Starling Associates GOFW2015

User's Manual

GOFW2015 License Agreement

The license agreement given below is the normal license agreement for GOFW2015. It can be noted according to condition number 11 that "This agreement constitutes the sole understanding between the parties concerning GOFW2015 and may only be modified in writing agreed to by all parties." If your company has agreed to a modified license agreement, a record of this modified license agreement should reside in your company's records.

This Agreement is by and between:

Starling Associates, Inc. 1324 Brookside Drive, Norman OK 73072, U.S.A. (hereinafter referred to as "DEVELOPER") and Licensee (hereinafter referred to as "USER") for the use of a certain proprietary computer software product known as GOFW2015 and its related documentation (herein referred to as "MANUALS") which together have been developed by DEVELOPER.

DEVELOPER grants to USER a non-exclusive license to use GOFW2015 solely by USER or USER company personnel and solely using USER or USER company owned Windows-based personal computers. Use of GOFW2015 by any person other than USER or USER company personnel is prohibited. Installation of software using GOFW2015 on any computer not owned by the USER or USER company is prohibited. Installation of software using GOFW2015 on any intranet or internet server is prohibited. The following conditions also apply.

1. License Fee. USER must pay the current license fee.

2. Activation. USER must activate the software only on the number of computers for which the license fee has been paid (Windows based personal computers). For each installed computer, USER must supply a file containing GOFW2015 security information, so DEVELOPER can supply a GOFW2015 license file for each installed computer. Any change in this activation process must be agreed between USER and DEVELOPER.

3. Support Service. DEVELOPER will provide one instance per installed computer, up to a maximum of ten instances per licensee, of reactivation or e-mail support service during the first year of this license agreement. Additional support will be billed at then current rates. Support service involving issues specific to computer operating systems and/or Microsoft Office software and/or other software or systems which affect the use of GOFW2015 will be billed at current rates at the time of service.

4. Copyright. USER will abide by the Copyright laws with respect to GOFW2015. USER may copy MANUALS for use by USER and/or USER company employees. Selling or distributing this software or executable programs (including intranet or internet applications) using this software without written permission from Starling Associates, Inc. is prohibited.

5. Disclaimer. GOFW2015 and the information contained therein are provided "as is." DEVELOPER and any agent, representative, publisher, or distributor of GOFW2015, or any of their respective directors, officers, employees, agents, representatives or members make no guarantee or warranty of any kind, either express or implied, including, but not limited to warranties

of merchantability or fitness for any particular use or any other warranties implied by law and USER specifically releases all such Developer and all such person from any such warranties and representations.

6. INDEMNIFICATION
Starling Associates, and any agent, representative, publisher or distributor of GOFW2015, or any of their respective directors, officers, employees, agents, representatives or members (the "Indemnified Parties") shall have no liability for, and User shall defend, indemnify and hold each of the Indemnified Parties harmless from and against any judgment, liability, loss, cost or damage (including any settlement amount, litigation costs, reasonable attorneys' fees, and other legal expenses) incurred as a result of any suit, action, or claim arising out of, pertaining to, or resulting in any way from, the use or possession of, or information contained in GOFW2015 by User and/or any of its users directors, officers, employees, representatives, agents or contractors.

7. LIMITATIONS OF LIABILITY

A. User acknowledges that each of the Indemnified Parties' obligations and liabilities with respect to GOFW2015 are exhaustively defined in this Agreement. NONE OF THE INDEMNIFIED PARTIES NOR ANY OF ITS DIRECTORS, OFFICERS, EMPLOYEES, AGENTS, REPRESENTATIVES, OR MEMBERS SHALL BE LIABLE TO USER, WHETHER UNDER CONTRACT, TORT (INCLUDING NEGLIGENCE) OR OTHERWISE, FOR ANY LOSS OF PROFITS, LOSS OF BUSINESS, INTERRUPTION OF BUSINESS OR INDIRECT, SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES OF ANY KIND RESULTING FROM ANY BREACH OF ITS AGREEMENT OR FROM ANY USE OF GOFW2015, EVEN IF THE DAMAGED PARTY HAS ADVISED THE OTHER PARTY OF THE POSSIBILITY OF SUCH LOSS. WITHOUT LIMITING THE FOREGOING, THE INDEMNIFIED PARTIES' AGGREGATE LIABILITY TO USER SHALL BE LIMITED TO THE AMOUNT RECEIVED BY DISTRIBUTOR FROM USER HEREUNDER.

B. If at any time an allegation of infringement of any rights of any third party is made, or in the Indemnified Parties' opinion is likely to be made, with respect to GOFW2015, Distributor may, at its option and at its own expense (i) obtain for User the right to continue using GOFW2015, (ii) modify or replace GOFW2015 or any portion thereof so as to avoid any such claim of infringement, or (iii) refund to User the License Fee. The Indemnified Parties shall have no liability to User if any claim of infringement would have been avoided except for users refusal to use any modified or replacement GOFW2015 supplied or offered to be supplied pursuant to this Section 7(b) or to otherwise cease using GOFW2015.

C. Section 7(b) states the entire liability of the Indemnified Parties with respect to the infringement or alleged infringement of any third party rights of any kind whatsoever by any of GOFW2015.

8. Effective Date and Termination.

a. This Agreement shall become effective on the date of license fee purchase by USER.
b. For a one year license, the GOFW2015 license will continue from the date of purchase of license fee by the USER for one year.
c. For a three year license, the GOFW2015 license will continue from the date of purchase of license fee by the USER for three years.

9. GOVERNING LAW. This Agreement shall be governed and construed in accordance with the laws of the United States and with the laws of the state of Oklahoma applicable to contracts entered into and to be performed entirely therein without regard to any choice or law or conflict of law provisions.

10. DISPUTE RESOLUTION. In the event of a dispute arising from or relating to this Agreement, each Party shall appoint a senior management representative to negotiate a resolution. If such efforts are not successful within thirty (30) days or as otherwise agreed by the Parties, then the Parties may submit any dispute arising from or related to this Agreement to non-binding mediation in a neutral location mutually agreeable to the Parties. If the Parties cannot agree on a neutral location within thirty (30) days, then the mediation shall be in Norman, Oklahoma. If such mediation is not chosen or is not successful, then the Parties shall submit the dispute to arbitration by a single arbitrator in accordance with the Rules for Commercial Arbitration of the American Arbitration Association in a neutral location mutually agreeable to the parties. If the Parties cannot agree on a neutral location within thirty (30) days, then the arbitration shall be in Norman, Oklahoma. The arbitrator shall have the power to award damages, costs and attorneys' fees in his/her discretion and subject to the principles of equity.

11. Miscellaneous.
- This agreement constitutes the sole understanding between the parties concerning GOFW2015 and may only be modified in writing agreed to by all parties.
- Any obligations and duties which by their nature extend beyond the expiration or termination of this Agreement shall survive the expiration or termination of this Agreement.

Disclaimer, Copy and Copyright Notice

Visit our Web Site at http://www.starlingassoc.com

The **GOFW2015** V1.0, Release 1.0 Manual
May 4, 2015

Acknowledgments

The technical information which provides the basis for the present computer program for natural gas orifice and linear meter flow was developed through the cooperative efforts of many individuals and organizations, including the Gas Research Institute, the American Gas Association, the American Petroleum Institute, the Gas Processors Association, the Chemical Manufacturers Association, the Canadian Gas Association, the International Standards Organization, the Gaz European Recherches Groupe, the European Community, Norway, Japan, and others.

The algorithms and equations for orifice meters which are in the present computer program are based on the AGA Reports No. 3.3(2013) and No. 8(1994), the 1992 AGA Report No. 3, the 1985 AGA Reports Nos. 3 and 8, the 1962 AGA Report NX-19 and the 2009, 1996 and1986 G.P.A. 2172 Standards. The AGA 7 and AGA 9 Linear Meters calculations are based on AGA 7 - Measurement of Gas by Turbine Meters, Transmission Measurement Committee Report No. 7(2005) and AGA 9 – Measurement of Gas by Multipath Ultrasonic Meters, Transmission Measurement Committee Report No. 9 (2007). Note that AGA Report No. 3.3 and API MPMS Ch. 14.3.3 are equivalent reports and that AGA Reports No. 8 and API MPMS Ch. 14.2 are equivalent reports.

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GOFW2015 Product Support

Starling Associates Inc. is committed to providing the best possible technical support for **GOFW2015** and all our products. Please follow the procedure outlined below.

The Starling Associates web site is the fastest and most efficient way to locate information about our products including maintenance files and contact information. The web site is available 24 hours a day and allows you to send your questions, comments and suggestions by e-mail to sai@starlingassoc.com.

Technical Support

When requesting technical support, please provide the following information:

- Your name and the name of the registered user, if different.
- Address, phone and fax number, and email address, if available.
- System information of the computer you are using including the operating system, the amount of memory and system resources and any relevant devices or peripherals.
- A detailed description of the problem. Describe error messages exactly as they appear. List the steps and conditions that led to the problem.

Contacting Starling Associates, Inc.

Starling Associates website	http://www.starlingassoc.com
E-mail	sai@starlingassoc.com

Activating the License for GOFW2015

Click the GOFW2015 License Manager in the Starling Associates GOFW2015 License Manager folder on the Start Menu and save the .c2v file on your PC with a name of your choice. Send this file to sai@starlingassoc.com. A file with the extension .v2c will be returned to you; you can check it in using the GOFW2015 License Manager and your license will be activated for the previously agreed term.

Chapter 1

Introduction

*Congratulations on licensing **GOFW2015**. Discover how easy it is to perform flow calculations and to evaluate the economic impact of using different standards to measure natural gas flow.*

ICON KEY
🗁 Valuable information
✎ Steps
🕮 Contents

Installation

System Requirements

Please check that the system on which you will be installing **GOFW2015** meets these requirements:

🗁 Personal Computer with a 486 or higher microprocessor

🗁 Minimum 8 MB RAM

🗁 Microsoft Windows Operating System (XP or later)

🗁 Hard disk space requirement: 60 MB (+ 24 MB for Acrobat reader).

Installing GOFW2015

If your installation is from a setup executable program, merely follow the instructions provided. If your installation is from a CD-ROM follow the instructions below.
Start Windows and close all open applications

✎ Insert the supplied diskettes/CD-ROM

✎ Click the Start button on the Windows taskbar.

✎ Point to Settings and click on Control Panel. In the Control Panel window, click on the Add/Remove Programs icon.

✎ Follow the instructions on the screen.

Check List

After installation you should have the following items installed in C:\Starling Associates GOFW2015\.

- GOFW2015 program files
- GOFW2015 MANUAL.PDF
- Example-As Found.CS1
- Comparison of Qv and Y1 using 1992 and 2012 Standards
- Dry Gas Orifice Meter Energy Flow Rate Calculation.CS1
- Water Saturated Methane Gross HV at Base Conditions.CS1
- Turbine Meter Qb Calculation.CS1
- Coriolis Meter Calculation.CS1
- GOFW2015.INI
- LICENSE
- GOFW2015 License Manager

Manual File

The file GOFW2015 MANUAL.PDF is a copy of the GOFW2015 User Manual. It is installed during GOFW2015 installation. If the Adobe Acrobat reader is installed on the user computer, the manual may be viewed by clicking "GOFW2015 Manual" in the GOFW2015 folder on the Start taskbar. The Adobe Acrobat reader software also is available on the Internet. Note that the "Find" option in the "Edit" menu available with Adobe Acrobat provides the user with an effective tool for searching the **GOFW2015 Manual** for specific topics of interest. Also, viewing the index of the **GOFW2015 Manual** can be helpful in locating numerous topics.

The appendices for **GOFW2015** provide useful information. Appendix A, titled Warnings and Errors, provides tables of warning and error codes which may be indicated by **GOFW2015**. Appendix B, titled Discussion of Differences in the 1992 and 2012 Flange Tapped Orifice Meter Standards, presents calculations which focus on the effects of changes in the equation for the expansion factor and changed limits for the ratio of differential pressure to absolute upstream static pressure. Appendix C, titled Discussion of Energy Flow Rate Calculations, Gross Heating Value and Differences in Standards for Wet Gases, presents calculations illustrating how these quantities are calculated in **GOFW2015**. Appendix D, titled **GOFW2015** Calculations for Linear Meters, presents a discussion of the general equations for the flow rate for linear meters and performs example calculations for turbine meters and coriolis meters.

Running GOFW2015

- In Windows, click on the Start button and choose All Programs. Select **Starling Associates GOFW2015** and click on the **GOFW2015** icon.

- The **GOFW2015** welcome screen appears while program initialization is taking place.

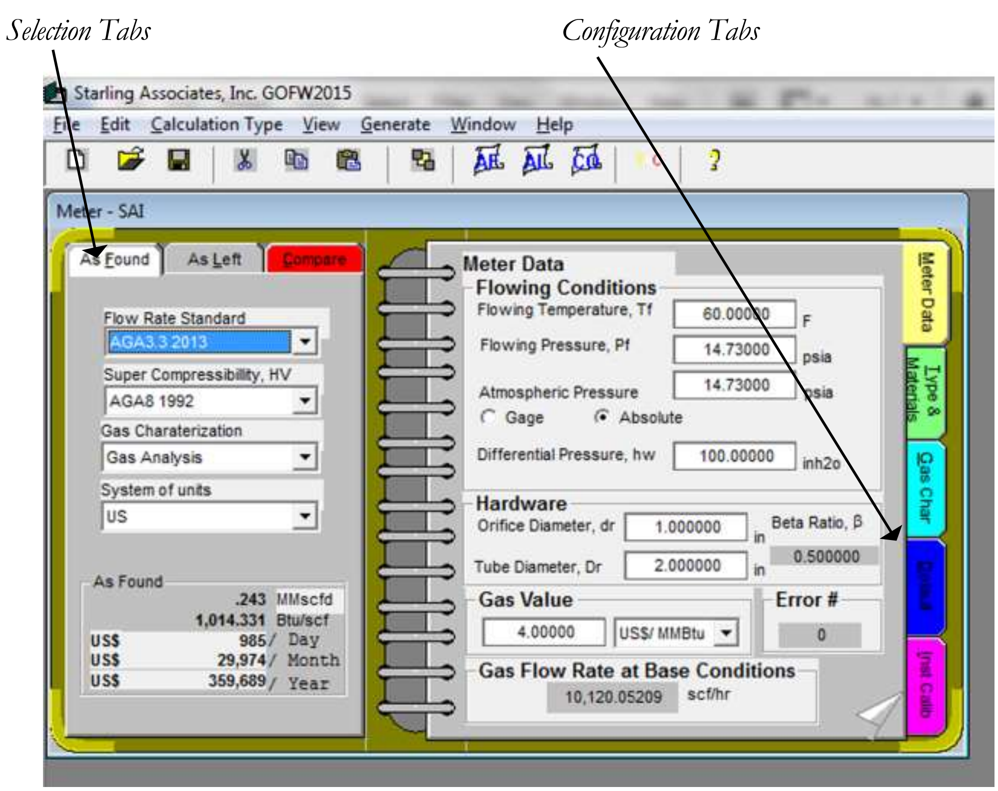
- You have successfully launched **GOFW2015.**

User Interface

Although many terms in this manual are familiar to Windows users, two terms relate specifically to the format of the **GOFW2015** program. These are the **GOFW2015** Notebook and the **GOFW2015** Tabs.

The **GOFW2015** interface is presented in an easy-to-use format referred to as the **GOFW2015** Notebook (shown below). Accessing various parts of **GOFW2015** requires a simple click on a Tab of the Notebook. Chapters 4 through 8 contain detailed descriptions of the **GOFW2015** Configuration Tabs found on the right side of the Notebook. The **GOFW2015** Selection Tabs (found on the left side of the Notebook) are used to specify the As Found and As Left conditions. The Compare Selection Tab shows a comparison of those conditions.

GOFW2015 Notebook



The other parts of the **GOFW2015** screen follow the familiar Windows format. They are explained below.

The Titlebar
The titlebar shows the software name, **Starling Associates, Inc. GOFW2015**.

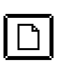
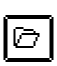
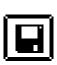
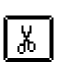
The Meter Titlebar
The Meter Titlebar displays the meter's name.

The Menu Bar
The **GOFW2015** Menu Bar is always visible within **GOFW2015**. It contains the following drop-down menus:

- The **File** menu contains New Meter, Open, Save As, Save, Close, Print Setup and Exit
- The **Edit** menu contains Cut, Copy, Paste, Delete, AF-AL/AL-AF
- The **Calculation Type** menu contains Volume Flow Rate, Mass Flow Rate, Differential Pressure, Orifice Size
- The **View** menu contains As Found, As Left, Comparison, Meter Properties, Toolbar, Statusbar
- The **Generate** menu contains As Found Report, As Left Report and Comparison Report
- The **Window** menu contains Unit Converter and all active windows in **GOFW2015**
- The **Help** menu contains Help Topics and About **GOFW2015**

The Toolbar
Many essential **GOFW2015** Tools are included on the toolbar located at the top of the **GOFW2015** Notebook.

- The toolbar can be toggled on and off on the View menu

Button	Name	Function
	New meter	Opens a New Meter for a new calculation, comparison, etc.
	Open	Opens an existing **GOFW2015** file
	Save	Saves your **GOFW2015** file under its current name and location with the default .CS1 extension
	Cut	Cuts the selected text and places it on the clipboard
	Copy	Copies the selected text and places it on the clipboard
	Paste	Pastes the text from the clipboard at the point where the cursor is located

	AF-AL/ AL-AF	If the As Found Selection Tab is selected when this tool button is clicked, the configuration in the As Found Tab is copied to the As Left Tab. If the As Left Tab is selected when this tool button is clicked, the configuration in the As Left Tab is copied to the As Found Tab (note that this operation also occurs with the AF-AL/AL-AF selection on the Edit drop-down menu on the **GOFW2015** Menu Bar.
	AF	Opens the As Found report
	AL	Opens the As Left report
	CO	Opens the Comparison report
F→C	F→C	Opens the Units Converter

Meter Properties

Meter Properties is the first **GOFW2015** screen encountered after program initialization. Meter Properties also can be accessed from the drop-down menu under **View** on the **GOFW2015** menu bar. Meter Properties allows the user to record information pertinent to the meter. There are two Tabs in Meter Properties which are used to identify the meter:

General

In the General Tab, the user identifies the meter for which a calculation is being performed.

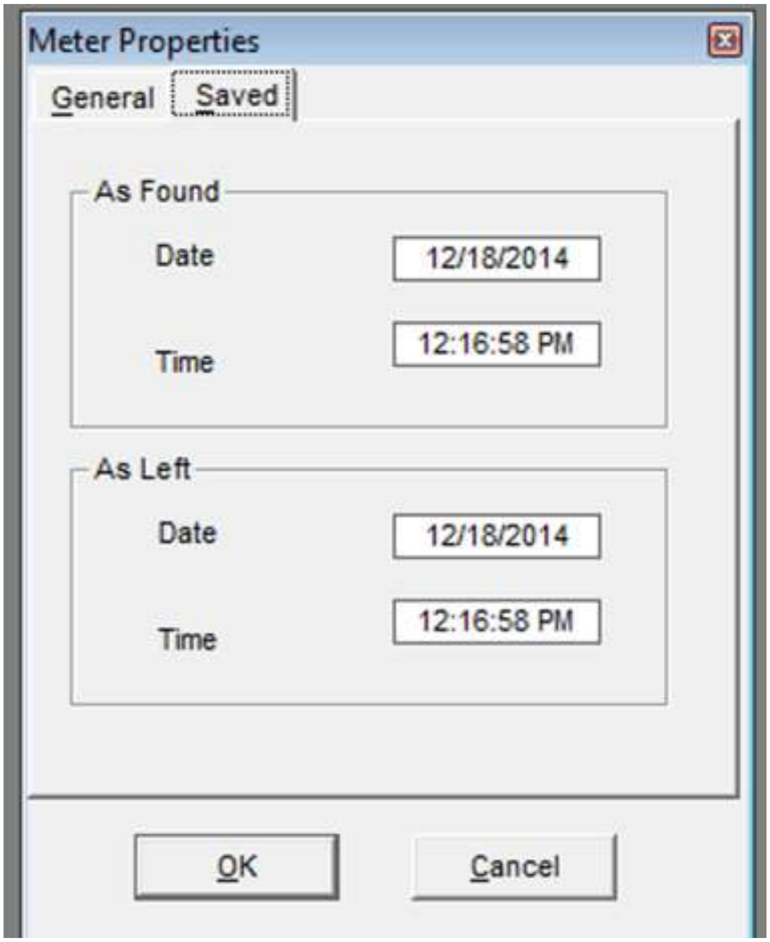
Identification fields on the General Tab are:

- Meter #.
- Field.
- Well.
- Lease.
- Meter Tag

Only Meter # must be specified in order to continue. The other fields are optional identifiers. When the OK button is clicked, the entry in the Meter # field will be shown at the top of the **GOFW2015** Notebook.

Saved

The Saved Tab shows the time at which the configurations for the meter As Found and As Left came into effect. The default for the Date and Time for both the As Found and As Left conditions is the time at which the new **GOFW2015** file was opened. The user may change those times for proper reporting and record.



GOFW2015 Help

GOFW2015 features a full-function online reference.

Information in **GOFW2015** can be easily located with any of the following methods:

🗁 Clicking on highlighted text in the Contents window displays a discussion about the item of interest.

🗁 Clicking the Search button located on the toolbar displays an alphabetical list of **GOFW2015** topic titles. You can select a topic from the list or search for an entry by entering a word in the search field.

🗁 Within Help, you can access any topic highlighted in green by clicking on the text including:

🕮 The location of **GOFW2015** variables in the reference standards and their use in **GOFW2015**. These can be accessed from the first screen in Help (Variables Description).

🕮 A description of error and warning messages used in **GOFW2015**. These are available by placing the cursor on the Error Indicator field of the Meter Data Configuration Tab and pressing F1.

🕮 The list of outputs generated by **GOFW2015**. These can be accessed from the opening Help screen by choosing Variables Description, then Output Variables, then Outputs.

Unit Converter

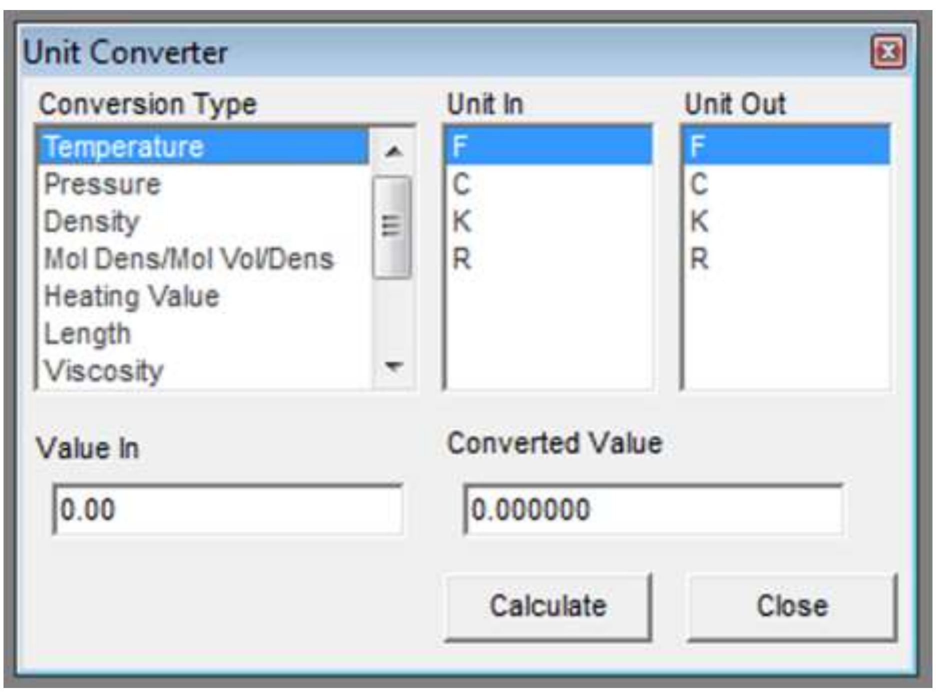
The unit converter is a useful feature for conversions of many different types of units. The results can be copied and pasted into the **GOFW2015** Notebook. To access Unit Converter, choose Unit Converter on the Window menu of the **GOFW2015** menu bar.

To perform a conversion, follow these steps:

- Click within the Conversion Type box to choose the unit conversion desired
- Click within the Unit In box to choose the unit of the quantity to be converted
- Click within the Unit Out box to choose the desired units of the quantity being converted.
- Enter the quantity to be converted in the Value In box and click the Calculate button.

A conversion is made each time you choose a Unit In or a Unit Out. However, if the Value In changes and the Unit In and Unit Out remain the same, you must use the Calculate button to obtain the desired conversion.

- After highlighting the Converted Value, a click on the right mouse button opens a menu allowing cut/paste, copy/paste, and delete operations on the fly. Note that the Edit menu on the **GOFW2015** Menu Bar also can be used for delete, cut/paste, and copy/paste operations.



Generating a Report

Three reports can be generated with **GOFW2015**:

🗁 An As Found Report

🗁 An As Left Report

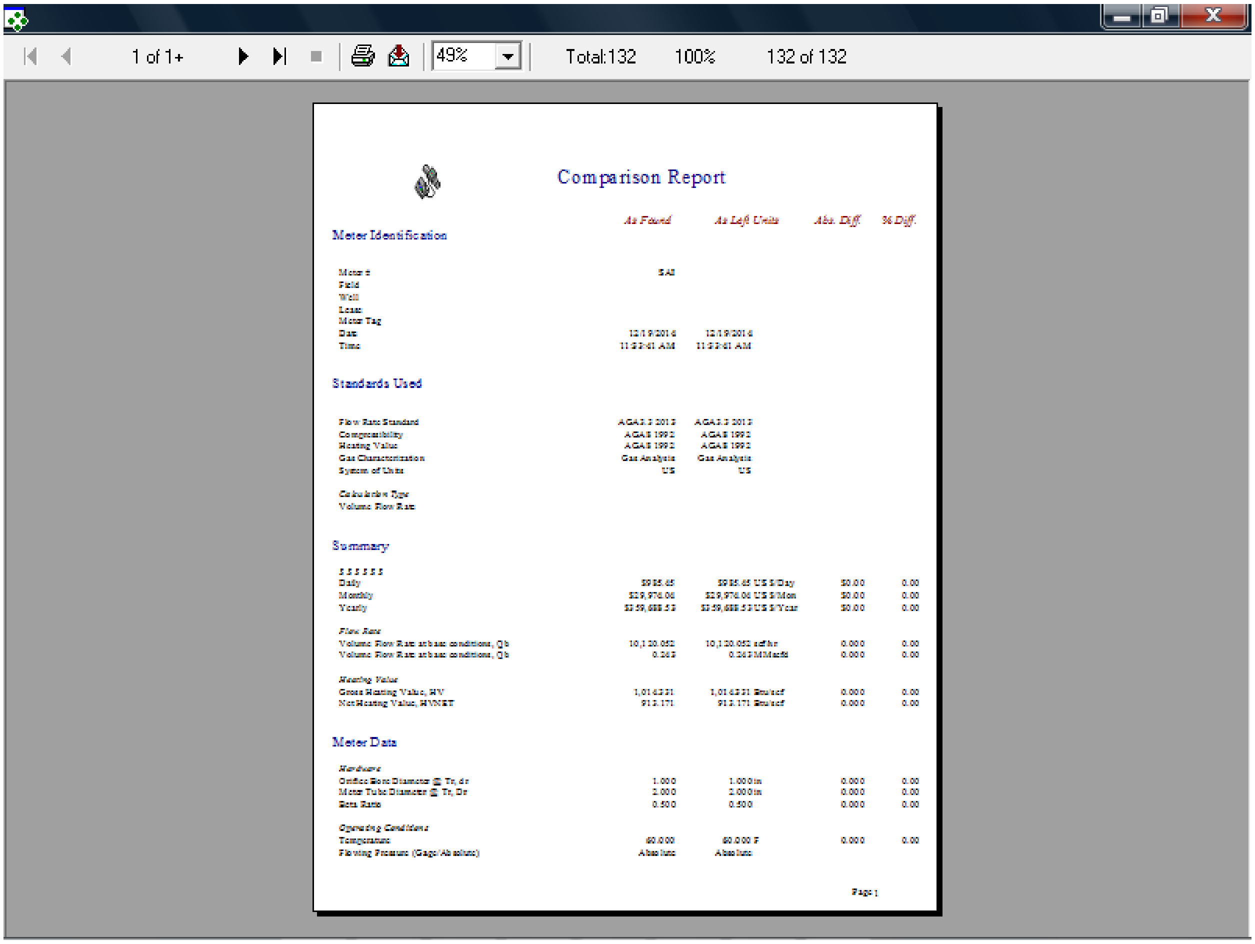
🗁 A Comparison Report

The Comparison Report contains the information in the As Found Report and the As Left Report plus additional information about the numerical differences and percent differences between the As Found and As Left Conditions (As Left-As Found). **GOFW2015** uses Crystal Reports technology to generate the reports. Information in the reports is written into a database that is replaced each time a report is generated. The reports included allow the user to perform the following functions:

🗁 Choose among three different reports, each with its own screen display.

🗁 Export a given report. The Crystal Reports technology includes an export button on the report screen display with a number of choices for the format of the exported report file and a number of choices for the destination of the exported report file. To avoid problems related to different versions of software applications such as Microsoft Word, it is recommended that "Rich Text Format" be selected as the format of the exported report file and that "Disk file" be selected as the destination of the exported report file. The resulting Rich Text Format (*.rtf) report file can be saved in the desired computer subdirectory folder. When the Rich Text Format (*.rtf) report file is opened, it can be saved by the user in one of the formats available on the user's computer, for example as a Microsoft Word document (*.doc or *.docx) or a portable file document (*.pdf).

