3 as measured by SMV 3000
T_{norm}	Temperature Compensation Term		$T_{norm} = T_b / T_f$ (*See Note*)
T_{std}	Temperature at Standard (base) Conditions	°F	T_{std} = constant, *Entered by user*

Note: Compensation terms calculated using temperature in absolute units. T_{std} entered by user in °F, and converted by the SMV 3000 to Kelvin.

Table 10 Formulas for Equation Types

Equation Type	Formula
Constant	$Y = A_0$
Polynomial, order n	$Y = A_0 + A_1 \bullet X + A_2 \bullet X^2 + \ldots + A_n \bullet X^n$
Piece-wise Linear Fit	$Y = m \bullet X + b$
Generic Equation 1	$Y = \left[\frac{A_0 \bullet X^{3/2}}{X + A_1}\right] \bullet \left[\frac{X + A_2}{X + A_3}\right]$

LF Equation Output Forms

Table 11 provides a listing of the flow outputs available in the SMV 3000 with LF option, along with the formulas used.

Table 11 Equation Output Forms

Flow Output	Type	Formulas
Volumetric Flow Rate at Standard Conditions	05	$StdFlow = K_{LF} \bullet Flow \bullet \mu_{ratio} \bullet T_{norm} \bullet P_{norm} \bullet \rho_{adjust}$ in CFM where: K_{LF} = User Meter Factor, constant **Flow** = f(DP) * **DP** = Differential Pressure (PV1) $\mu_{ratio} = \frac{\mu_{std}}{\mu_{flow} \bullet \mu_{adjust}}$ $\mu_{std} = f(T_{std})$ * $\mu_{flow} = f(T_{Flow})$ * $\mu_{adjust} = f(T_{Flow})$ * $T_{norm} = \frac{T_{std}}{T_{flow}}$ T_{std} = Temperature at Standard Conditions T_{flow} = Measured Process Temperature (PV3) $P_{norm} = \frac{P_{flow}}{P_{std}}$ P_{flow} = Measured Absolute Pressure (PV2) P_{std} = Pressure at Standard conditions, constant $\rho_{adjust} = f(T_{Flow})$ *

* Configurable equation term

Continued on next page

Table 11 Equation Output Forms, continued

Flow Output	Type	Formulas
Mass Flow Rate	25	MassFlow = StdFlow • ρ_{std} in lbs/hr where: $StdFlow = K_{LF} \bullet Flow \bullet \mu_{ratio} \bullet T_{norm} \bullet P_{norm} \bullet \rho_{adjust}$ in CFM ρ_{std} = Density at standard conditions in lb/ft^3
Custom Flow	15	$CustomFlow = K_{LF} \bullet Flow \bullet \left(\frac{\mu_{std}}{\mu_{flow} \bullet \mu_{adjust}} \right) \bullet \rho_{adjust}$ where: Units are custom, as defined by the user For Actual Volumetric Flow rate in CFM, set the ρ_{adjust} term to 1: $ActFlow = K_{LF} \bullet Flow \bullet \left(\frac{\mu_{std}}{\mu_{flow} \bullet \mu_{adjust}} \right)$

* Configurable equation term

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