Daniel Ultrasonic Gas Flowmeter

Reference, Installation and Operations Manual

DANIEL MEASUREMENT AND CONTROL, INC.
AN EMERSON PROCESS MANAGEMENT COMPANY
HOUSTON, TEXAS

Supporting
Multipath SeniorSonic^{TM} - Model 3400
Single Path JuniorSonic^{TM} - Model 3410
Dual Path JuniorSonic^{TM} - Model 3420

Part Number 3-9000-740
Revision H

November 2007

Important Instructions

Daniel Measurement and Control, Inc. (Daniel) designs, manufactures and tests its products to meet many national and international standards. Because these instruments are sophisticated technical products, you must properly install, use and maintain them to ensure they continue to operate within their normal specifications. The following instructions must be adhered to and integrated into your safety program when installing, using and maintaining Daniel products.

- Read all instructions prior to installing, operating and servicing the product. If this instruction manual is not the correct manual, call 1-713-827-6314 (24-hour response number for both Service and Sales Support) and the requested manual will be provided. Save this instruction manual for future reference.
- If you do not understand any of the instructions, contact your Daniel representative for clarification.
- Follow all warnings, cautions and instructions marked on and supplied with the product.
- Inform and educate your personnel in the proper installation, operation and maintenance of the product.
- Install your equipment as specified in the installation instructions of the appropriate instruction manual and per applicable local and national codes. Connect all products to the proper electrical and pressure sources.
- To ensure proper performance, use qualified personnel to install, operate, update, program and maintain the product.
- When replacement parts are required, ensure that qualified people use replacement parts specified by the manufacturer. Unauthorized parts and procedures can affect the product's performance and place the safe operation of your process at risk. Look-alike substitutions may result in fire, electrical hazards or improper operation.
- Ensure that all equipment doors are closed and protective covers are in place, except when maintenance is being performed by qualified persons, to prevent personal injury.
- ALWAYS READ AND FOLLOW THE DANIEL ULTRASONIC GAS FLOW METER MARK III REFERENCE, INSTALLATION, AND OPERATIONS MANUAL AND ALL PRODUCT WARNINGS AND INSTRUCTIONS.
- Use of this equipment for any purpose other than its intended purpose may result in property damage and/or serious personal injury or death.
- Before opening the flameproof enclosure in a flammable atmosphere, the electrical circuits must be interrupted.

DANIEL MEASUREMENT AND CONTROL, INC.
Daniel Ultrasonic Gas Flow Meter Reference, Installation and Operations Manual

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INTRODUCTION

The Daniel Ultrasonic Gas Flow Meter Reference Manual (P/N 3-9000-740) provides descriptions and explanations of the Daniel Multipath SeniorSonic™ - Model 3400, Single Path JuniorSonic™ - Model 3410 and the Dual Path JuniorSonic™ - Model 3420.

The Daniel Ultrasonic Flow Meter was originally developed and tested by British Gas. The unit was further developed by Daniel and features hardware and electronics designed for easy use and minimum maintenance. All parts and assemblies have been tested prior to shipment. Daniel holds an exclusive license from British Gas, which it obtained in 1986, to manufacture and sell this product.

1.1 MANUAL OVERVIEW

This manual consists of the following sections and appendices:

Sections

- Section 1 - Introduction
- Section 2 - Product Overview
- Section 3 - Installation
- Section 4 - Meter Configuration, Firmware
- Section 5 - Theory of Operation
- Section 6 - Maintenance

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- Appendix A - Conversion Factors
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- Appendix C - Block List and Index of Registers
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- Appendix E - System Set-up
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1.2 DEFINITIONS, ACRONYMS, ABBREVIATIONS

The following terms, acronyms, and abbreviations are used in this document:

Acronym or Abbreviation	Definition
°C	Degrees Celsius (temperature unit)
°F	Degrees Fahrenheit (temperature unit)
ADC	Analog-to-Digital Converter
AGA	American Gas Association
ASCII MODBUS	A Modbus protocol message framing format in which ASCII characters are used to delineate the beginning and end of the frame. ASCII stands for American Standard Code for Information Interchange.
Btu	British Thermal Unit (heat unit)
cPoise	Centipoise (viscosity unit)
CPU	Central Processing Unit
CTS	Clear-to-Send; the RS-232C handshaking signal input to a transmitter indicating that it is okay to transmit data — i.e., the corresponding receiver is ready to receive data. Generally, the Request-To-Send (RTS) output from a receiver is input to the Clear-To-Send (CTS) input of a transmitter.
DAC	Digital-to-Analog Converter
DFI	Diagnostics and Frequency Interface (board)
dm	Decimeter (10^{-1} meters, length unit)
EEPROM	Electrically-Erasable, Programmable Read-Only Memory
ft	Feet (length unit)
g-mol	Gram mole
Host processor	CPU Board Host processor
hr	Hour (time unit)

Acronym or Abbreviation	Definition
Hz	Hertz (cycles per second, frequency unit)
I/O	Input/Output
K	Kelvin (temperature unit)
kg	Kilogram (mass unit)
kg-mol	Kilogram mole
kHz	Kilohertz (10^3 cycles per second, frequency unit)
kJ	Kilojoule (10^3 joules, heat unit)
lbm	Pound mass
lbm-mol	Pound mass mole
m	Meter (length unit)
mA	Milliamp (current unit)
MPa	Megapascal (equivalent to 10^6 Pascal) (pressure unit)
NOVRAM	Non-Volatile Random Access Memory
Pa	Pascal, equivalent to 1 newton per square meter (pressure unit)
Pa·s	Pascal Second (viscosity unit)
PC	Personal Computer
PFC	Peripheral Field Connection (board)
PN	Part Number
ppm	Parts Per Million
PS	Power Supply (board)
psi	Pounds per Square Inch (pressure unit)
psia	Pounds per Square Inch Absolute (pressure unit)
psig	Pounds per Square Inch Gage (pressure unit)
RAM	Random Access Memory
RTS	Request-to-Send; the RS-232C handshaking signal output by a receiver when it is ready to receive data

Acronym or Abbreviation	Definition
RTU MODBUS	A Modbus protocol framing format in which elapsed time between received characters is used to separate messages. RTU stands for Remote Terminal Unit.
s	Second (time unit, metric)
sec	Second (time unit, U.S. Customary)
USM	Ultrasonic Gas Flow Meter
V	Volts (electric potential unit)

1.3 REFERENCES

[1] *Gould Modbus Protocol Reference Guide*, Rev. B, PI-MBUS-300

[2] *Measurement of Fuel Gas By Turbine Meters*, American Gas Association, Transmission Measurement Committee Report No. 7, Second Revision, April 1996 (also referred to as AGA7)

[3] *Compressibility Factors of Natural Gas and Other Related Hydrocarbon Gases*, American Gas Association, Transmission Measurement Committee Report No. 8, Second Edition, Second Printing, July, 1994 (also referred to as AGA8)

[4] *Manual of Petroleum Measurement Standards*, Chapter 21 – Flow Measurement Using Electronic Metering Systems, Section 1 – Electronic Gas Measurement, American Gas Association and American Petroleum Institute, First Edition, September, 1993

PRODUCT OVERVIEW

2.1 DESCRIPTION

The Daniel SeniorSonic™ - Model 3400 has four measurement paths to accurately determine the flow of gas, especially natural gas, to custody transfer standards. Computer simulations of various gas velocity profiles demonstrate that four-path measurements provide an optimum solution for measuring asymmetric flow. An array of eight ultrasonic transducers are placed at angles across the bore of the unit to measure sound travel times in four parallel planes. Sound transit times are measured with and against the flow through the meter. Since the travel time with the flow is less than that against the flow, and the transducer locations are a known constant, the mean velocity of the gas can be calculated by appropriately averaging the measurements from each plane. The symmetry of the system provides bi-directional capability.

The Daniel JuniorSonic™ Meters (Model 3410 Single Path and Model 3420 Dual Path) measure the transit times of ultrasonic waves passing through the flowing gas in a pipeline to determine the average velocity of the gas movement. Both meters have measurement paths angled with respect to the pipe axis and incorporate two bi-directional transducers per path. The transducers act alternately as transmitters or receivers permitting the upstream and downstream transit times to be measured. Since the path lengths and angles are known, and since the electronic characteristics of the transducer pairs can be measured, the transit time measurements contain all of the information necessary to determine the velocity of the moving gas along the measurement paths. The dual-path version provides an extra center-path measurement. See Section 4.1.6 and see Section 5.5.6 for Reynolds correction information.

Advantages and features of the SeniorSonic™ Model 3400 include:

- field-proven reliability for dry gas
- easy installation
- little or no maintenance
- no moving parts requiring lubrication

- no flow obstruction to cause pressure drop
- dry calibration requiring no flow calibration
- a large flow range
- velocity measurement unaffected by gas properties
- bi-directional flow measurement
- digital waveform sampling
- digital signal processing
- self diagnostics to insure proper performance

The JuniorSonic™ Models 3410 and 3420 have all of the advantages of the SeniorSonic™ Model 3400 noted above, but are less accurate and are somewhat flow-profile sensitive. Since the JuniorSonic™ Meters use centerline paths, a flow profile correction factor (sometimes called a Reynold's Number) is needed to reduce the value of the measured velocity to the correct average for the cross-sectional area. This can be accomplished by either using a fixed value, or more accurately by measuring pressure and temperature, and then applying an active correction to the measured transit times. Once the corrected mean velocity is determined, the flow rate is calculated by multiplying the average velocity by the cross-sectional area of the pipe.

The Ultrasonic Meter can use measured or specified flow condition temperature and pressure values for use in velocity profile-effect correction (for single-path and dual-path meters) and for volumetric flow rate conversion to a user-specified base temperature/pressure condition.

Beginning with firmware version 3.00, the DFI adds event and data logging capability compliant with the *Manual of Petroleum Measurement Standards*, Chapter 21 (ref. [4]).

Adding the event and data logging requires only a firmware upgrade. The DFI electronics already contain all the necessary components for event and data logging.

The following sections describe general specifications for the DFI accessory to the USM.

2.2 COMPONENT PARTS

The Daniel Ultrasonic Gas Flow Meters are available in various configurations to meet a broad range of customer requirements. Each unit comes fully assembled from Daniel.

2.2.1 Main Electronics Assembly

Explosion-proof housing that is divided into two compartments containing the following electronic assemblies (see Figure 2-1):

- a DFI Board, CPU Board, Power Supply Board, and Intrinsically safe Interface Board in the first compartment
- a Field Connection Board and Peripheral Field Connection Board for making electrical connections in the second compartment

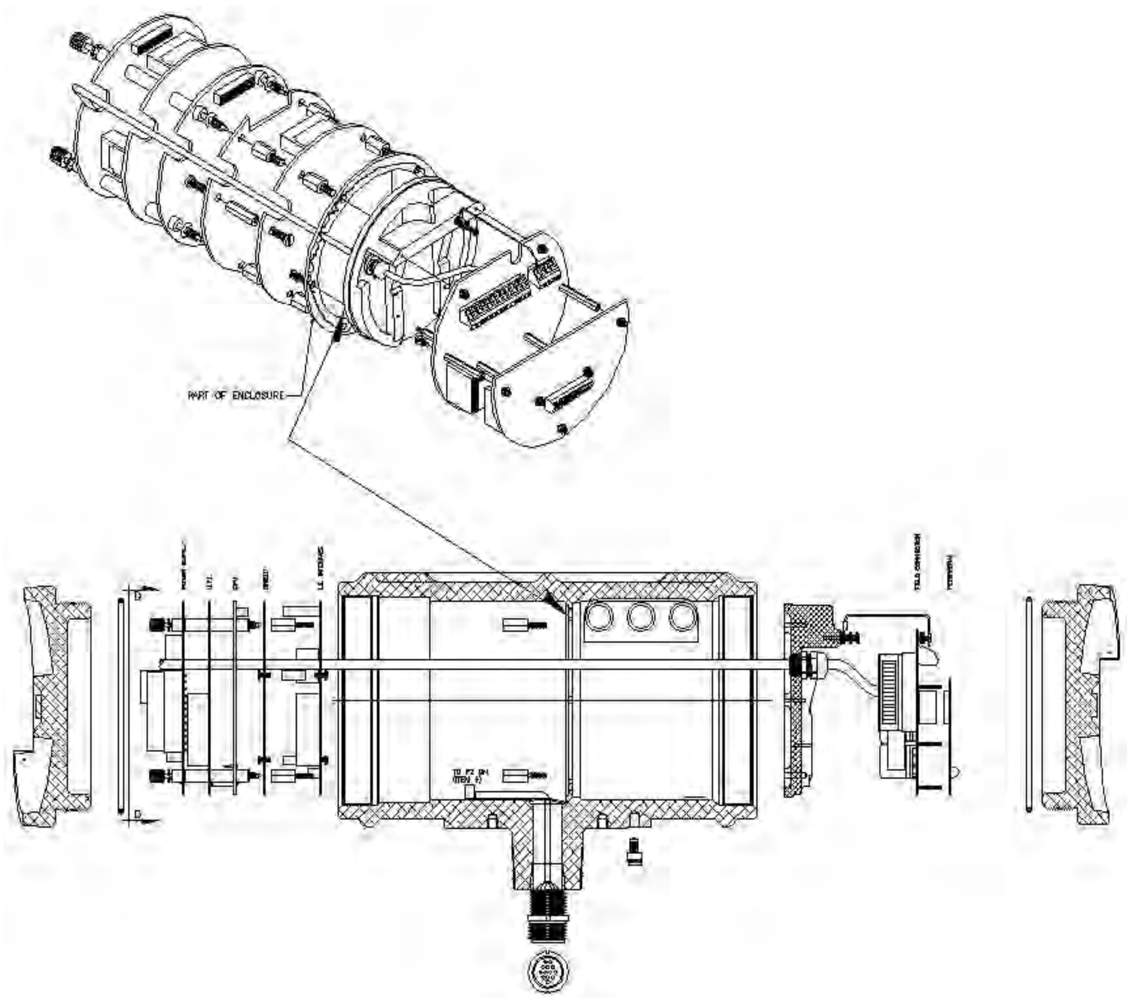


Figure 2-1 Main Electronics Assembly

2.2.2 Model 3400 SeniorSonic^{TM} Meter Housing

See Figure 2-2

- Serves as the patented core of the unit
- Features the multipath, acoustic-signal scheme measuring travel time on four parallel planes for sampling and measuring gas flow under asymmetric and swirl conditions
- Has "port" connections for mounting the unit's ultrasonic transducers