🗁 Print the report. The Crystal Reports technology includes a print button on the report screen display which allows printing of the report on the computer default printer.



Comparison Report

	As Found	As Left Units	Abs. Diff.	% Diff.
Meter Identification				
Meter #	SAI			
Field				
Well				
Lease				
Meter Tag				
Date	12/19/2016	12/19/2016		
Time	11:52:41 AM	11:52:41 AM		
Standards Used				
Flow Rate Standard	AGA3.3 2013	AGA3.3 2013		
Compressibility	AGA8 1992	AGA8 1992		
Heating Value	AGA8 1992	AGA8 1992		
Gas Characterization	Gas Analysis	Gas Analysis		
System of Units	US	US		
Calculation Type				
Volume Flow Rate				
Summary				
$ $ $ $ $ $				
Daily	$985.65	$985.65 US $/Day	$0.00	0.00
Monthly	$29,974.06	$29,974.06 US $/Mon	$0.00	0.00
Yearly	$359,688.53	$359,688.53 US $/Year	$0.00	0.00
Flow Rate				
Volume Flow Rate at base conditions, Qb	10,120.052	10,120.052 scf/hr	0.000	0.00
Volume Flow Rate at base conditions, Qb	0.243	0.243 MMscfd	0.000	0.00
Heating Value				
Gross Heating Value, HV	1,014.231	1,014.231 Btu/scf	0.000	0.00
Net Heating Value, HVNET	912.171	912.171 Btu/scf	0.000	0.00
Meter Data				
Hardware				
Orifice Bore Diameter @ Tr, dr	1.000	1.000 in	0.000	0.00
Meter Tube Diameter @ Tr, Dr	2.000	2.000 in	0.000	0.00
Beta Ratio	0.500	0.500	0.000	0.00
Operating Conditions				
Temperature	60.000	60.000 F	0.000	0.00
Flowing Pressure (Gage/Absolute)	Absolute	Absolute		

Page 1

CHAPTER 2

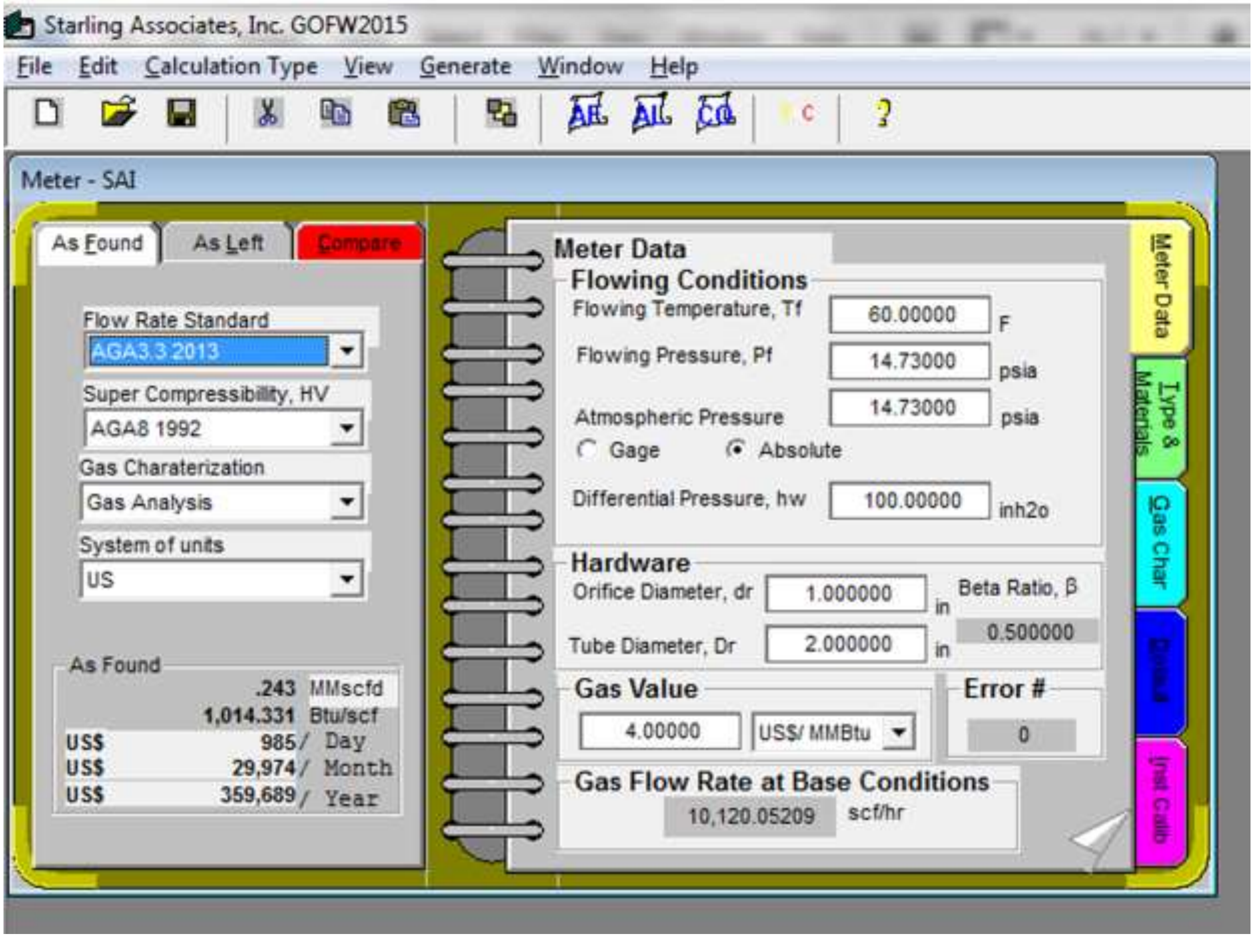
A Quick Tutorial

The **GOFW2015** program allows the user to compare the flow rate in the As Left condition with the As Found condition following a linear meter or orifice meter calibration. In this tutorial, we will use **GOFW2015** to find the difference in flow rate after the calibration of an orifice meter differential pressure gage. The technician equipped with a laptop and the **GOFW2015** software can immediately calculate the difference in flow rate (and other quantities) and with the click of an icon generate a detailed report which can be saved for subsequent use, printed or emailed.

This tutorial will familiarize users with the major features of **GOFW2015** for orifice meter (calculations for turbine meters and coriolis meters are discussed in Appendix D). Follow along with the steps below:

- ✐ Launch **GOFW2015** by clicking on the Windows Start button and selecting All Programs. Select **Starling Associates GOFW2015** and click on the **GOFW2015** icon.

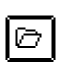
- ✐ Click the OK button on the Meter Properties screen. The **GOFW2015** Notebook opens with the default configuration (see Chapter 7 for information on changing the default configuration).

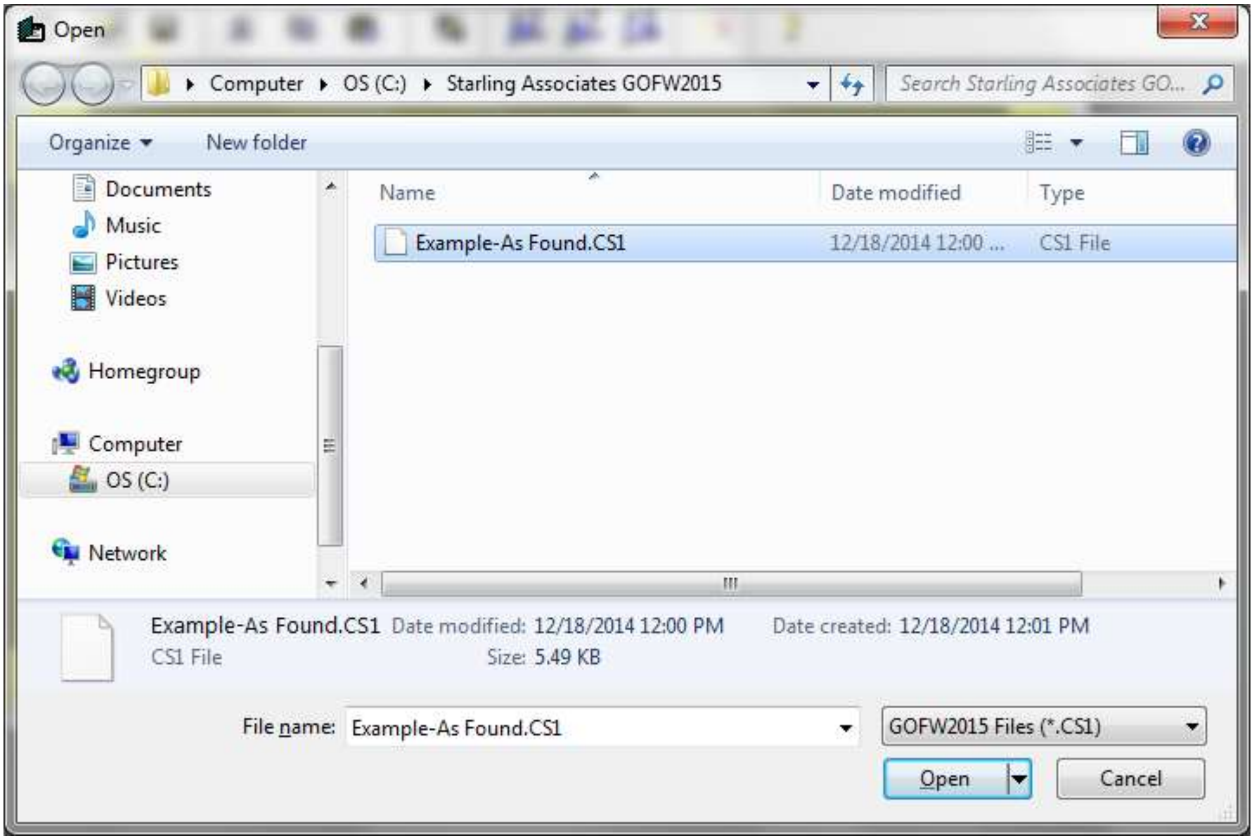


The As Found and As Left Conditions are the same. The default configuration is:

- Flow Rate Standard: AGA3.3 2013
- Compressibility Factor, HV: AGA8 1992
- Gas Characterization: Gas Analysis
- System of Units: US

Next, open the following file provided with **GOFW2015**: Example-As Found.CS1

- Click on the Open button  and select the file Example-As Found.CS1 from the Open screen.



The **GOFW2015** Notebook will display the Meter Properties screen, with the entries Example-As Found, Gulf Coast Gas, Composition, AGA 8 1992, PAGE 74 (note that the calculated compressibility factor can be verified by comparison with the AGA8 1992 standard for this composition).

✐ Click the OK button on the Meter Properties screen. The **GOFW2015** Notebook will display the input values for the meter in Example-As Found.CS1, in the As Found condition (before calibration).

✐ Click on the Configuration Tabs to view the As Found input values. The As Found conditions in Example-As Found.CS1 correspond to the meter conditions "as found" before meter calibration was performed. The As Found conditions have been copied into the As Left conditions in Example-As Found.CS1 so that this tutorial can correspond to an example of calibration of a meter.

✐ Click on the As Left tab to see that Example-As Found.CS1 initially has the same meter conditions for As Left and for As Found.

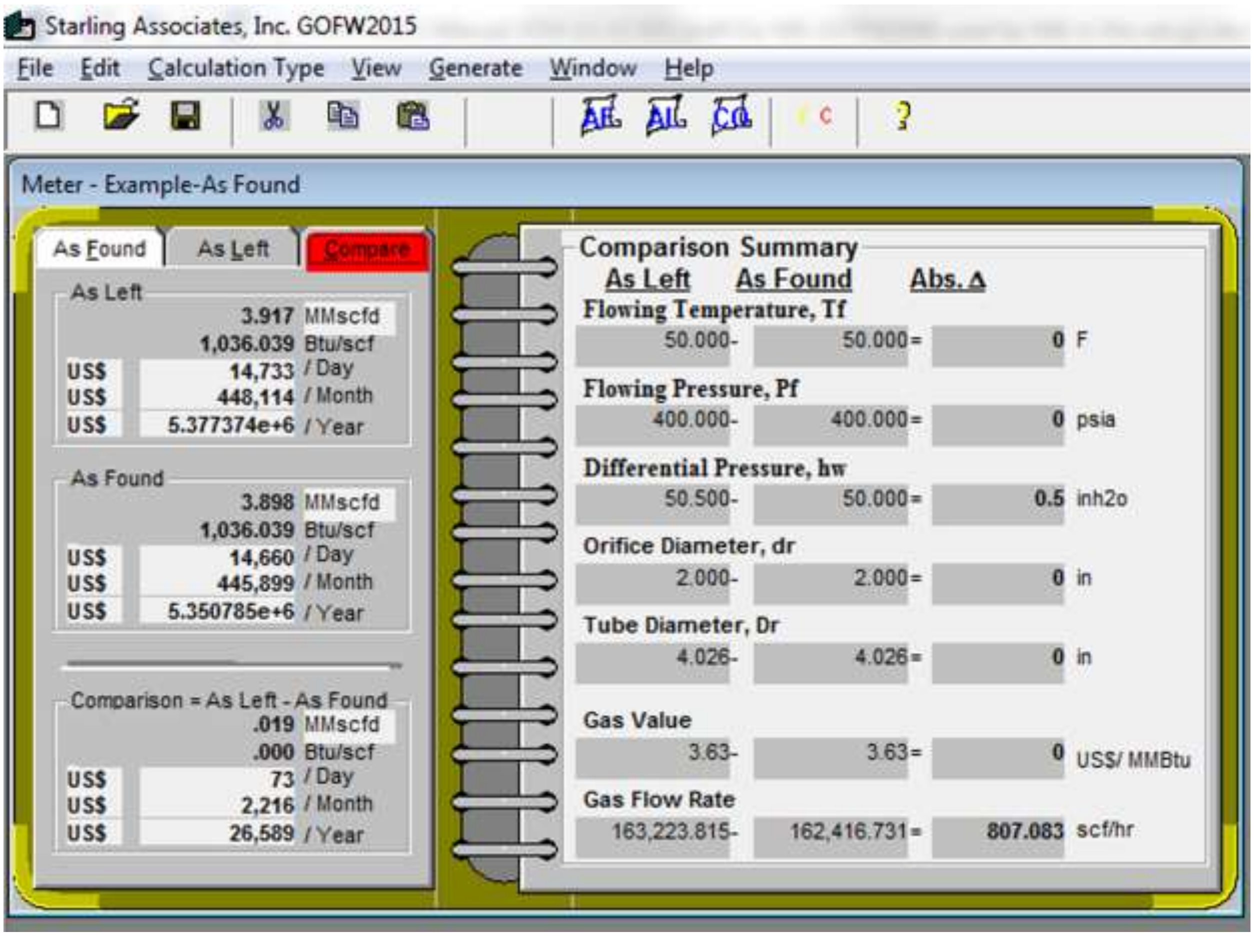
The Compare tab shows a comparison of the As Left and As Found values for certain quantities, including Meter Data, Hardware and Gas Flow Rate.

✐ Click on the Compare tab to see this comparison (the differences between As Left and As Found initially are zero).

After meter calibration, the meter may be left in a configuration which results in a calculated gas flow rate (As Left) which differs from values calculated before the calibration (As Found). Consider an example for which the calibration of the differential pressure gage results in h_w (As Left) = 50.5 inches of water, compared to h_w (As Found) = 50.0 inches of water.

Change the Differential Pressure, h_w for the As Left condition from 50.0 to 50.5.

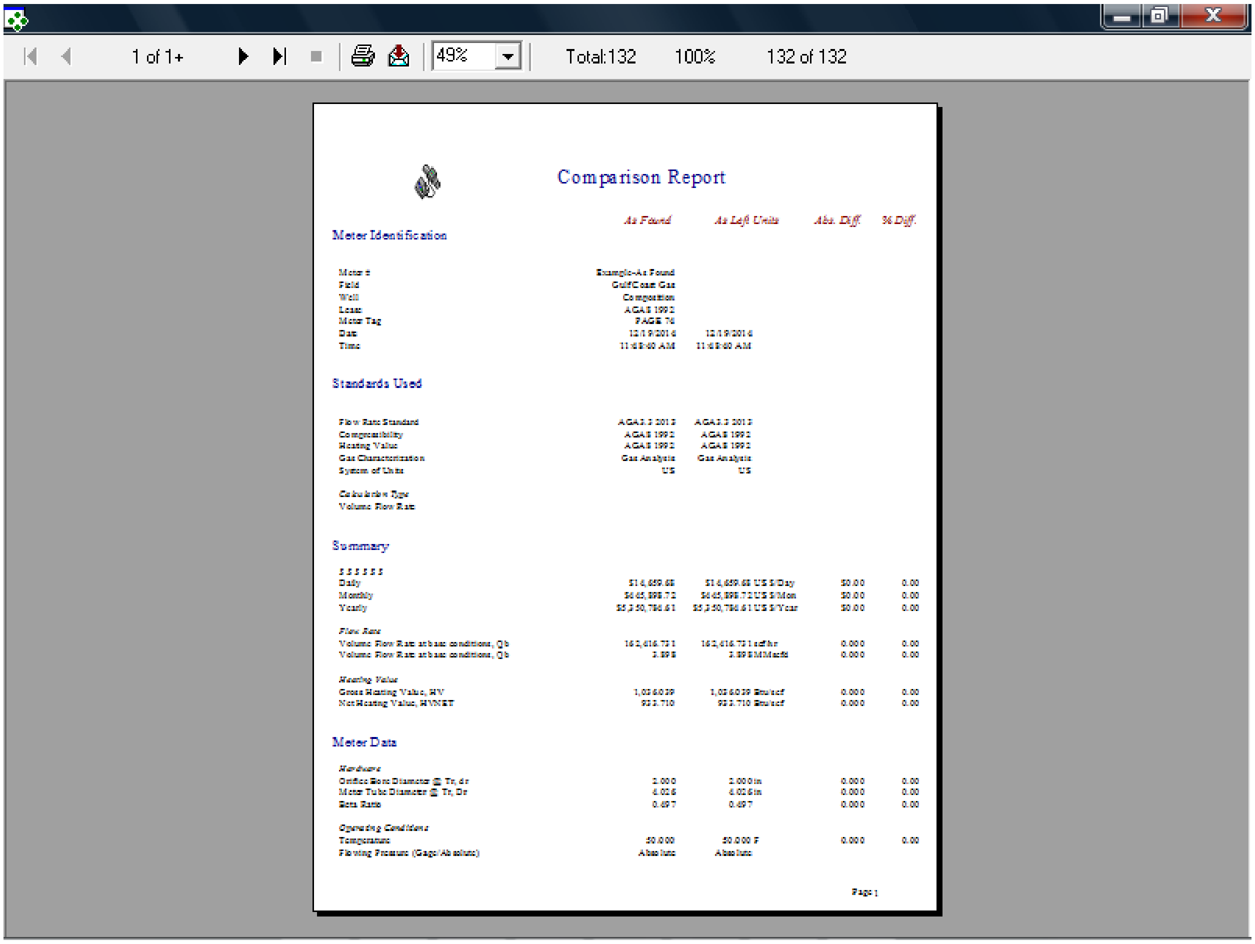
✎ Click on the Compare tab to view the effect of this calibration of the differential pressure gage.



Notice on the Compare screen that the increase in Differential Pressure h_w from 50.0 to 50.5 inches of water yields an increase in the calculated Gas Flow Rate from 3.898 to 3.917 MMscfd. The Gas Analysis used (viewed by clicking the Gas Char tab) yields a calculated Gross HV = 1036.04 Btu/scf (viewed by clicking the meter Data tab then clicking the "dog ear" on that page to reveal the second page of the Meter Data section of the Notebook). On the Comparison Report a Gas Value of 3.63 US$/MMBtu has been used resulting in a gas value increase from $14,660 to $14,733 per Day.

The Compare Tab shows only a summary of the differences between the As Left and As Found conditions. **GOFW2015** also prepares reports with detailed information on inputs and calculated outputs. Click on Generate on the **GOFW2015** menu bar to view the drop-down menu which allows the report options As Found Report, As Left Report and Comparison Report (the Toolbar options AF, AL and CO also provide these report options).

✎ Next, generate a Comparison Report. Simply choose Comparison Report from the Generate menu (or click on the CO button on the toolbar).



✎ Click on the Maximize button to have a full screen for the report window

✎ Click on the Print button  to print the report using the computer default printer

🗁 Click on the Export button  to export the report. The Crystal Reports technology includes an export button on the report screen display with a number of choices for the format of the exported report file and a number of choices for the destination of the exported report file. However, to avoid problems related to different versions of software applications such as Microsoft Word, it is recommended that "Rich Text Format" be selected as the format of the exported report file and that "Disk file" be selected as the destination of the exported report file. The resulting Rich Text Format (*.rtf) report file can be saved in the desired computer subdirectory folder. When the Rich Text Format (*.rtf) report file is opened, it can be saved by the user in one of the formats available on the user's computer, for example as a Microsoft Word document (*.doc or *.docx) or a portable file document (*.pdf).

✎ Return now to the computer monitor display and perform the following steps to save the As Left configuration in a GOFW2015 file named Example-As Left.CS1. First, click the As Left tab. Next, access the drop-down menu under Edit on the GOFW2015 menu bar and click on AF-AL/AL-AF.

This step moves all of the As Left input variable values into the As Found input text boxes, causing the As Found information to be the same as the As Left information. Next, access the drop-down menu under View on the GOFW2015 menu bar and click on Meter Properties. In the Meter# textbox, type Example-As Left and click the OK button. Then, access the drop-down menu under File on the GOFW2015 menu bar and click on Save As. In the File name dialog box type Example-As Left, then click the Save button, which saves the GOFW2015 file named Example-As Left.CS1.

✐ Note that the As Found information still is in the original GOFW2015 file named Example-As Found.CS1 and the As Left information is in the newly created GOFW2015 file named Example-As Left.CS1. The next section provides a more general discussion of GOFW2015 file handling.

Creating, Saving and Reopening GOFW2015 Input Files

When GOFW2015 is started, a set of default values appear on the GOFW2015 window. GOFW2015 uses the file GOFW2015.ini for this initial default configuration. The file GOFW2015.ini is placed in the subdirectory in which the GOFW2015 software is installed.

The first screen which appears when GOFW2015 is started up has a form on the left hand side titled Meter Properties. The Meter# box is already filled in with “SAI”, which comes from the initialization file GOFW2015.ini. Clicking OK in the Meter Properties form places “Meter – SAI” on the banner of the next window which appears.

A new input file can be created by modifying the entries in the boxes in the GOFW2015 windows. Accessing the drop-down menu under View on the GOFW2015 menu bar and clicking on Meter Properties allows changing the Meter# from “SAI” to a Meter# corresponding to the newly created calculation. Then accessing the drop-down menu under File on the GOFW2015 menu bar and clicking on Save As allows entering a file name for the newly created input file.

Similarly, another input file can be created by modifying the entries in the boxes in the GOFW2015 windows, changing the Meter# and saving the input file with an appropriate name. Then to reopen an input file which was created earlier, access the drop-down menu under File on the GOFW2015 menu bar and click on Open. You will be asked if you wish to save the information for the current meter before opening a new meter. It is best if you have saved the current information previously so you can click No. If you click No, you will immediately be allowed to reopen any previously saved GOFW2015 input file. When this meter reopens, be sure to click OK on the Meter Properties screen to preserve the Meter# associated with the meter calculation.

To insure that you know whether a GOFW2015 .CS1 file contains As Found information or As Left information, it is recommended that the As Left information be moved into the As Found input textboxes and that the file be saved using an easily identified file name. The procedure is (1) click the As Left tab, (2) access the drop-down menu under Edit on the GOFW2015 menu bar and click on AF-AL/AL-AF, (3) access the drop-down menu under View on the GOFW2015 menu bar and click on Meter Properties, (4) in the Meter# textbox, type text identifying the meter information as being in the As Left description and click the OK button, (5) access the drop-down menu under File on the GOFW2015 menu bar and click on Save As, (6) in the File name dialog box type the desired file name, then click the Save button, which saves the GOFW2015 file with extension .CS1. An easy way to be reminded of what the configuration is for a GOFW2015 input (.CS1) file is to use the same file name as the Meter# textbox entry (as was done in the previous section for Example-As Found.CS1 and Example-As Left.CS1).

The format of the GOFW2015 user interface is similar to a notebook with tabs in which there are two major sections. These two major sections are the As Found section with all of the inputs as found, and the As Left section with all of the inputs as left. The As Left section inputs include any changes to the meter affecting the meter calculation inputs, such as the change of an orifice plate, the calibration of a pressure or differential pressure transducer, etc.

To view and compare the changes in calculated quantities for the As Left versus As found meter conditions requires the generation of a comparison report. To retain a record of the information in the comparison report requires saving the comparison report. As noted earlier, if the comparison report is saved as a Rich Text Format (.rtf) file, it can be viewed subsequently on the vast majority of computers. On the other hand, a GOFW2015 input (.CS1) file, saved from the comparison calculations generally will not yield the outputs which were successfully saved in the (.rtf) file. The reason is because when the input (.CS1) file is opened the inputs in the As Found section generally are copied into the As Left section before the GOFW2015 user interface appears. Thus, before saving a GOFW2015 input (.CS1) file, it is useful to be sure that the As Found section contains the inputs desired when the file is reopened at a later time.

The user of GOFW2015 needs to be aware that two different outcomes can result when saving a GOFW2015 project file, dependent on the procedures utilized by the user.

As discussed earlier, the SaveAs method is used to name a GOFW2015 project file and save the file with the assigned name. Subsequently, when the file is closed the user is given the choice to save the file with a Yes or No option.

If the user clicks Yes, the GOFW2015 project file will be saved with the inputs in the AsLeft tab input boxes copied into the AsFound tab input boxes. The purpose of this procedure is to provide the user with the opportunity to open the GOFW2015 project file for the subject meter at a later date, for example at the time of a new meter inspection or instrument calibration, and enter new inputs in the AsLeft tab input boxes.

Conversely, if the user clicks No, the GOFW2015 project file will be saved with the inputs in the AsFound tab input boxes copied into the AsLeft tab input boxes. This is the reason that it is recommended that the As Left information be moved into the As Found input textboxes before closing the GOFW2015 project file.

CHAPTER 3

GOFW2015 Standards and Calculation Types

GOFW2015 is a powerful analysis and calculation tool for orifice meters and linear meters, including turbine meters, ultrasonic meters and coriolis meters. It allows the user to compare the volumetric flow rate in the As Left condition with the As Found condition following meter calibration. In a similar manner, it can be used to compare the use of different measurement standards. In addition to the volumetric flow rate, **GOFW2015** can be used to calculate the mass flow rate and other quantities for the meter. For orifice meters, **GOFW2015** can be used to size an orifice plate or to estimate the differential pressure for a specified flow rate. This chapter will discuss the standards and calculations available using **GOFW2015**.

Standards Covered

The flow rate standard used in a **GOFW2015** calculation is selected on the left side of the Notebook. The choices for Flow Rate Standard (🕮) and associated compressibility Z (or density) and gross heating value HV include:

🕮 AGA3.3 2013 (default for flow rate)

Z, HV AGA8 1992 (default for Z and HV)

Z, HV AGA8 1992,HV=GPA2172-09

Z, HV User Input (user input for Z or density, HV)

🕮 AGA3 1992 (flow rate)

Z, HV AGA8 1992 (AGA8 1992 for Z and HV)

Z, HV AGA8 1992,HV=GPA2172-96

Z, HV User Input (user input for Z or density, HV)

🕮 AGA 3 1985 (flow rate)

Z AGA 8 1985

Z AGA 8 1995 (Alternate Method)

Z NX19 1962

Z User Input

🕮 AGA 7 - AGA 9 - Linear Meters

Z, HV AGA8 1992 (default for Z and HV)

Z, HV AGA8 1992,HV=GPA2172-09

Z, HV AGA8 1992,HV=GPA2172-96

Z AGA 8 1985

Z AGA 8 1985 (Alternate Method)

Z NX19 1962

Z, HV User Input (user input for Z or density, HV)

For the instances of AGA8 1985 and NX19 1962, the gross heating value HV is calculated using GPA2172-86.

The algorithms and equations for orifice meters which are in the present computer program are based on the AGA Reports No. 3.3(2013) and No. 8(1994), the 1992 AGA Report No. 3, the 1985 AGA Reports Nos. 3 and 8, the 1962 AGA Report NX-19 and the 2009, 1996 and1986 G.P.A. 2172 Standards. The AGA 7 and AGA 9 Linear Meters calculations are based on AGA 7 - Measurement of Gas by Turbine Meters, Transmission Measurement Committee Report No. 7(2005) and AGA 9 – Measurement of Gas by Multipath Ultrasonic Meters, Transmission Measurement Committee Report No. 9 (2007). Note that AGA Report No. 3.3 and API MPMS Ch. 14.3.3 are equivalent reports and that AGA Reports No. 8 and API MPMS Ch. 14.2 are equivalent reports. Coriolis meter calculations are discussed in Appendix D.

