

## **Bi-directional gas flow** AutoSERIES of Thermo Scientific Flow Computers

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# **Revision History**

Revision	Date
01	02-01-2023

## **1. Introduction**

The intent of this technical note is to demonstrate to end user, methodology of implementing bi-directional flow through a meter using two distinct methods. Bi-directional is defined by using a single meter run (orifice/USM/turbine/etc), so that measurements/volumes can be calculated both in a forward and reverse manner while maintaining compliance to API 21.1. The two methods elaborated in this document are two of many methods to accomplish bi-directional flow. For example, PLC logic and/or Table 67-Sequencing & Direction can also be used to control directional measurement. For other methods, contact your local regional sales manager or application expert.

# 2. Typical Application(s): Natural Gas Storage

In natural gas storage, the gas is injected into and stored within a geological formation. The natural gas stored must be measured going into the formation and when removed from the formation. To minimize equipment cost, a bi-directional measurement methodology can be implemented. Bi-directional measurement is a function of performing two distinct measurements (forward and reverse) using a single physical primary device such as an ultra-sonic flow meter, while maintaining compliance to API 21.1. This methodology can be applied to multiple runs utilizing AutoCONFIG software.

## 2.1 Method One

### 2.1.1 Math Table (Table-68)

One approach to measurement Bi-direction gas (AGA-3) is to utilize the Math calculation. When flowing in reverse the forward run has negative DP and the reverse run has a positive DP. The math table combined with "DP Cutoff" will allow the user to mutually exclude one run from the other when calculating volumes. This method will create independent flow calculation for forward and reverse operations.

In the example below, we will be measuring both the forward and reverse flow with a single differential meter run. First, user needs to configure both flow runs (i.e. DP Flow #1 and DP Flow #2) to be identical regarding their inputs for static data (DP, Static Pressure, Temp, GC Data, orifice, pipe dia., etc). As well as all other shared static parameters.

#### Run #1

Process variables for static data will be connected directly to the physical data points (process variable and static parameters) for this run.

#### Run#2

The shared process variables for Run#2 will be Run#1 Static Pressure and Temperature. The exception to Run #2, will be the DP input. The DP process variable will be the output of the Math Table (Table-68) where we will multiply Run #1 DP\*-1 (A\*B=C).

For Run#2, or the Reverse Flow meter run, the GQ Data Definition Block will typically need to be changed to reference the same GQ Data Block as Run 1.

Note: The GQ Data Blocks for each bi-directional setup will typically be the same.

#### Math Table (Table-68) Setup

- Calculation: Enable (Math#1 (or next available Function))
- Function 1: A\*B=C
- Input A: Copy "Differential Pressure" from Run #1 Instantaneous tab and paste to Input A.
- Input B: Type value of "-1" into field.
- **Output:** Copy and Paste onto "Differential Pressure" of Run#2 Instantaneous tab.

Editing of Audits for Method One: This eliminates duplicate audits within your historical archive.

**Note:** It is recommended that shared parameters between Run#1 and Run#2 are connected so that audits can be logged in Run#1 Audit Archive while simultaneously changing in both runs. Utilizing Method One, the user must disable the Audits for Run #2 by completing the below changes.

• Set Audit Register Offset in Run#2 Historical Archive Settings to "0" (default in program is 8001).

### 2.1.2 Table 38 Default History Settings

Audit Register Offset		8001
Periodic Data Block Index	Table192: Entry #2	-
Daily Data Block Index	Table192: Entry #1	-
Audit/Alarm Data Block Index	Table193: Entry #1	-
Alarm Data Block Index	Not Assigned	Ψ.

Figure 1. Default Setting

#### 2.1.3 Table 38 Required History Setting for Method One

Audit Register Offset		Ø
Periodic Data Block Index	Table192: Entry #2	-
Daily Data Block Index	Table192: Entry #1	-
Audit/Alarm Data Block Index	Table193: Entry #1	-
Alarm Data Block Index	Not Assigned	+

Figure 2. Required Setting for Method One

Once above configuration has been completed and flow has reversed, the DP in Run#1 will read negative. Since the DP will be below the DP cutoff, a no flow state will be active. Run#1 DP will then be multiplied by -1 in the Math Table, producing a positive value in the Output of Function 1. This positive DP will then be displayed and used in Run#2 thereby showing a positive DP and the Flow Status will then switch to "Flowing".