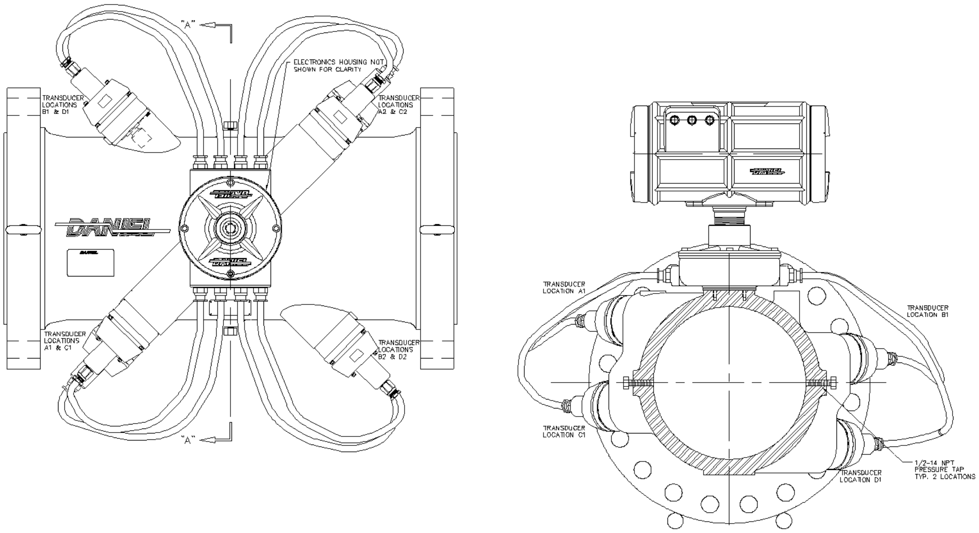


Figure 2-2 Model 3400 Meter SeniorSonic^{TM} Meter Housing

2.2.3 Model 3410 Single Path JuniorSonic^{TM} Meter Housing

See Figure 2-3

- Serves as the core of the unit
- Features a single-path, on one center chord, acoustic-signal scheme measuring travel time on one plane for sampling and measuring gas flow
- Has "port" connections for mounting the unit's ultrasonic transducers
- Chord is located to allow natural drainage under wet gas conditions

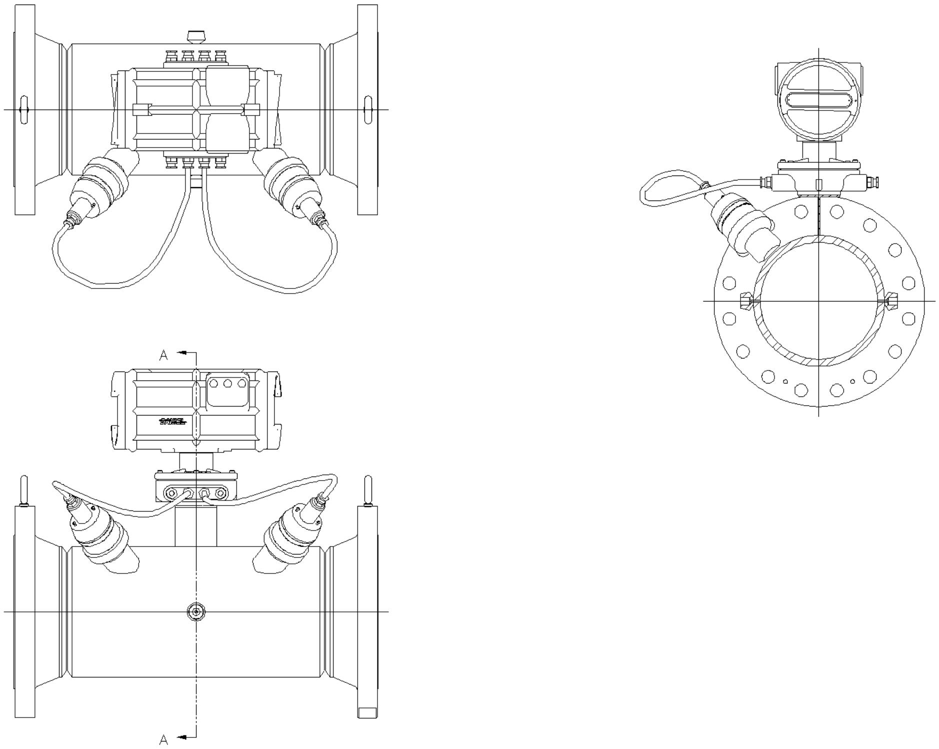


Figure 2-3 Model 3410 Single Path JuniorSonic^{TM} Meter Housing

2.2.4 Model 3420 Dual Path JuniorSonic™ Meter Housing

See Figure 2-4

- Serves as the core of the unit
- Features a dual-path, on two center chords - 90 degrees apart, acoustic-signal scheme measuring travel time for sampling and measuring gas flow
- Has "port" connections for mounting the unit's ultrasonic transducers
- Chords are arranged to allow natural drainage under wet gas conditions

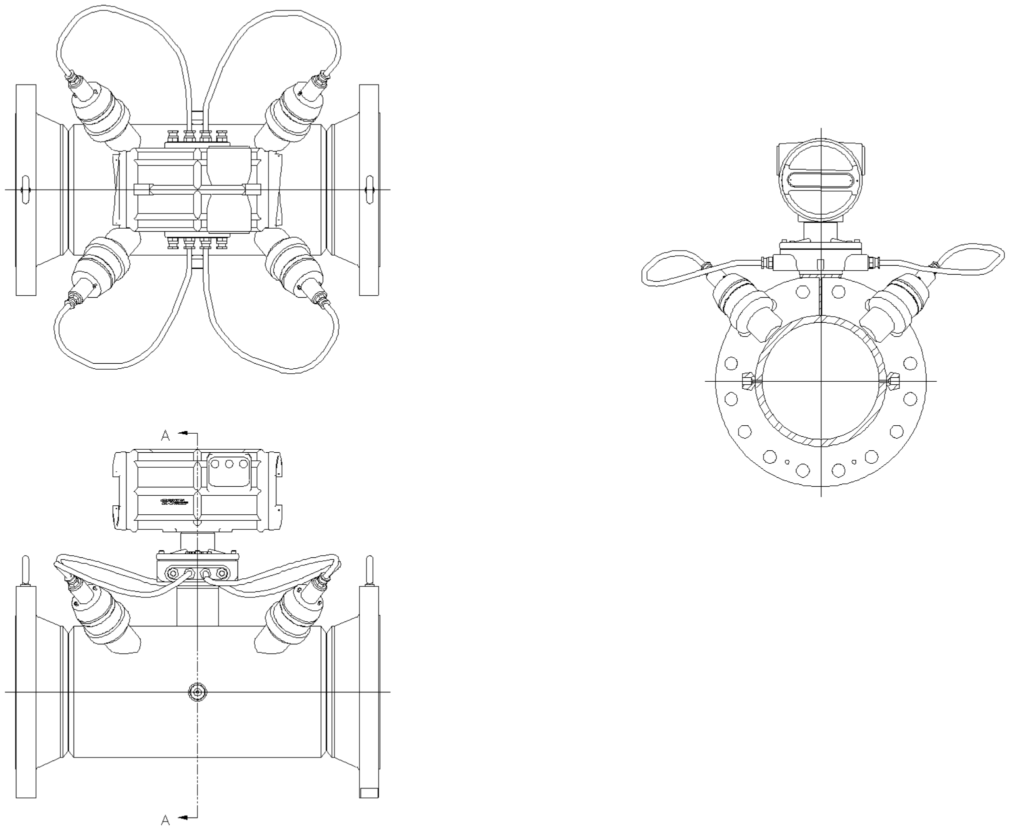


Figure 2-4 Model 3420 Dual Path JuniorSonic™ Meter Housing

2.2.5 Ultrasonic Base Unit

See Figure 2-5

- Connects the main electronics assembly to the Meter Housing
- Provides housing for the intrinsically-safe Driver/Preamp Board which excites transducers in the transmit mode and pre amplifies signals from transducers in the receive mode.

Note that the base unit is the same for the SeniorSonic™ Meter and both JuniorSonic™ Meters with the exception of the number of transducer connection ports. The SeniorSonic™ has eight, the Single Path JuniorSonic™ has two and the Dual Path JuniorSonic™ has four.

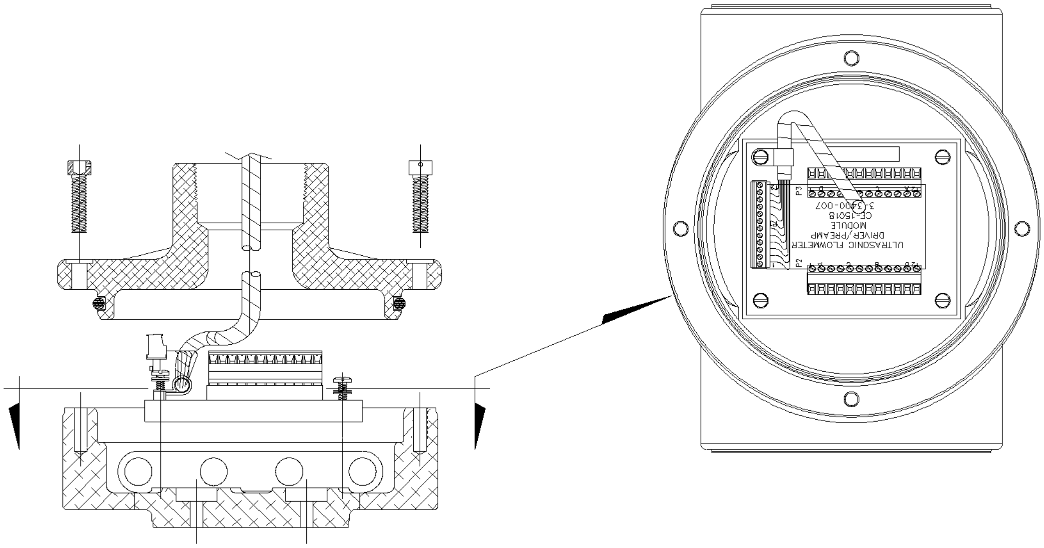


Figure 2-5 Ultrasonic Base Unit

2.2.6 Transducers and Cabling

The standard transducers are designated the T-11, T-12 and T-17. The T-11 is a direct replacement for the older T-2 transducers. The T-12 is a small diameter version of the T-11, suitable for small meters such as a 4-inch meter, as well as the 8 inch, 10 inch and 12 inch 60° SeniorSonic ™ meters.

The T-17 is a transducer which is a combination of a T-12 transducer and a transducer holder that provides high corrsion resistance. It is available in 8 inch, 10 inch and 12 inch ANSI 300/600 60° SeniorSonic ™ meters.

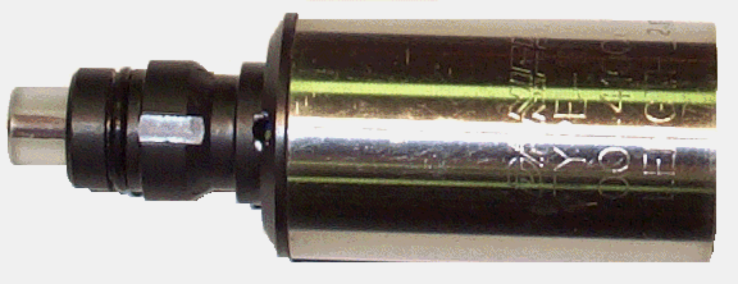


Figure 2-6 T-11 Transducer

Figure 2-7 T-12 Transducer

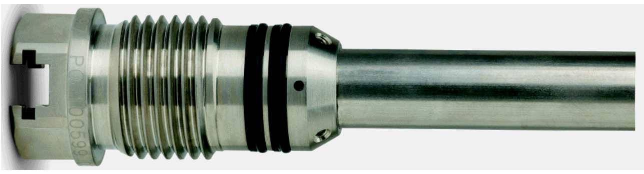


Figure 2-8 T-17 Transducer

Table 2-1 Transducer Connection Ports and Transducers

Model	Meter	Ports	Transducers
3400	SeniorSonic^{TM}	8	8
3410	(Single-Path) JuniorSonic^{TM}	2	2
3420	(Dual-Path) JuniorSonic^{TM}	4	4
3422	SeniorSonic^{TM} with half-radius chords	8	8

2.3 GENERAL UNIT SPECIFICATIONS

The following section describes general specifications for all Daniel Ultrasonic Gas Flow Meters.

2.3.1 The Application

The application is for high-pressure gases. Minimum operating pressure is typically 10 bar (150 psi).

2.3.2 Available Sizes

For the SeniorSonic Meters the nominal pipe sizes for the meter housings include 100 mm to 900 mm (4" - 36"). The JuniorSonic Meters can be configured for pipe sizes from 100 mm to 600 mm (4" - 24").

Daniel should be consulted for larger pipe size availability.

2.3.3 Pressure Range

In accordance with ANSI B16.5, the meter housings are available in ANSI Pressure Classes 300, 600, 900 and 1500.

Daniel should be consulted for higher pressures.

2.3.4 Flow Range Limits

The following tables, Table 2-2, Table 2-3, Table 2-4, Table 2-5, and the following figures, Figure 2-9, Figure 2-10, Figure 2-11, Figure 2-12, can be used to indicate flow range at reference conditions for SeniorSonic™ Meters of 100 mm to 900 mm (4" to 36").

Daniel should be consulted before establishing the actual meter capacity for a particular application.