The combinations of standards supported by **GOFW2015** are illustrated in the table below:

Flow Rate Standard	**Z, HV**	**Gas Characterization (GOFW2015 Syntax)**	**Standard Name**
AGA3.3 2013, AGA7, AGA9, LINEAR METERS	AGA8 1992	Gas Analysis	*Detail Method*
		HV-GR-CO2	*Gross Characterization Method 1*
		GR-CO2-N2	*Gross Characterization Method 2*
	AGA8 1992, GPA2172-96	Gas Analysis	*Detail Method*
	User Input	User Input –Densities, HV	
		User Input - Zs, HV	
AGA3 1992, AGA7, AGA9, LINEAR METERS	AGA8 1992	Gas Analysis	*Detail Method*
		HV-GR-CO2	*Gross Characterization Method 1*
		GR-CO2-N2	*Gross Characterization Method 2*
	AGA8 1992, GPA2172-96	Gas Analysis	*Detail Method*
	User Input	User Input –Densities, HV	
		User Input - Zs, HV	
AGA3 1985, AGA7, AGA9, LINEAR	AGA8 1985, GPA2172-86	HV-GR-CO2	*The Gravity, Heating Value, Carbon Dioxide Method*

METERS		GR-CO2-N2	*The Gravity, Carbon Dioxide, Nitrogen Method*
		Gas Analysis	*Primary, Compositional Analysis Method*
		HV-GR-CO2-N2	*The Gravity, Heating Value, Carbon Dioxide, Nitrogen Method*
		HV-CO2-N2	*The Heating Value, Carbon Dioxide, Nitrogen Method*
		GR-CH4-CO2-N2	*The Gravity, Methane, Carbon Dioxide, Nitrogen Method*
	AGA8 1985 (Alternate Method), GPA2172-86	HV-GR-CO2	*The Gravity, Heating Value, Carbon Dioxide Method*
		GR-CO2-N2	*The Gravity, Carbon Dioxide, Nitrogen Method*
		Gas Analysis	*Primary, Compositional Analysis Method*
		HV-GR-CO2-N2	*The Gravity, Heating Value, Carbon Dioxide, Nitrogen Method*
		HV-CO2-N2	*The Heating Value, Carbon Dioxide, Nitrogen Method*
		GR-CH4-CO2-N2	*The Gravity, Methane, Carbon Dioxide, Nitrogen Method*
	NX19 1962, GPA2172-86	GR-CO2-N2	*Standard Method*
		Gas Analysis	*Analysis Method*
		HV-CO2-N2	*Heating Value Method*
		GR-CH4-CO2-N2	*Methane – Gravity Method*
	User Input	User Input – Densities, HV	
		User Input - Zs, HV	

- Among the choices for Compressibility Factor, HV for flow rate standard AGA3 1985, the user will notice the choice of AGA 8 1985 Alt Meth. The Alternate Method is a non-standard choice. The Gross Methods available for gas characterization in AGA Report No. 8 utilize gravity, heating value and diluent content to form a pseudo gas composition. This composition is then used to generate the properties of the gas using an equation of state. The Alternate Method makes a check to verify that the pseudo composition generated gives back the gravity input and adjusts the pseudo composition of the gas to return the input gravity.

Units

The US system of units is the initial default units for **GOFW2015** and a number of calculation types, such as orifice sizing, can be performed only in US units. For volume flow rate and mass flow rate calculations, the System of Units menu includes SI, Metric and IP units in addition to US units.

Calculation Types

GOFW2015 calculation types for orifice meters are discussed below. **GOFW2015** calculation types for linear meters, with examples for turbine meters and coriolis meters, are discussed in Appendix D.

GOFW2015 supports four different orifice meter calculation types. They are found under Calculation Type on the menu bar. The four Calculation Types (discussed below) are:

🗁 Volume Flow Rate

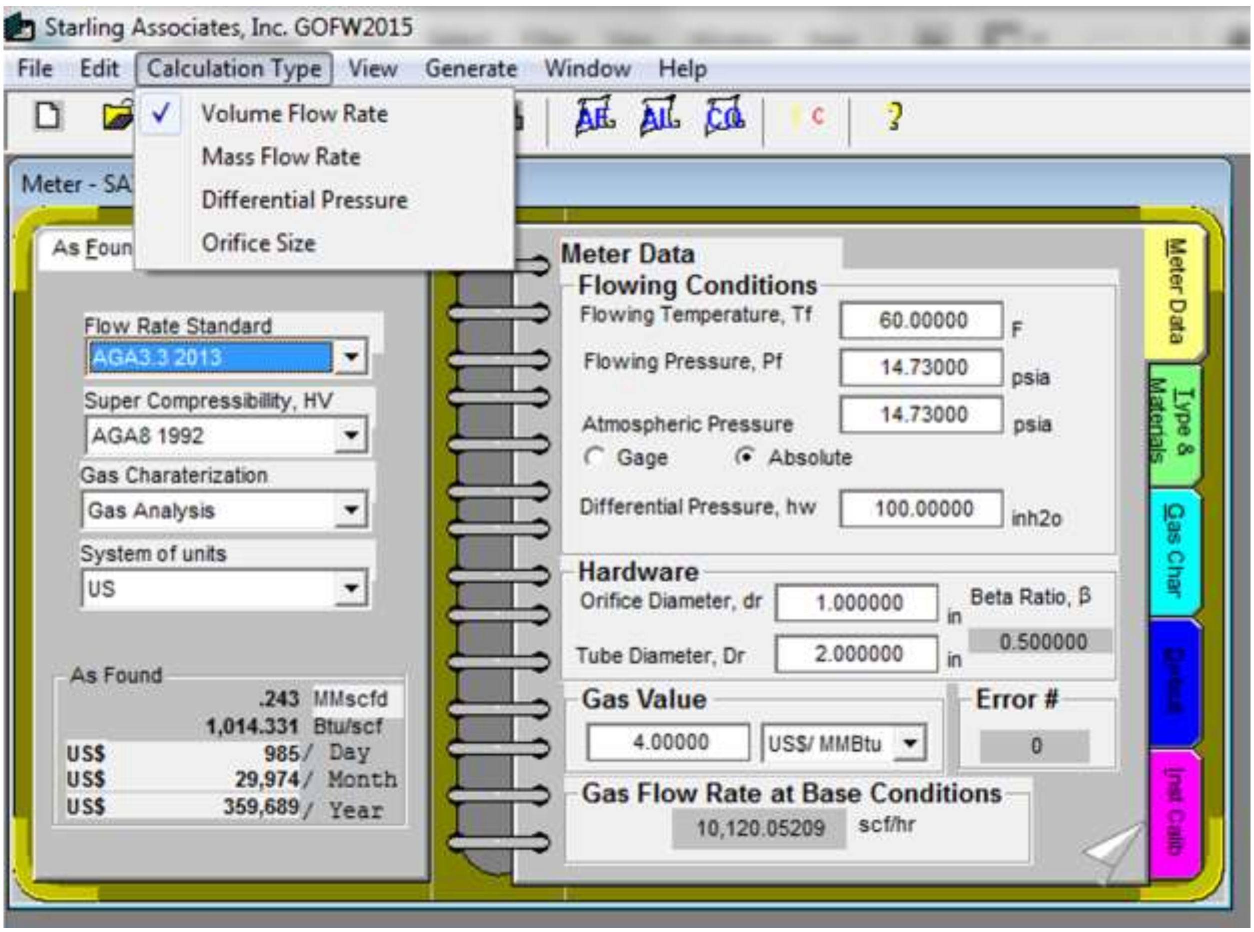
🗁 Mass Flow Rate

🗁 Differential Pressure

🗁 Orifice Size

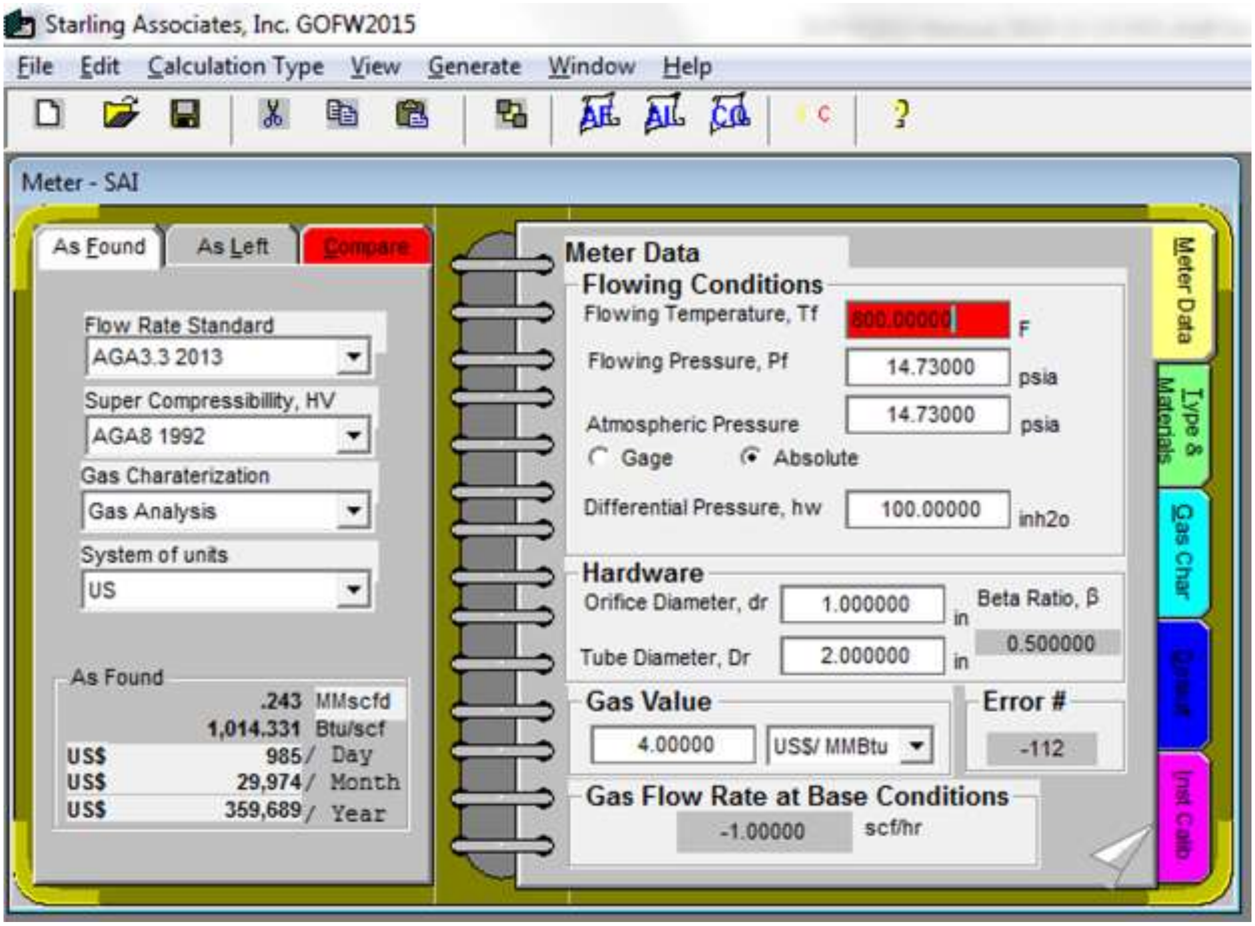
Volume Flow Rate

The default orifice meter calculation for **GOFW2015** is volumetric flow rate. When this calculation is selected, a check mark appears next to Volume Flow Rate on the Calculation Type menu.



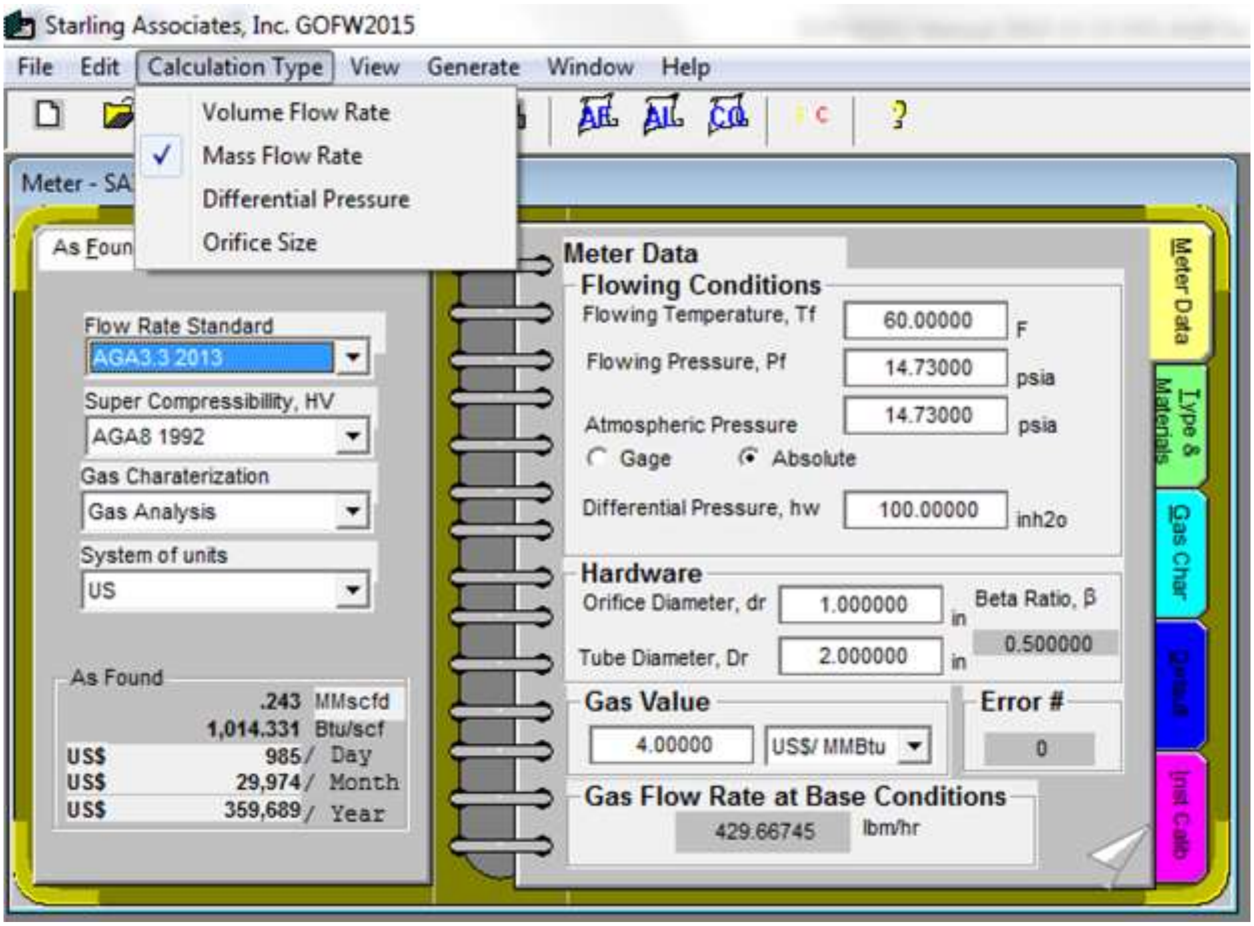
GOFW2015 opens with default conditions that generate an orifice meter volumetric flow rate calculation. A new calculation is made each time an entry changes. The volume flow rate is returned in the Gas Flow Rate field on the Meter Data Tab in standard cubic feet per hour for the default US units. It is also displayed in million standard cubic feet per day on the summary section of the As Found and As Left Tabs.

When a value of -1 is returned in the Gas Flow Rate field, an input variable has been entered which is out of range or in error. **GOFW2015** indicates the error by returning the value of -1 as the Gas Flow Rate and displays the error number in the text box labeled "Error #". For most errors, the text box with the erroneous input quantity is highlighted in red. The input must be corrected for the calculation to proceed. When an input variable is outside the normal range but within the calculation limit range, **GOFW2015** displays the warning number in the text box labeled "Error #". For most warnings, the text box with the out of range input quantity is highlighted in yellow. In the figure below, a Flowing Temperature, Tf, of 800°F has been entered (maximum temperature in the normal range is 143°F). In the **GOFW2015** display, the temperature field is red. Note the value of -1 in the Gas Flow Rate field and the error number -112 in the text box labeled "Error #". See Appendix A for a complete discussion of **GOFW2015** warnings and errors.



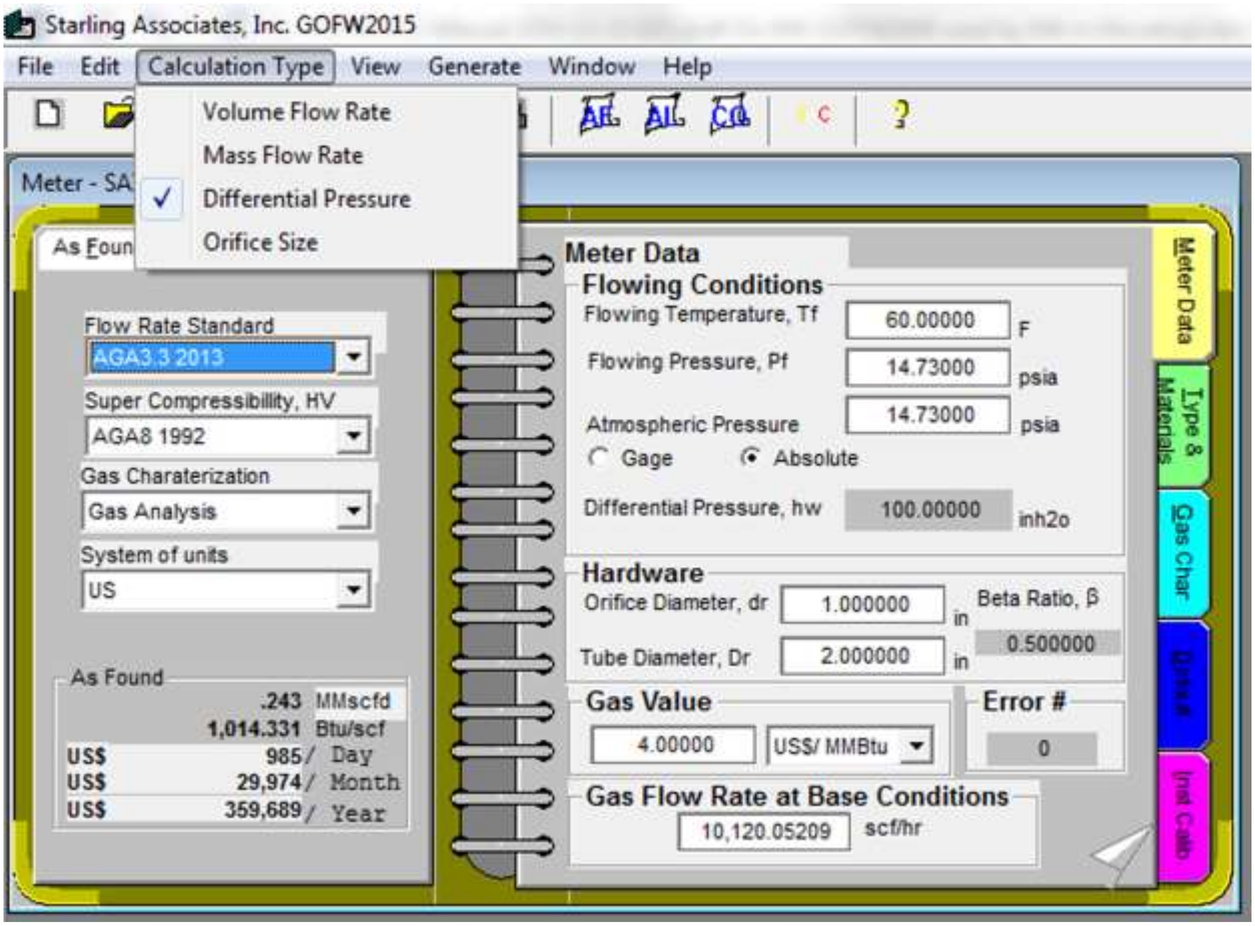
Mass Flow Rate

To determine mass flow rate, select Mass Flow Rate under the Calculation Type menu. The units in the Gas Flow Rate field will change to reflect mass flow rate. The As Found, As Left and Comparison Reports will reflect the choice of a mass flow rate calculation.



Differential Pressure

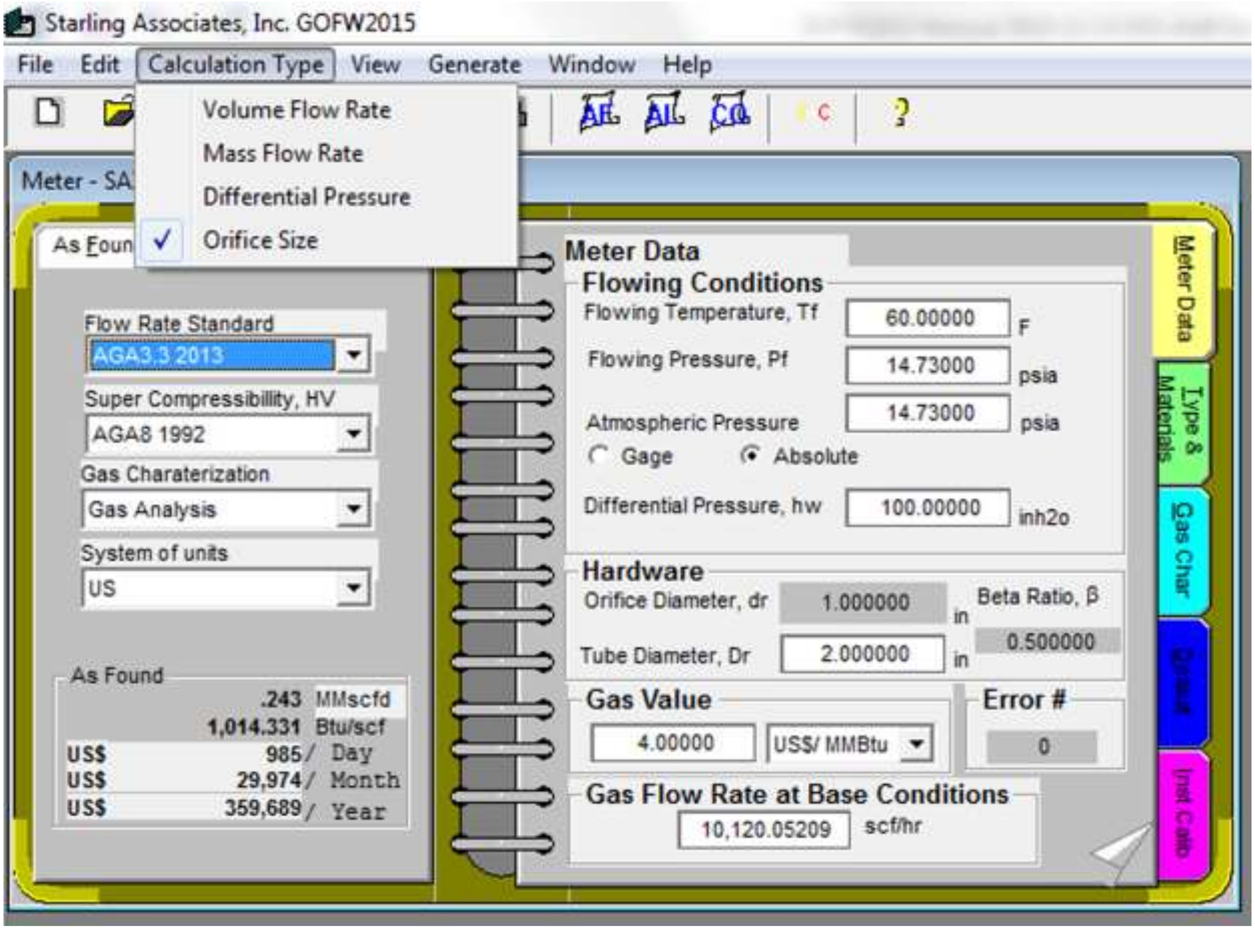
To determine the pressure drop between the pressure taps upstream and downstream of the orifice plate for a given volumetric flow rate, under the Calculation Type menu select Differential Pressure. The Gas Flow Rate field becomes an input (enabled) and the Differential Pressure field becomes an output (disabled). A new differential pressure calculation is performed each time a field entry changes. The As Found, As Left and Comparison Reports will reflect a differential pressure calculation.



➢ **GOFW2015** will only perform Differential Pressure calculations in US units. Additionally "User Input" Compressibility Factor, HV cannot be used for Differential Pressure calculations.

Orifice Size

To determine the appropriate orifice size given a volumetric flow rate and assigned differential pressure, under the Calculation Type menu, first Volume Flow Rate and then select Orifice Size. The Gas Flow Rate field becomes an input (enabled) and the Orifice Diameter field becomes an output (disabled). An orifice size calculation is made each time a field entry changes. The As Found, As Left and Comparison Reports will reflect an orifice size calculation.



- **GOFW2015** will only perform Orifice Size calculations in US units. Additionally "User Input" Compressibility Factor, HV may not be used for Orifice Size calculations.

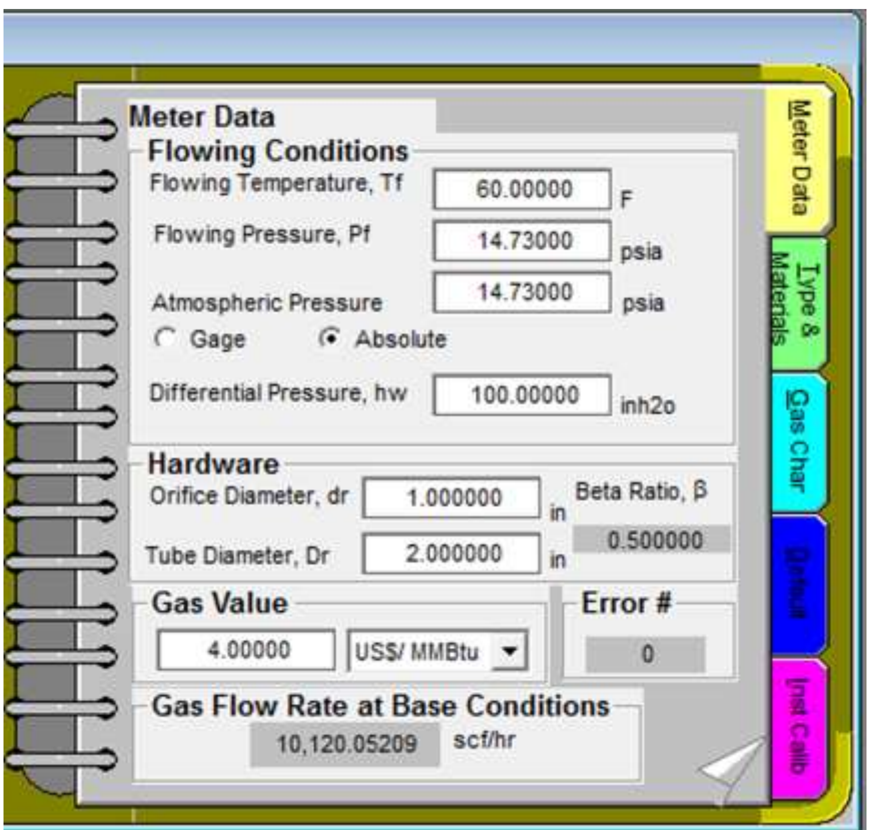
CHAPTER 4

Meter Data Tab

The Meter Data Tab contains basic meter information necessary to perform a calculation. Additionally, it contains gas value information and a calculation error indicator.

Meter Data

The Meter Data Tab appears when the **GOFW2015** Notebook is opened. There are two pages in the Meter Data Tab. The page can be changed by clicking on the "dog ear" on the current page. Most of the information in this tab is self-explanatory so only a brief description of the fields is given below.



Flowing Conditions

The flowing conditions for an orifice meter calculation are Flowing Temperature, Tf, Flowing Pressure, Pf and Differential Pressure, hw. The ranges of applicability of the flowing conditions vary depending on the standard chosen. A click on the field of entry displays the range of applicability for the flowing condition in the statusbar at the bottom of the screen.

GOFW2015 allows the use of either absolute pressure or gage pressure for the input flowing pressure.

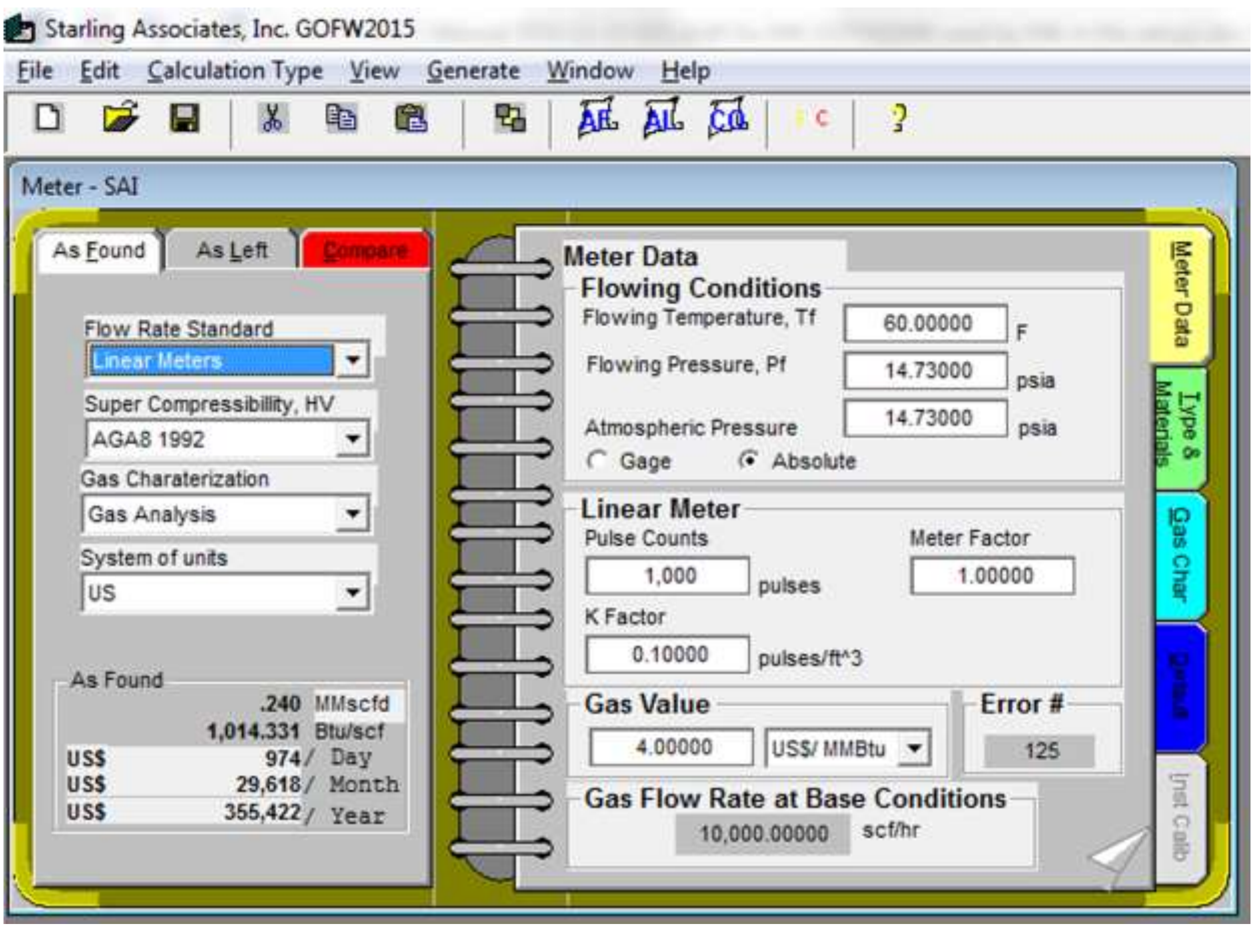
Linear Meters

The Linear Meter Frame appears when AGA7, AGA9 or LINEAR METER is indicated under the "flow rate standard" combo box and disappears otherwise.