The images below indicate the positive and negative DP when the reverse Run#2 is flowing. In the forward run is active, you would see positive DP on Run #1 and negative DP on Run #2.

The screen shot below indicates Run#1 negative DP.

😔 - Bi-Directional Flow Example 1.cfg								_		
System Files Tools Options	Colors Programmable Screen	lelp								
<b>(</b>										
:  <b>f f</b>   <b>Q</b> 6 <mark>1</mark>	1 🔗 🛞 🕒 🏷 🥝		<b>D</b>					😽 Adv	anced	a N
Navigation Bar 🛛 🗛	Dp Flow Calculation - Forward									4
Physical Data Point(s) 🛛 🛛 🎽 📥	Auto Refresh F2 Refresh	F3 Apply	1	F1 H	leip 😵					
alculation(s) *		·	<b>-</b> , ,			,				
→ 32-Calculation Thread Allocation → 33-PID	Static Instantaneous	Eng. Unit	Min/Max	History	Energy/Fwv/Well	Stream	Location Facto		Visc.	_
- 34-Proportional Output										
- 35-High/Low Selection	Zb Factor	0.9977396		Gasle	emperature		65.5 °F			
38-Differential Pressure Flow	ZfFactor	0.9866125		Differen	ntial Pressure		-50 inH20	ManOv	/rd/	
Percent (Rate=0.0, DP=-50.	Zs Factor	0.9977272		Static F	[ 038.001.036 ] Connec	ts To 17-Physica	al Smart XDucer In	put [ 017.00	1.004 ]	
DP Elow Cale#2	Fpv Factor	1.005623		Sqrt. E	Differential Pressure: T	he differential p	ressure.			1
DP Flow Calc#4										
39-AGA 7 Flow	Curr Hour Volume	0	MCF	Curr M	onth Volume		0 MCF			
40-AGA 10 Speed of Sound	Prev Hour Volume	0	MCE	Prev M	Ionth Volume		0 MCF			
41-Meter Station	Curr Hour Energy	0	MMBTU	CurrM	onth Energy		0 MMBTU			
43-Historical Average	Brow Hour Energy	0	MMDTU	Drow M	lonth Energy		0 MMBTU			
46-Discrete Logical OR	Prev Hour Energy	0	MINDIO	Previv	ionun Energy		0 MINDTO			
49-PLC Program									_	ń
51-Liquid Flow	Flow Status	Not Flowing		Curren	t Day Flow Time		0 Hour			
53-Prover Calculation	Flow Time This Period	0	Hour	Previo	us Day Flow Time		0 Hour			
54-Discrete Point NOT	Hourly Flow Rate	0	MCF/Hour	Hourly	Energy Rate		0 MMBTU/Ho	ur		
56-Density Calculation	Daily Flow Rate	0	MCF/Day	Daily E	nergy Rate		0 MMBTU/Da	v		
57-Station Control	Totalized Volume	4.342706	MCF	Totaliz	ed Energy	4 34	2706 MMBTU	·		
65-Plunger Lift	Current Day Volume	0	MCF	Curren	t Day Energy	1.54	0 MMBTU			
66-CallOut	Previous Day Volume	0	MCF	Previo	us Day Energy	-	0 MMBTU			
68-Math				1 Iono	as bay chorgy		U WIND I U			
- 128-Gas Quality Data				10.000	25 (19-17-1		1.1.1.1	_		1
- 129-Product Table	AGA2530 Beta	0.4980764		AGA25	530 Fsl	0.00159	5594			

Figure 3. Run#1/Forward Negative DP

The screen shot below indicates Run#2 positive DP.