The meter capacity at reference (base) conditions of pressure and temperature may be calculated using the following formula (see Equation 2-1):

$$Q_{ref} = Q_f \frac{P_f T_{ref} Z_{ref}}{P_{ref} T_f Z_f}$$

Equation 2-1 Meter Capacity - Reference Conditions of Pressure and Temperature

Where

Qref = flow rate at reference conditions (Nm3/h, Scfh)

Pref = absolute pressure at reference conditions (Pa; psia)

Tref = absolute temperature at reference conditions (K; R)

Qf = low rate at operating conditions (m3/h, cfh)

Pf = absolute pressure at flowing conditions (Pa; psia)

Tf = absolute temperature at flowing conditions (K; R)

Zf = compressibility of gas at flowing conditions

Zref = compressibility of gas at reference conditions

Table 2-2 SeniorSonic^{TM} Minimum Flow Rates Schedule 40 Bore

Press.	4"	6"	8"	10"	12"	16"	20"	24"	30"	36"
100	0.18	0.40	0.70	1.10	1.57	2.47	3.89	5.62	9.08	13.07
200	0.34	0.77	1.33	2.09	2.97	4.69	7.38	10.67	17.23	24.82
300	0.50	1.14	1.98	3.11	4.42	6.98	10.97	15.87	25.63	36.91
400	0.67	1.52	2.64	4.16	5.91	9.33	14.67	21.22	34.27	49.34
500	0.84	1.92	3.33	5.24	7.44	11.75	18.48	26.72	43.15	62.14
600	1.02	2.33	4.03	6.35	9.02	14.23	22.39	32.38	52.29	75.30
700	1.21	2.75	4.75	7.49	10.64	16.79	26.41	38.20	61.69	88.83
800	1.40	3.17	5.50	8.67	12.30	19.42	30.54	44.17	71.33	102.72
900	1.59	3.61	6.26	9.87	14.01	22.11	34.78	50.30	81.23	116.97
1000	1.79	4.07	7.04	11.10	15.75	24.87	39.11	56.57	91.35	131.54
1100	1.99	4.53	7.84	12.36	17.54	27.68	43.54	62.98	101.70	146.45
1200	2.20	5.00	8.65	13.64	19.36	30.56	48.06	69.52	112.26	161.66
1300	2.41	5.47	9.48	14.94	21.21	33.48	52.66	76.16	122.99	177.11
1400	2.62	5.96	10.32	16.26	23.08	36.44	57.31	82.89	133.86	192.76
1500	2.83	6.45	11.16	17.60	24.98	39.43	62.02	89.70	144.85	208.59
1600	3.05	6.94	12.01	18.94	26.88	42.44	66.74	96.53	155.89	224.48
1700	3.27	7.43	12.87	20.29	28.79	45.45	71.49	103.40	166.97	240.44
1800	3.48	7.92	13.72	21.63	30.69	48.45	76.21	110.23	178.00	256.32
1900	3.70	8.41	14.56	22.96	32.58	51.44	80.91	117.02	188.98	272.13
2000	3.91	8.89	15.40	24.28	34.45	54.39	85.55	123.73	199.81	287.73

Flow rates are based upon 3fps

Table 2-3 SeniorSonic^{TM} Maximum Flow Rates Schedule 40 Bore

Pressure	4" 100'/s	6" 100'/s	8" 100'/s	10" 90'/s	12" 90'/s	16" 85'/s	20" 85'/s	24" 85's	30" 85'/s	36" 75'/3
100	5.92	13.46	23.32	33.08	46.95	70.01	110.11	159.26	257.18	326.76
200	11.24	25.56	44.27	62.81	89.14	132.92	209.06	302.37	488.28	620.41
300	16.71	38.02	65.83	93.41	132.57	197.67	310.90	449.67	726.16	922.65
400	22.34	50.83	88.02	124.89	177.25	264.29	415.69	601.23	970.90	1233.62
500	28.14	64.01	110.85	157.28	223.21	332.82	523.48	757.13	1222.66	1553.49
600	34.10	77.57	134.32	190.59	270.48	403.30	634.33	917.46	1481.58	1882.47
700	40.22	91.51	158.46	224.83	319.08	475.77	748.32	1082.32	1747.80	2220.74
800	46.51	105.81	183.23	259.98	368.96	550.15	865.30	1251.51	2021.03	2567.89
900	52.96	120.49	208.65	296.05	420.16	626.48	985.36	1425.16	2301.45	2924.19
1000	59.56	135.51	234.65	332.94	472.51	704.53	1108.13	1602.72	2588.19	3288.52
1100	66.31	150.87	261.25	370.68	526.07	784.40	1233.74	1784.40	2881.58	3661.30
1200	73.20	166.53	288.37	409.16	580.68	865.83	1361.82	1969.65	3180.72	4041.38
1300	80.19	182.45	315.93	448.27	636.19	948.59	1492.00	2157.93	3484.77	4427.70
1400	87.28	198.57	343.85	487.88	692.40	1032.41	1623.83	2348.60	3792.67	4818.92
1500	94.45	214.88	372.09	527.95	749.27	1117.20	1757.19	2541.49	4104.16	5214.70
1600	101.65	231.25	400.44	568.18	806.36	1202.33	1891.09	2735.15	4416.90	5612.06
1700	108.87	247.69	428.91	608.58	863.69	1287.81	2025.54	2929.61	4730.93	6011.06
1800	116.06	264.05	457.24	648.78	920.74	1372.88	2159.33	3123.12	5043.42	6408.12
1900	123.22	280.34	485.44	688.78	977.51	1457.53	2292.48	3315.69	5354.40	6803.24
2000	130.28	296.40	513.26	728.26	1033.54	1541.08	2423.89	3505.75	5661.33	7193.22

Flow rates are based upon 3fps

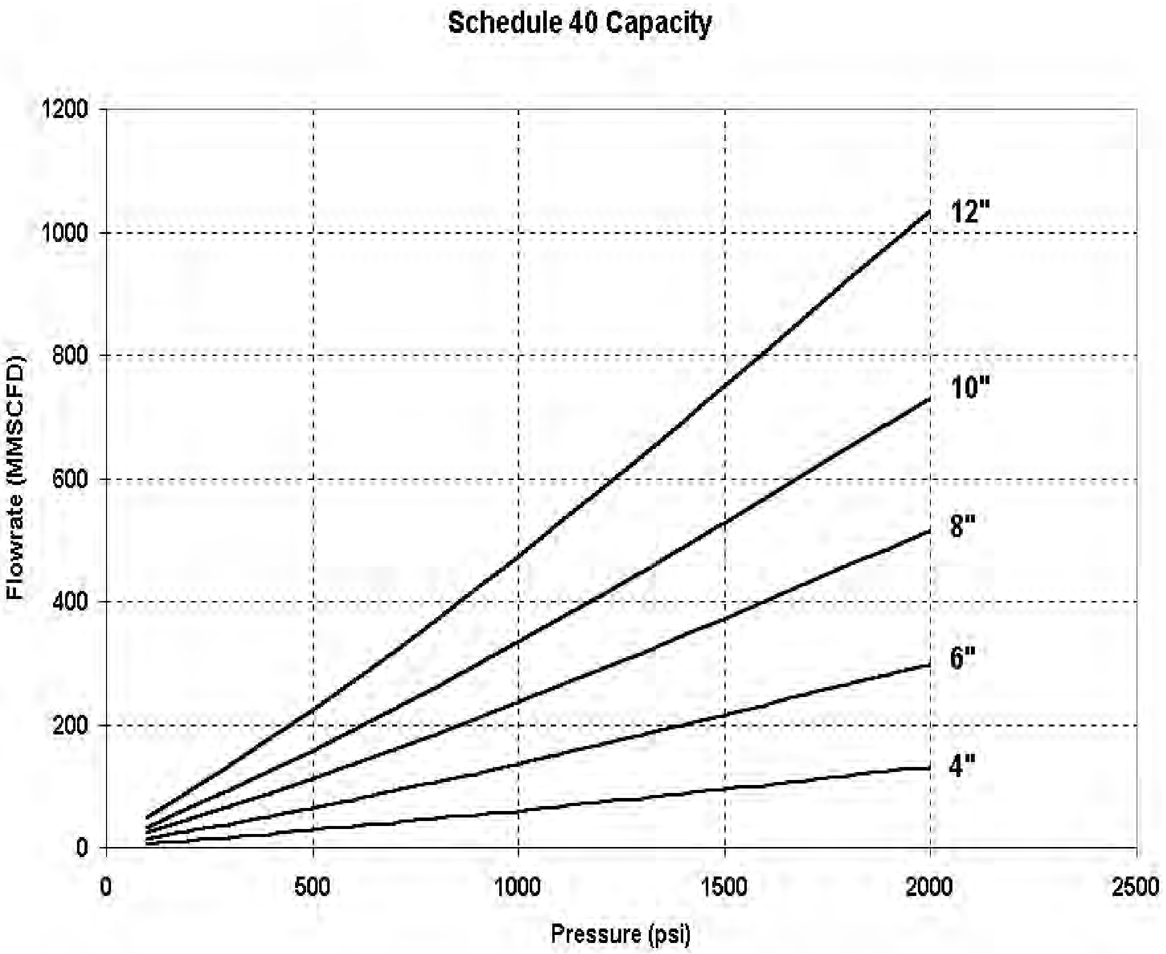


Figure 2-9 4"-12" SeniorSonic^{TM} Schedule 40 Graph

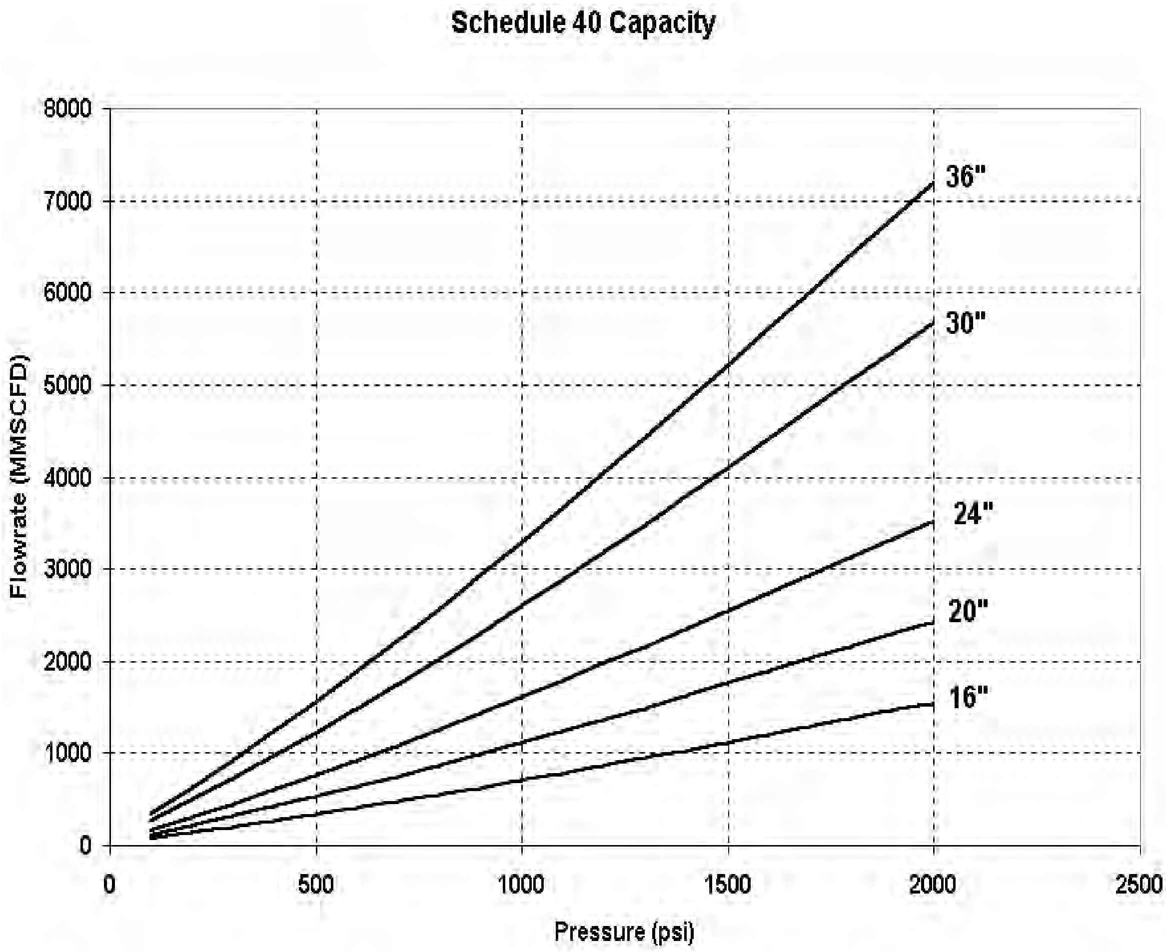


Figure 2-10 16”-36” SeniorSonic^{TM} Schedule 40 Graph

Table 2-4 SeniorSonic^{TM} *Minimum Flow Rate Schedule 80*

Pressure	4"	6"	8"	10"	12"	16"	20"	24"
100	0.16	0.36	0.64	1.00	1.42	2.25	3.53	5.11
200	0.31	0.69	1.21	1.91	2.70	4.27	6.71	9.69
300	0.45	1.03	1.80	2.84	4.01	6.35	9.98	14.42
400	0.61	1.38	2.41	3.79	5.36	8.49	13.34	19.27
500	0.76	1.73	3.04	4.77	6.75	10.69	16.80	24.27
600	0.93	2.10	3.68	5.78	8.18	12.96	20.36	29.41
700	1.09	2.48	4.34	6.82	9.65	15.29	24.01	34.70
800	1.26	2.86	5.02	7.89	11.16	17.68	27.77	40.12
900	1.44	3.26	5.71	8.99	12.71	20.13	31.62	45.69
1000	1.62	3.67	6.43	10.10	14.30	22.64	35.56	51.38
1100	1.80	4.08	7.15	11.25	15.92	25.20	39.59	57.21
1200	1.99	4.51	7.90	12.42	17.57	27.82	43.70	63.14
1300	2.18	4.94	8.65	13.60	19.25	30.48	47.88	69.18
1400	2.37	5.37	9.42	14.81	20.95	33.17	52.11	75.29
1500	2.57	5.82	10.19	16.02	22.67	35.90	56.39	81.48
1600	2.76	6.26	10.97	17.24	24.40	38.63	60.69	87.68
1700	2.96	6.70	11.74	18.47	26.13	41.38	65.00	93.92
1800	3.15	7.15	12.52	19.69	27.86	44.11	69.29	100.12
1900	3.35	7.59	13.29	20.90	29.58	46.83	73.57	106.30
2000	3.54	8.02	14.05	22.10	31.27	49.52	77.78	112.39

Flow rates are based upon 3fps

Table 2-5 SeniorSonic^{TM} Maximum Flow Rate Schedule 80

Pressure	4"	6"	8"	10"	12"	16"	20"	24"
100	5.36	12.15	21.28	30.12	42.62	63.73	100.12	144.65
200	10.17	23.07	40.41	57.19	80.92	121.00	190.08	274.65
300	15.13	34.30	60.09	85.05	120.34	179.95	282.69	408.45
400	20.23	45.86	80.35	113.72	160.90	240.60	377.96	546.11
500	25.47	57.76	101.18	143.20	202.62	302.99	475.97	687.71
600	30.87	69.99	122.61	173.53	245.53	367.15	576.76	833.35
700	36.42	82.56	144.64	204.71	289.65	433.13	680.40	983.09
800	42.11	95.47	167.25	236.71	334.92	500.84	786.76	1136.78
900	47.95	108.72	190.45	269.55	381.40	570.33	895.93	1294.51
1000	53.93	122.26	214.18	303.14	428.91	641.39	1007.55	1455.79
1100	60.04	136.12	238.46	337.50	477.53	714.09	1121.77	1620.81
1200	66.27	150.25	263.21	372.54	527.11	788.22	1238.22	1789.07
1300	72.61	164.62	288.38	408.15	577.49	863.57	1356.58	1960.09
1400	79.02	179.16	313.86	444.21	628.52	939.88	1476.45	2133.28
1500	85.51	193.88	339.63	480.70	680.14	1017.07	1597.71	2308.48
1600	92.03	208.65	365.51	517.32	731.97	1094.57	1719.45	2484.39
1700	98.57	223.48	391.50	554.10	784.01	1172.39	1841.70	2661.02
1800	105.08	238.25	417.36	590.71	835.80	1249.83	1963.35	2836.79
1900	111.56	252.94	443.09	627.13	887.33	1326.89	2084.41	3011.71
2000	117.95	267.44	468.49	663.08	938.19	1402.95	2203.89	3184.35