Specify the pulse counts, meter factor and k factor.

The volume through the meter at flowing conditions is calculated with the simple relation:

Volume at flowing conditions = pulse counts * meter factor / k factor.



The volume at flowing conditions is converted to base conditions using the Compressibility Factor, HV method specified.

Hardware

The Hardware section of the Meter Data Tab is used to specify Orifice Diameter and Meter Tube Diameter. It outputs the ratio of the orifice plate diameter to the tube diameter (commonly known as Beta Ratio). Since it is possible for both diameters to be within the range of the applicable standard, while their ratio is not, the Beta Ratio field follows the color formats used to display warnings and errors.

Gas Value

The Gas Value is used to indicate the monetary value of the energy unit which is driven by the market. Depending on the System of Units used, the Gas Value may be expressed in different units.

Gas Flow Rate

The Gas Flow Rate shows the volume in scf/hr flowing through a pipeline. If an error occurs in the calculation, the Gas Flow Rate shown is -1.

Error Indicator

When an error or warning occurs in the calculation, a number corresponding to an error or warning description will be displayed in the error indicator field (zero indicates no error or warning was detected in the calculations). The meaning of the error indicator can be obtained by positioning the cursor on the error indicator field. The error/warning short description will appear in the statusbar.

Useful Outputs

The second page of the Meter Data Tab is titled Useful Outputs. These outputs include the Gas Relative Density, the Gross Heating Value, the Net Heating Value, the Molecular Weight (Molar Mass), the Critical Temperature and Critical Pressure (calculated by the Kay's rules method) and the Reduced Temperature and Reduced Pressure.

Heating Value

The Heating Value of the gas is needed to evaluate the economic value of a gas stream (discussion of how the Heating Value is used in the calculation of the energy flow rate is given in Appendix C). When the full composition of the gas is specified, the Heating Value is automatically calculated and displayed in the Heating Value field. When a Gross Method or User Input gas characterization is used, **GOFW2015** outputs -1 for the Heating Value of the gas indicating that the Heating Value has not been calculated. The -1 output as well as any other gross heating value output from **GOFW2015** can be overwritten if user wishes to input the gross heating value of the gas. Simply check the HV Overwrite check box and then input the desired Heating Value which will then be used for the economic evaluation performed by **GOFW2015** for either As Found or As Left, depending upon which tab has been clicked. Note that while the As Found tab display is still open, an As Found Report will display the overwritten HV. Similarly, while the As Left tab display is still open, an As Left Report will display the overwritten HV. To reduce the possibility of use of an overwritten HV when the user did not intend its use, the As Found check box for HV Overwrite is returned to the default unchecked status when the As Left tab has been clicked and the user subsequently returns to the As Found tab. Consequently, the user should avoid the above sequence before generating a Comparison Report and also before saving a file to disk.

CHAPTER 5

Type and Materials Tab

The Type and Materials Tab is used to specify the configuration of the orifice meter and the materials used in meter tube and orifice plate manufacture.

Type and Materials

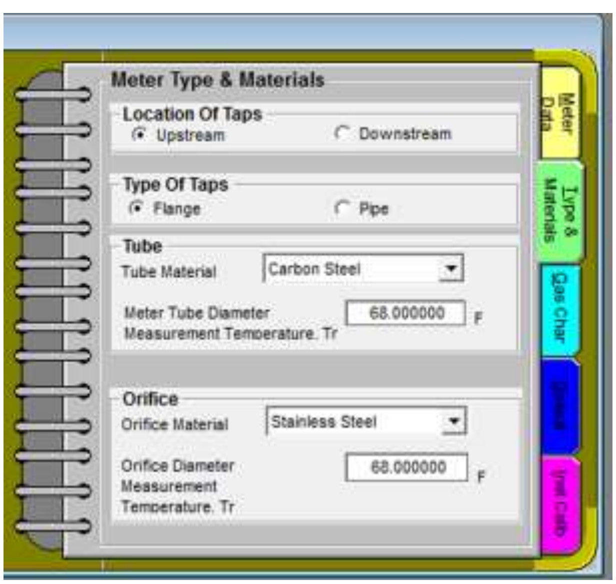
Type and Materials can be accessed by clicking on the Type and Materials Tab of the **GOFW2015** Notebook.

Type of Taps

There are two types of taps supported in AGA Report No. 3, flange and pipe taps. Cases of mixed taps are not supported by **GOFW2015**. Select calculations for Flange or Pipe Taps by clicking on the option button desired.

Location of Tap for Measurement of Flowing Pressure

Specify whether the flowing pressure tap is located before the orifice plate (upstream) or after the orifice plate (downstream).



Tube Material

Tube material must be specified to account for thermal expansion of the meter tube at different temperatures since metals have different thermal expansion coefficients. The linear coefficient of thermal expansion is tabulated for five materials in AGA Report No. 3, Part 3 (2013).

🗁 Carbon Steel

🗁 Monel

🗁 Stainless Steel

🗁 304 Stainless Steel

🗁 316 Stainless Steel

The linear coefficient of thermal expansion is tabulated for three materials in AGA Report No. 3 (1985 and 1992), Carbon Steel, Monel, and Stainless Steel.

The category Stainless Steel tabulated linear coefficient of thermal expansion is the average of 304 Stainless Steel and 316 Stainless Steel. The category Monel tabulated linear coefficient of thermal expansion is slightly different in AGA Report No. 3 (1985 and 1992) from AGA Report No. 3, Part 3 (2013), which specifically specifies Monel 400 (alloy).

Carbon steel is the default meter tube material since it is most commonly used in orifice meter installations.

Meter Tube Diameter Measurement Temperature, Tr

The Meter Tube Diameter Measurement Temperature refers to the tube temperature when the tube diameter was measured. When a tube diameter is given, a temperature must accompany it since the diameter is sensitive to temperature changes. A default temperature of 68°F is given.

Orifice Material

Orifice material must be specified to account for thermal expansion of the orifice at different temperatures since metals have different thermal expansion coefficients. . The linear coefficient of thermal expansion is tabulated for five materials in AGA Report No. 3, Part 3 (2013).

🗁 Stainless Steel

🗁 Monel

🗁 Carbon Steel *

🗁 304 Stainless Steel

🗁 316 Stainless Steel

The linear coefficient of thermal expansion is tabulated for three materials in AGA Report No. 3 (1992), Stainless Steel, Monel, and Carbon Steel, and for only two materials in AGA Report No. 3 (1985), Stainless Steel and Monel.

The category Stainless Steel tabulated linear coefficient of thermal expansion is the average of 304 Stainless Steel and 316 Stainless Steel. The category Monel tabulated linear coefficient of thermal expansion is slightly different in AGA Report No. 3 (1985 and 1992) from AGA Report No. 3, Part 3 (2013), which specifically specifies Monel 400 (alloy).

* Carbon Steel as the orifice material is not supported in AGA Report No.3, 1985. If the user selects Carbon Steel with AGA3 1985 as the flow rate standard, the program will issue a warning and change the selection to Stainless Steel. If Carbon Steel has been selected and the user changes the flow rate standard to AGA 3 1985, **GOFW2015** will change the Carbon Steel selection to Stainless Steel

Stainless steel is the default orifice material since it is most commonly used for orifice plates.

Orifice Diameter Measurement Temperature, Tr

The Orifice Diameter Measurement Temperature refers to the orifice temperature when the orifice diameter was measured. When an orifice diameter is given, a temperature must accompany it since the diameter is sensitive to temperature changes. A default temperature of 68°F is given.

CHAPTER 6

Gas Characterization Tab

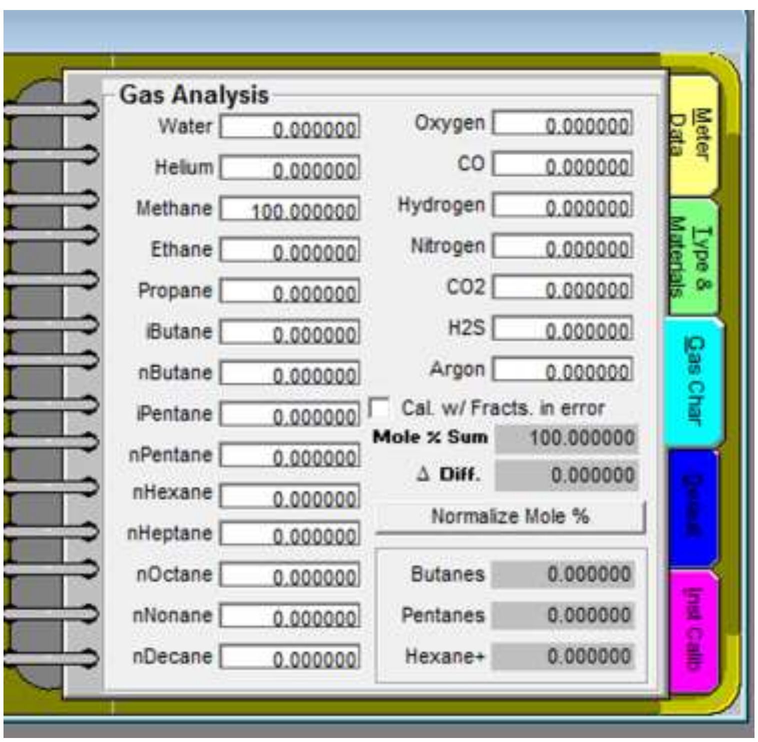
The Gas Characterization Tab is used to specify the composition of the gas or the means to characterize its physical properties.

Gas Characterization

The Gas Characterization Tab changes according to the Gas Characterization option chosen on the left side of the **GOFW2015** Notebook.

Gas Analysis

The Gas Analysis screen is used when the full compositional analysis of the gas mixture is known. The Gas Analysis screen is displayed on the Gas Characterization Tab when the Gas Analysis option is chosen under Gas Characterization on the left side of the Notebook.



The Gas Analysis screen permits the user to enter values for 21 components. However, when the Gas Analysis Method under AGA8 1985 or NX19 1962 is used argon is excluded. A click on the field of entry displays the range of applicability for the component mole percentage in the statusbar at the bottom of the screen.

The Cal. w/Fracts. in error Checkbox

A check in the **Cal. w/Fracts. in error** (calculate with fractions in error) checkbox allows computations to be performed even if the mole percent of a gas component is outside the range recommended for some standards. For example, AGA Report No. 8 was developed and tested within certain limits. The accuracy of calculations made with components outside the tested range cannot be assured. If, however, a computation is required under these circumstances, the **Cal. w/Fracts. in error** checkbox prevents **GOFW2015** from checking fractions and allows the calculation to proceed. Since the numbers entered are outside the tested limit, an unexpected math error may occur. The user is cautioned that the use of this override is not in conformance with the limits of the standards and therefore this override is not recommended.

The Normalize Mole % Button

A useful feature of the Gas Analysis Method is the Normalize Mole % button. When the sum of the user input mole percentages is very close to 100% this button can be clicked to normalize all component percentages so that the sum equals 100%.

Other Features

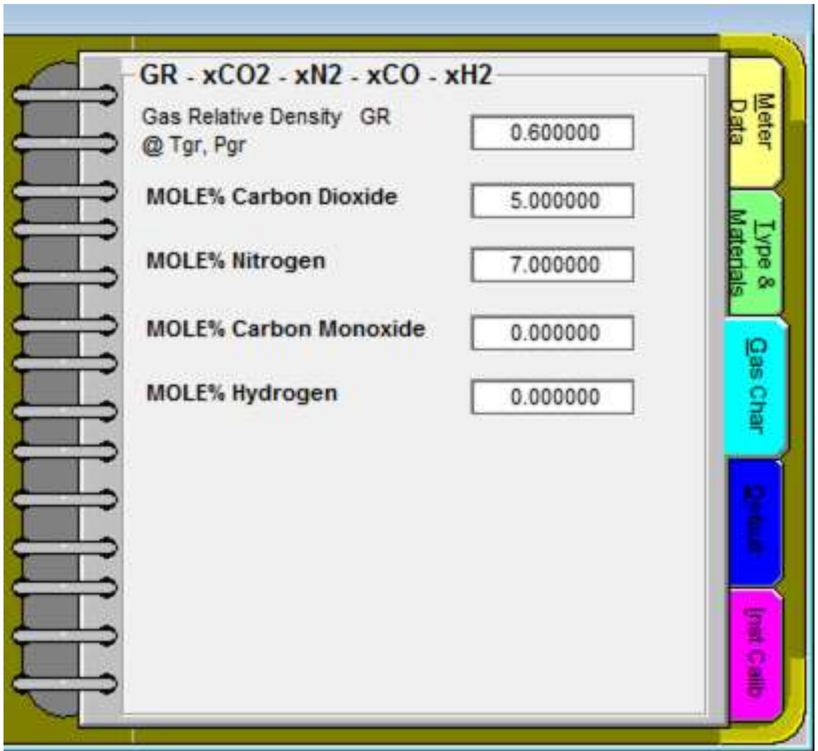
Other features of the Gas Analysis input screen include the Mole % Sum and the Δ Diff labels. They assist the user in assessing the deviation of the total of the input mole percentages from 100%.

The Gas Analysis input screen carries a summation of butanes, pentanes and hexane+ percentages. It is possible for individual percentages to be within the accepted range while their sum is not. For example, if AGA Report No. 8 is used to characterize a gas with 3.5% n-butane and 3.5% i-butane, the individual components are within the allowed range but their sum is not. **GOFW2015** indicates the error by displaying the Butanes summation label in red.

Gross Methods

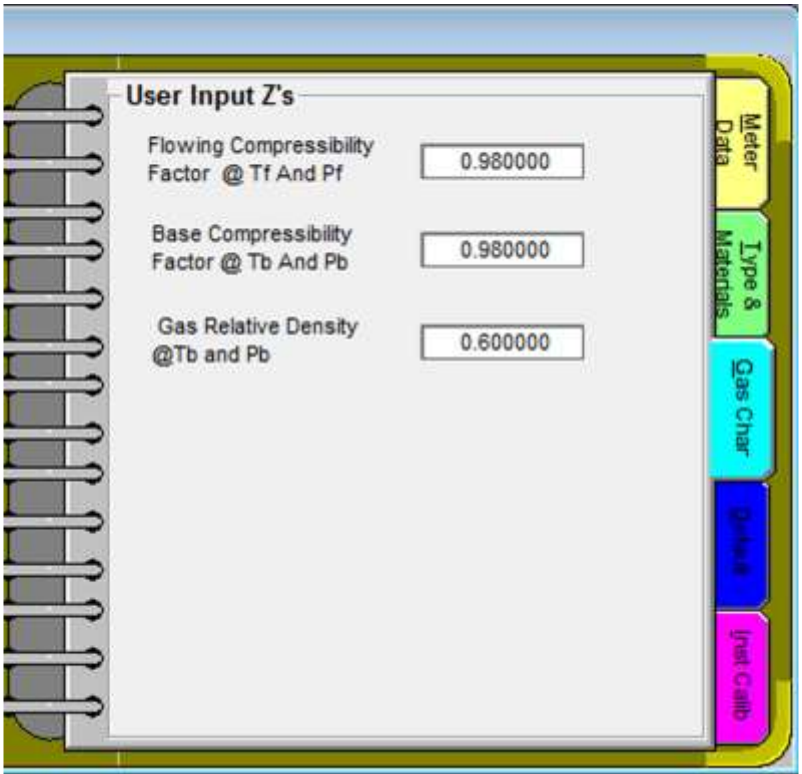
Gross Methods include all the characterization methods that use a combination of Relative Density, Heating Value, Mole Percent of Nitrogen, Carbon Dioxide, Methane, Hydrogen and Carbon Monoxide.

Gross Methods in **GOFW2015** are those which are characterized neither as Gas Analysis Methods nor as User Input Methods. An example of a Gross Method is the Gross Characterization Method 2 in AGA Report No. 8 (1992).



User Input Method

A gas can also be characterized directly in **GOFW2015** by specifying the gas densities at base and flowing conditions or by specifying the compressibility factor of the gas at base and flowing conditions and the gas relative density. These are equivalent since, if the temperature and pressure of the gas are known, having the density at base and flowing conditions allows one to calculate the compressibility factor at base and flowing conditions as well as the gas relative density at base conditions. Nevertheless, either screen may be used to input known properties.


User Input Z's
Flowing Compressibility Factor @ Tf And Pf
0.980000
Base Compressibility Factor @ Tb And Pb
0.980000
Gas Relative Density @Tb and Pb
0.600000
Meter Data
Type & Materials
Gas Char
Inst Calib

CHAPTER 7

Default Tab

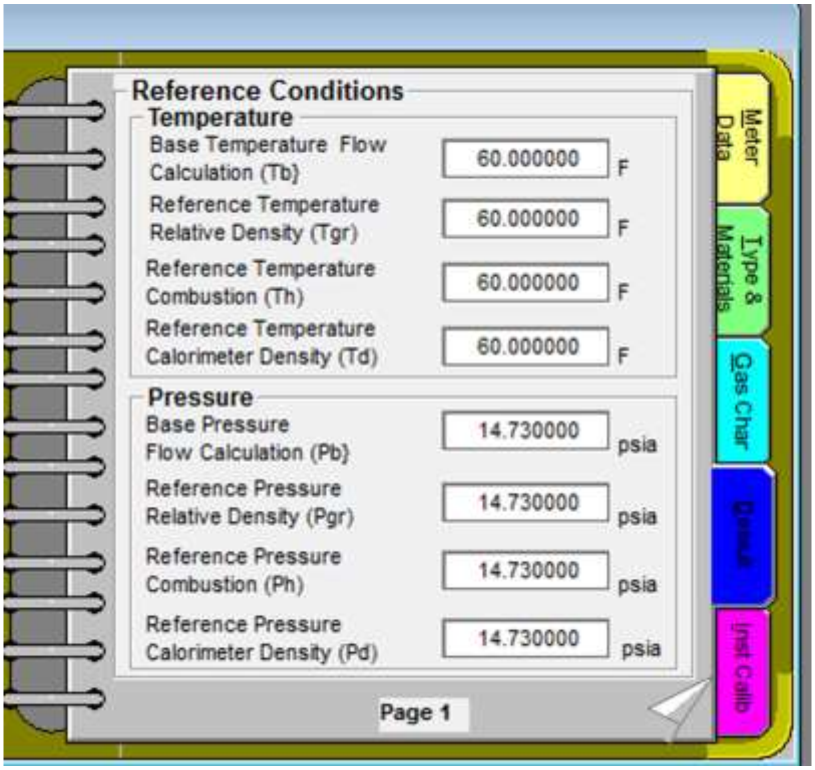
Default Quantities

The Default Configuration Tab in the **GOFW2015** Notebook has three pages. The user can change the page by clicking on the "dog ear" on the current page. Page 1 of the Default Tab is used to configure default temperatures and pressures.

Reference Conditions

The various reference temperatures and pressures include the following:

- The contract temperature and pressure or base conditions (T_b, P_b)
- The reference temperature and pressure for relative density (specific gravity) (T_{gr},P_{gr})
- The reference temperature and pressure for the mass (and molar) heating value, the reference temperature and pressure of gas combustion (T_h, P_h)
- The reference temperature and pressure for gas calorimetric density (T_d, P_d). T_d and P_d is used for conversion of mass (or molar) heating value to volumetric heating value, the gas density used for calorimeter/heating value calculations.



Appendix C of AGA Report No. 8 (1992) can be consulted for a detailed discussion of reference conditions. The default reference temperatures of 60°F and reference pressures of 14.73 psia are commonly used in the U.S. gas industry.

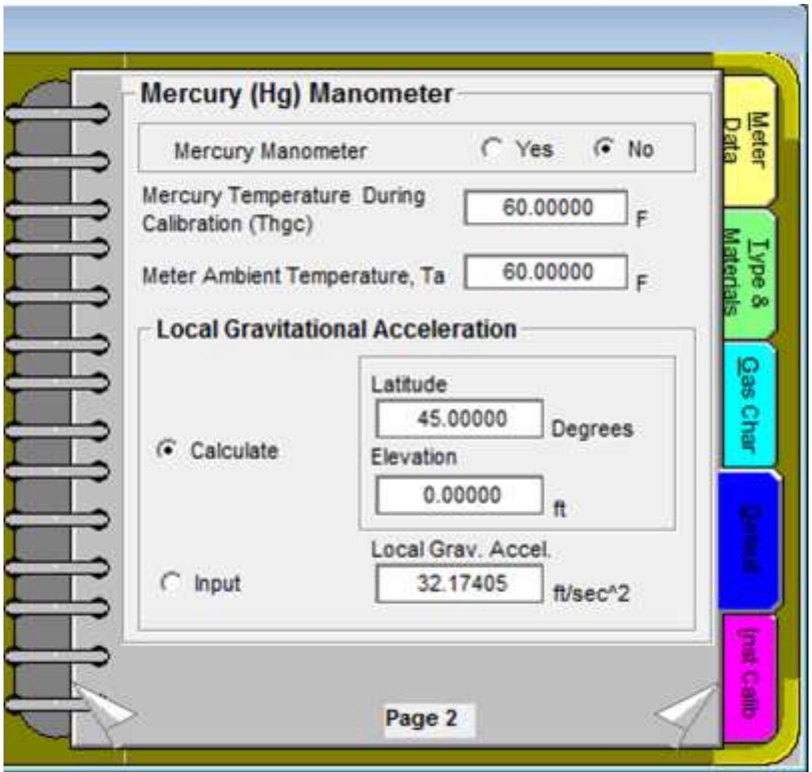
GPA 2172-09 provides gross heating value calculations for only two temperatures, 60.0 F and 15.0 C (59.0 F). Because 60.0 F is the base temperature most used within the United States and 15.0 C (59.0 F) is the base temperature most used outside of the United States, this GPA 2172-09 restriction generally should not be a limitation encountered in practice.

The contract pressure and temperature (P_b and T_b) are used for all standard options to calculate the gas volume flow rate at base conditions. However, all other reference pressures and temperatures are only used when AGA Report No. 3.3 (2013) or AGA Report No. 3 (1992) is combined with AGA Report No. 8 (1992) and in other standards' combinations that include a full gas composition analysis.

Mercury (Hg) Manometer

Page 2 of the Default Tab, Mercury (Hg) Manometer, is needed only if a mercury manometer is used to measure the differential pressure. It should be noted that AGA Report No. 3.3 (2013) does not support calculations involving the use of mercury manometers. If earlier standards for a metering system using a mercury manometer are utilized, then the calculation of the factors Fhgm, Fhgl and Fhgt require:

- The temperature of the mercury when the manometer was calibrated.
- The meter ambient temperature.
- The gravitational acceleration at the meter location.



The gravitational acceleration can be either input or calculated. If calculated, the required quantities are the meter latitude and the meter elevation above sea level (the elevation is negative below sea level). The default values are 60°F for the mercury temperature when the manometer was calibrated, 60°F for the meter ambient temperature, the input option (not the calculate option) for the gravitational acceleration at the meter location and 32.17405 ft/sec^2 for the gravitational acceleration. If the calculate option is used for the gravitational acceleration at the meter location, the meter latitude and elevation can be revised from the default values 0.0 feet and 45 degrees.

The alternative values are the actual conditions.

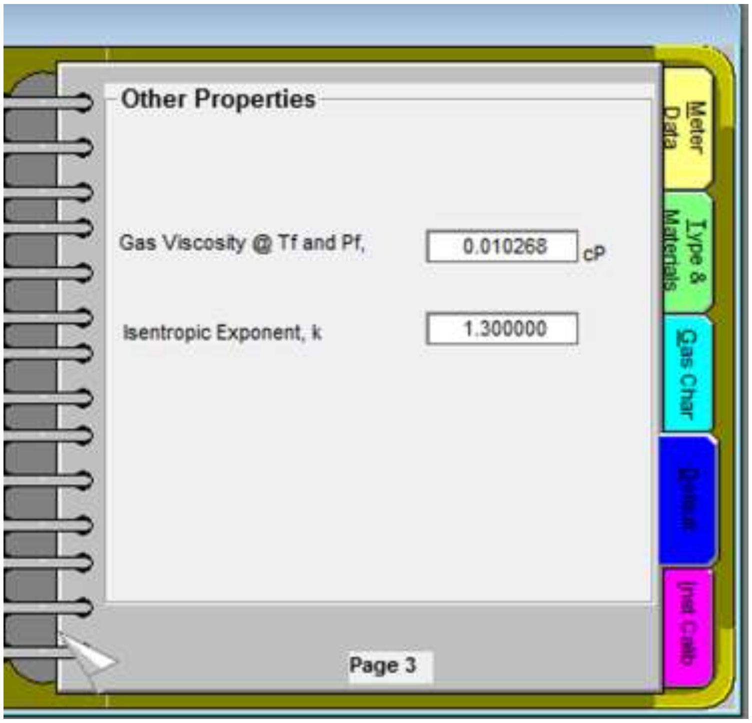
Other Properties

Page 3 of the Default Tab, Other Properties, is available when the flow rate standard is AGA Report No. 3.3 (2013) or AGA Report No. 3 (1992). The defaults are the following conditions:

- A natural gas absolute viscosity at flowing conditions, Tf and Pf of 0.0102680 cP
- A natural gas isentropic exponent, k of 1.3.

Alternatives are the following conditions:

- The natural gas viscosity at flowing conditions
- The natural gas isentropic exponent.



AGA Report No. 3.3 (2013) and AGA Report No. 3 (1992) note that the default value for viscosity is an average value for natural gases with relative density from 0.55 to 0.75 in the temperature range from 30 to 90°F. For gases with viscosity outside the range 5.9E-6 to 7.9E-6 pounds mass per foot-second and/or flow outside the above ranges, particularly at low Reynolds numbers, the default value should be replaced by a more accurate gas viscosity input value.

Discussions in AGA Report No. 3.3 (2013) and AGA Report No. 3 (1992) state that for many applications, the real compressible fluid isentropic exponent is nearly identical to the ideal gas isentropic exponent. This is nearly identical to the perfect gas isentropic exponent, and accepted practice for natural gas applications is to use 1.3 for the isentropic exponent. For gases with isentropic exponents significantly different from 1.3, the default should be replaced with a more accurate value.

How to Change the Default Configuration

GOFW2015 uses the file GOFW2015.ini for the default configuration. This file is placed in the subdirectory in which you install the software. The format of **GOFW2015**.ini is the same as the .CS1 files. If you prefer a different set of default values when you run **GOFW2015**, simply edit a **GOFW2015** file to the desired defaults and save it. Then, in Windows Explorer, rename the saved .CS1 file to **GOFW2015**.ini and replace the original **GOFW2015**.ini file.

CHAPTER 8

Instrument Calibration Correction Factors Tab

Instrument Calibration

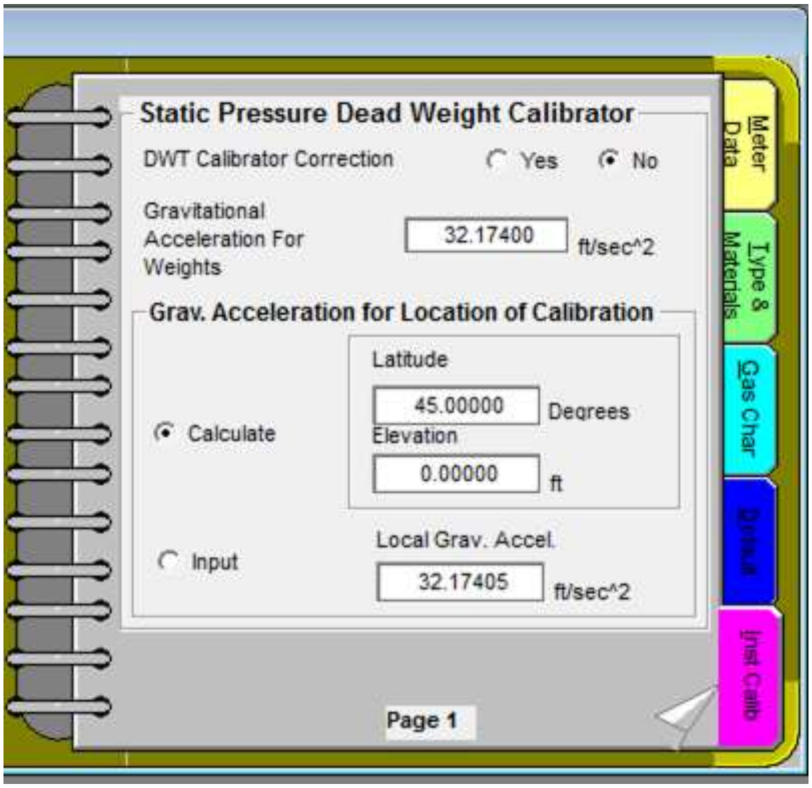
The Instrument Calibration Tab is used if instrument calibration is required. The default for **GOFW2015** is not to use instrument calibration corrections.