🤞 - Bi-Directional Flow Example 1.cfg					-	
System Files Tools Options	Colors Programmable Screen	Help				
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Navigation Bar 4	Dp Flow Calculation - Forward Dp F	low Calculation - Re	verse			4 Þ
Physical Data Point(s) 🛛 👻 📥	Auto Refresh F2 Refresh	F3 Apply		F1 Help		
Calculation(s)			<b>_</b>	, <u> </u>		
- 32-Calculation Thread Allocation	Static Instantaneous	Eng. Unit	Min/Max	History Energy/Fwv/We	Il Stream Location Factor	Misc.
. 33-PID	2					
34-Proportional Output		0.0077000			0.5.15	
35-High/Low Selection	Zb Factor	0.9977396		Gas Temperature	65.5 °F	
38-Differential Pressure Flow	Zf Factor	0.9865454		Differential Pressure	50 inH20	
Powerce (Pate=295.4 DP=-50.	Zs Factor	0.9977272		Static Pressure [ 038.002.036	1 Connects To 68-Math [ 068.001.007 ]	
	Fpv Factor	1.005657		Sqrt. Ext. Differential P	ressure: The differential pressure.	
DP Flow Calc#4						
39-AGA 7 Flow	Curr Hour Volume	13,70469	MCF	Curr Month Volume	13.70469 MCF	
40-AGA 10 Speed of Sound	Prev Hour Volume	0.082064	MCE	Prev Month Volume	0.082064 MCF	
41-Meter Station	Curr Hour Energy	13 70469	MMBTU	Curr Month Energy	13 70469 MMBTU	
43-Historical Average	Brow Hour Energy	0.092064	MARTI	Brow Month Energy	0.082064 MMBTU	
46-Discrete Logical OR     47 Discrete Logical AND	Flev Hour Energy	0.002004	WINDTO	Flev Month Energy	0.002001 1111210	
4-49-PLC Program						
51-Liquid Flow	Flow Status	Flowing		Current Day Flow Time	0.04666667 Hour	
53-Prover Calculation	Flow Time This Period	0.04638889	Hour	Previous Day Flow Time	0 Hour	
54-Discrete Point NOT	Hourly Flow Rate	295.4304	MCF/Hour	Hourly Energy Rate	295 4304 MMBTU/Hour	
• 56-Density Calculation	Daily Flow Rate	7090.33	MCF/Day	Daily Energy Rate	7090 33 MMBTLI/Day	
57-Station Control	Totalized Volume	68.38924	MCF	Totalized Energy	68 38924 MMBTU	
5. S. Dunger Lift	Current Day Volume	13,78675	MCF	Current Day Energy	12 79675 MMDTU	
66-CallOut	Previous Day Volume	0	MCE	Previous Day Energy	13.70075 MIMBTU	
68-Math	Literious buy volume	0	in or	Frevious Day Energy	0 MMB10	
🖶 128-Gas Quality Data						
129-Product Table	AGA2530 Beta	0.4980757		AGA2530 Fsl	0.00159457	
a 1234 IOGUCE TABLE	AGA2000 Deta	0.4980757		AGA2000 FSI	0.00159457	

Figure 4. Run#2/Reverse Positive DP

The screen shot below indicates the setup for the Math Table: Math#1 Function 1.