Flow rates are based upon 3fps

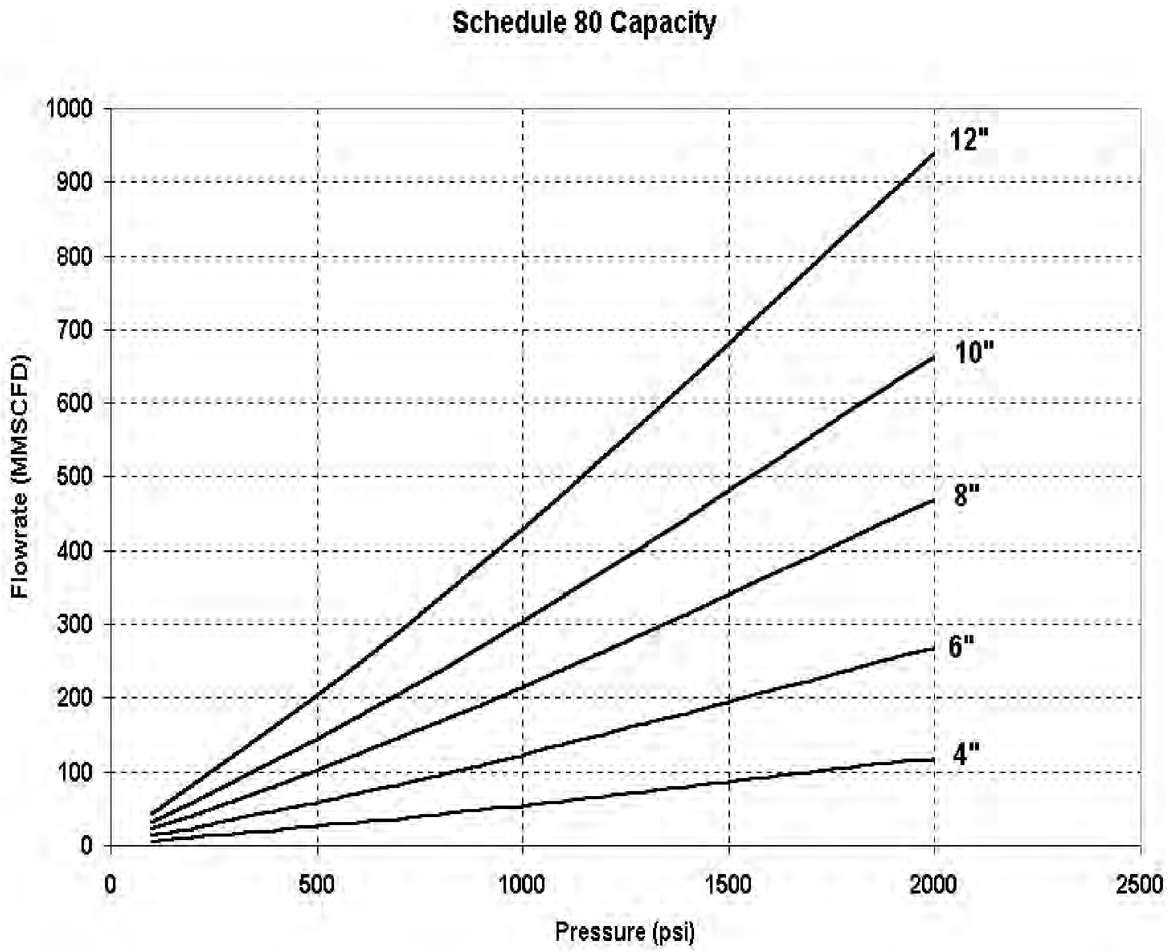


Figure 2-11 4"-12" SeniorSonic^{TM} *Schedule 80 Graph*

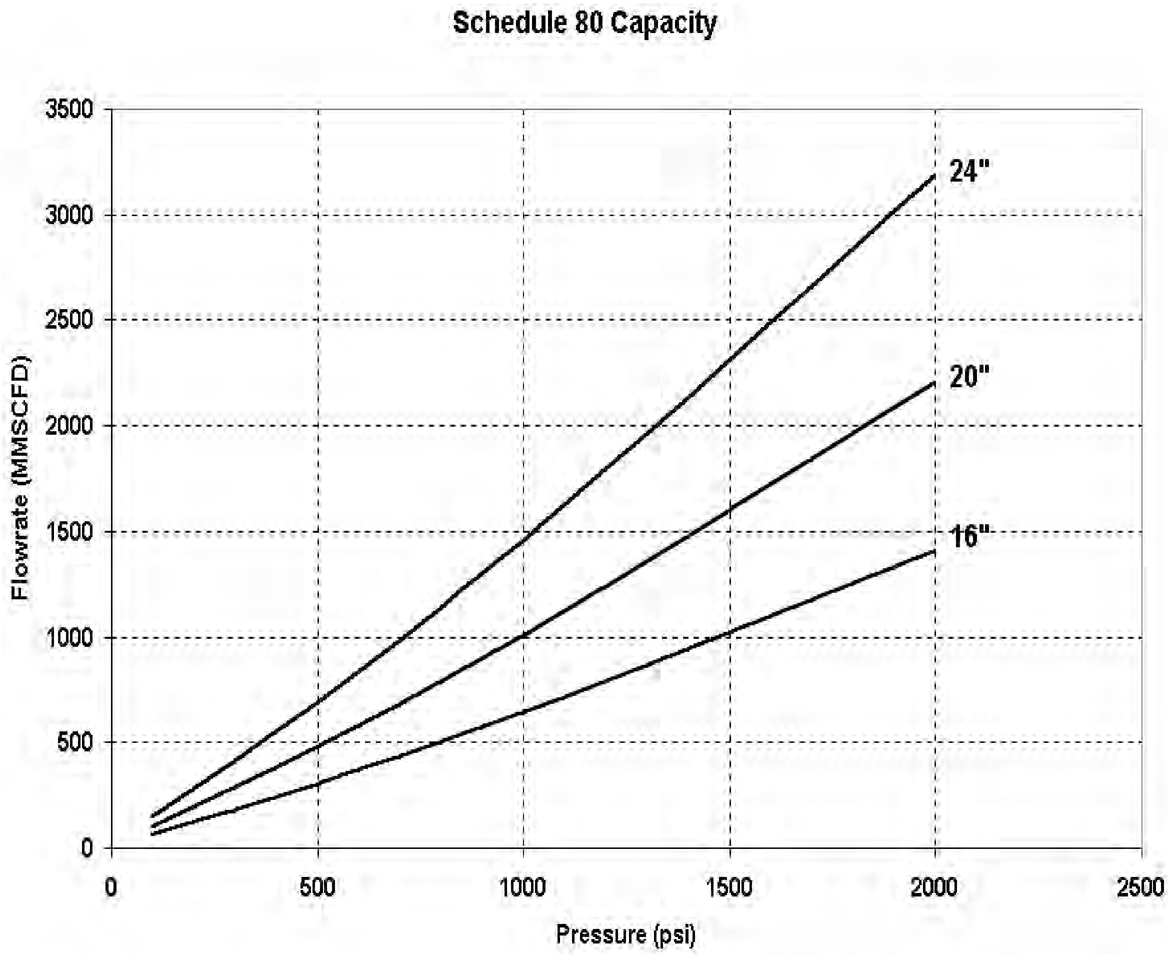


Figure 2-12 16”-24” SeniorSonic^{TM} Schedule 80 Graph

2.3.5 Flange Facing

The meter housings are available with raised face or ring-type joint flange facings. Consult Daniel Industries, Inc. for others.

2.3.6 Gas Temperature Range

The gas temperature ranges for the standard T-2 transducer, the T-11 transducer, the T-12 and T-17 transducer are as follows:

Standard T-2	-20° C to 55° C (-4° F to 131° F)
T-11	-20° C to +100° C (-4° F to 212° F)
T-12	-20° C to +100° C (-4° F to 212° F)
T-17	-20° C to +100° C (-4° F to 212° F)

Consult Daniel for higher temperature applications.

2.3.7 Repeatability

Repeatability precision is ±0.2% of reading in the specified velocity range.

2.3.8 Accuracy Limits

SeniorSonic™ accuracy limits are typically ±0.5% without a flow calibration. This accuracy can be certified at reference conditions with a flow calibration.

JuniorSonic™ accuracy limits are typically ±1% without a flow calibration.

2.4 ELECTRONIC SPECIFICATIONS

2.4.1 Power

The total power consumption for the UFM does not exceed 15 Watts, as supplied by AC (115/230 VAC ± 10%, 47 to 63 Hz) or DC (24 VDC ± 10%).

Unregulated, isolated power of 24 VDC at 50 mA is provided for temperature and pressure transmitters.

2.4.2 Analog Inputs

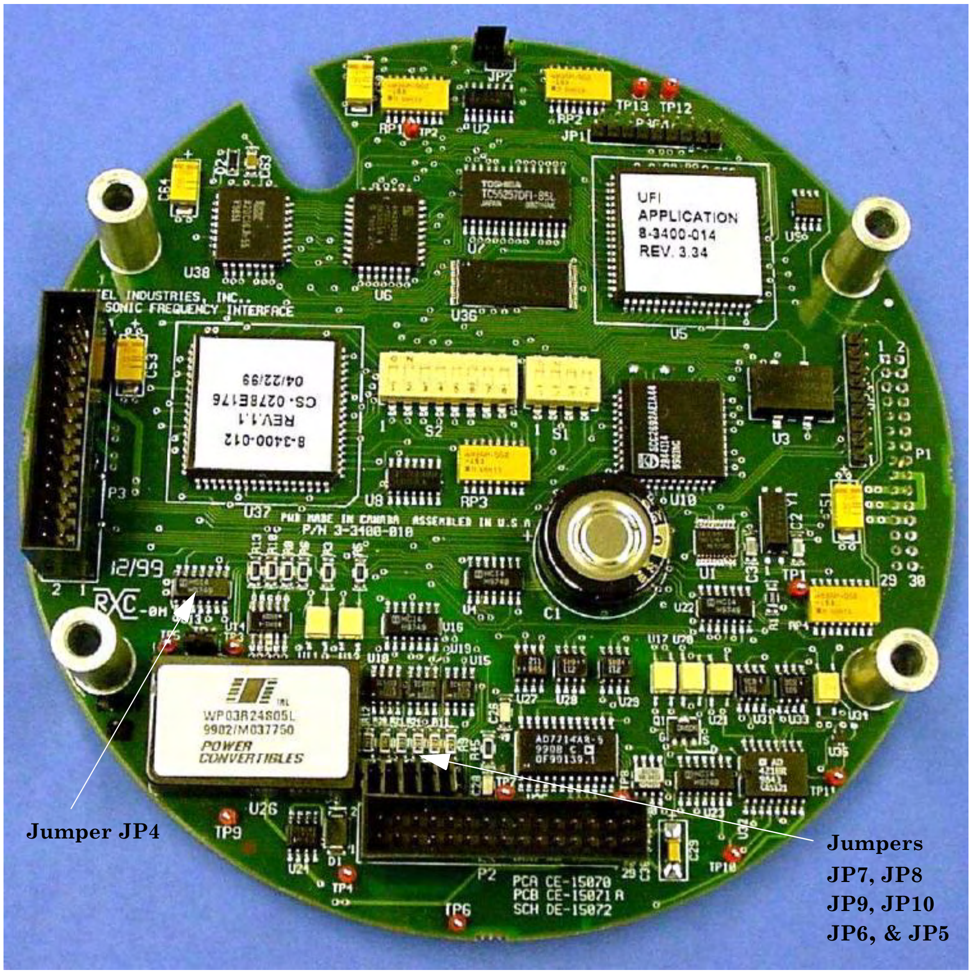
The DFI provides for one temperature analog input signal and one pressure analog input signal. The input range for each analog input is 4-20 mA or 1-5 V, depending on which Peripheral Field Connection (PFC) board is installed. The analog-to-digital accuracy is within ±0.05% of full scale over the operating temperature range.

2.4.3 Outputs

All outputs are opto-isolated from the main DFI board (with a withstand of at least 500 Volt rms dielectric).

2.4.4 Digital Outputs

There are two supported configurations for the digital output circuits: internally powered and “open collector”. Jumpers on the PFC board are used to set these configurations. DFI jumpers JP4, JP7, JP8, JP9, JP10, JP6, and JP5 (see Figure 2-13) should always be installed. Maximum cable length for the digital outputs should not exceed 2000 feet.



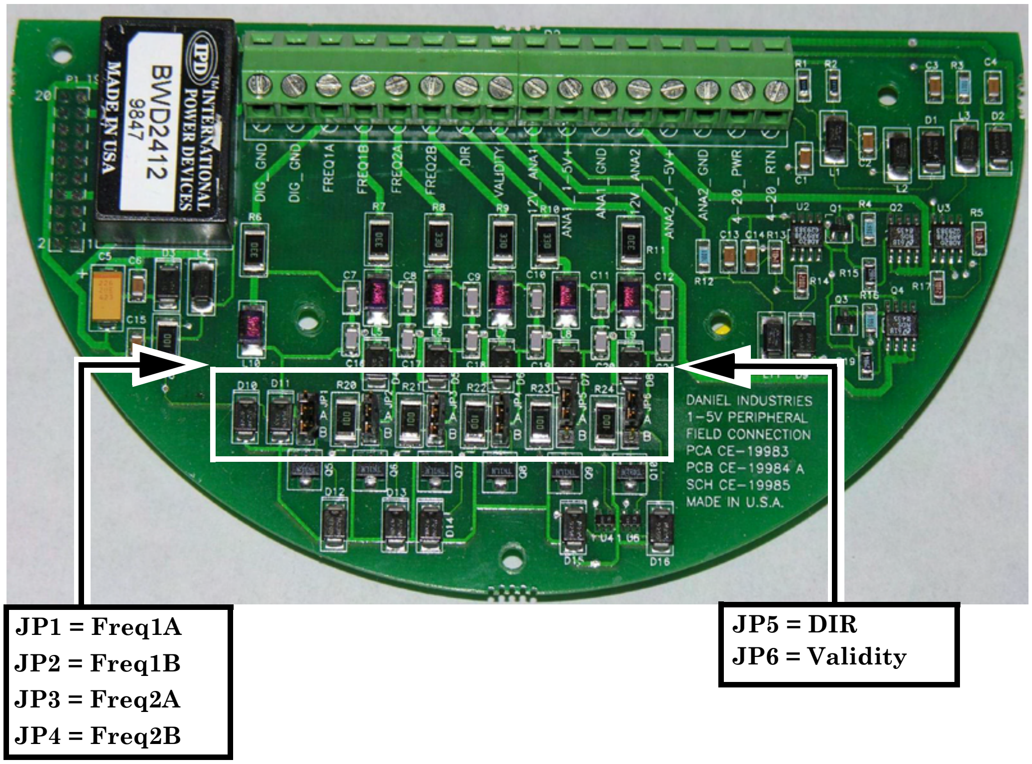
Jumper JP4

Jumpers
JP7, JP8
JP9, JP10
JP6, & JP5

Figure 2-13 DFI Board

Internally powered mode

Outputs are powered from an internal 5 VDC bus. Set PFC board jumpers JP5 and JP6 (see Figure 2-15) to the “A” position.