Four different instrument calibration options are provided

- Static pressure instrument calibration with a deadweight calibrator
- Differential pressure instrument calibration with a deadweight calibrator
- Differential pressure instrument calibration using a water manometer (with air in both manometer legs)
- User Input calibration factor (to allow for alternative calibration techniques). Calculations of factors are made using methods in AGA Report No. 3.3 (2013) and the 1985 and 1992 AGA Reports No. 3.

Static Pressure Deadweight Calibrator

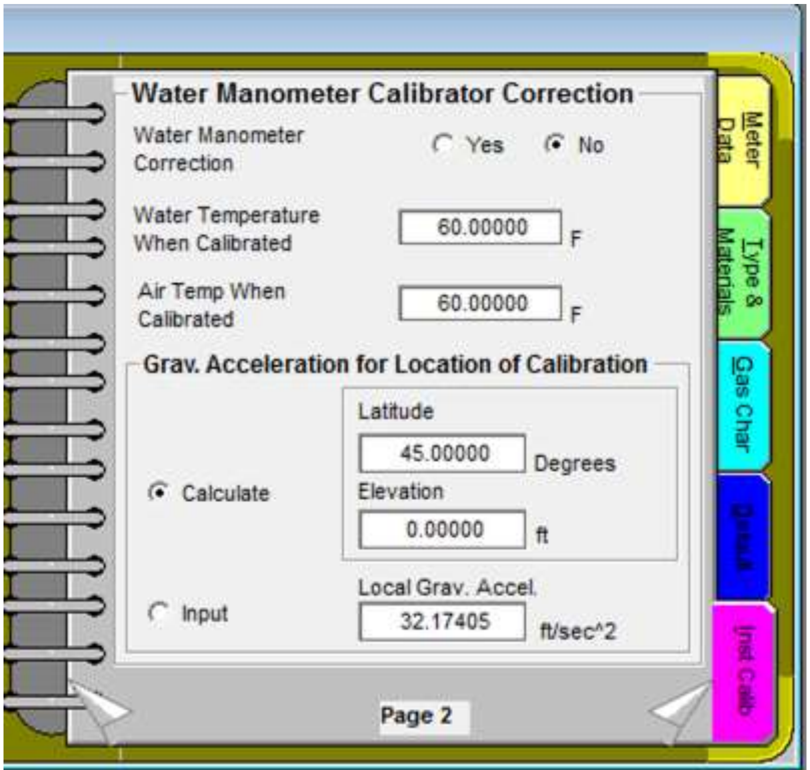
Page 1 of the Inst. Calib. Tab contains entries for the Static Pressure Dead Weight Calibrator.



Select Yes for the DWT (Dead Weight) Calibration Correction if static pressure instrument adjustment with a calibration factor is required and the static pressure sensor was calibrated with a deadweight calibrator. The weights used for most calibrators are based on the default value of the gravitational acceleration at 45 degrees latitude and sea level, which is the standard acceleration of gravity, 32.17405 ft/sec^2. If the weights are based on a gravitational acceleration different from 32.17405 ft/sec^2 it should be input. The option is provided to either input or calculate the gravitational acceleration at the location where the static pressure measurement was calibrated (usually the meter location). If the input option is used, the default will be replaced by the input value. If the calculate option is used, the location (latitude and elevation) where the static pressure measurement instrument was calibrated is required.

Water Manometer Calibration Correction

Page 2 of the Inst. Calib. Tab contains entries for the Water Manometer Calibrator.

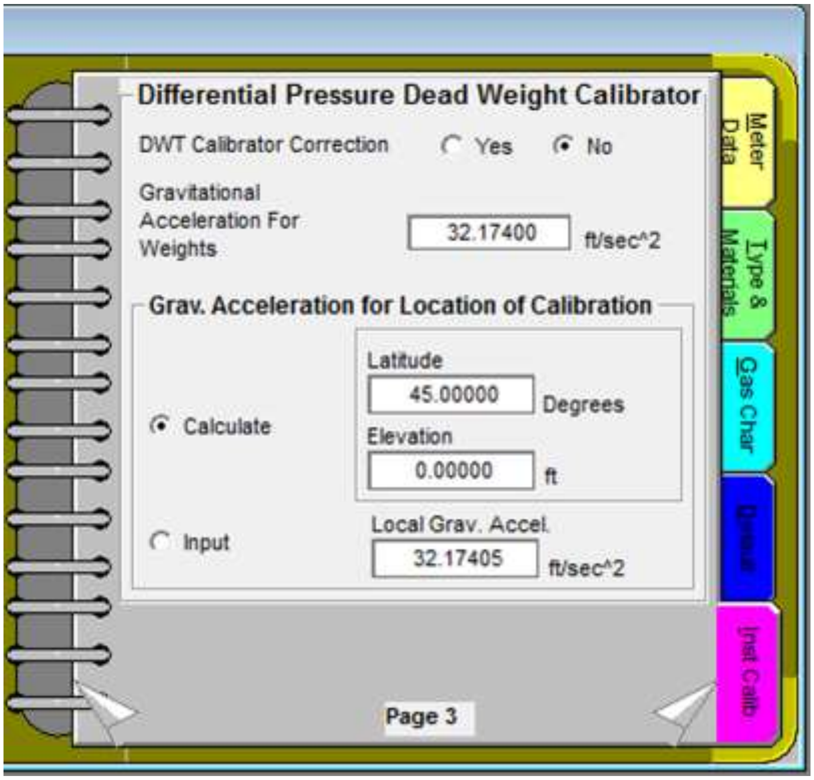


Select Yes for the Water Manometer Correction if differential pressure instrument adjustment with a water manometer is required and the differential pressure sensor was calibrated with a water manometer. Quantities required for the calculation of correction factors are the water temperature when calibrated, the air temperature when calibrated (using air in both legs of the water manometer), and the elevation and gravitational acceleration at the location of calibration of the differential pressure instrument.

The option is provided to input or to calculate the gravitational acceleration at the location of the calibration of the differential pressure instrument. If the input option is used, the default value will be replaced by the input value. If the calculated value is used, the location (latitude and elevation) where the differential pressure instrument was calibrated using the water manometer are required (the elevation is required in every case in which water manometer correction factors are used).

Differential Pressure Dead Weight Calibrator

Page 3 of the Inst. Calib. Tab contains entries for the Differential Pressure Dead Weight Calibrator.

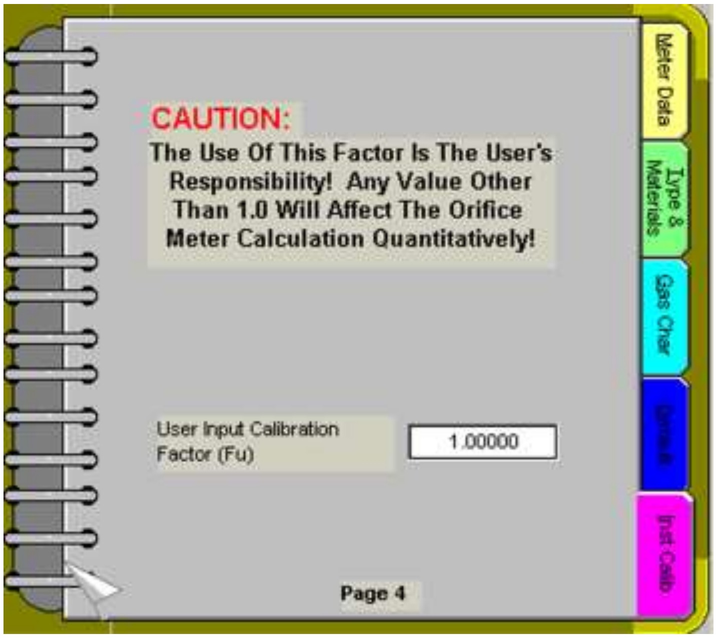


Select Yes for the DWT (Dead Weight) Calibration Correction if differential pressure instrument adjustment with a calibration factor is required and the differential pressure sensor was calibrated with a deadweight calibrator. The weights used for most calibrators are based on the default value of the gravitational acceleration at 45 degrees latitude and sea level, which is the standard acceleration of gravity, 32.17405 ft/sec^2. If the weights are based on a gravitational acceleration different from 32.17405 ft/sec^2 , it should be input. The option is provided to either input or calculate the gravitational acceleration at the location where the static pressure measurement was calibrated (usually the meter location). If the gravitational acceleration at the location of the calibration is input, the default will be replaced by the input value. If the calculate option is used for the gravitational acceleration, the location (latitude and elevation) where the differential pressure measurement instrument was calibrated is required.

User Input Calibration Factor

Page 4 of the Inst. Calib. Tab contains the User Input Calibration Factor.

The User Input calibration factor is needed only in unusual situations where a factor not provided by other options in **GOFW2015** is required. One example is the use of a prover to calibrate the orifice meter. In any case, the user is cautioned that any value other than the default value of 1.0 for the user input calibration factor will change the calculated meter flow rate proportional to the user input calibration factor.


CAUTION:
The Use Of This Factor Is The User's Responsibility! Any Value Other Than 1.0 Will Affect The Orifice Meter Calculation Quantitatively!
User Input Calibration Factor (Fu)
1.00000
Page 4
Meter Data
Type & Materials
Gas Char
Inst Calib

Appendix A

Warnings and Errors

Introduction

This appendix discusses warnings and errors which can be encountered when running the **GOFW2015** program for orifice meter calculations. Each warning or error has a number (positive for warnings and negative for errors) and a one-line message associated with it. Numbers are shown in the error indicator field located in the Meter Data Tab and one-line messages are shown on the statusbar.

GOFW2015 displays input errors by highlighting the relevant field in red. The calculation cannot be made until the error is corrected. An error is encountered if (1) the user attempts to make an invalid program selection, (2) an input quantity is outside the calculation limit range of the selected calculation method or (3) the resultant calculation encounters an instance where the calculation is not valid.

GOFW2015 displays input warnings by highlighting the relevant field in yellow. If a warning is encountered, the calculation is allowed to continue. A warning occurs when (1) an input quantity is outside the normal range but inside the calculation limit range or (2) the calculated value is outside the tested limits of the correlation used. For a more detailed discussion of the normal and calculation limit ranges, refer to the referenced technical documentation listed in the following sections.

GOFW2015 Program Selection Errors, Input Quantity Warnings and Errors and Calculation Warnings and Errors

GOFW2015 warnings and errors can be divided into two categories shown in Table A-1:

Table A-1

Warning and Error Categories

Number Range	Description
110-128, 139, 141, 142	Input Quantity Warning or Error
129-138, 140	Calculation Warning or Error

An input quantity error occurs when an input is outside the calculation limit range (outside the acceptable or tested limits for the selected method). An input quantity warning occurs when an input is outside the normal range. This occurs when the input quantity is outside the specified range as defined by AGA Report No. 8 (1992), where the compressibility factor is within a 0.1% average uncertainty, or outside the specified range of AGA Report No 8 (1985), or outside the specified range of the 1962 NX-19 Standard; (2) outside the specified range as defined by ISO/CD 12213, Part 3, 1994 Draft, where the calculated compressibility factor is within a 0.1% average uncertainty (for OPTION 1) or (3) outside the specified range of AGA Report No. 3, Part 3 (1992) standard or the AGA Report No 3.

A calculation warning occurs if during the calculation an abnormal situation is encountered in which the resultant calculated values are outside the tested limits of the method. A calculation error occurs if, during the calculation, an abnormal situation is encountered in which the resultant calculated values are known to be incorrect.

Numbers and one-line messages for warnings and errors are listed in Table A-2. Table A-3 provides information regarding input warnings and errors. Table A-4 provides descriptions of calculation warnings and errors.

Table A-2

GOFW2015 Warnings and Errors

Warning or Error Number	One-Line Message
-109	Instrument Factor Input out of range
-110	User Input Calibration Factor out of range
+111	Flowing Pressure in expanded range
-111	Flowing Pressure out of range
+112	Flowing Temperature in expanded range
-112	Flowing Temperature out of range
+113	Heating Value in expanded range
-113	Heating Value out of range
+114	Relative Density in expanded range
-114	Relative Density out of range
+115	A Component Mole % in expanded range
-115	A Component Mole % out of range
+116	Sum of Comp. Mole %'s <99.99 or >100.01
-116	Sum of Component Mole %'s out of range
-117	User Input of Density out of range
-118	User Input of Z Factor out of range
-119	Reference Temperature out of range
-120	Reference Pressure out of range
+121	Meter Tube Diameter less than 2.0 inches
-121	Meter Tube Diameter out of range
+122	Orifice Diameter less than 0.45 inches
-122	Orifice Diameter out of range

Warning or Error Number	One-Line Message
+123	Diameter Measurement Temperature not 68 Deg.F
-123	Diameter Measurement Temperature out of range
+124	Beta Ratio < 0.1 or > 0.75
-124	Beta Ratio out of range
-125	Differential Pressure out of range
-126	Gas Viscosity out of range
-127	Isentropic Exponent out of range
-128	Gas Flowrate out of range
-129	Density Root out of range
-130	DGROSS iterations out of range
-131	VIRGS Calculation out of range
-132	Pressure Derivative out of range
+133	Density in BRAKET out of range
-134	No. of BRAKET iterations out of range
-135	No. of DDETAIL iterations out of range
+136	Reynolds Number out of range
-137	Gr, HV and CO2 not consistent
-138	VIRGS term out of range
-139	Differential Pressure exceeds Upstream Static Pressure
-140	Calculated Expansion Factor Y is negative
-141	Th or Td outside GPA2172-09 range 58.99 F to 60.01 F
-142	AGA3.3 2013 Mercury Manometer calcs. not allowed

Table A-3

Input Quantity Warnings and Errors

Reference Symbol	Actual Reference
8	AGA Report No. 8 (July 1994 Printing)
3	AGA Report No. 3, Part 3 (2013)
2172	GPA 2172-09 (2009)

Warning or Error Number	Input Quantity	Input Quantity Reference Ref-Pg-Eq	Standard Option and Gas Analysis Method	Warning (+) or Error (-)	Input Quantity Acceptable Range	Input Quantity Range Reference Ref-Pg
110	User Cal. Factor		All Standards	(-)	0 < Fu	
111	Pressure (psia)	3-5-(3-2)	AGA8'92 -AGA3.3'13 Gr-HV-CO2	(+)	0 < Pf <= 1200	8-7
			AGA8'92 Gr-N2-CO2	(-)	0 < Pf <= 1740	8-7
			AGA8'92 Full Gas Analysis	(+)	0 < Pf <= 1750	8-6
				(-)	0 < Pf <= 40000	8-3
			User Input	(-)	0 < Pf <= 40000	
			AGA3 '85 - NX19 '62 All Methods	(+)	0 < Pf <= 5014.7	
				(-)	0 < Pf	
			AGA3 '85 AGA8 '85 All Methods	(+)	0 < Pf <= 20000	
				(-)	0 < Pf	
112	Temperature (Deg F)	3-5-(3-2)	AGA8'92 -AGA3.3'13 Gr-HV-CO2	(+)	32 <= Tf <= 130	8-7
			AGA8'92 -AGA3.3'13 Gr-N2-CO2	(-)	14 <= Tf <= 149	8-7
			AGA8'92 -AGA3.3'13 Full Gas Analysis	(+)	17 <= Tf <= 143	8-6
				(-)	-200 <= Tf <= 760	8-3

Warning or Error Number	Input Quantity	Input Quantity Reference Ref-Pg-Eq	Standard Option and Gas Analysis Method	Warning (+) or Error (-)	Input Quantity Acceptable Range	Input Quantity Range Reference Ref-Pg
			User Input	(-)	-200 <= Tf <= 760	
			AGA3 '85 - NX19 '62 All Methods	(+)	-40 <= Tf <= 240	
			AGA3 '85 AGA8 '85 All Methods	(+)	-200 <= Tf <= 400	
113	Heating Value (Btu/ft^3)	8-142-(C.5-1)	AGA8'92 -AGA3.3'13 Gr-HV-CO2	(+)	805 <= HV <= 1208	8-3
				(-)	477 <= HV <= 1211	
			AGA3 '85 All Methods with HV	(-)	0 < HV <=1800	
114	Relative Density	8-132-(C.3-10)	AGA8'92 - AGA3.3'13Gr-HV-CO2	(+)	0.55 <= Gr <= 0.8	
			AGA8'92 - AGA3.3'13Gr-N2-CO2	(-)	0.55 <= Gr <= 0.87	8-3
			User Input	(-)	0.07 <= Gr <= 1.52	8-3
			AGA3 '85 - NX19 '62 All Methods with Gr	(+)	Gr <=0.75	
			AGA3 '85 All Methods with Gr	(-)	0.07 <= Gr <=1.52	
115	Component Mole %	8-29-(25)	AGA8'92 - AGA3.3'13Gr-HV-CO2	(+)	0 <= CO2 <= 20.0	
			AGA8'92 - AGA3.3'13Gr-N2-CO2	(-)	0 <= CO2 <= 30.0	8-3
				(+)	0 <= H2 <= 0	
				(-)	0 <= H2 <= 10.0	
				(+)	0 <= CO <= 0	8-3
				(-)	0 <= CO <= 3.0	8-3
			AGA8'92 - AGA3.3'13Gr-N2-CO2	(+)	0 <= N2 <= 20.0	
				(-)	0 <= N2 <= 50.0	8-3
		8-17-(12)	AGA8'92 - AGA3.3'13Full Gas	(+)	0 <= H2O <= 0.05	8-3

Warning or Error Number	Input Quantity	Input Quantity Reference Ref-Pg-Eq	Standard Option and Gas Analysis Method	Warning (+) or Error (-)	Input Quantity Acceptable Range	Input Quantity Range Reference Ref-Pg
			Analysis			
				(-)	0 <= H_2O <= 10.0	
				(+)	0 <= He <= 0.2	8-3
				(-)	0 <= He <= 3.0	8-3
				(+)	45.0 <= Meth <= 100.0	8-3
				(-)	0 <= Meth <= 100.0	8-3
				(+)	0 <= Ethane <= 10.0	8-3
				(-)	0 <= Ethane <= 100.0	8-3
				(+)	0 <= Prop <= 4.0	8-3
				(-)	0 <= Prop <= 12.0	8-3
				(+)	0 <= Butanes <= 1.0	8-3
				(-)	0 <= Butanes <= 6.0	8-3
				(+)	0 <= Pentanes <= 0.3	8-3
				(-)	0 <= Pentanes <= 4.0	8-3
				(+)	0 <= Hexanes + <= 0.2	8-3
				(-)	0 <= Hexanes + <= 10.0	
				(+)	0 <= O_2 <= 0.0	8-3
				(-)	0 <= O_2 <= 21.0	8-3
				(+)	0 <= CO <= 3.0	8-3
				(-)	0 <= CO <= 3.0	8-3
				(+)	0 <= H_2 <= 10.0	8-3
				(-)	0 <= H_2 <= 100.0	8-3
				(+)	0 <= N_2 <= 50.0	8-3
				(-)	0 <= N_2 <= 100.0	8-3
				(+)	0 <= CO_2 <= 30.0	8-3
				(-)	0 <= CO_2 <= 100.0	8-3
				(+)	0 <= H_2S <= 0.02	8-3

Warning or Error Number	Input Quantity	Input Quantity Reference Ref-Pg-Eq	Standard Option and Gas Analysis Method	Warning (+) or Error (-)	Input Quantity Acceptable Range	Input Quantity Range Reference Ref-Pg
				(-)	0 <= H2S <= 100.0	8-3
				(+)	0 <= Argon <= 0.0	8-3
				(-)	0 <= Argon <= 1.0	8-3
			AGA3 '85 - NX19 '62 All Methods with CO2	(+)	0 <= CO2 <= 15.0	
				(-)	0 <= CO2 <= 100.0	
			AGA3 '85 - NX19 '62 All Methods with N2	(+)	0 <= N2 <= 15.0	
				(-)	0 <= N2 <= 100.0	
			AGA3 '85 - NX19 '62 Full Gas Analysis	(-)	0 <= Any Component <= 100.0	
			AGA3'85 -AGA8'85 All Methods with CO2	(+)	0 <= CO2 <= 50.0	
				(-)	0 <= CO2 <= 100.0	
			AGA3'85 -AGA8'85 All Methods with N2	(+)	0 <= N2 <= 50.0	
				(-)	0 <= N2 <= 100.0	
			AGA3'85 -AGA8'85 Full Gas Analysis	(+)	0 <= H2O <= 1.0	
				(+)	0 <= He <= 1.0	
				(+)	50.0 <= Meth <= 100.0	
				(+)	0 <= Ethane <= 20.0	
				(+)	0 <= Prop <= 5.0	

Warning or Error Number	Input Quantity	Input Quantity Reference Ref-Pg-Eq	Standard Option and Gas Analysis Method	Warning (+) or Error (-)	Input Quantity Acceptable Range	Input Quantity Range Reference Ref-Pg
				(+)	0 <= Butanes <= 3.0	
				(+)	0 <= Pentanes <= 2.0	
				(+)	0 <= Hexanes + <= 1.0	
				(+)	0 <= O2 <= 0.0	
				(+)	0 <= CO <= 1.0	
				(+)	0 <= H2 <= 1.0	
				(+)	0 <= N2 <= 50.0	
				(+)	0 <= CO2 <= 50.0	
				(+)	0 <= H2S <= 1.0	
				(-)	0 <= Any Component <= 100.0	
116	Sum of Mole %'s		Full Gas Analysis	(+)	99.99 <= Sum <= 100.01	
				(-)	98.0 <= Sum <= 102.0	
117	Densities	3-5-(3-1)	User Input	(-)	0 < Rho @ Tf & Pf	
	(Lbm/Ft^3)	3-6-(3-4a)		(-)	0 < Rho @ Tb & Pb	
118	Z Factors	3-5-(3-2)	User Input	(-)	0 < Z @ Tf & Pf	
		3-7-(3-7)		(-)	0 < Z @ Tb & Pb	
119	Reference Temp.	8-11-(7)		(-)	32.0 <= Tb <= 77.0	8-143
	(Deg. F)	8-12-(9)		(-)	32.0 <= Tgr <= 77.0	8-143
		8-136-(C.4-5)		(-)	32.0 <= Th <= 77.0	8-143
		8-142-(C.5-1)		(-)	32.0 <= Td <= 77.0	8-143
120	Reference Press.	8-11-(7)		(-)	13.0 <= Pb <= 16.0	8-143
	(psia)	8-12-(9)		(-)	13.0 <= Pgr <= 16.0	8-143
		8-142-(C.5-1)		(-)	13.0 <= Pd <= 16.0	8-143
121	Pipe Diameter	3-9-(3-13)		(+)	2.0 <= Dr	3-10
	(inches)			(-)	0.0 < Dr < 100.0	
122	Orifice Diameter	3-9-(3-12)		(+)	0.45 <= dr	3-10

Warning or Error Number	Input Quantity	Input Quantity Reference Ref-Pg-Eq	Standard Option and Gas Analysis Method	Warning (+) or Error (-)	Input Quantity Acceptable Range	Input Quantity Range Reference Ref-Pg
	(inches)			(-)	0 < dr < 100.0	
123	Measurement Temp.	3-9		(+)	Tr not equal 68 Deg. F	
124	BETA Ratio	3-9-(3-11)		(+)	0.1 <= dr/Dr <= 0.75	3-10
				(-)	0 < dr/Dr < 1.0	
125	Differential Press. (inches H2O)	3-7-(3-9)		(-)	0 < hw	
126	Gas Viscosity	3-12-(3-26)	AGA3.3'13AGA8'92Gr-Hv/N2-CO2	(-)	0.01 <= Visc <= 0.1	
	(Centipoise)		AGA3.3'13AGA8'92Detail/User	(-)	0.005 <= Visc <= 0.5	
127	Isentropic Exp.	3-14-(3-38)	AGA3.3'13AGA8'92	(-)	1.0 < k < 2.0	
139	Differential Pressure		AGA3.3'13	(-)	Hw/27.7072/Pf1<0	
141	Th or Td		GPA2172-09	(-)	Th or Td< 58.99F OR Th or Td>60.01F	
142	Mercury Manometer		AGA3.3'13	(-)	Mercury Manometer not allowed	

Table A-4

Calculation Warnings and Errors

Warning or Error Number	Description
-129	Density search failed. A default density might be used. The compressibility factor calculation cannot be made.
-130	No convergence in density search for gross methods. The compressibility factor calculation cannot be made.
-131	Gross Method Error: Attempt to take the square root of a negative number. The compressibility factor calculation cannot be made.
-132	Detail Method Error: Pressure has a negative density derivative. Default gas density used. One cause of this error is that the system may contain liquid.
133	Detail Method Warning: Density found exceeded maximum allowable density. Default procedure used.
-134	Detail Method Error: Maximum number of iterations in to find density exceeded. Default density used.

Warning or Error Number	Description
-135	Detail Method Error: Maximum number of iterations in Density Search exceeded.
136	Flowrate Calculation Warning: Reynolds number is less than 4000.
-137	Gross Method Error: Combined value of gas relative density (Gr), heating value (HV) and mole % CO2 are not consistent. This error is encountered when these three values entered are not consistent or realistic. The compressibility factor cannot be calculated.
-138	Gross Method Error: Invalid term. The compressibility factor cannot be calculated.
-140	Calculated Expansion Factor Y is negative

Appendix B

Discussion of Differences in the 1992 and 2012 Flange Tapped Orifice Meter Standards

INTRODUCTION

The focus of information presented below is on the differences between the 1992 and 2012 US standards for flange tapped orifice meters, with a primary interest in changes in the equation for the expansion factor and changed limits for the ratio of differential pressure to absolute upstream static pressure.

The topics discussed in this appendix are addressed in detail in the paper "Comparisons of Natural Gas Orifice Meter Calculations using 2012 and 1992 US Standards", by Kenneth E. Starling and Stephen L. Starling, Proceedings of the American Gas Association Operating Conference, 2015.

The 1992 standard is Orifice Metering of Natural Gas and Other Related Hydrocarbon Fluids, Part 1, AGA Report No. 3, Part 1 (American Gas Association Report No.3, Part 1), API 14.3.1 (American Petroleum Institute Manual of Petroleum Measurement Standards, Chapter 14.3.1), and GPA 8185, Part 1 (Gas Processors Association Standard GPA 8185, Part 1), 1992.

The 2012 standard is Orifice Metering of Natural Gas and Other Related Hydrocarbon Fluids – Concentric, Square-edged Orifice Meters, Part 1, AGA Report No. 3, Part 1 (American Gas Association Report No.3, Part 1), API 14.3.1 (American Petroleum Institute Manual of Petroleum Measurement Standards, Chapter 14.3.1), 2012.

It should be noted that the **GOFW2015** states that the algorithms and equations for orifice meters which are in the **GOFW2015** computer program are based on the AGA Report No. 3, Part 3 (2013), which is specifically for natural gas applications. However, AGA Report No. 3, Part 3 (2013) refers to AGA Report No. 3, Part 1 (2012) for the details of changes from the 1992 standards; consequently, the 2012 standard is referenced in this appendix.

Differences in the 1992 and 2012 Flange Tapped Orifice Meter Standards

The following equation for the volume flow rate for flange tapped orifice meters Qv is the same for both the 1992 and 2012 US standards. However, as will be discussed subsequently, the calculations of some of the quantities in the equation have been changed in the 2012 standard to achieve improved accuracy.

Qv = 359.072* Y1*Cd*Ev*(d^2)*SQRT(RHOTP*Hw)/RHOS

where

Qv is the volume flow rate in cubic feet per hour at reference base conditions (Ts, Ps);

Y1 is the expansion factor (dimensionless);

Cd is the coefficient of discharge for the flange-tapped orifice meter (dimensionless);

d is the orifice plate bore diameter, in inches, calculated at flowing temperature (Tf);

Ev is the velocity of approach factor (dimensionless);

Hw is the orifice differential pressure, in inches of water at 60 °F;

RHOTP is the gas density at upstream flowing conditions (Tf, Pf) in pounds mass per ft^3;

RHOS is the gas density at reference base conditions (Ts, Ps) in pounds mass per ft^3.

Relatively small changes were made to make the calculation of the density of water and the coefficients of linear thermal expansion of metals more accurate. Large changes were made in the equation for the expansion factor; calculations will be discussed below to illustrate these changes.

A significant difference between the standards is the 2012 standard allows for a larger range for x1, the ratio of differential pressure to absolute upstream static pressure. The 1992 standard had the upper limit criterion x1 (1992 standard) $\leq$ 0.2. In contrast, the 2012 standard has the upper limit criterion x1 (2012 standard) <0.25.