🔞 - Bi-Directional Flow Example 1.cfg									×
<u>System Files Tools Options</u>	Colors Program	nable Screen <u>H</u> elp							
t (f f (d 4 🛙	i   🖉 🕒 1	b   �   ∽ (						Advance	d Mode
Navigation Bar 🛛 🕈	Dp Flow Calculation	- Forward Dp Flow C	alculation - Reverse	Byte Value - Math#1					4 Þ 🗙
Physical Data Point(s) 🛛 🗧 📥	Auto Refresh	F2 Refresh	F3 Apply		F1 Help				
Calculation(s)									
	Calculation	Enabled	-						
	Descriptor		Math#1						
34-Proportional Output	ID		68001						
35-High/Low Selection	100-00								
38-Differential Pressure Flow	Function 1	A*B=C	<ul> <li>Input A</li> </ul>	-50 Input B	-1	Output	50		
H 40 ACA 10 Speed of Sound	Eunction 2	NONE					10		
+ 40-AGA TO Speed of Sound	runction 2	NONE	[ 068.001	.005 J Connects Io 17-Phys	ical Smart XDucer Inpu	t[017.001.004]			
	Function 3	NONE	<ul> <li>Inpace</li> </ul>	o inpuco	lo.	output	0		
⊕ 46-Discrete Logical OR	Function 4	NONE	<ul> <li>Input A</li> </ul>	0 Input B	0	Output	0		
47-Discrete Logical AND	Function 5	NONE	Input A	0 Input B	0	Output	0		
49-PLC Program	Constitution C	HONE				0			
51-Liquid Flow	Function 6	INONE	Input A	U Input B	0	Output	10		
53-Prover Calculation     54 Discuss Deint NOT	Function 7	NONE	<ul> <li>Input A</li> </ul>	0 Input B	0	Output	0		
+ 56-Density Calculation	Function 8	NONE	<ul> <li>Input A</li> </ul>	0 Input B	0	Output	0		
	Function 0	NONE		0 Invest		0			
	Function 9	NONE	<ul> <li>Input A</li> </ul>	U Input B	0	Output	0		
⊕ 65-Plunger Lift	Function 10	NONE	<ul> <li>Input A</li> </ul>	0 Input B	0	Output	0		
i 66-CallOut	Function 11	NONE	Input A	0 Input B	0	Output	0		
i⊒⊷ 68-Math	Eunction 12	NONE		0 Input P	0	Output			
Math#1	runcuon 12	INONE .	input A	input b	l <sup>o</sup>	Output			
·····Watn#2	Function 13	NONE	<ul> <li>Input A</li> </ul>	0 Input B	0	Output	0		

Figure 5. Math#1 Function 1

After completion of the above configuration, Run#1 will be indicative of Forward flow and Run#2 will be Reverse flow.

### 2.1.4 Calibration Requirement for Method 1

Note: The following assumes a typical orifice meter run.

Users must now calibrate the Differential Pressure, Static Pressure and Temperature. This document will only detail the calibration process for the Differential Pressure, as it differs from the standard method. For details on the standard method of calibration for the Static Pressure and Temperature, refer to the AutoCONFIG Startup Guide, PN 1-0485-068.

We recommend connecting a five-way valve between the pressure transmitter and the orifice meter. The standard five-way valve ports are identified as: High Pressure Block Valve (HPBV), Low Pressure Block Valve (LPBV), High Pressure Equalizing Valve (HPEV), Low Pressure Equalizing Valve (LPEV), and Vent Valve. To calibrate DP, connect a calibrated pressure output device (such as a dead-weight tester or PK-tester) to one of the 1/4 inch NPT vents.

- 1. In AutoCONFIG, click **Tools >Calibrate**. This will activate the calibration wizard.
- 2. Select the run number and click Next.

Velcome to the AutoCONFIG Calibration Wizard Please indicate which run you would like to calibrate then click on "Next" to proceed.	
Select Run For Calibration	
DP Run # 1	
DP Run # 2	
DP Run # 3 DP Run # 4	
DP Run # 5	
DP Run # 6 DP Run # 7	
DP Run # 8	
	$\nabla$
Cancel < Back	Next >

Figure 6. Selecting Run Number

3. Click **Yes** to continue freezing the run and enter calibration mode.

4. Select Differential Pressure Input to calibrate and click Next.

on to proceed.	
	Ŷ
	Exit < Back

Figure 7. Indicating Analog Point

5. Select Calibrate Run Input for Selected Run and click Next.

😔 Calibrate				- 0 X
Welcome to the AutoCONFIG C Please indicate which of the following to	alibration Wi	izard e to performthen click	on the "Next" button to proceed.	
C Verify Inputs "/	As Found" for S Input for Selecte As Left" for Sele	elected Run. d Run. cted Run.		
No. of Decimal	Default	-		
Kellash kate	Teonandoos	<u> </u>		
				_
			Exit< Bac	k Next >

Figure 8. Selecting Calibrate Run Input

6. Select 3-Point Calibration and click Next.

Calibrate	
Welcome to the AutoCONFIG Calibration Wizard	•
Please indicate the type of Calibration method you would like to calibrate your analog point then click on the "Next button to proceed.	
C 1 - Point Calibration	
C 2 - Point Calibration	
( 3 - Point Calibration	
	V
Exit < Back	Next >

Figure 9. Selecting 3-Point Calibration

7. Connect the calibrated pressure output device to the "Low Pressure" side of the five-way valve via the 1/4" NPT vent connection and configure the five-way manifold. Isolate and bleed the manifold. Close the HPBV and LPBV. Close the LPEV and open the HPEV and Vent Valve.