JP1 = Freq1A
JP2 = Freq1B
JP3 = Freq2A
JP4 = Freq2B

JP5 = DIR
JP6 = Validity

Figure 2-14 1-5V Peripheral Field Connection Bd. (PFC)

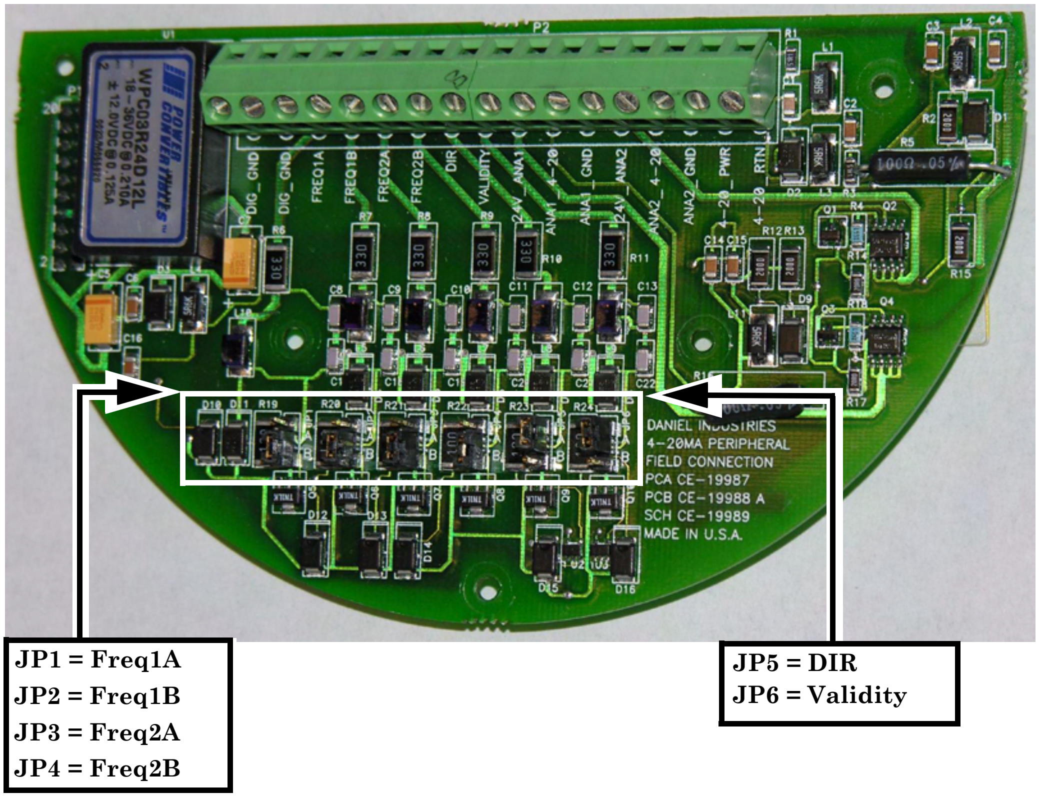


Figure 2-15 4-20 mA Peripheral Field Connection Bd. (PFC)

The digital output logic level voltage definition and drive capability are as follows: (see Table 2-6)

Table 2-6 Voltage Level and Drive Capability per Logic Level

Logic Value	Voltage Level	Drive Capability
0	< 0.7 V	maximum sinking current: 50 mA
1	> 3.5 V	maximum sourcing current: 50 mA

“Open Collector” mode

Applied input voltage on each line should not exceed 30 VDC. Set PFC board jumpers JP5 and JP6 to the “B” position. Maximum current sinking or sourcing must not exceed 50 mA.

2.4.5 Frequency Outputs

The range of the frequency outputs is user-selectable as either 0-1000 Hz or 0-5000 Hz. The worst case frequency output granularity is 3 Hz at 5000 Hz. The accuracy of the volume represented by the frequency outputs is within ±0.01%.

The output mode for the frequency output lines is set via jumpers on the PFC board. The maximum cable length is 2000 feet except when the “open collector” mode is selected. For that configuration with a pull-up resistor of 1K ohms the maximum length is 400 feet when 0-5000 Hz is set, or 1000 feet for 0-1000 Hz.

Internally powered mode

Outputs are powered from an internal 5 VDC bus. Set PFC board jumpers JP1, JP2, JP3, and JP4 to the “A” position. For the digital output logic level voltage definition and drive capabilities, see Table 2-7.

Table 2-7 Voltage Level and Drive Capability per Logic Level

Logic Value	Voltage Level	Drive Capability
0	< 0.7 V	maximum sinking current: 50 mA
1	> 3.5 V	maximum sourcing current: 50 mA

“Open Collector” mode

Applied input voltage on each line should not exceed 30 VDC. Set PFC board jumpers JP1, JP2, JP3, and JP4 to the “B” position. Maximum current sinking or sourcing must not exceed 50 mA.

2.4.6 Analog Output

The analog output is a 4-20 mA current output with a zero scale offset error within ±0.1% of full scale and a gain error within ±0.2% of full scale. The total output drift is within ±50 ppm of full scale per °C.

2.5 SAFETY

Suitable for use in Class 1, Division 1, Groups C and D hazardous locations.

Cenelec version is suitable for installation in a Zone 1 Gas Group 11B Temperature Class T4 Hazardous area as defined in BS EN 60079-10: 1996.

2.6 COMMUNICATIONS

The DFI provides two serial communication ports which are referred to as Port A and Port B. Port A is expected to be used for communication with a flow computer and Port B is expected to be used for diagnostic purposes (such as communicating with a personal computer running a utility program). Both ports are Modbus Slaves, neither is a Master.

The Modbus communication protocol, Modbus address, driver and baud rate are selectable via switches and jumpers; the selections are summarized in Table 2-8.

Table 2-8 DFI Serial Communication Outputs

	Port A	Port B
Communication Protocol	ASCII Modbus (7 data bits, even parity, 1 stop bit) or RTU Modbus (8 data bits, no parity, 1 stop bit) (selected protocol applies to both ports)	
Modbus Address	1 - 32 (selected Modbus Address applies to both ports)	
Driver‡	RS-232C (RTS/CTS handshaking optional) or RS-485 (can be multi-dropped)	RS-232C (no handshaking) or RS-485 (no multi-drop)
Baud Rate	1200, 2400, 4800, or 9600	2400 or 9600

‡ When Belden wire No.9940 or equivalent is used, the maximum cable length for the RS-232C communication cable is 88.3 meters (250 ft). and the maximum cable length for the RS-485 communication cable is 600 meters (1970 ft).

2.7 FCC COMPLIANCE

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

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INSTALLATION

3.0 INSTALLATION INSTRUCTIONS

⚠WARNING

DEATH OR SERIOUS INJURY MAY OCCUR

Hazardous Voltage Inside

Before installation of an Ultrasonic Flow Meter, all electrical power supplied to the unit should be switched OFF or disconnected.

There are two scenarios for installing a DFI:

- installing both a DFI and a USM
- installing the DFI as an add-on to an existing USM

Both scenarios are covered in this section.

⚠WARNING

DEATH OR SERIOUS INJURY MAY OCCUR

Hazardous Voltage Inside

Do not open in flammable gas area. Failure to follow the instructions in this manual may result in serious injury or death.

⚠WARNING

DEATH OR SERIOUS INJURY MAY OCCUR

Explosion Hazard

Do not disconnect equipment unless power has been removed or the area is known to be non-hazardous.

This section discusses the electronics configuration and mechanical installation of the meter.

3.1 USM LIFTING INSTRUCTIONS AND PRECAUTIONS

⚠WARNING

DEATH OR SERIOUS INJURY MAY OCCUR

Lifting Hazard

Read, Understand, and Follow all instructions contained in this section prior to lifting the Daniel Ultrasonic Meter.

⚠WARNING

DEATH OR SERIOUS INJURY MAY OCCUR

Lifting Daniel Ultrasonic Meter with Other Equipment

The following lifting instructions are for installation and removal of the Daniel Ultrasonic Meter ONLY. The instructions below do not address lifting the Daniel ultrasonic meter while it is attached, bolted, or welded to meter tubes, piping, or other fittings.

Using these instructions to maneuver the Daniel Ultrasonic Meter while it is still attached, bolted, or welded to a meter tube, piping, or other fitting may result in equipment damage, serious injury, or death.

The operator must refer to their appropriate company's hoisting and rigging standards, or the "DOE-STD-1090-2004 Hoisting and Rigging" standard if such company standards do not exist, for lifting and maneuvering any assembled meter tube and associated piping.

A Daniel Ultrasonic Meter can be safely lifted and maneuvered into and out of a meter run for installation or service by obeying the following instructions.

When lifting only a Daniel Ultrasonic Meter by itself, Daniel recommends two methods. These methods are;

1. Using an appropriately rated Safety Engineered Swivel Hoist Rings Installed in the Daniel Ultrasonic Meter end flanges (Refer to Section 3.1.1)
2. Using appropriately rated lifting slings positioned at designated areas of the Daniel Ultrasonic Meter (Refer to Section 3.1.2)

   Both methods must be used in conjunction with all appropriate company hoisting and rigging standards or the DOE-STD-1090-2004 HOISTING AND RIGGING standard if such company standards do not exist. Refer to the following sections for more information on these two methods.

⚠WARNING

DEATH OR SERIOUS INJURY MAY OCCUR

Lifting Hazard

Lifting Hazard for Daniel Ultrasonic meters with Original Equipment Eyebolts

For Daniel Ultrasonic meters with threaded eyebolts, the eyebolts may be safely used to lift the meter if ALL of the following conditions are met:

- They have been inspected and show no signs of corrosion, scarring, or damage (including bending)
- They have not been left in the meter after installation and exposed to the environment
- A spread bar is used during lifting to eliminate angular loading

If any of the conditions described above can not be met, the operator must remove, destroy, and discard the "Eye Bolt" immediately and use slings around meter body as outlined in these instructions in conjunction with company approved hoisting and rigging procedures or the **DOE-STD-1090-2004 HOISTING AND RIGGING** standard if such company standards do not exist.

3.1.1 Use of Appropriate Safety Engineered Swivel Hoist Rings in Ultrasonic Meter End Flanges

All Daniel Ultrasonic meters come equipped with a tapped hole located on the top of each meter body end flange. A flat machined surface surrounds each tapped hole (See Figure 3-1). This feature provides complete surface contact ONLY between the meter flange and an OSHA compliant Safety Engineered Swivel Hoist Ring as shown below (See Figure 3-2).

Operators SHALL NOT use Eye Bolts (see Figure 3-2) in the Daniel Ultrasonic Meter flange tapped holes to aid in lifting or maneuvering the unit.

Operators SHALL NOT use other Hoist Rings that do not fully seat flush with the counter bore on the top of the meter flanges.

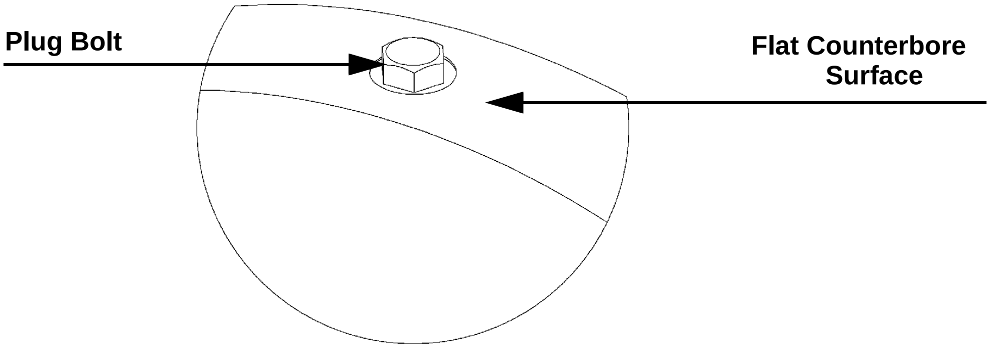
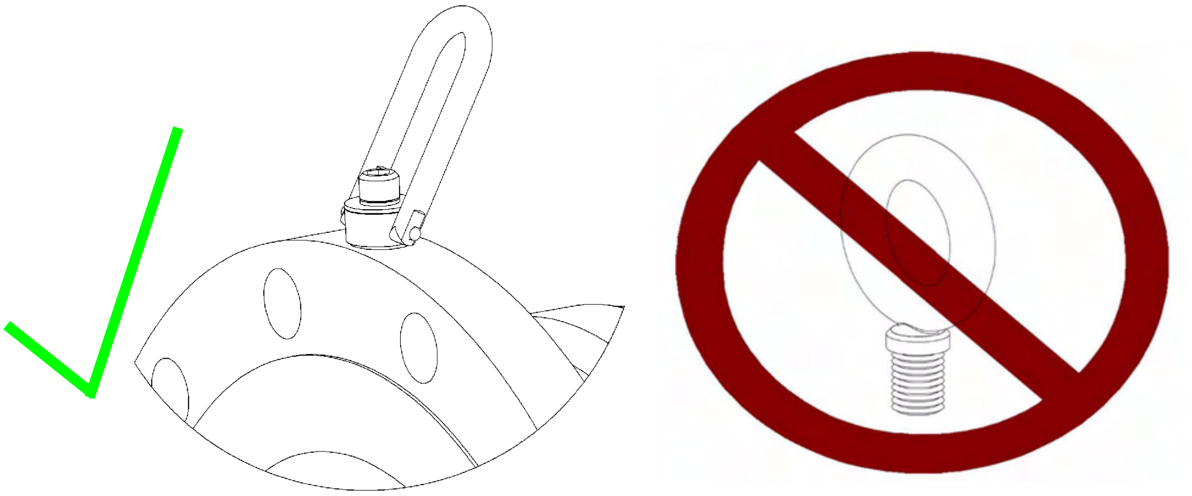