The expansion factor Y1 is calculated in the 1992 standard using the following equation

$$Y1\ (1992\ standard) = 1 - (0.41 + 0.35\ \beta^4)\ (x1/k)$$

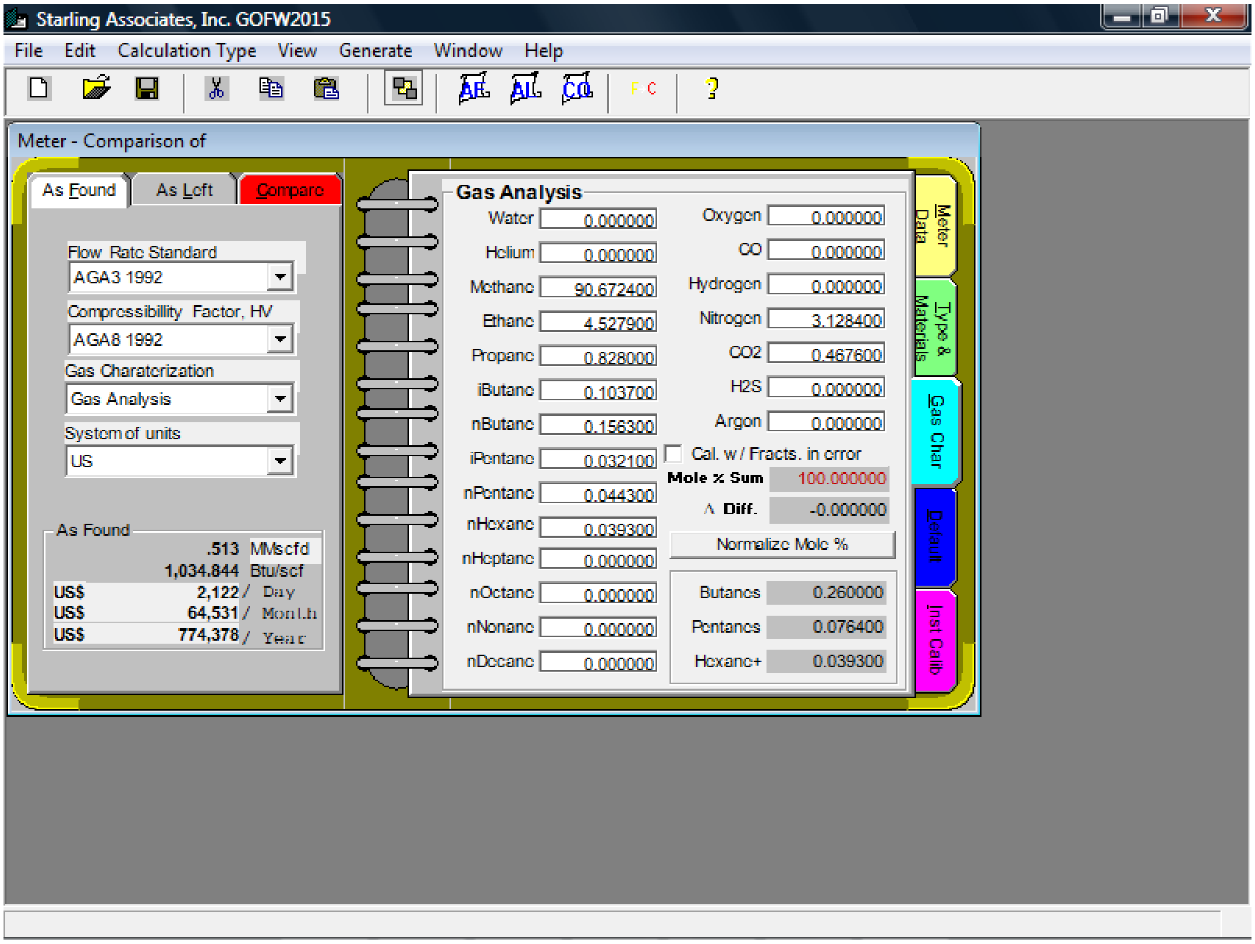
where
Y1 (1992 standard) is the expansion factor (dimensionless) given in the 1992 standard;
β is the diameter ratio (dimensionless);
x1 is the ratio of the differential pressure to the absolute upstream static pressure (dimensionless);
k is the isentropic exponent (dimensionless).
The expansion factor Y1 is calculated based in the 2012 standard using the following equation

$$Y1\ (2012\ standard) = 1 - (0.3625+0.1027\ \beta^4 +1.132\ \beta^8)\ \{1-(1-x1)^{(1/k)}\}$$

where
Y1 (2012 standard) is the expansion factor (dimensionless);
β is the diameter ratio (dimensionless);
x1 is the ratio of the differential pressure to the absolute upstream static pressure (dimensionless);
k is the isentropic exponent (dimensionless).

Comparison of Qv and Y1 using the 1992 and 2012 standards with x1 = 0.2

Consider the following example orifice meter calculation for dry natural gas. The natural gas composition is the "AGA8 Amarillo Gas Composition" given in Table B.6-1 of AGA Report No. 8 1992 (1994 Reprint). The "AGA8 Amarillo Gas Composition" is shown on the screenshot below.



The inputs to the calculations are listed below. Descriptions of these input variables and how they are used in the calculation of the volume flow rate Qv are presented in the 1992 and 2012 standards.

d is the mean orifice bore diameter at *Tr* of 68 °F, in inches = 1.000.

D is the mean meter tube internal diameter at *Tr* of 68 °F, in inches = 2.000.

Hw is the average differential pressure, in inches of water at 60 °F = 200.0.

Pb is the contract base pressure, in psia = 14.73.

Pf1 is the upstream absolute static pressure, in psia = 36.092.

Tb is the contract base temperature of 60 °F, in degrees Rankine (60 °F + 459.67) = 519.67.

Tf is the flowing temperature of 68 °F, in degrees Rankine (68 °F + 459.67) = 527.67.

k is the isentropic exponent = 1.3.

a1 is the linear coefficient of thermal expansion for the stainless steel orifice plate, in inches per inch-°F = 0.00000925.

a2 is the linear coefficient of thermal expansion for the carbon steel meter tube, in inches per inch-ºF = 0.00000620.

VISC is the dynamic viscosity, in pounds mass per foot-second = 0.0000069, in centipoises = 0.010268.

RHOTP is the gas density at upstream flowing conditions (Tf, Pf) in pounds mass per ft^3 = 0.112729.

RHOS is the gas density at reference base conditions (Ts, Ps) in pounds mass per ft^3 = 0.046578.

x1 is the ratio of differential pressure to absolute upstream static pressure = 0.2; the 1992 standard upper limit is x1 (1992 standard) $\leq$ 0.2).

Calculations were performed for both the 1992 standard and the 2012 standard. The outputs from the calculations which are of interest are the following.

Qv (1992 standard) = 21355.70 cubic feet per hour

Qv (2012 standard) = 21528.26 cubic feet per hour

Y1 (1992 standard) = 0.933558

Y1 (2012 standard) = 0.941115

Y1 (2012 standard) is 0.81% larger than Y1 (1992 standard). Because all calculations are nearly the same for the 1992 and 2012 standards except for the calculation of Y1, and Qv is proportional to Y1, it follows that Qv(2012 standard) is 0.81% larger than Qv(1992 standard).

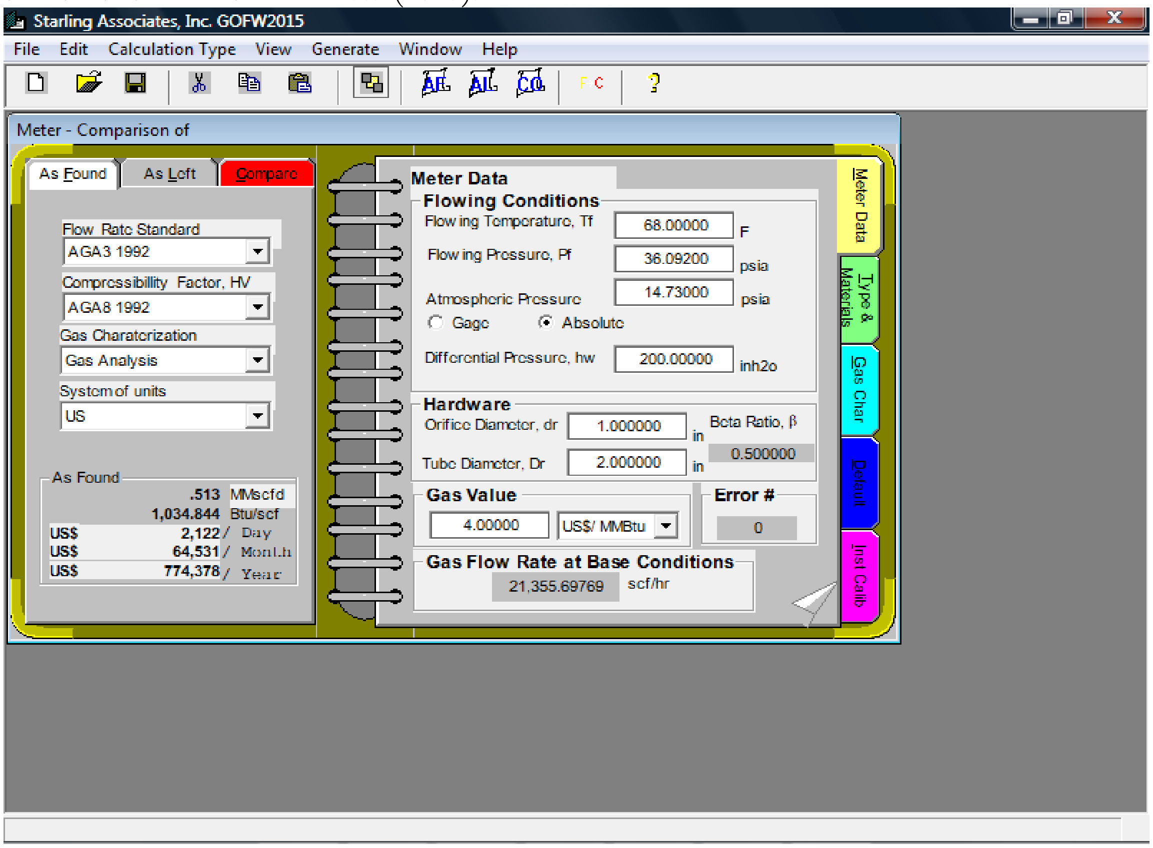
It also is of interest to calculate the uncertainties of Y1 (1992 standard) and Y1 (2012 standard). U [Y1 (1992 standard)] is the %uncertainty of Y1 (2012 standard) at the 95% confidence level. U [Y1 (2012 standard)] is the %uncertainty of Y1 (1992 standard) at the 95% confidence level. The 1992 standard and the 2012 standard utilize the following equations for these uncertainties.

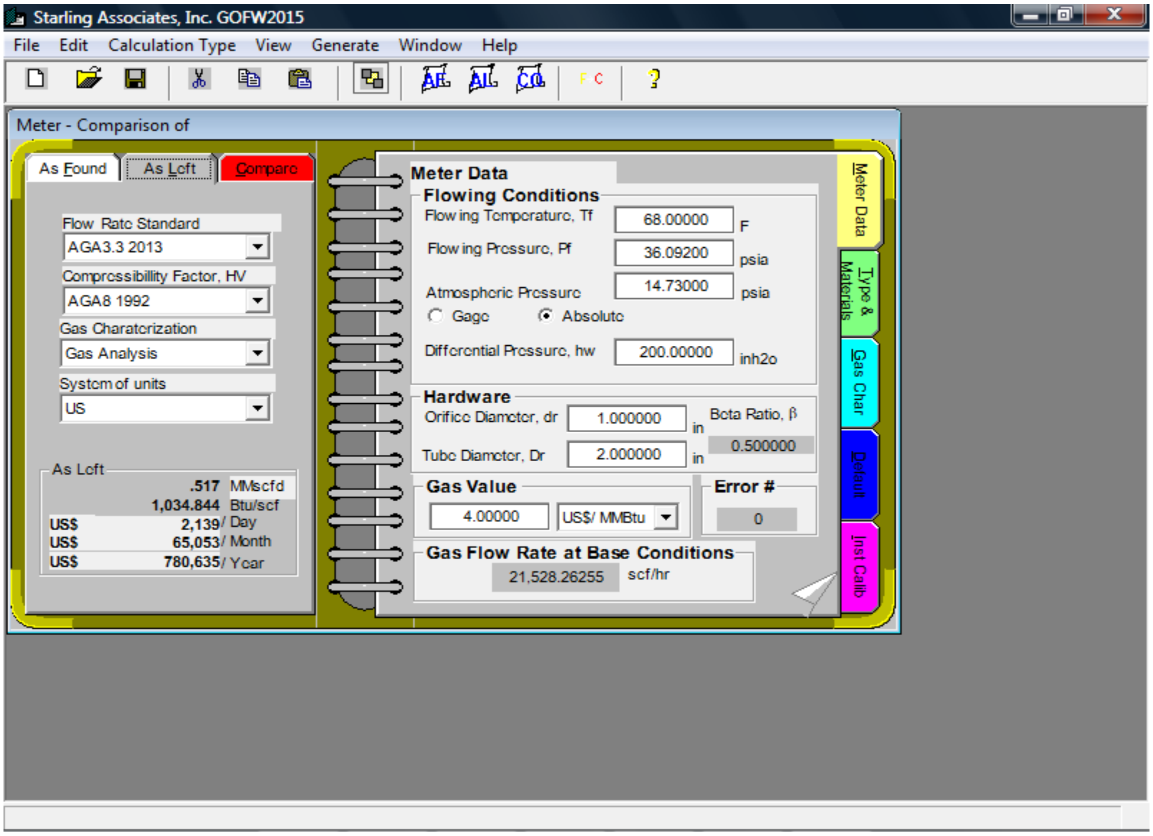
U [Y1 (1992 standard)] = +/- 4.0*x1 = +/- 4.0*0.2 = +/- 0.80%

U [Y1 (2012 standard)] = +/- 2.6*x1 = +/- 2.6*0.2 = +/- 0.52%

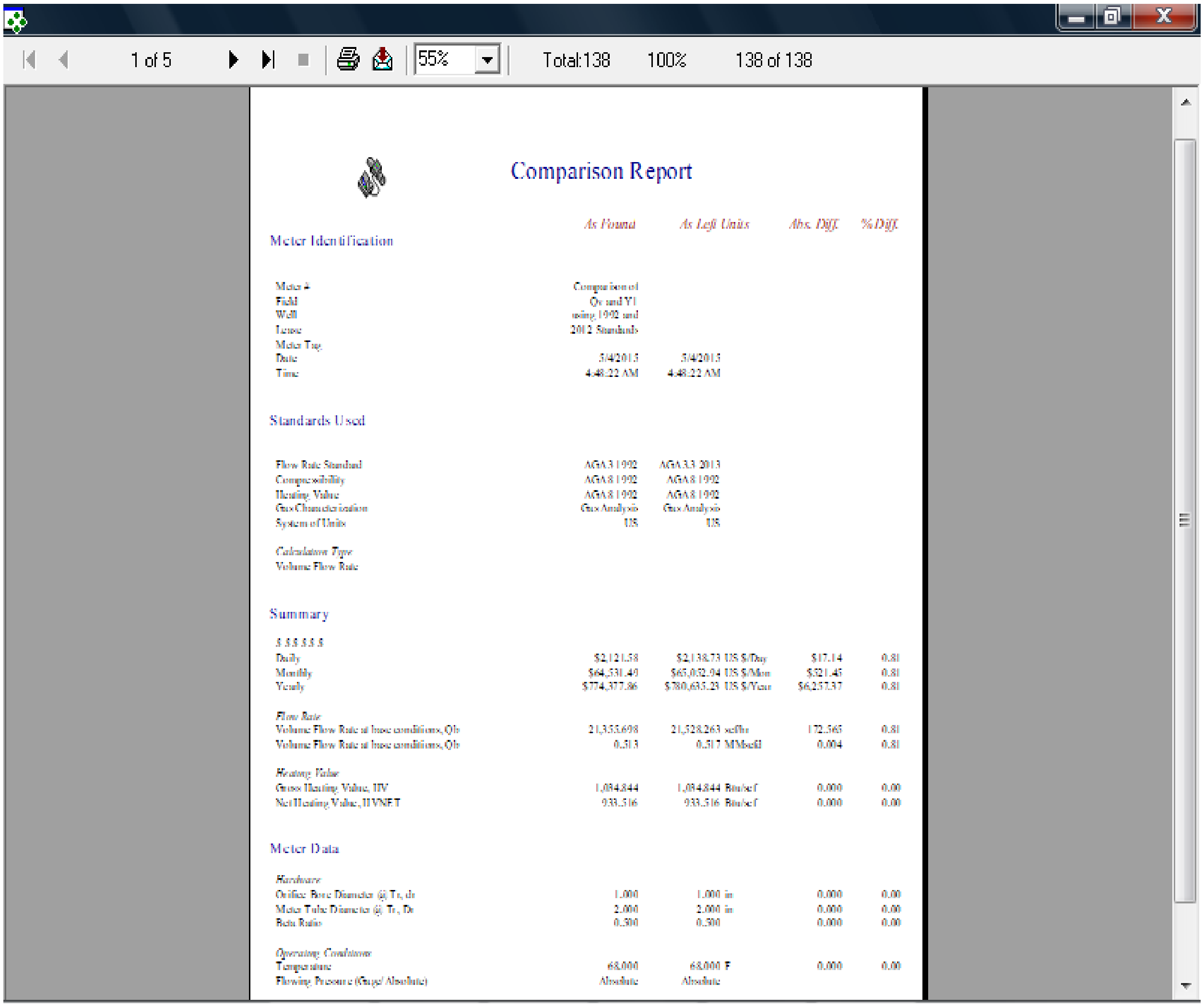
These results and the fact that in the calculations above Y1 (2012 standard) is 0.81% larger than Y1 (1992 standard) indicates that there was bias in Y1 (1992 standard).

The following **GOFW2015** screenshots show key inputs and outputs for the calculations discussed above. The As Found screenshot is for the 1992 standard. The As Left screenshot is for the 2012 standard as utilized in AGA3.3 (2013).





Detailed comparisons of the As Found calculations using the 1992 standard and the As Left calculations using the 2012 standard can be reviewed by generating a comparison report, the first page of which is shown below.



Comparison Report

	As Found	As Left Units	Abs. Diff.	% Diff.
Meter Identification				
Meter #	Comparison of			
Field	Qv and Y1			
Well	using 1992 and			
Lease	2012 Standards			
Meter Tag				
Date	5/4/2015	5/4/2015		
Time	4:48:22 AM	4:48:22 AM		
Standards Used				
Flow Rate Standard	AGA3 1992	AGA3.3 2013		
Compressibility	AGA8 1992	AGA8 1992		
Heating Value	AGA8 1992	AGA8 1992		
Gas Characterization	Gas Analysis	Gas Analysis		
System of Units	US	US		
Calculation Type				
Volume Flow Rate				
Summary				
$ $$ $$ $				
Daily	$2,121.58	$2,138.73 US $/Day	$17.14	0.81
Monthly	$64,531.49	$65,052.94 US $/Mon	$521.45	0.81
Yearly	$774,377.86	$780,635.23 US $/Year	$6,257.37	0.81
Flow Rate				
Volume Flow Rate at base conditions, Qb	21,355.698	21,528.263 scf/hr	172.565	0.81
Volume Flow Rate at base conditions, Qb	0.513	0.517 MMscfd	0.004	0.81
Heating Value				
Gross Heating Value, HV	1,034.844	1,034.844 Btu/scf	0.000	0.00
Net Heating Value, HVNET	933.516	933.516 Btu/scf	0.000	0.00
Meter Data				
Hardware				
Orifice Bore Diameter @ Tr, dr	1.000	1.000 in	0.000	0.00
Meter Tube Diameter @ Tr, Dr	2.000	2.000 in	0.000	0.00
Beta Ratio	0.500	0.500	0.000	0.00
Operating Conditions				
Temperature	68.000	68.000 F	0.000	0.00
Flowing Pressure (Gage/ Absolute)	Absolute	Absolute		

Calculation of Qv and Y1 using the 2012 standard with x1 = 0.249999

Calculations of Qv and Y1 follow using the 2012 standard where x1 = 0.249999, which approaches the upper limit of the 2012 standard, x1 < 0.25. The larger range of x1 using the 2012 standard enables a company to accurately calculate flowrates for a given orifice over larger ranges of differential pressure and/or static pressure than the 1992 standard.

The inputs to the calculations for are identical to the inputs for the previous calculations except that Pf1, the upstream absolute static pressure, in psia = 28.87. Note that because the upper limit in the 1992 standard is x1 (1992 standard) $\leq$ 0.2, the calculations which follow will be performed only for the 2012 standard.

The outputs from the calculations which are of interest are the following.

Qv (2012 standard) = 18939.25 cubic feet per hour

Y1 (2012 standard) = 0.925887

Because the static pressure in these calculations is lower than in the previous calculations, both the density RHOTP of the flowing natural gas and Y1 (2012 standard) are lower and consequently Qv is lower than in the previous calculations.

The calculation of U [Y1 (2012 standard)], the %uncertainty of Y1 (2012 standard) at the 95% confidence level for Case B yields the following result.

U [Y1 (2012 standard)] = +/- 2.6*x1 = +/- 2.6*0.249999 = +/- 0.65%

Note that because the upper limit in the 1992 standard is x1 (1992$\leq$ 0.2, the calculations in the present case should not be performed using Y1 (1992 standard). In fact, in the upstream static pressure range from Pf1= 36.092 psia (previous calculations) to Pf1= 28.87 psia (present calculations), x1 varies from x1=0.2 (previous calculations) to x1=0.249999 (present calculations) so that x1 is outside the x1 upper limit in the 1992 standard except when x1 = 0.2. This means that the 2012 standard allows a significant increase in the operating range of the upstream static pressure compared to the 1992 standard. The increased upstream static pressure operating range using the 2012 standard includes conditions which, using the 1992 standard, would have required an orifice plate change in order to achieve the same flow rates.

It is clear from the set of volume flow rate calculations presented above that the new expansion factor equation in the 2012 orifice meter standard provides not only improved accuracy in natural gas flow rate calculations but increases the allowed operating ranges for the differential pressure and/or the static pressure without orifice plate replacements. The improved accuracy is of general benefit to commerce through reductions in bias in custody transfer. The increases in allowed operating ranges are of benefit to the natural gas industry in reducing flow measurement operating costs.

Appendix C

Discussion of Energy Flow Rate Calculations, Gross Heating Value and Differences in Standards for Wet Gases

INTRODUCTION

Information is presented below regarding how the energy flow rate, ENERGY_FLOWRATE, is calculated in **GOFW2015.** In addition, the differences in the definitions for the wet gas gross heating value used in different standards are discussed. An example calculation is given using **GOFW2015** to compare the heating value of water saturated methane calculated using GPA2172-09 and AGA8 1992.

ENERGY FLOW RATE

The ENERGY_FLOWRATE in MMBtu/hr is calculated in **GOFW2015** using the equation below.

ENERGY_FLOWRATE = QB_IDEAL*HV_IDEAL/1000000

In this equation, QB_IDEAL is the ideal gas volume flow rate.

QB_IDEAL = Qb/Zb

Qb is the volume flow rate in scf/hr calculated using the Flow Rate Standard, for example, AGA3.3 2013. Zb is the natural gas compressibility factor at base conditions, Tb and Pb, calculated using the Compressibility Factor standard, for example, AGA8 1992. HV_IDEAL is the ideal gas gross heating value.

HV_IDEAL = HV*Zhv

HV is the natural gas gross heating and Zhv is the natural gas compressibility factor at base conditions; both HV and Zhv are calculated using the heating value standard, for example, GPA2172-09. Although the differences between Zb and Zhv are small for lean dry natural gases, the differences increase for gases containing water. Consequently, for accounting purposes, the above equation for ENERGY_FLOWRATE should be used. Note that the heating value standard GPA2172-09 as well as **GOFW2015** use the above equation for ENERGY_FLOWRATE. This topic is discussed in the paper "Heating Value and Orifice Standards Integration Methods", by Kenneth E. Starling and Don Sextro, Proceedings, Gas Processors Association Convention, 2013.

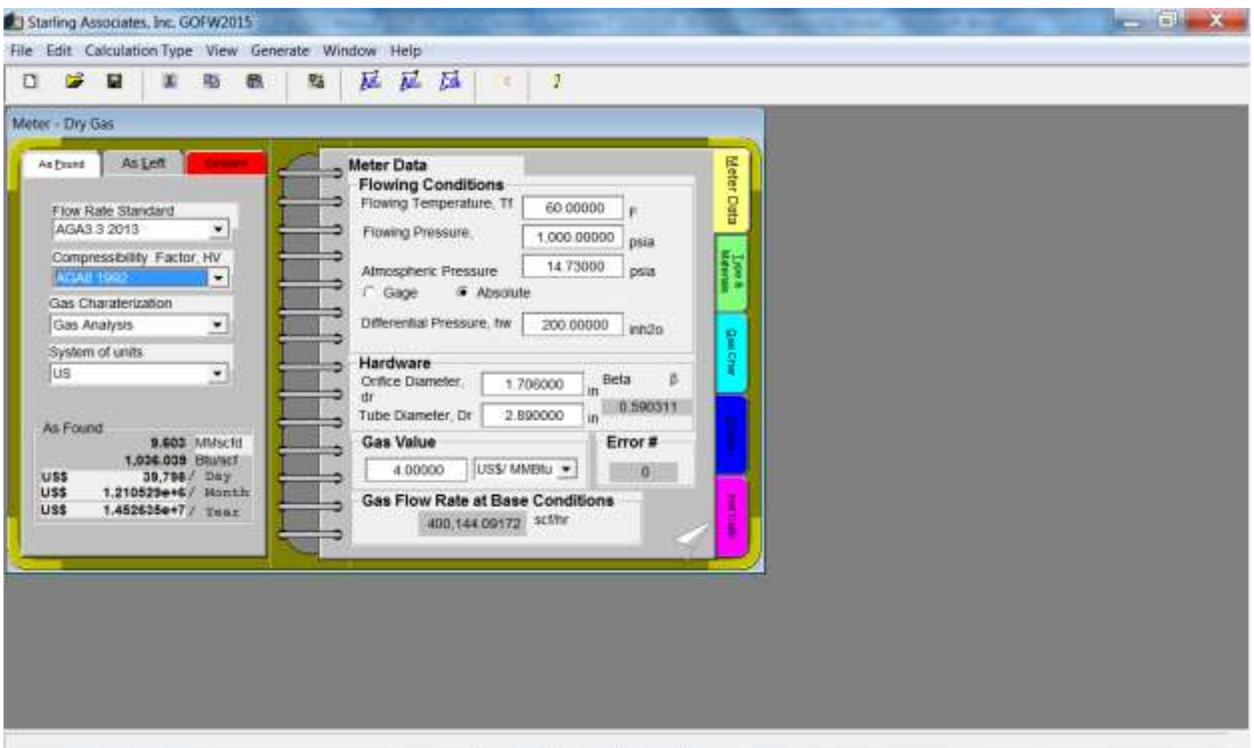
ENERGY_FLOWRATE in MMBtu/hr, QB_IDEAL in scf/hr and HV_IDEAL in Btu/scf are in the last three lines of numerical outputs of the **GOFW2015** AsFound, AsLeft and Comparison reports.

EXAMPLE CALCULATIONS FOR DRY GAS ENERGY FLOW RATE

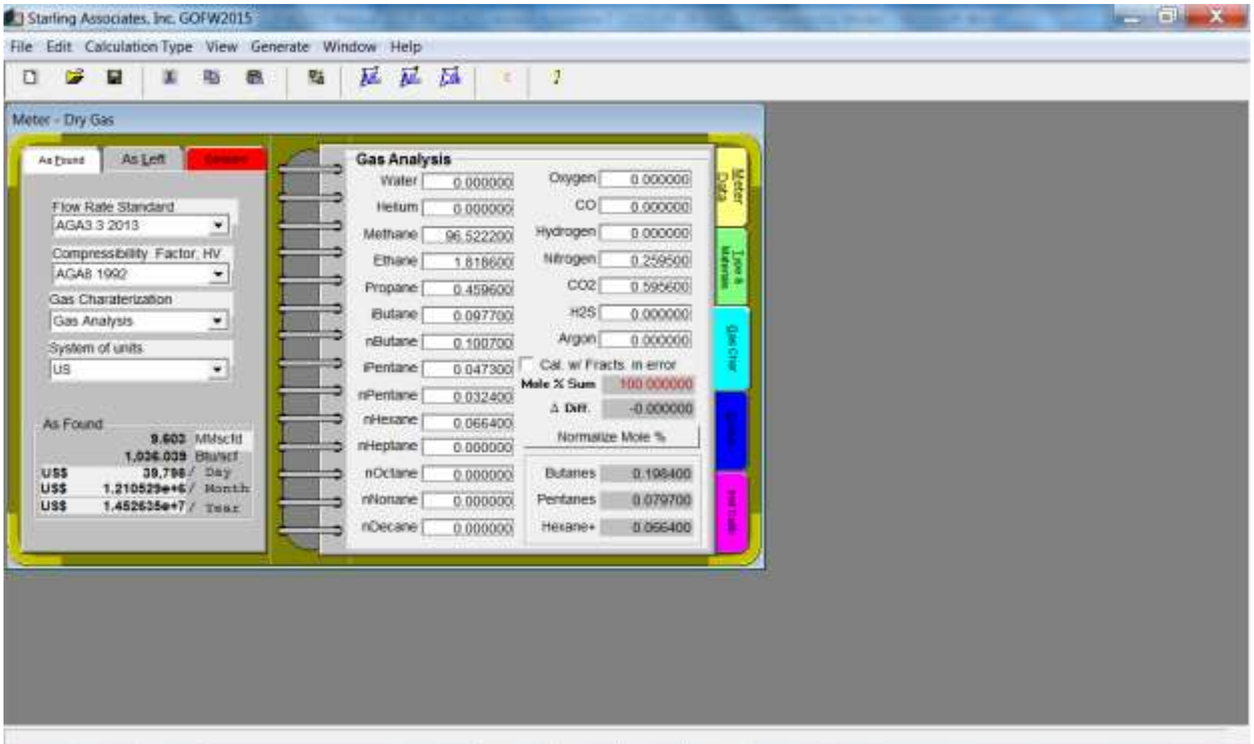
Consider the following example orifice meter calculation for dry natural gas. The natural gas composition is the "AGA8 Gulf Coast Composition" given in Table B.6-1 of AGA Report No. 8 1992 (1994 Reprint). Base conditions are dry gas, Tb=60 F and Pb=14.73 psia.