8. The Lo-Diff Pressure will be calibrated to negative 250 inches. Using a dead-weight tester or other calibration device, apply pressure until the Lo Diff Pressure value stabilizes, click on **Click this when steady**, Click **Yes** to use the value and enter the desired input value, (-250) and press Enter.

vercome to	the AutoCONFIG	6 Calibrat	ion Wizard			8
Please click on Calibration dat	the steady button wh a.	nen your curr	ent value is stable th	en click on the "Accep	t" button to save you	ur 人
	Curren	t Value	New Value			
Diff Pres	-25	0	-250	Click this when a	iteady!	=
id Diff Pres	0.1	049		Click this when s	steady!	
Diff Pres				Click this when s	teady!	
Static Press Tes	t Temperature Tes As Found	t Diff Pres	s Test AsLeft	Deviation	%Deviation	
Static Press Tes Test *	t   Temperature Tes As Found	t Diff Pres Test	s Test   AsLeft	Deviation	%Deviation	
itatic Press Tes Test *	t   Temperature Tes AsFound	t Diff Pres Test	s Test AsLeft	Deviation	%Deviation	
itatic Press Tes Test *	t Temperature Tes AsFound	t Diff Pres Test	s Test AsLeft	Deviation	% Deviation	
itatic Press Tes Test * Highlight - R	t Temperature Tes AsFound ght/Click to Delet	t Diff Pres Test	s Test AsLeft	Deviation	% Deviation	on Req.
Static Press Tes Test Highlight - R 8/29/2022	t) Temperature Tes AsFound ght/Click to Delete	t Diff Pres Test	s Test AsLeft	Deviation	X Deviation	in Req.
itatic Press Tes Test Highlight - R 8/29/2022	t) Temperature Tes As Found ght/Click to Delet	t Diff Pres Test	s Test AsLeft Y	Deviation	% Deviation	on Req.

Figure 10. Lo-Diff Pressure Calibration

9. The Mid Diff Pressure will be 0 DP at atmosphere. Open the HPEV, LPEV and Vent to bleed any pressure to atmosphere. When the displayed count of the Mid Diff Pressure value stabilizes, select **Click this when steady**, Click **Yes** to use the value and enter the desired input value, (0) and press Enter.

<b>Velcome</b> to	the AutoCONFIC	G Calibrat	ion Wizard			9
Please click on Calibration da	the steady button wi ta.	hen your curr	ent value is stable t	hen click on the "Accep	t" button to save your	
	Curren	t Value	New Value			
o Diff Pres	-2	50	-250	Click this when s	steady!	
id Diff Pres	0.1	106	0	Click this when a	steady!	i i
i Diff Pres	0.1	079		Click this when a	steady!	
Static Press Te	st   Temperature Tes As Found	st Diff Pres Test	s Test AsLeft	Deviation	%Deviation	
Static Press Te Test *	st Temperature Tes	t Diff Pres Test	s Test AsLeft	Deviation	%Deviation	
Static Press Te Test *	st Temperature Te: As Found	st Diff Pres Test	s Test AsLeft	Deviation	% Deviation	
Static Press Te Test # Highlight - R	ist   Temperature Te: AsFound ight/Click to Delet	t Diff Pres Test	s Test AsLeft	Deviation	% Deviation	Req.
Static Press Te Test Highlight - R 8/29/202	as Found	t Diff Pres Test	s Test AsLeft	Deviation	% Deviation	Req.

Figure 11. Mid Diff Pressure Calibration

- 10. The Hi Diff Pressure will be positive 250 inches DP. Connect the calibrated pressure output device to the "High" side of the five-way valve assembly via the ¼" NPT vent port and configure the five-way manifold. Close the HPEV, open the LPEV, and Vent Valve. Using a dead-weight tester or other calibration device, apply pressure until the Hi Diff Pressure value stabilizes, select **Click this when steady**, Click **Yes** to use the value, enter the desired input value, (250) and press Enter.
- 11. Click Accept.