Figure 3-1 Meter End Flange with Tapped Flat-Counterbore Hole for Hoist Ring



Saftey Engineered Swivel Hoist Ring

Eye Bolt

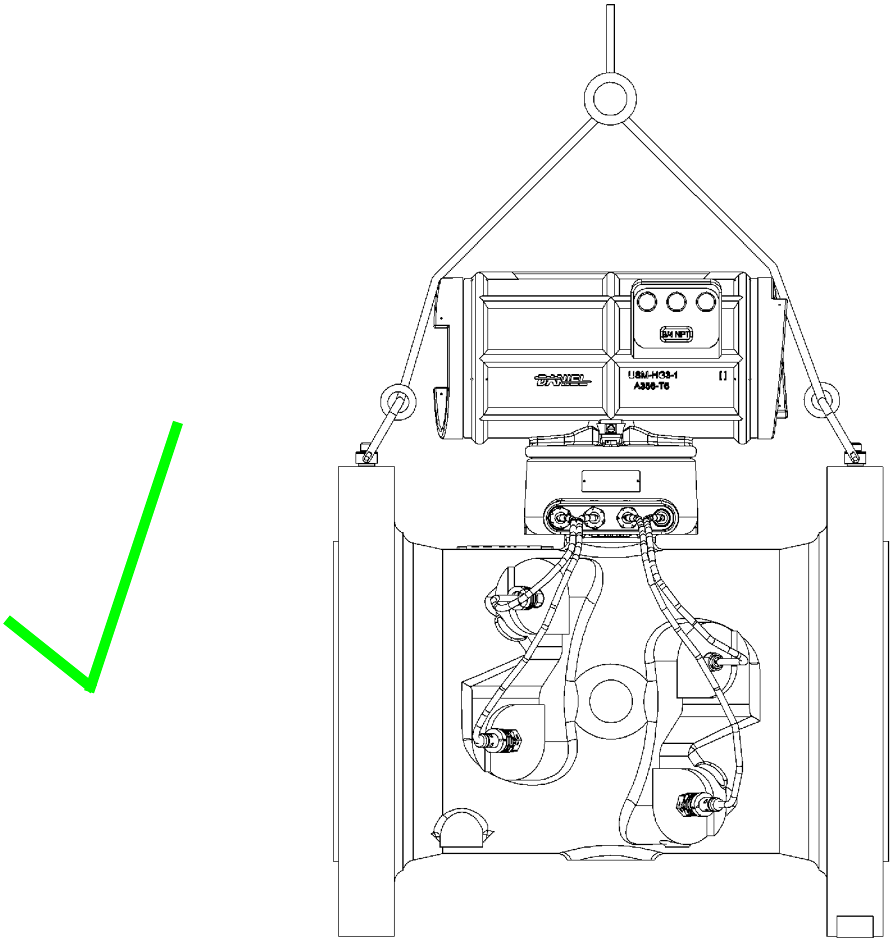
Figure 3-2 Safety Approved Hoist Ring and Non-Compliant Eye Bolt

Safety Precautions Using Safety Engineered Swivel Hoist Rings on Daniel Ultrasonic Meters

Read and follow the Safety Precautions listed below:

1. Meters must only be lifted by personnel properly trained in the safe practices of rigging and lifting.
2. Remove the plug bolts installed in the tapped holes on the top of the flanges. Do not discard the bolts as they must be reinstalled once the lifting operation is complete to prevent corrosion of the tapped holes.
3. Make sure the tapped holes on the meter are clean and free of debris before installing the hoist rings.
4. Use only the Safety Engineered Swivel Hoist Rings that are rated for lifting the meter. Do not use any other type of hoist rings with the same screw size or heavy duty hoist rings. The meter tapping and counter bore size are suitable only for the hoist rings specified by Daniel.

5. When installing a hoist ring, make sure the base surface of the hoist ring fully contacts the machined flat surface of the tapped hole. If the two surfaces do not come in contact then the hoist ring will not hold its full rated load. Torque the hoist ring attachment bolts to the limit indicated on the hoist rings.
6. After installation of the hoist rings, always check that the ring rotates and pivots freely in all directions.
7. NEVER attempt to lift the meter using only one hoist ring.
8. Always use separate slings to each hoist ring. NEVER reeve one sling through both hoist rings. The slings must be of equal length. Each sling must have a load rating that equals or exceeds the hoist ring load rating. The angle between the two slings going to the hoist rings must never exceed 90 degrees or the load rating of the hoist rings will be exceeded.



9. NEVER allow the slings to contact the electronics enclosure. Damage to the enclosure may occur. If the slings do come in contact with the electronic enclosure then remove the two bolts holding the enclosure to its base and temporarily remove the head from the meter during the lifting operation. You will need to unplug the cable from J3 on the Acquisition Module. Two screws hold this cable in place.

   Once the lifting operation is complete, reattach and secure the electronics cable to J3 on the Acquisition Module, return the electronics enclosure to its original position, replace the bolts, and secure the enclosure in place. Lifting the meter with the upper enclosure installed but with out the bolts installed, may cause the electronics to fall and cause personal injury or equipment damage.

10. NEVER apply shock loads to the meter. Always lift the meter gradually. If shock loading ever occurs, the hoist ring must be inspected per manufacturer's recommendations prior to be placed in any further service. If a proper inspection cannot be performed, discard the hoist ring.
11. NEVER lift with any device, such as hooks, chains, or cables that could create side pulls that could damage the ring of the hoist ring.

12. NEVER lift more than the ultrasonic meter assembly including electronics and transducers with the hoist rings. The only exception is that it is safe to lift the meter with one ASME B16.5 or ASME B16.47 blind flange bolted to each end flange of the meter. NEVER use the hoist rings on the meter to lift other components such as meter tubes, piping or fittings attached to the meter. Doing so will exceed the load rating of the hoist rings.
13. Remove the hoist rings from the meter after lifting is completed and store them in an appropriate case or container per their manufacturer's recommendation.
14. Apply heavy lubricant or anti-seize to the threads of the plug bolts and reinstall the plug bolts to keep the tapped holes free of debris and to prevent corrosion.

How to Obtain Safety Engineered Swivel Hoist Rings

The following is a list of manufacturers of approved safety engineered hoist rings:

- American Drill Bushing Company (www.americandrillbushing.com)
- Carr Lane Manufacturing Company (www.carrlane.com)

The following is a list of known suppliers that can supply these safety-engineered hoist rings. This is not intended to be a complete list.

- Fastenal (www.fastenal.com)
- Reid Tools (www.reidtool.com)

The appropriate hoist rings can also be purchased directly from Daniel. The following table provides part numbers for reference:

Daniel Part Number*	Hoist Ring Thread Size & Load rating	American Drill Bushing Co. P/N*	Carr Lane Manufacturing Co. P/N*
1-504-90-091	3/8"-16UNC, 1000 lb.	23053	CL-1000-SHR-1
1-504-90-092	1/2"-13UNC, 2500 lb	23301	CL-23301-SHR-1
1-504-90-093	3/4"-10UNC, 5000 lb.	23007	CL-5000-SHR-1
1-504-90-094	1"-8UNC, 10000 lb.	23105	CL-10000-SHR-1
1-504-90-095	1-1/2"-6UNC, 24000 lb.	23202	CL-24000-SHR-1

*** The part numbers include only one hoist ring. Two hoist rings are required per meter.**

What Size Safety Engineered Swivel Hoist Ring Do You Need

To determine the size of the hoist rings required for your meter, use the appropriate table below. Look down the column that matches the ANSI rating of your meter. Find the row that contains your meter size. Follow the row to the end to find the appropriate hoist ring part number.

*Table 3-1 Hoist Ring Lookup Table for Daniel Gas SeniorSonic^{TM} Meters**

ANSI 300	ANSI 600	ANSI 900	ANSI 1500	Daniel Part Number
4" to 10”	4" to 8”	4" to 8”	4" to 6”	1-504-90-091
12" to 18”	10" to 16”	10" to 12”	8" to 10”	1-504-90-092
20" to 24”	18" to 20”	16" to 20”	12”	1-504-90-093
30" to 36”	24" to 30”	24”	16" to 20”	1-504-90-094
	36”	30" to 36”	24" to 36”	1-504-90-095

***4" to 6" 45 degree meters and 8" to 36" 60 degree meters**

Table 3-2 Hoist Ring Lookup Table for Daniel Gas JuniorSonic^{TM} Meters

ANSI 300	ANSI 600	ANSI 900	ANSI 1500	Daniel Part Number
4" to 12”	"4"to 8”	4" to 8”	4" to 6”	1-504-90-091
16" to 18”	10" to 16”	10" to 12”	8" to 10”	1-504-90-092
20" to 30”	18" to 20”	16" to 20”	12”	1-504-90-093
36”	24" to 30”	24”	16" to 20”	1-504-90-094
	36”	30" to 36”	24" to 36”	1-504-90-095

3.1.2 Using Appropriately Rated Lifting Slings on Daniel Ultrasonic Meters

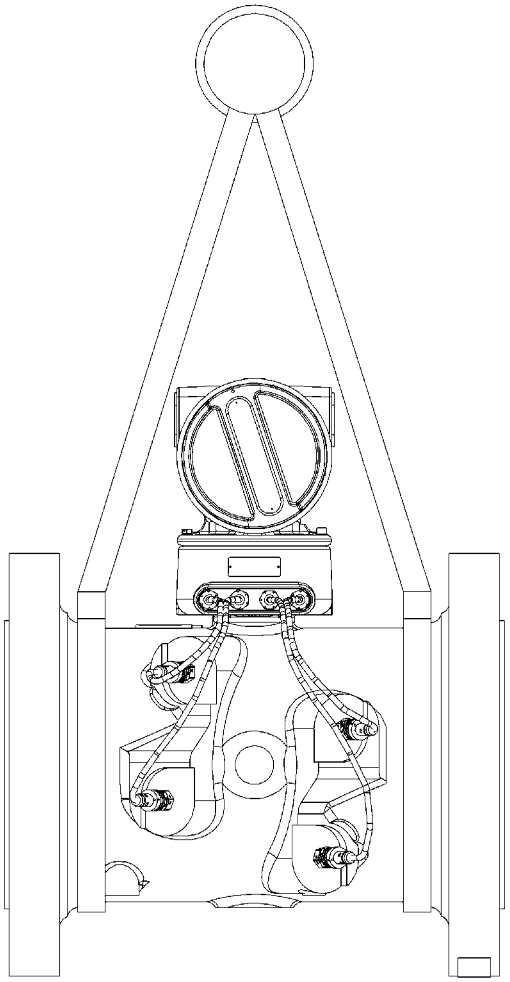
The following instructions are intended to provide general guidelines for proper slinging of a Daniel Ultrasonic meter by itself. They are intended to be followed in addition to your company's standards or the **DOE-STD-1090-2004 HOISTING AND RIGGING** standard if such company standards do not exist.

Safety Precautions Using Appropriate Rated Lifting Slings on Daniel Ultrasonic Meters

Read and follow the Safety Precautions listed below:

1. Meters must only be lifted by personnel properly trained in the safe practices of rigging and lifting.
2. NEVER attempt to lift the meter by wrapping slings around the electronics.

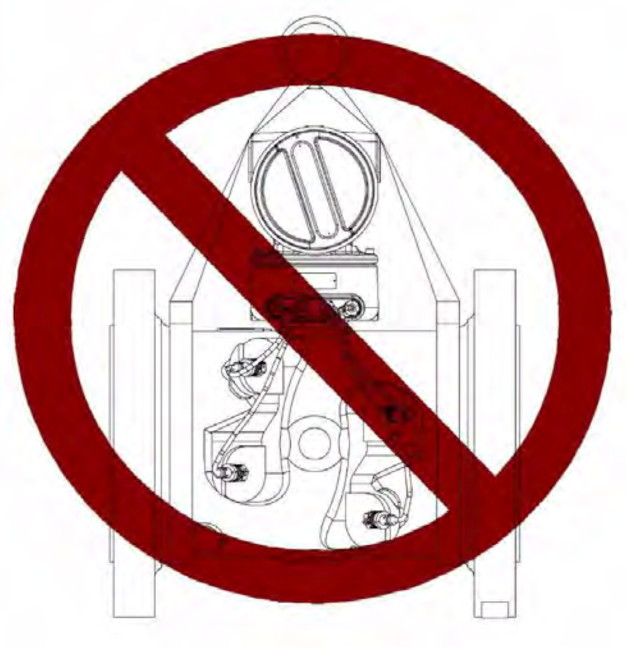
3. NEVER attempt to lift the meter using only one sling around the meter. Always use two slings wrapped around each end of the body as shown below. A choker style sling is recommended.



4. Visually inspect the slings prior to use for any signs of abrasion or other damage. Refer to the sling manufacturer's procedures for proper inspection of the particular sling you are using.
5. Only use slings with ratings that exceed the weight to be lifted. Reference your company's standards for safety factors that must be included when calculating the load rating.

6. NEVER allow the slings to contact the electronics enclosure or transducer cabling. Damage to the enclosure or cabling may occur. If the slings do come in contact with the electronic enclosure then remove the two bolts holding the enclosure to its base and temporarily remove the head from the meter during the lifting operation. You will need to unplug the cable from J3 on the Acquisition Module. Two screws hold this cable in place.

   Once the lifting operation is complete, reattach and secure the electronics cable to J3 on the Acquisition Module, return the electronics enclosure to its original position, replace the bolts, and secure the enclosure in place. Lifting the meter with the upper enclosure installed but with out the bolts installed, may cause the electronics to fall and cause personal injury or electronics damage.



7. NEVER apply shock loads to the meter. Always lift the meter gradually. If shock loading ever occurs, the slings must be inspected per manufacturer's procedures prior to being placed in any further service.

3.2 JUMPER AND SWITCH SETTINGS

Before beginning the mechanical installation, the various jumpers and switches should be set to their proper position while they are easily accessible.

3.2.1 USM Communication Settings

In order for the DFI to communicate with the USM Host processor on the CPU board, the following default settings must be used:

The CPU board must be configured to 9600 baud ASCII Modbus communication with Modbus Address 32 (all CPU board JP7 jumpers must be set to the “open” or “no jumper” position). See Section 5.3.3 for details on setting Host processor communication settings.

The USM firmware must be revision 5.62 or later for revision A CPU boards and revision 5.80 or later for revision B or later CPU boards in order to operate correctly with the DFI option.

For CPU switch and jumper settings see Figure 3-3.