The measured average inside pipe diameter is Dr=2.89 inches at 68 F. The measured orifice bore diameter is d=1.706 inches at 68 F. The flowing conditions are Pf=1000.0 psia and Tf=60 F. The differential pressure is hw=200.0 inh2o.

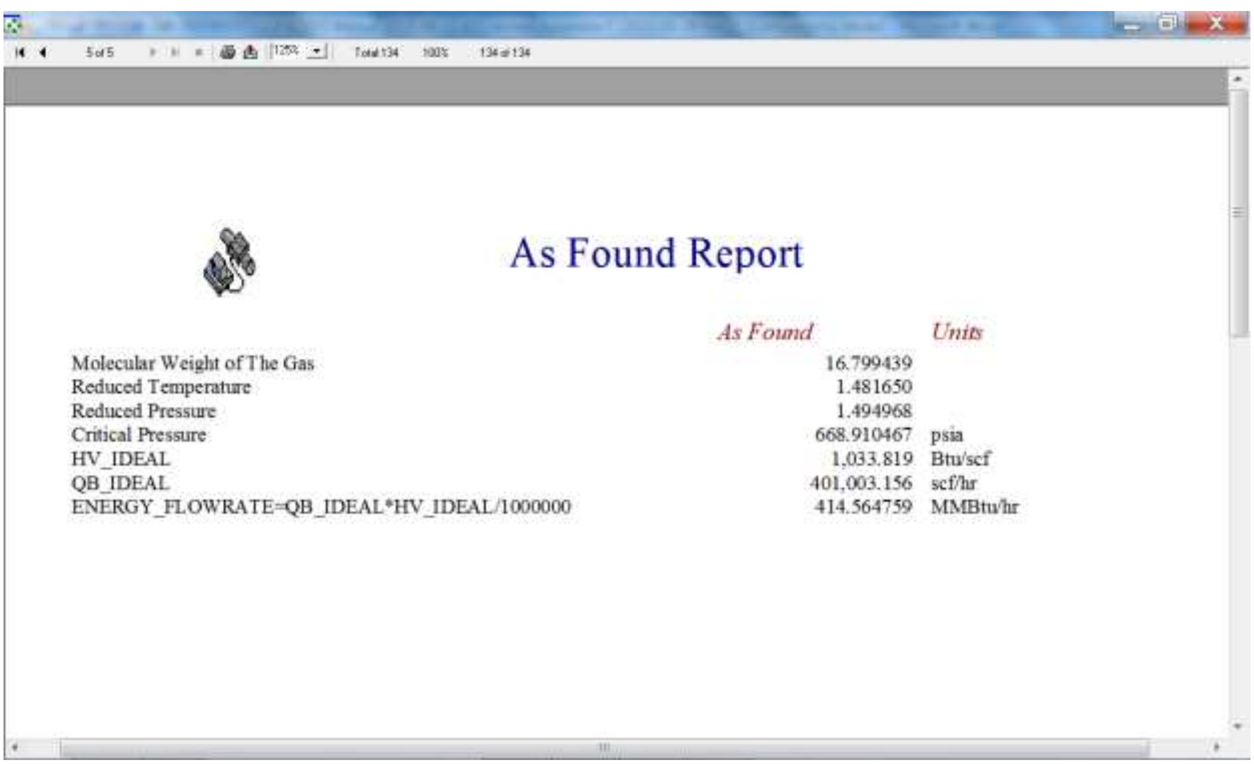
Open **GOFW2015** and enter the input quantities. The resultant **GOFW2015** input screen is shown below. Note that the Compressibility Factor, HV selection is AGA8 1992, so that the gross heating value HV=1036.039 Btu/scf was calculated using AGA8 1992. The Meter Data tab displays the orifice meter inputs, as shown below.



The Gas Char tab shows the natural gas composition, which is the "AGA8 Gulf Coast Composition" given in Table B.6-1 of AGA Report No. 8 1992 (1994 Reprint).



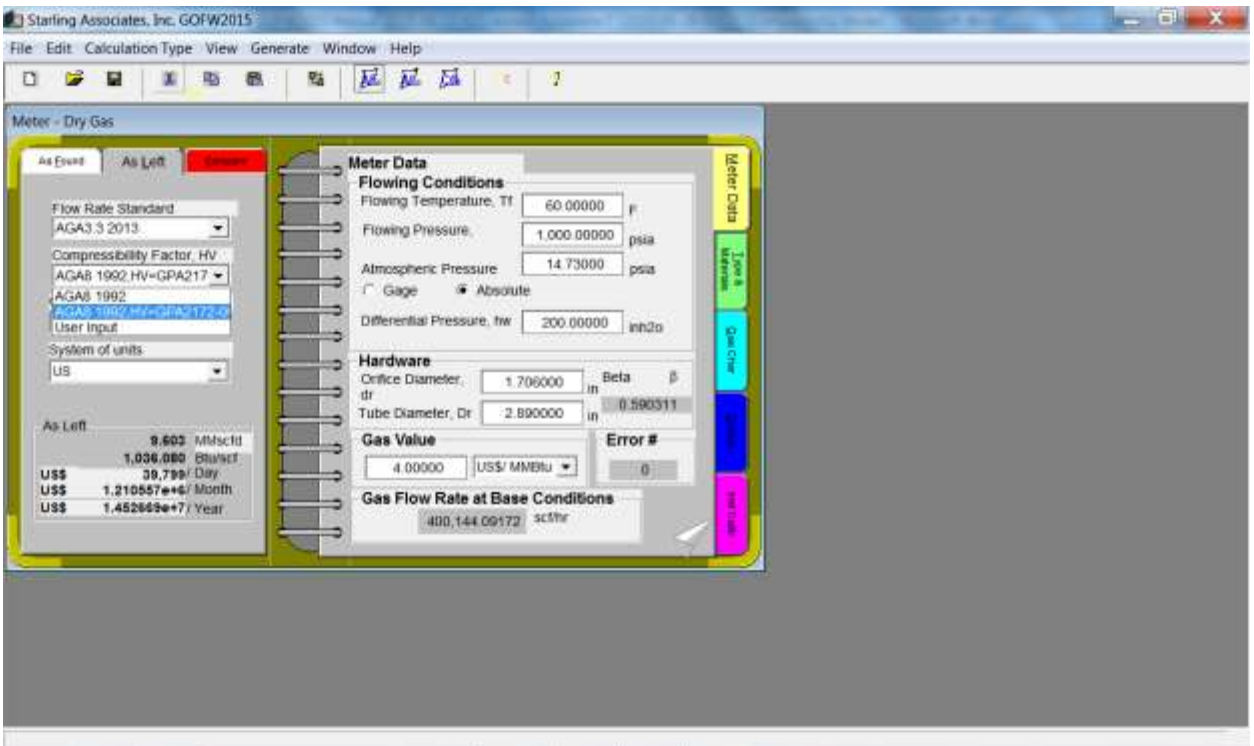
To view the calculated values of ENERGY_FLOWRATE in MMBtu/hr, QB_IDEAL in scf/hr and HV_IDEAL in Btu/scf, generate the As Found report by clicking on the "AF" icon.



ENERGY_FLOWRATE in MMBtu/hr, QB_IDEAL in scf/hr and HV_IDEAL in Btu/scf are in the last three lines of numerical outputs of the **GOFW2015** AsFound report.

A **GOFW2015** input (.CS1) file corresponding to the calculations discussed above is included with the **GOFW2015** product. The name of this **GOFW2015** input (.CS1) files is Dry Gas Orifice Meter Energy Flow Rate Calculation.CS1.

The GPA2172-09 dry gas gross heating value HV will now be calculated in the As Left tab. Click on the "Edit" dropdown menu and select "AF-AL/AL-AF" to copy the As Found inputs into the As Left input textboxes. Click on the "As Found" tab and change the Compressibility Factor, HV selection from AGA8 1992 to AGA8 1992, HV=GPA2172-09, as shown below.



The resultant As Left **GOFW2015** screen shows that the Compressibility Factor, HV=GPA2172-09 calculated dry gas gross heating value is HV=1036.080 Btu/scf, which is only 40 parts per million different from the AGA8 1992 dry gas gross heating value, HV=1036.039 Btu/scf. It will be shown in a subsequent section that when the base condition is water saturated natural gas, the difference in the water saturated gas gross heating value HV using these different HV methods is much greater.

DIFFERENCES IN STANDARDS FOR WET GAS GROSS HEATING VALUE

If the natural gas mixture contains water vapor, the definition of the ideal gas gross heating value (HV_IDEAL) used in AGA 8 1992, GPA 2172-86, ISO 6976 1992 and AGA5 2009, requires that this water vapor be in the liquid state after combustion, so that the mole fraction of water times the ideal enthalpy of vaporization of water must be included in the ideal gas gross heating value. The ideal enthalpy of vaporization of water is the enthalpy of water as an ideal gas at Th minus the enthalpy of water as a saturated liquid at its vapor pressure at Th. GPA 2172-96 and GPA 2172-09 do not include the ideal enthalpy of vaporization of the water in the gas mixture in the ideal gas gross heating value calculation. Thus, although there is close agreement among AGA 8 1992, GPA 2172-86, GPA 2172-96 and GPA 2172-09 for ideal gas gross heating value calculations for dry natural gases, the differences increase with increasing water content for natural gases containing water.

WATER SATURATED GAS GROSS HEATING VALUE CALCULATIONS

Water saturated methane gross heating value calculations for GPA 2172-09 and AGA 8 1992 are compared below to illustrate the magnitude of differences in HV standards for wet gases.

Both GPA 2172-09 and AGA 8 1992 explain that the mole fraction of water in the water saturated natural gas, Xw, is the ratio of the vapor pressure of water, Pw, at the base temperature Tb, divided by the base pressure, Pb.

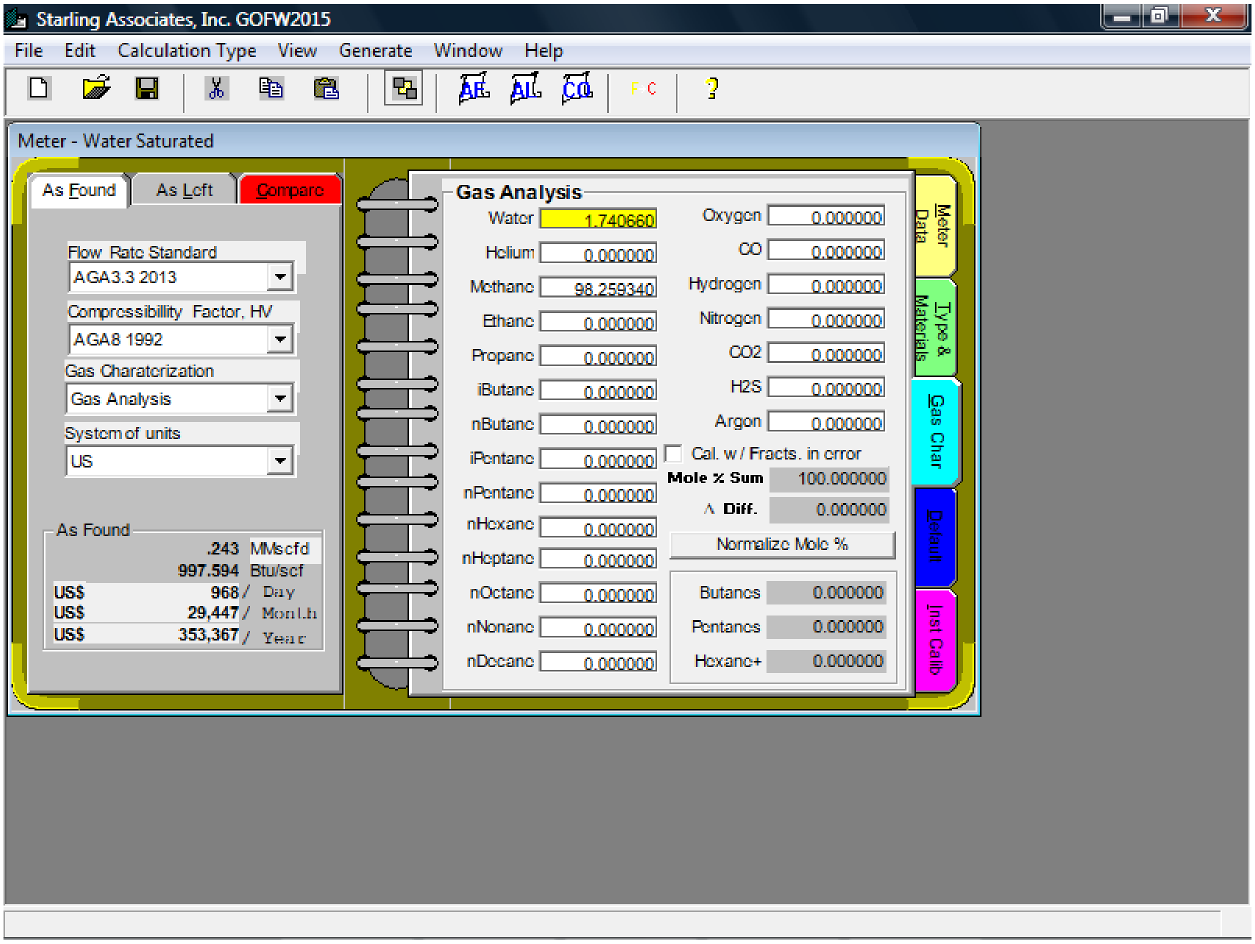
Xw = Pw/Pb

At Tb=60 F, Pw=0.25640 psia, so that for the base Pb=14.73 psia, Xw=0.0174066, as shown below.

Xw = Pw/Pb = (0.25640 psia) /(14.73 psia) = 0.0174066

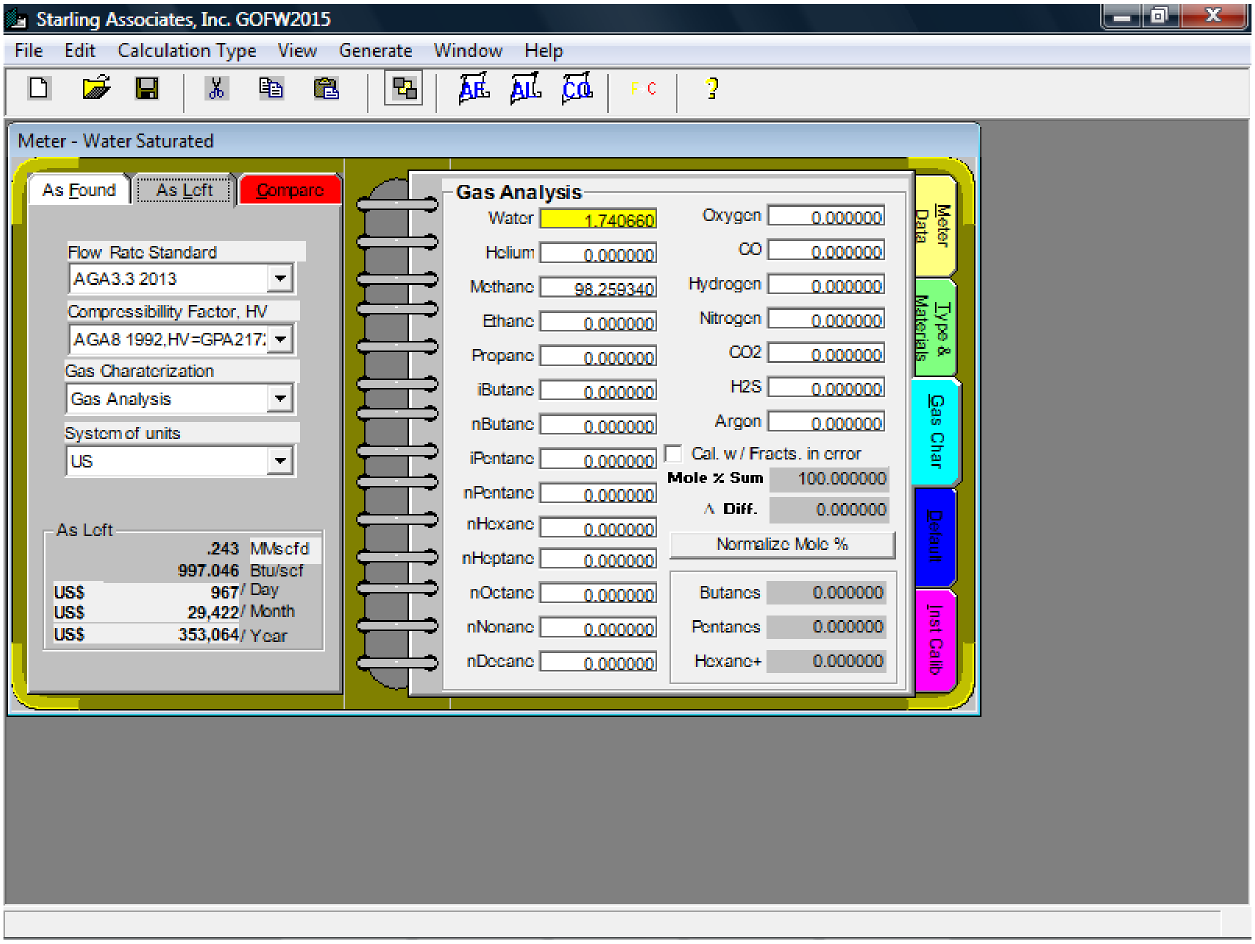
Thus, the composition of water saturated methane at Tb=60 F and Pb=14.73 psia is 1.74066 mole percent water and 98.25934 mole percent methane.

Open **GOFW2015**, click the Gas Char tab and input the water saturated methane gas composition, as shown below.



Note that with the Compressibility Factor, HV selection is AGA8 1992, so that the water saturated methane gross heating value HV=997.594 Btu/scf was calculated using AGA8 1992.

The GPA2172-09 water saturated methane gross heating value will now be calculated in the As Left tab. Click on the "Edit" dropdown menu and select "AF-AL/AL-AF" to copy the As Found inputs into the As Left input textboxes. Click on the "As Found" tab and change the Compressibility Factor, HV selection from AGA8 1992 to AGA8 1992, HV=GPA2172-09, as shown below.



The resultant As Left **GOFW2015** screen shows that the Compressibility Factor, HV=GPA2172-09 calculated water saturated methane gross heating value is HV=997.046 Btu/scf, which is 550 parts per million different from the AGA8 1992 water saturated methane gross heating value, HV=997.594 Btu/scf.

To view the calculated values of ENERGY_FLOWRATE in MMBtu/hr, QB_IDEAL in scf/hr and HV_IDEAL in Btu/scf, generate the Comparison report by clicking on the “CO” icon.

Comparison Report

	As Found	*As Left Units*	*Abs. Diff.*	*% Diff.*
Molecular Weight of The Gas	16.077331	16.077331	0.000000	0.00
Reduced Temperature	1.454413	1.454413	0.000000	0.00
Reduced Pressure	0.020715	0.020715	0.000000	0.00
Critical Temperature	NA	NA F	NA	NA
Critical Pressure	711.092660	711.092660 psia	0.000000	0.00
HV_IDEAL	995.593	994.739 Btu/scf	-0.853208	-0.09
QB_IDEAL	10,129.326	10,129.326 scf/hr	0.000000	0.00
ENERGY_FLOWRATE=QB_IDEAL*HV_IDEAL/100000	10.084683	10.076040 MMBtu/hr	-0.008642	-0.09

Warnings and Errors For As Found
Warning Number =115. - A Component Mole % in expanded

The GPA2172-09 calculated water saturated methane ideal gas gross heating value is HV_IDEAL=994.739Btu/scf, which is 857 parts per million different from the AGA8 1992 water saturated methane ideal gas gross heating value, HV_IDEAL =995.593 Btu/scf.

A difference of 857 parts per million in the monetary value of gas calculated by the buyer and the seller in custody transfer can lead to disagreements between buyer and seller. Consequently, it is important that gas contracts clearly specify the standard that will be used for the calculation of the wet gas gross heating value and that within a company, flow computers, field technicians and office software all conform to the contract specifications.

The topic of the differences in the calculations of the compressibility factor at base conditions for gases containing water is discussed in the paper "A Simple Water Content Correction to the Natural Gas Summation Factors Method Second Virial Coefficient", by Kenneth E. Starling, Proceedings, Gas Processors Association Convention, 2014.

Appendix D

GOFW2015 Calculations for Linear Meters

INTRODUCTION

A number of calculations for linear meters can be performed using **GOFW2015**. Linear meters are commonly classified as any meter for which the volume or mass flow rate is proportional to a measured quantity.

For a turbine meter, the volume flow rate is proportional to the rotational speed of the turbine. For an ultrasonic meter, the volume flow rate is proportional to the pipe cross section average fluid velocity, which is determined by analysis of pulses by the ultrasonic meter. For a coriolis meter, the flow in the pipeline passes through a vibrated tube; the mass flow rate is proportional to the measured inertial force of the mass in the vibrated tube. For a positive displacement meter, the volume flow rate is proportional to the number of discrete volumes displaced through the meter divided by the displacement time.

For linear meters, **GOFW2015** utilizes the following equation for Qf, the volume flow rate at flowing conditions of temperature Tf and pressure Pf.

Qf = (NUMBER_OF_COUNTS / K_FACTOR)* METER_FACTOR

NUMBER_OF_COUNTS = Number of Counts for a linear meter (pulses)

K_FACTOR = K factor for a linear meter, for example, pulses/cubic foot

METER_FACTOR = Meter factor for a linear meter (unitless)

EXAMPLE CALCULATIONS FOR A TURBINE METER

Consider the following example calculation for a turbine meter. The natural gas composition is the "AGA8 Gulf Coast Composition" given in Table B.6-1 of AGA Report No. 8 1992 (1994 Reprint). Base conditions are Tb=60 F and Pb=14.73 psia.

The pipe nominal inside diameter is D=3.0 inches. The flowing conditions are Pf=1000.0 psia and Tf=60 F. Using METER_FACTOR=1.0, the turbine meter coefficient is expressed as the K factor in the units of pulses per actual cubic foot at flowing conditions. From calibration of the meter, K_FACTOR=190.0 pulses/ft^3. The recorded number of counts (pulses) for the installed turbine meter for a one hour period was 966306.0 pulses. The calculated average volume flow rate Qf in actual cubic feet per hour is determined by the following calculation.

Qf = (966306.0 pulses/hr)/(190.0 pulses/ft^3) = 5085.821 ft^3/hr

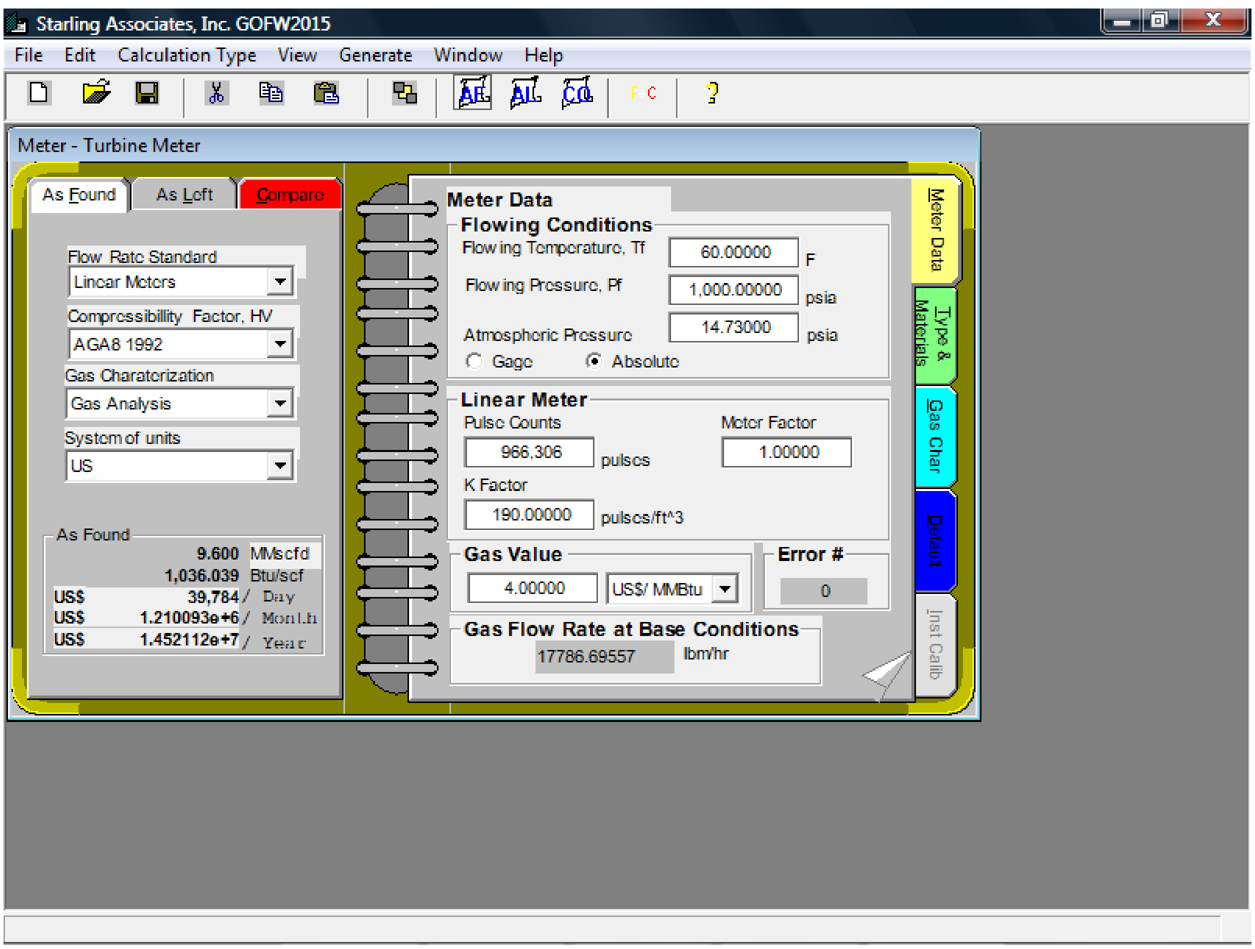
The mass flow rate Qm can be calculated from the volume flow rate Qf and the gas density at flowing conditions using the following equation, where RHOTP is the mass density of the natural gas at the flowing conditions of pressure and temperature Pf=1000.0 psia and Tf=60 F.

Qm = Qf*RHOTP

For the "AGA8 Gulf Coast Composition" natural gas at the flowing conditions of pressure and temperature of Pf=1000.0 psia and Tf=60 F, the AGA8 1992 calculated mass density is RHOTP = 3.497311 lbm/ft^3, so that the calculation for Qm yields the following result.

Qm = (5085.821ft^3/hr)*(3.497311 lbm/ft^3) = 17,786.70 lbm/hr

The **GOFW2015** calculation of mass flow rate Qm for the turbine is shown below.



Qb, the volume flow rate at base conditions of temperature and pressure, Tb and Pb, can be calculated from the volume flow rate Qf at flowing conditions using the following equation, where

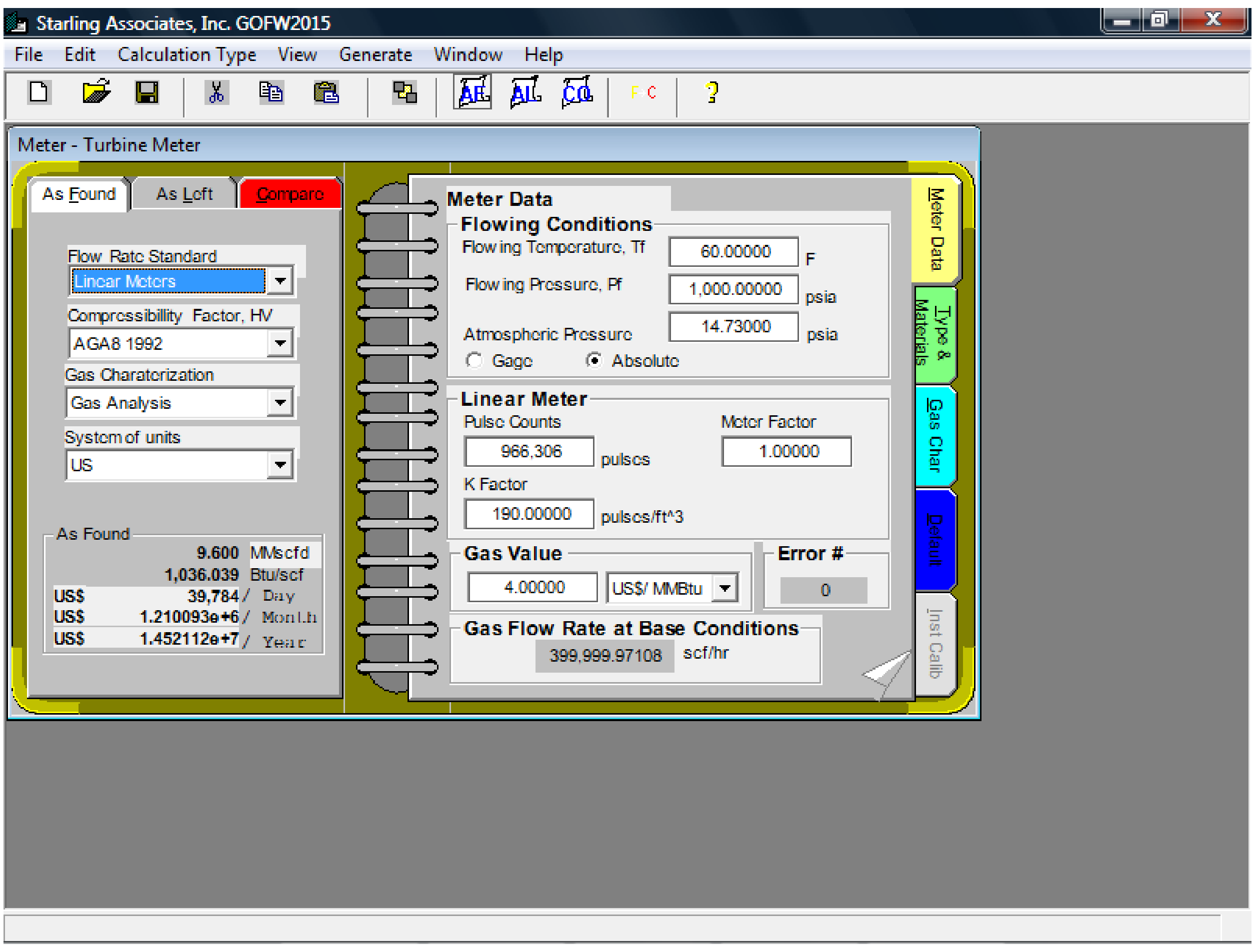
RHOTP is the mass density of the natural gas at the flowing conditions and RHOB is the mass density of the natural gas at the base conditions.