	Current	t Value	New Value		
Diff Pres	-25	0	-250	Click this when	steady!
d Diff Pres	0.11	149	0	Click this when	steady!
Diff Pres	250	)	250	Click this when	steady!
n Pres Raw Va	lue 0.106	5719	- 1	Reset	ccept
itatic Press Test	lue 0.106	5719 t Diff Prest	ss Test AsLeft	Reset A	*Deviation
itatic Press Test Test K Highlight - Rig	Iue 0.106	t Diff Pres	As Left	Reset A	% Deviation

Figure 12. Hi Diff Pressure Calibration

#### 12. Click **Download Diff Press Entries** to save.

Note: Before this step, you can verify the inputs for "As Left" data. Once completed, click the **Download Diff Press Entries** button.

🖳 Calibrate	ini ini ini		-A.	
Welcome to the A Please indicate which	of the following t	Calibration Wizard ask youwould like to perform	then click on the "Next" button	to proceed.
	Verify Inputs " Calibrate Run Verify Inputs " No. of Decimal Refrash Rate Selected I Calib	As Found" for Selected Run. Input for Selected Run. As Left" for Selected Run. Default Continuous Run Input Point Entered	d	
,	Downlo	ad Diff Press Entries		
			Ext	< Back Next >

Figure 13. Click Download Diff Press Entries

- 13. At this point you can reconfigure the manifold to be in service with your process.
- 14. Click Exit.
- 15. Click **Yes** if you are sure.

16. Decide whether you wish to generate a calibration report or not, in this example we will select **No** to skip the calibration report generation process.

🖳 Calibrate		
Welcome to the Auto Please indicate which ana	CONFIG Calibration Wizard og point you would like to calibrate then click on the "Next" button to proceed.	
	C Static Pressure Input AutoCFG X Generate Calibration Report Run #1 Meter Name > DP Flow Calc#1 Meter Number > Mtr# AGA3#1	
	Yes No	
	Exit <	Back Next>

Figure 14. Skipping The Calibration

- 17. Select **Yes** to continue and exit calibration mode.
- 18. Yes, again if you are really sure.
- 19. Once the run is "unfrozen", the DP will be in tolerance no matter if flow is forward or reverse.

## 2.2 Method Two

### 2.2.1 Manual Flow Cutoff Using Flow Direction Indicator Input

Application: Typically used with Table 39 (AGA-7: Linear devices).

Note: Can be used with Table 38-Differential Pressure Flow.

Requirements: Directional flow via Discrete Inputs.

The intent of this example is to demonstrate how the directional input discrete input will be utilized to switch between forward and reverse flow runs. This will use the "Manual Flow Cutoff" field.

Note: Actual physical Discrete input may vary for your application. This example assumes the use of DI1 and DI2.

Physical Wiring of Instrument Directional Output (AutoPILOT PRO represented in this example).

- Forward Direction
  - Wire (+) to DI1 (APPRO TB6)
- Reverse Direction (Inverted input/Inverted flow)
  - Wire (+) to DI2 (APPRO TB6)



Figure 15. Common/Typical Wiring Diagram

### 2.2.2 Configuration of Table 39 Run#1 and Run#2

In the example below, we will be measuring both the forward and reverse flow with a single physical meter run. First, user needs to configure two separate AGA7 flow runs (i.e. AGA7 Calc# 1 and AGA7 Calc# 2) to be identical regarding their inputs for static data (Accumulator, Static Pressure, Temp, GC Data, K-Factor, M-Factor, etc).

#### Run #1 and #2 Configuration

• Copy Table 19 Discrete In#1 field "Current Value" and Paste onto Run#1 "Manual Flow Cutoff" in the Static tab.

Note: Descriptor #1 can be edited to read Forward Flow.

• Copy Table 19 Discrete In#2 field "Current Value" and Paste onto Run#2 "Manual Flow Cutoff" in Static tab.

Note: Descriptor #1 can be edited to read Reverse Flow.

• In Table 19 Entry Discrete In#2 "Invert Input" field and select "Invert Input" from the drop-down menu.

After completion of the above configuration, Run#1 will be indicative of Forward flow and Run#2 will be Reverse flow.



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