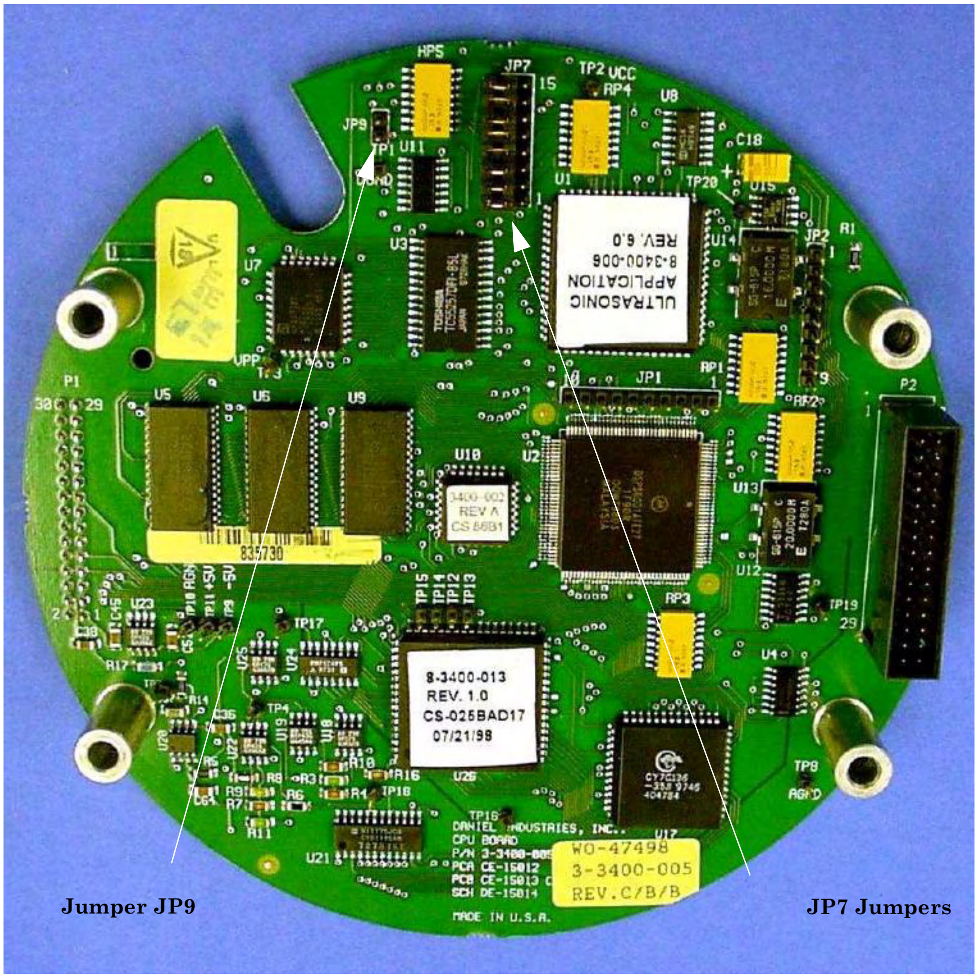


Figure 3-3 CPU Board Switch and Jumper Settings

3.2.2 DFI Communication Settings

The DFI external serial communication parameters are set via two banks of DIP switches on the DFI board, a sliding switch on the PFC board, and six jumpers on the PS board. The use of switches and jumpers (outlined in this section) was chosen so that the PFC and PS boards could be used as part of the USM whether or not the DFI option is used.

The two DFI board switch banks (see Figure 3-4) are identified as Switch Bank 1 (four switches) and Switch Bank 2 (eight switches). For both switch banks, a switch in the "ON" or upper position (as indicated on the switch) corresponds to a logic 0 and a switch in the lower ("OFF") position corresponds to a logic 1. See Figure 3-7 for the switch bank specifications.

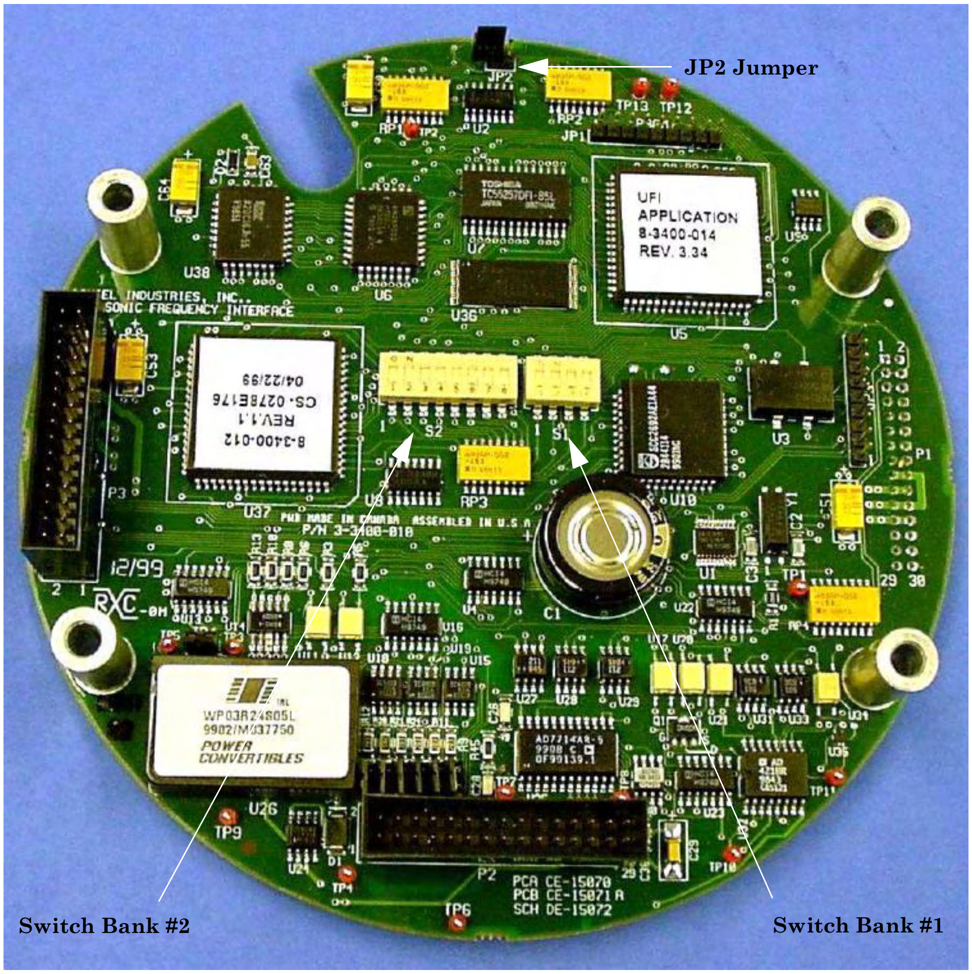


Figure 3-4 DFI Board Showing Switch Banks

Serial Communication Port Driver

The driver to be used for each serial communication port is selectable between RS-232C and RS-485 by using Field Connection board switch S1 (see Figure 3-5) and PS board jumpers JP1 through JP6. See Figure 3-6 and see Table 3-3 along with the wiring connections.

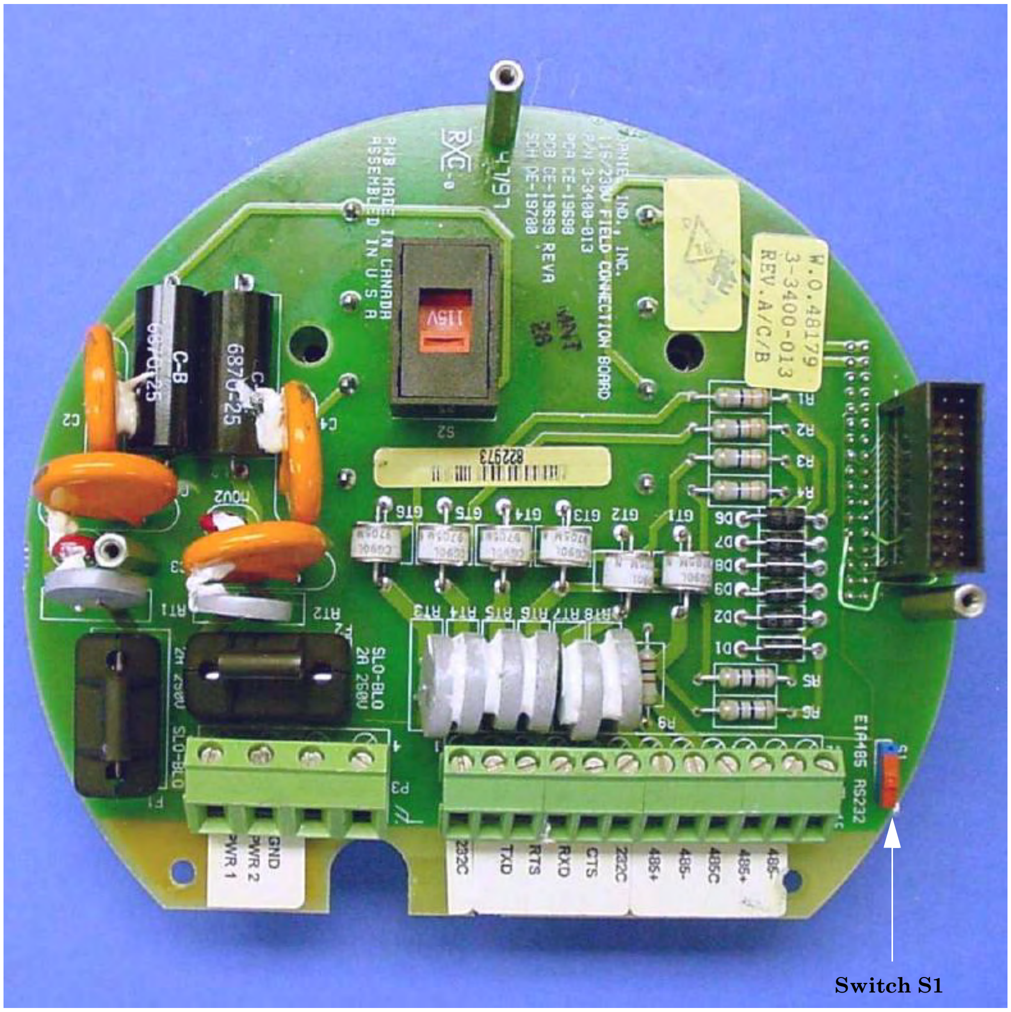


Figure 3-5 Field Connection Board Showing Switch S1

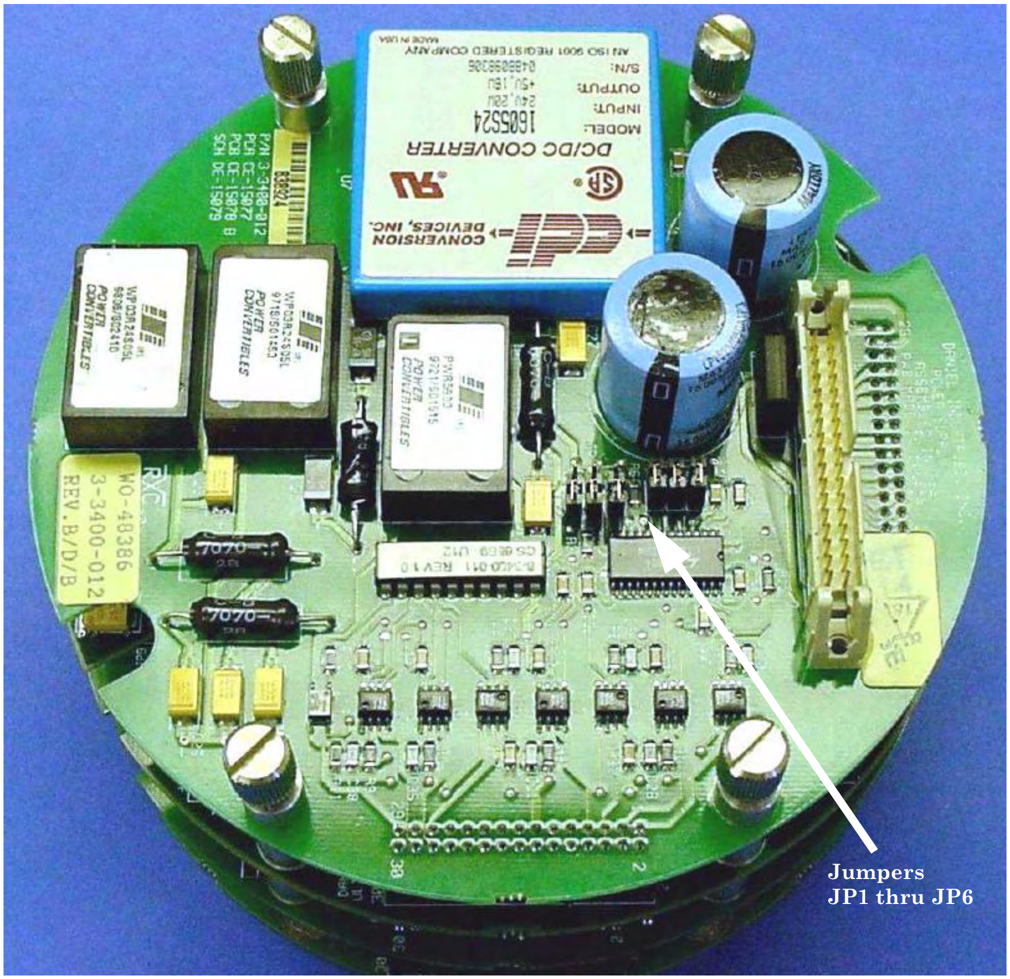


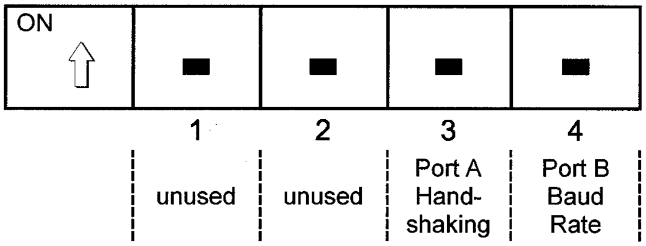
Figure 3-6 Power Supply Board Jumpers

Table 3-3 Serial Communication Port Driver Selection and Wiring

Port A driver	Port B driver	Port A Wiring Connections		Port B Wiring Connections		PFC Board	PS Board					
		Wire	Connector	Wire	Connector	S1	JP1	JP2	JP3	JP4	JP5	JP6
RS-485	RS-485	485+ 485- 485C	485+ 485- 485C	485+ 485- 485C	RTS RXD 232C	EIA485	closed	closed	closed	closed	closed	closed
RS-485	RS-232C	485+ 485- 485C	485+ 485- 485C	232TXD 232RXD 232C	TXD RXD 232C	EIA485	closed	closed	closed	open	open	open
RS-232C	RS-232C	232TXD 232RXD 232C 232RTS* 232CTS*	TXD RXD 232C RTS CTS	232TXD 232RXD 232C	485+ 485- 485C	RS232	open	open	open	open	open	open
RS-232C	RS-485	232TXD 232RXD 232C 232RTS* 232CTS*	TXD RXD 232C RTS CTS	485+ 485- 485C	485+ 485- 485C	RS232	closed	closed	closed	open	open	open

* RS-232C handshaking signals (RTS/CTS) are optional for Port A.