Qb = Qf*RHOTP/RHOB

For the "AGA8 Gulf Coast Composition" natural gas at the base conditions of pressure and temperature of Pb=14.73 psia and Tf=60.0 F, the AGA8 1992 calculated mass density is RHOB = 0.044467 lbm/ft^3, so that the calculation for Qm yields the following result.

Qb = (5085.821 ft^3/hr)*(3.497311 lbm/ft^3)/(0.044467 lbm/ft^3) = 399,997.6 scf/hr

The **GOFW2015** calculation of the volume flow rate Qb for the turbine is shown below. The difference between the **GOFW2015** calculation of the volume flow rate Qb and the manual calculation of the volume flow rate Qb is the fact that RHOB in the manual calculations has a precision on five significant figures, while the **GOFW2015** calculations use greater precision.



EXAMPLE CALCULATIONS FOR A CORIOLIS METER

All of the calculations discussed above are performed when **GOFW2015** is used for turbine meter calculations. The use of **GOFW2015** for other linear meters for which the meter output is proportional to the volume flow rate (such as ultrasonic meters and positive displacement meters) are essentially the same as the calculations described above for turbine meters. For coriolis meters, the meter output is proportional to the mass flow rate rather than the volume flow rate. Consequently, when using **GOFW2015**, the calculation procedure for coriolis meters is somewhat different from the calculation procedure described above for turbine meters.

As discussed in AGA Report No. 11 (2013), coriolis meters are typically calibrated on water at pressures below 65 psia by the manufacturer. Gas flow testing of a coriolis meter above the manufacturer's water calibration pressure typically will show that the flow rate from the coriolis meter flow computer is lower than the actual flow rate and therefore needs compensation for the pressure effect on the coriolis meter flow rate. Although there are a number of methods for pressure effect compensation, only the commonly used flow pressure effect compensation factor method is presented here.

An additional calibration adjustment factor (Fadj) can be applied to the uncompensated mass flow rate to minimize the calculated mass flowrate uncertainty when additional calibration information is available. An example is the use of "multi-point piecewise linear interpolation", discussed in the paper "New Developments to Improve Natural Gas Custody Transfer Applications with Coriolis Meters Including Application of Multi-Point Piecewise Linear Interpolation (PWL)", by Marc Butler, Tonya Wyatt, Karl Stappert, Ron Gibson, and Gary McCargar, Proceedings of the American Gas Association Operating Conference, 2015.

Consider a coriolis meter including a flow computer which outputs Qm(unadjusted), the mass flow rate without flow pressure effect compensation and without additional calibration adjustment. The mass flow rate with flow pressure effect compensation and with additional calibration adjustment, Qm(adjusted), is calculated using the following equation.

Qm(adjusted) = (Fadj)*(Fp)*Qm(unadjusted) = METER_FACTOR *Qm(unadjusted)

where

Fp = Flow pressure effect compensation factor

Fadj = Additional calibration adjustment factor

METER_FACTOR = (Fadj)*(Fp)

The flow pressure effect compensation factor Fp is calculated using the following equation

Fp = 1/[1+(Peffect/100)*(Pf-Pcalibration)]

where

Fp = Flow pressure effect compensation factor

Peffect = Flow pressure effect in percent of rate per psi

Pf = Measurement fluid static pressure in psi

Pcalibration = Calibration static pressure in psi

Note that both Fp and Fadj are factors which typically have been determined from meter calibration data. In the use of **GOFW2015** for coriolis meter calculations, the product (Fadj)*(Fp) can be entered as the **GOFW2015** METER_FACTOR input.

The **GOFW2015** user should note that neither Fp nor Fadj is determined by **GOFW2015**; consequently, the user must determine Fp and Fadj in order to determine the **GOFW2015** METER_FACTOR input.

For gas accounting purposes, the natural gas industry customarily uses Qb, the volume flow rate at base conditions of temperature and pressure, Tb and Pb, rather than using the mass flow rate, Qm. Consequently, important uses of **GOFW2015** for coriolis meter calculations include (1) conversion of the mass flow rate, Qm, to the volume flow rate, Qb, (2) calculation of the natural gas gross heating value, HV, for use in energy flow rate calculations, and (3) calculation of the monetary value of the natural gas metered using the coriolis meter during a specified gas accounting period, such as one day, one month, or one year. Also, **GOFW2015** can be used to calculate the natural gas density used in coriolis meter sizing calculations discussed in AGA Report No. 11 (2013).

Consider the following example calculation for a coriolis meter. The pipe nominal inside diameter is D=3.0 inches. The natural gas composition is the "AGA8 Gulf Coast Composition" given in Table B.6-1 of AGA Report No. 8 1992 (1994 Reprint). Base conditions are Tb=60 F and Pb=14.73 psia. Calibration data using similar gas compositions indicate that with flow pressure effect compensation the coriolis meter mass flow rate uncertainty is within AGA Report No. 11 (2013) requirements with the use of Fadj=1.0.

For the example calculation, the flowing conditions are Pf=1000.0 psia and Tf=60 F. The coriolis meter mass flow rate without flow pressure effect compensation and without additional calibration adjustment is Qm(unadjusted) = 17,619.45 lbm/hr.

The flow pressure effect compensation factor Fp is calculated using the following equation.

Fp = 1/[1+(Peffect/100)*(Pf-Pcalibration)]

where

Fp = Flow pressure effect compensation factor

Peffect = Flow pressure effect in percent of rate per psi = -0.001 %/pai

Pf = Measurement fluid static pressure in psi = 1000.0 psia

Pcalibration = Calibration static pressure in psi = 59.0 psia

Fp = 1/[1+(-0.001/100)*(1000.0-59.0)] = 1.0095

The value of METER_FACTOR follows.

METER_FACTOR = (Fadj)*(Fp) = 1.0*1.0095 = 1.0095

The adjusted mass flow rate Qm(adjusted), is then the following.

Qm(adjusted) = METER_FACTOR * Qm(unadjusted) = 1.0095*17,619.45 = 17,786.84 lbm/hr

To use **GOFW2015** for this coriolis meter calculation, open **GOFW2015** and input the gas composition, the base temperature and pressure and the flowing temperature and pressure. Select "Linear Meters" for the "Flow Rate Standard". Select "Mass Flow Rate" from the "Calculation Type" drop down menu. In the "Meter Factor" textbox enter 1.0, in the "K Factor" textbox enter 1.0 and in the "Pulse Counts" textbox enter 1 (unity). The output textbox titled "Gas Flow Rate at Base Conditions" will then display 3.49731 lbm/hr.

In the calculation above **GOFW2015** utilizes the linear meter equation for Qf, the volume flow rate at flowing conditions of temperature Tf and pressure Pf.

Qf = (NUMBER_OF_COUNTS / K_FACTOR)* METER_FACTOR

With the inputs NUMBER_OF_COUNTS=1, K_FACTOR=1.0 and METER_FACTOR=1.0 the calculated value of Qf is Qf=1.0 ft^3/hr.

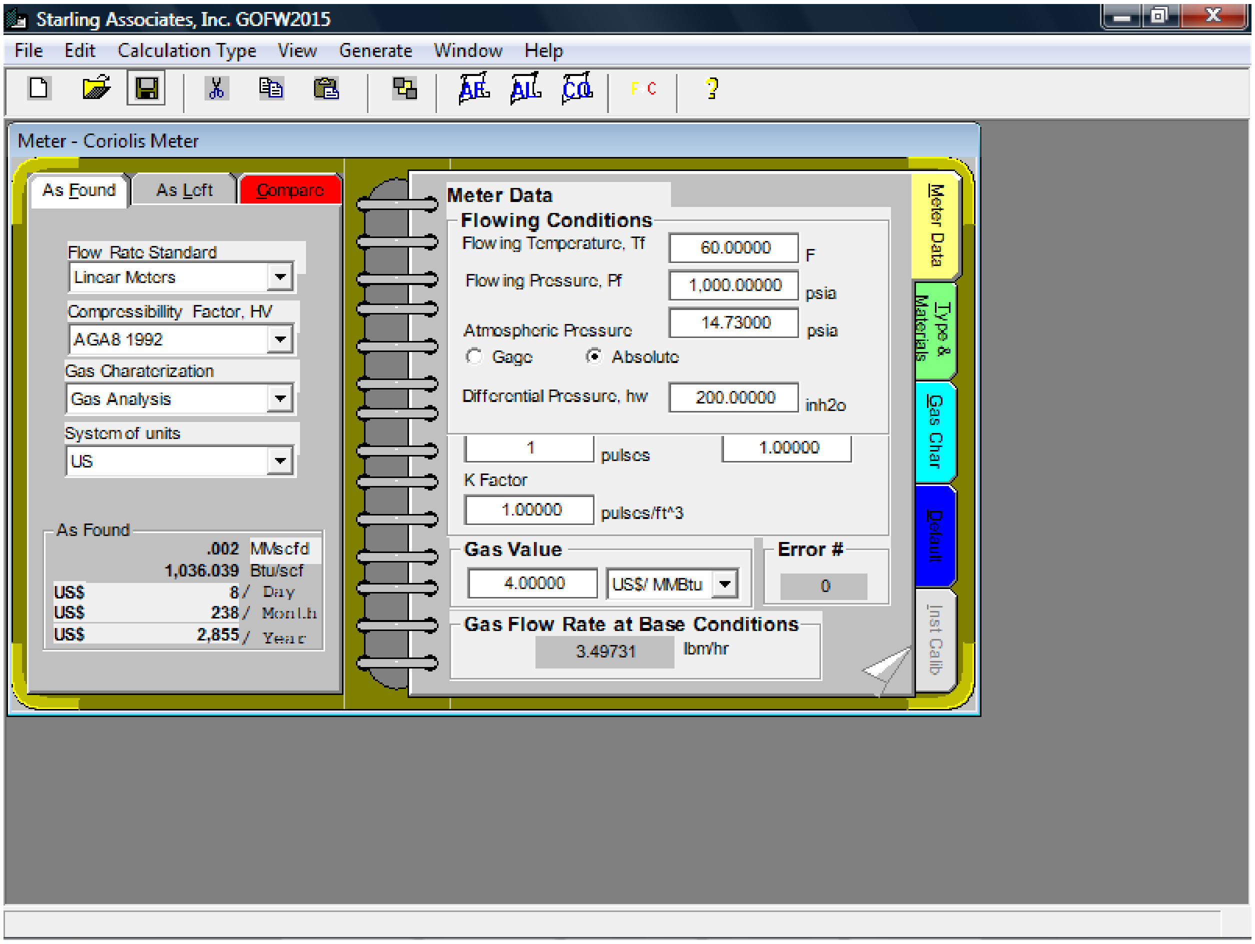
The mass flow rate Qm is calculated by **GOFW2015** from the volume flow rate Qf and the gas density at flowing conditions using the following equation, where RHOTP is the mass density of the natural gas at the flowing conditions of pressure and temperature Pf=1000.0 psia and Tf=60 F.

Qm = Qf*RHOTP

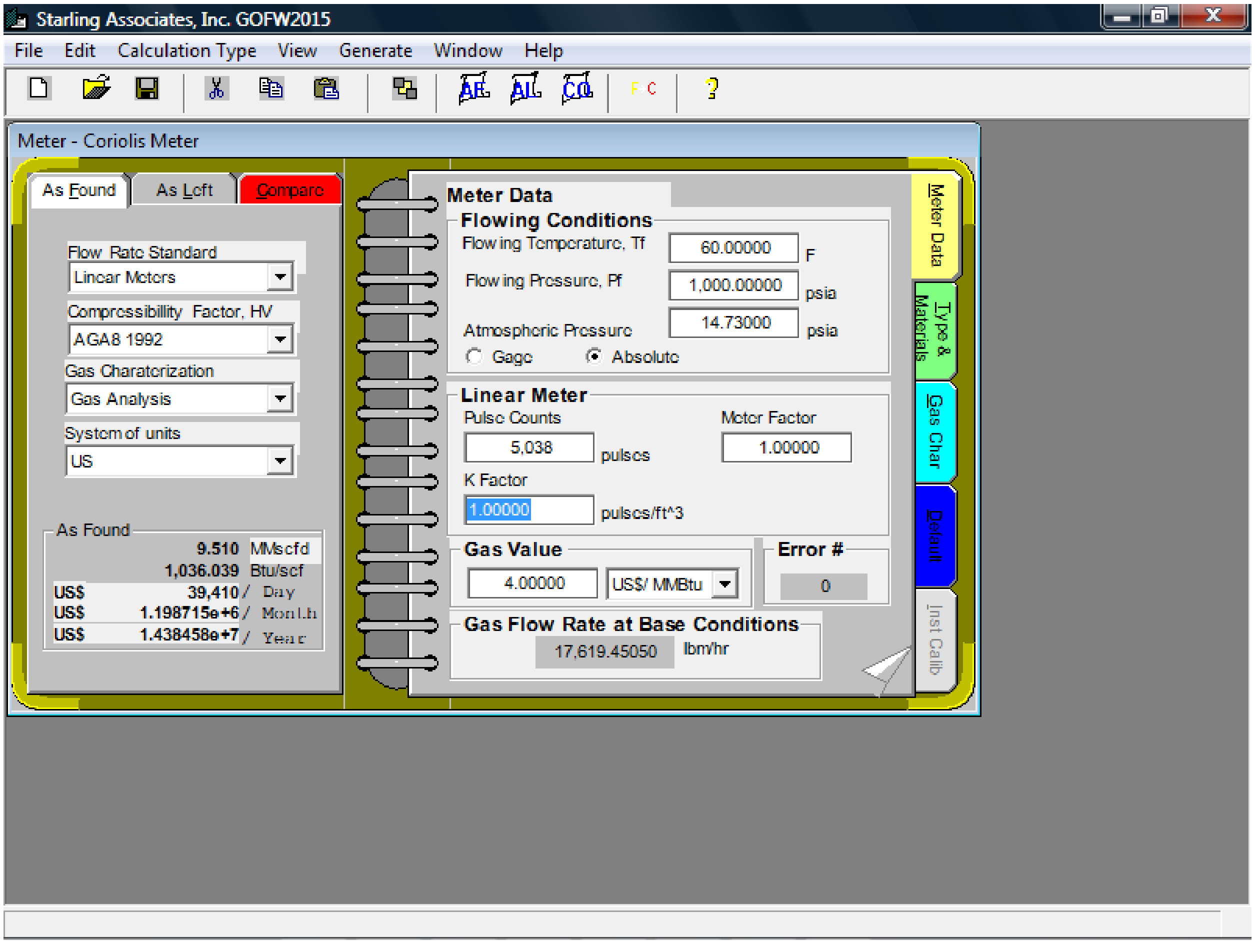
For the "AGA8 Gulf Coast Composition" natural gas at the flowing conditions of pressure and temperature of Pf=1000.0 psia and Tf=60 F, the AGA8 1992 calculated mass density is RHOTP = 3.49731 lbm/ft^3, so that the calculation for Qm yields the following result.

Qm = (1.0 ft^3/hr)*(3.49731 lbm/ft^3) = 3.49731 lbm/hr

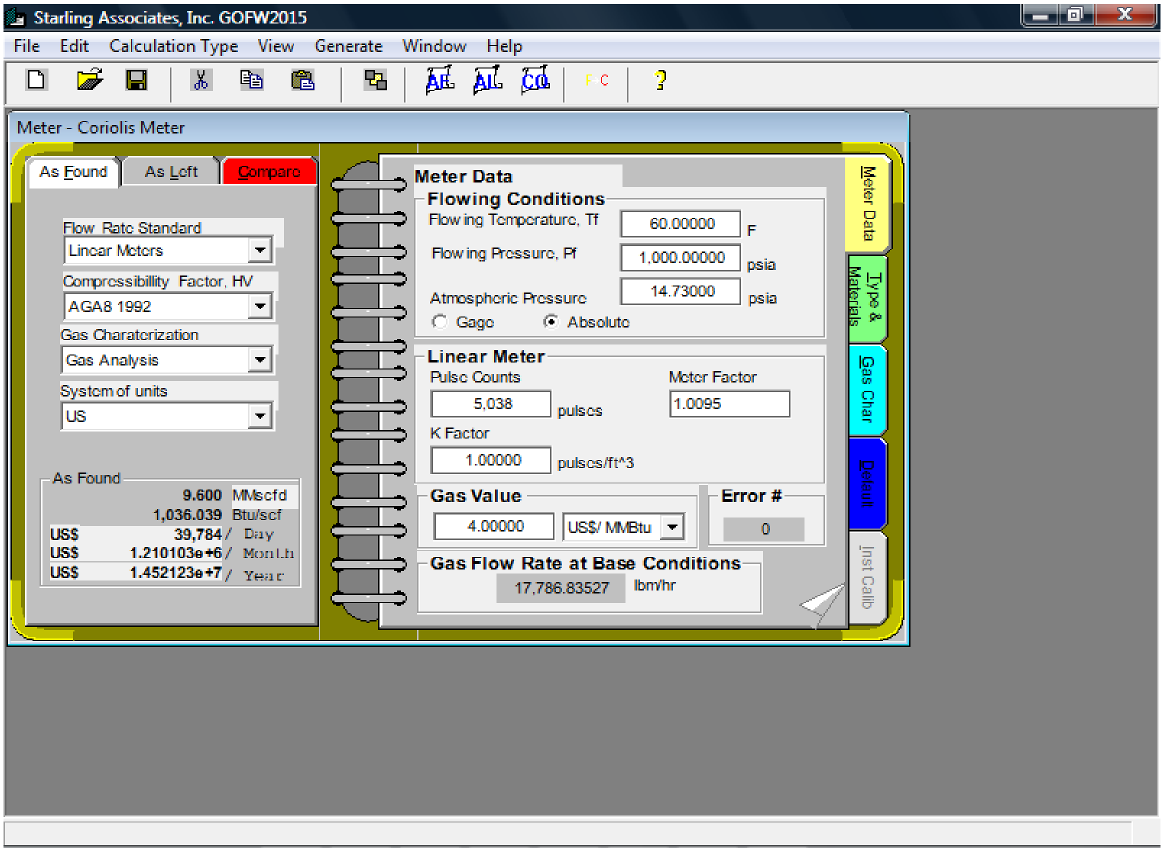
The **GOFW2015** inputs and output mass flow rate Qm for the coriolis meter for this case are shown below.

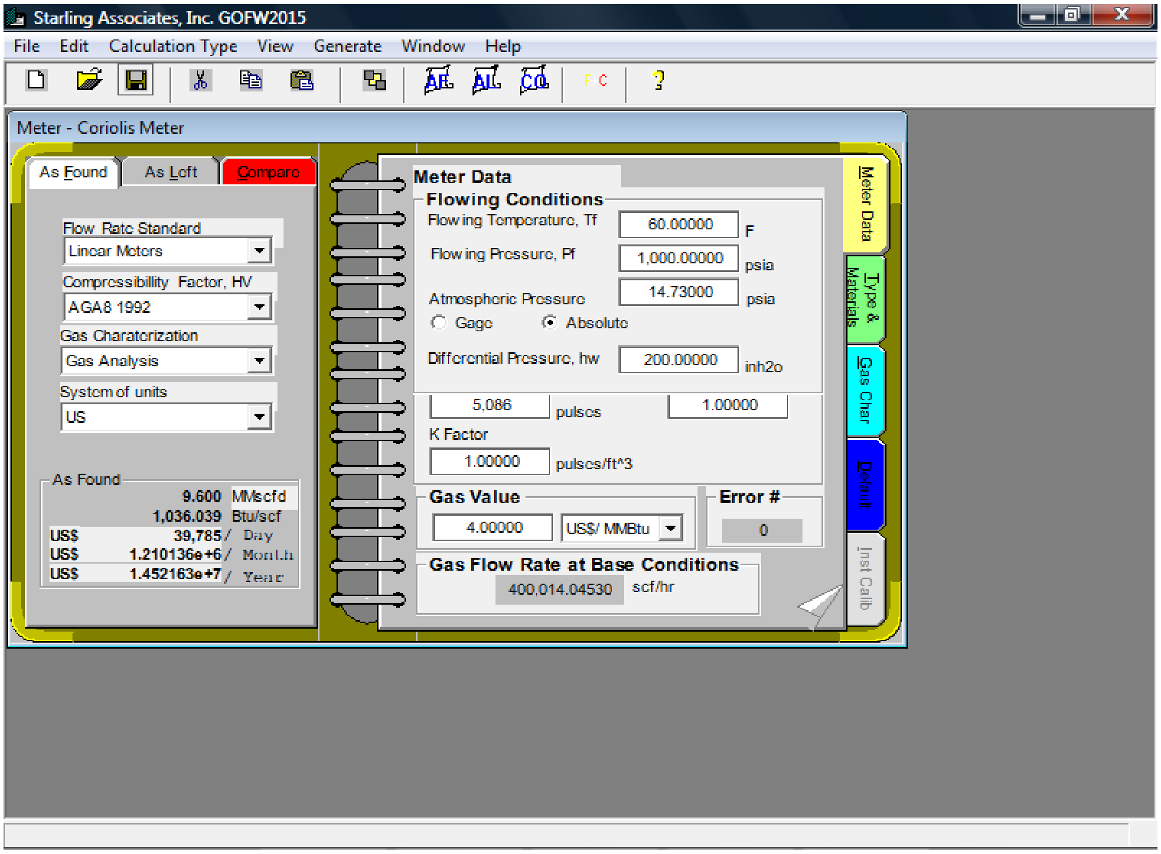


The input pulse counts in **GOFW2015** can be adjusted to obtain an output mass flow rate Qm which matches the coriolis meter flow pressure effect unadjusted mass flow rate of Qm(unadjusted) = 17,619.45 lbm/hr using NUMBER_OF_COUNTS=(17,619.45 lbm/hr)/(3.49731 lbm/hr)=5038. With the input pulse counts of 5038 in **GOFW2015**, the output unadjusted mass flow rate for the coriolis meter is Qm(unadjusted) = 17,619.45 lbm/hr, as shown for **GOFW2015** below.



To calculate the adjusted mass flow rate, Qm(adjusted), 1.0095 will be entered in the **GOFW2015** METER_FACTOR textbox. The resultant **GOFW2015** adjusted mass flow rate, Qm(adjusted)=17,786.84 lbm/hr, is shown on the **GOFW2015** screenshot below.

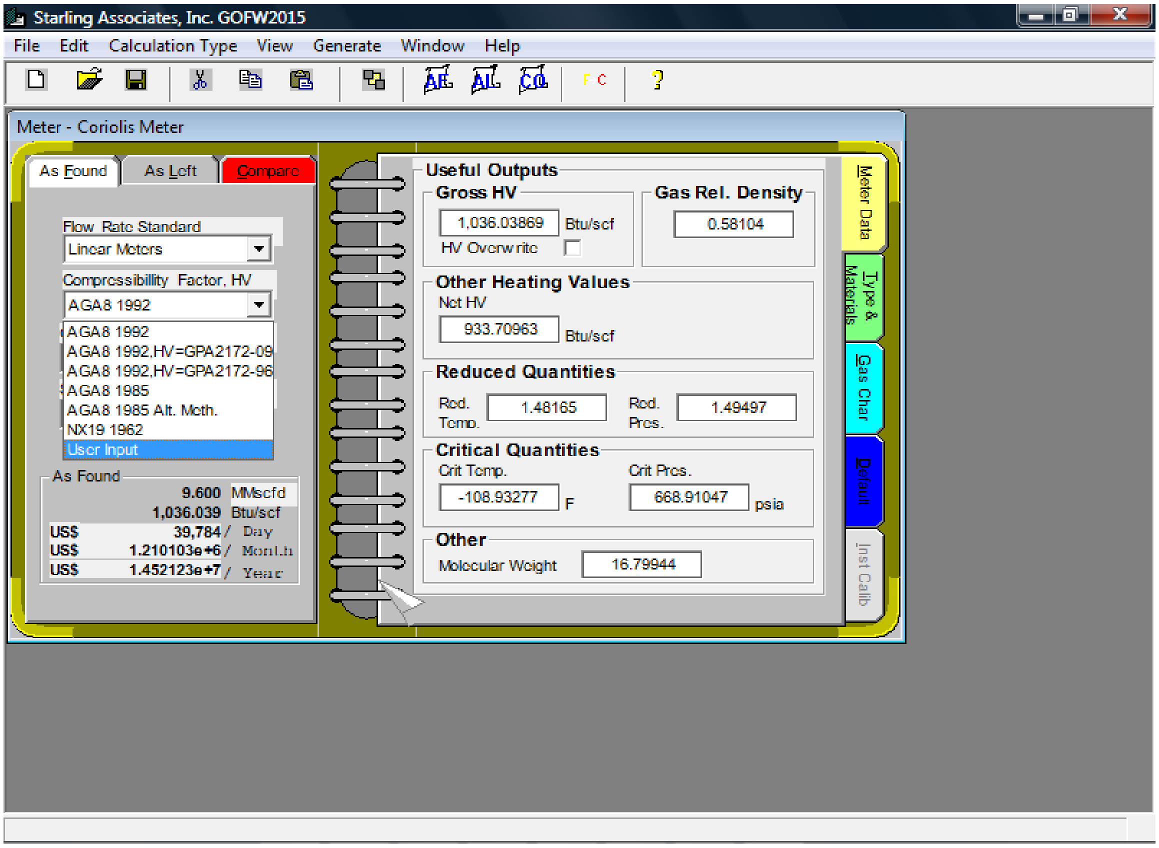

Starling Associates, Inc. GOFW2015
File Edit Calculation Type View Generate Window Help
Meter - Coriolis Meter
As Found
As Left
Compare
Flow Rate Standard
Linear Meters
Compressibility Factor, HV
AGA8 1992
Gas Charaterization
Gas Analysis
System of units
US
As Found
9.600 MMscfd
1,036.039 Btu/scf
US$ 39,784 / Day
US$ 1.210103e+6 / Month
US$ 1.452123e+7 / Year
Meter Data
Flowing Conditions
Flowing Temperature, Tf
60.00000
F
Flowing Pressure, Pf
1,000.00000
psia
Atmospheric Pressure
14.73000
psia
Gage
Absolute
Linear Meter
Pulse Counts
5,038
pulses
Meter Factor
1.0095
K Factor
1.00000
pulses/ft^3
Gas Value
4.00000
US$/ MMBtu
Error #
0
Gas Flow Rate at Base Conditions
17,786.83527
lbm/hr
Meter Data
Type & Materials
Gas Char
Default
Inst Calib



The second **GOFW2015** screen (above) results from changing the selection in the "Calculation Type" dropdown menu from "Mass Flow Rate" to "Volume Flow Rate". This **GOFW2015** screen displays the volume flow rate at base conditions of temperature and pressure, Tb and Pb, Qb= 400,003.1 scf/hr. The calculation of coriolis meter volume flow rate is useful, since for gas accounting purposes, the natural gas industry customarily uses Qb, the volume flow rate at base conditions of temperature and pressure, Tb and Pb, rather than using the mass flow rate, Qm.

As noted earlier, valuable uses of **GOFW2015** for coriolis meter calculations include (1) conversion of the mass flow rate, Qm, to the volume flow rate, Qb, (2) calculation of the natural gas gross heating value, HV, and (3) calculation of the monetary value of the natural gas metered using the coriolis meter during a specified gas accounting period, such as one day, one month, or one year. In addition, **GOFW2015** can be used to calculate the natural gas density used in coriolis meter sizing calculations discussed in AGA Report No. 11 (2013).

The second page of the Meter Data Tab is titled Useful Outputs. These outputs include the Gas Relative Density, the Gross Heating Value, the Net Heating Value, and the Molecular Weight (Molar Mass). The **GOFW2015** Gross Heating Value default method of calculation is AGA8 1992 (1994 Reprint) which yields HV= 1036.04 Btu/scf, as shown below.



Note on the above **GOFW2015** screen that the dropdown menu titled "Compressibility Factor, HV" that a number of choices are available for the combination of the two calculation types (1) Compressibility Factor (which includes gas density and other properties), HV (the Gross Heating Value). The **GOFW2015** default is AGA8 1992 (1994 Reprint) for both the Compressibility Factor (and gas density) and HV (the Gross Heating Value). Other choices include AGA8 1992, HV=GPA2172-09 and AGA8 1992, HV=GPA2172-96, which use AGA8 1992 (1994 Reprint) for the Compressibility Factor (and gas density) and GPA2172-09 or GPA2172-96 for HV (the Gross Heating Value).

Also note on the above **GOFW2015** screen that the calculation of the monetary value of the natural gas metered using the coriolis meter during a specified gas accounting period is shown for one day, one month, and one year.

TURBINE METER AND CORIOLIS METER GOFW2015 INPUT FILES

Two **GOFW2015** input (.CS1) files corresponding to the calculations discussed above for turbine meters and coriolis meters are included with the **GOFW2015** product. The names of these **GOFW2015** input (.CS1) files are Turbine Meter Qb Calculation.CS1and Coriolis Meter Calculation.CS1.

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