DFI Board Switch Bank S1



DFI Board Switch Bank S2

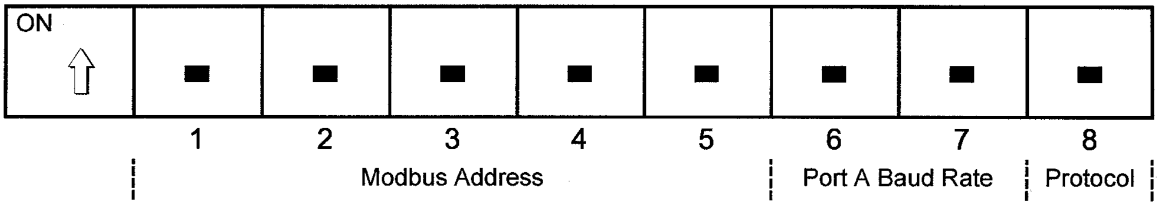


Figure 3-7 DFI Board Switch Banks for S1 and S2

Modbus Address

The Modbus Address has a range of 1-32 and applies to both external serial communication ports. The desired address is set via Switch Bank 2 switches 1 through 5 (see Figure 3-4). The desired address is the binary value of the five switches plus one. Examples of how to set the Modbus Address are shown in Table 3-4

Table 3-4 Modbus Address.

S2 Switches					Switch Decimal Equivalent	Modbus Address
5	4	3	2	1		
0 (ON)	0 (ON)	0 (ON)	0 (ON)	0 (ON)	0	1
0 (ON)	1 (OFF)	0 (ON)	0 (ON)	1 (OFF)	9	10
1 (OFF)	0 (ON)	0 (ON)	1 (OFF)	1 (OFF)	19	20
1 (OFF)	1 (OFF)	1 (OFF)	1 (OFF)	1 (OFF)	31	32

Switch 5 in Table 3-4 is the most significant bit; switch 1 is the least significant bit. The shaded area is the default settings.

Port A Baud Rate

The external serial communication port A baud rate is selected via Switch Bank 2 switches 6 and 7 (see Figure 3-4) and as shown in Table 3-5.

Table 3-5 Port A Baud Rate

S2 Switches		Port A Baud Rate
7	6	
0 (ON)	0 (ON)	1200
0 (ON)	1 (OFF)	2400
1 (OFF)	0 (ON)	4800
1 (OFF)	1 (OFF)	9600

The shaded area in Table 3-3 is the default settings.

Modbus Protocol

Both external serial communications ports must use the same Modbus protocol (either ASCII or RTU). The protocol to be used is selected via Switch Bank 2 switch 8 (see Figure 3-4) and as shown in Table 3-6.

Table 3-6 Modbus Protocol for S2

S2 Switch 8	**Selected Modbus Protocol**			
0 (ON)	RTU Modbus:	8 data bits	1 stop bit	no parity
1 (OFF)	ASCII Modbus:	7 data bits	1 stop bit	even parity

The shaded area in Table 3-4 is the default settings.

Port A Handshaking

If external serial communication port A is selected to use RS-232C (see below), then Switch Bank 1 switch 3 (see Figure 3-4) either enables handshaking (0, ON) or disables handshaking (1, OFF). When handshaking is enabled, port A expects both the RTS output and the CTS input to be active low.

Port B Baud Rate

The external serial communication port B baud rate is selected via Switch Bank 1 switch 4 (see Figure 3-4) as either 2400 baud (0, ON) or 9600 baud (1, OFF).

3.3 MECHANICAL INSTALLATION

The Daniel Ultrasonic Gas Flow Meters are assembled, configured, and tested at the factory. The two main units include the Daniel Ultrasonic Meter housing with Base Unit and the Main Electronics Assembly.

3.3.1 Pipeline Meter Housing Installation

- Unidirectional flow - The SeniorSonic™ meter housing requires a minimum 10 nominal pipe size diameter length of straight pipe upstream and a 5 nominal pipe size diameter length of straight pipe down stream to achieve full accuracy. The JuniorSonic™ Meters require 20 diameters of straight upstream pipe and five diameters of down stream pipe to achieve accurate flow measurement.
- Bi-directional flow - The meter housing requires a 10 nominal pipe size diameter length of straight pipe on each side for full accuracy for the SeniorSonic™ and 20 diameters for the JuniorSonic™.
- The bore of the mating piping should be within 1% in order to comply with AGA9.
- The Daniel Ultrasonic Meter housing is provided with dowel pins to align the meter housing bore with the bore of the mating piping.
- The SeniorSonic™ meter housing must be mounted in horizontal piping with the chord paths horizontal. The JuniorSonic™ meter housing should be oriented so that the chord paths are oriented 45 degrees off vertical. Other meter housing orientations may allow liquid to collect in the transducer ports which can adversely affect the transducer signals.
- Normally, the meter housing is installed so the electronics assembly is on the top of the meter. If there is insufficient space above the piping to accommodate this arrangement, the meter housing can be installed with the electronics assembly on the bottom (SeniorSonic™), or ordered with extra long transducer cables for remote mounting.
- A pressure tap is provided on the meter for pressure measurement.
- The mating piping should include connections for temperature measurement, which are to be located a minimum of three nominal pipe diameters length down stream of the meter housing.

- If the meter housing is not fitted with a means to vent line pressure, the down stream piping section should be provided with a vent valve to allow line pressure to be vented for maintenance.

3.3.2 Main Electronics Assembly - Daniel Ultrasonic Meter Housing

- Check that the serial number on the Ultrasonic Flow Transmitter matches the Daniel Ultrasonic Meter housing per the metrology report. System configuration and calibration is done with matched sets.
- Remove the cover of the base electronics housing and attach it to the upper electronics housing. Connect the preamplifier cable to the driver/preamp module in the base housing. Install the upper housing onto the base housing.

3.3.3 Transducer Cables/Appropriate Transducer

- The A1 cable should be connected to the transducer assembled in the meter housing transducer port A1. This procedure should then be repeated in numerical order for each one of the other transducers.
- The meter housing ports are identified by stamped or cast lettering adjacent to the transducer port counter bore and on tags attached to the transducer flanges.
- Remove the cap plug from the side of the electronics enclosure to expose the field wiring entry.

3.3.4 For Systems Using Explosion-Proof Conduit

1. Assemble conduit to the electronics enclosure.
2. If the conduit pipe is two inches or more, a conduit seal is required within 18 inches (150 mm) of the enclosure.
3. Remove the end cap nearest the conduit entry to gain access to the Field Connection Board.
4. Check to make certain that all power to the field wiring is turned OFF.
5. Pull the wires.
6. Complete connections to the Field Connection Board.
7. If line power is used, set the power switch to the correct voltage supplied, either 115 VAC or 230 VAC.
8. Select the communications driver by setting the EIA 485/RS232 switch (see Figure 3-5).
9. Replace the end cap. If desired, secure the end caps to the housing with seal wires.
10. Apply the sealing compound to the conduit seal and allow to set in accordance with manufacturer specifications.

3.3.5 For Systems that Use Flame-Proof Cable

1. Remove the end cap nearest the cable entries to gain access to the Field Connection Board.
2. Check to make certain that all power to the field wiring is turned OFF.
3. Install the cable and cable gland.
4. Make all connections to the Field Connection Board and Peripheral Field Connection Board.
5. If main power is used, set the power-selection switch to the correct voltage supplied, either 115 VAC or 230 VAC.
6. Select the communications driver by setting the EIA 485/RS232 switch.
7. Replace the end cap. If desired, secure the end caps to the housing with seal wires. Lock screws are also available on the end caps.

The customer has the option of selecting either a 24 Volt DC or 115/230 Volt AC Field Connection Board for the Ultrasonic Gas Flow Meter.

8. Connect a Flow Computer to the communications line on the Ultrasonic Gas Flow Meter.
9. Connect electrical power to the unit.
10. Set or Configure the software in the Flow Computer.

For additional installation information refer to the system wiring diagram (see Appendix G).

3.4 MEMORY PROTECTION

The protection of writable DFI Modbus registers that are stored in EEPROM and NOVRAM memory is controlled by DFI board jumper JP2 (see Figure 3-4). Specifically, Modbus Blocks 51, 53, 54 (except registers SpecFlowTemperature and SpecFlowPressure), and 56 are protected.

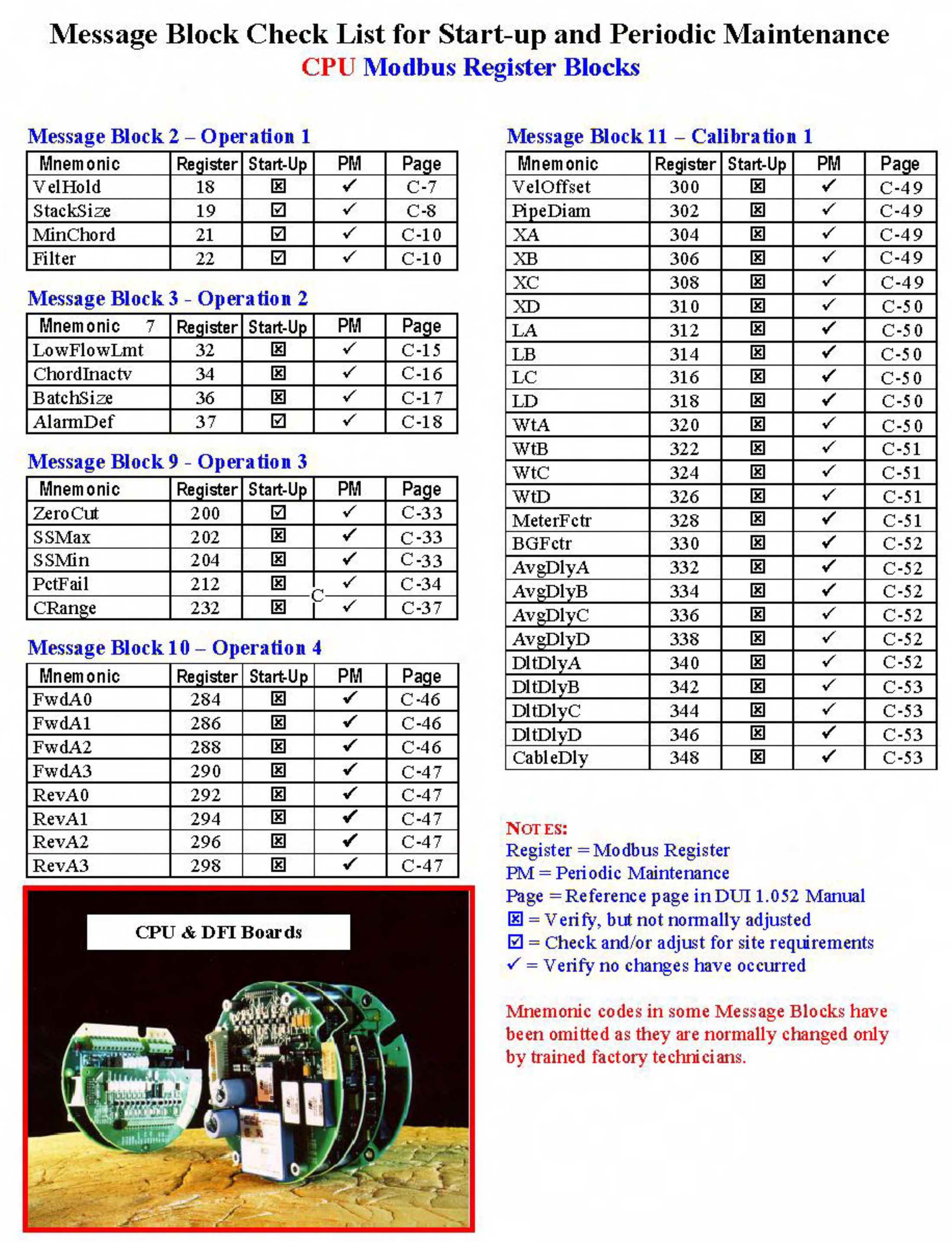
Beginning with firmware v3.62, the DFI memory protect jumper also protects the CPU board parameter registers (specifically all registers in Modbus Blocks 2, 3, 9, 10, and 11, and the registers ResetTrkParam and ResetProp in Block 4).

When JP2 is not installed, the registers are writable; when JP2 is installed, the registers are not writable. In addition, when memory is protected, the analog inputs and current output calibrations cannot be modified.

For firmware versions up to and including v3.34, this jumper (JP2 on the DFI board) only protects the DFI writable registers stored in EEPROM and NOVRAM; To protect the host processor writable registers stored in the EEPROM on the CPU board, install jumper JP9 on the CUP board (see Figure 3-3).

3.4.1 Message Block Check List

For Modbus Register Startup and Maintenance details see Figure 3-8 and Figure 3-9.



Message Block Check List for Start-up and Periodic Maintenance

CPU Modbus Register Blocks

Message Block 2 – Operation 1

Mnemonic	Register	Start-Up	PM	Page
VelHold	18	☒	✓	C-7
StackSize	19	☑	✓	C-8
MinChord	21	☑	✓	C-10
Filter	22	☑	✓	C-10

Message Block 3 - Operation 2

Mnemonic 7	Register	Start-Up	PM	Page
LowFlowLmt	32	☒	✓	C-15
ChordInactv	34	☒	✓	C-16
BatchSize	36	☒	✓	C-17
AlarmDef	37	☑	✓	C-18

Message Block 9 - Operation 3

Mnemonic	Register	Start-Up	PM	Page
ZeroCut	200	☑	✓	C-33
SSMax	202	☒	✓	C-33
SSMin	204	☒	✓	C-33
PctFail	212	☒	✓	C-34
CRange	232	☒	✓	C-37

Message Block 10 – Operation 4

Mnemonic	Register	Start-Up	PM	Page
FwdA0	284	☒	✓	C-46
FwdA1	286	☒	✓	C-46
FwdA2	288	☒	✓	C-46
FwdA3	290	☒	✓	C-47
RevA0	292	☒	✓	C-47
RevA1	294	☒	✓	C-47
RevA2	296	☒	✓	C-47
RevA3	298	☒	✓	C-47

CPU & DFI Boards

Message Block 11 – Calibration 1

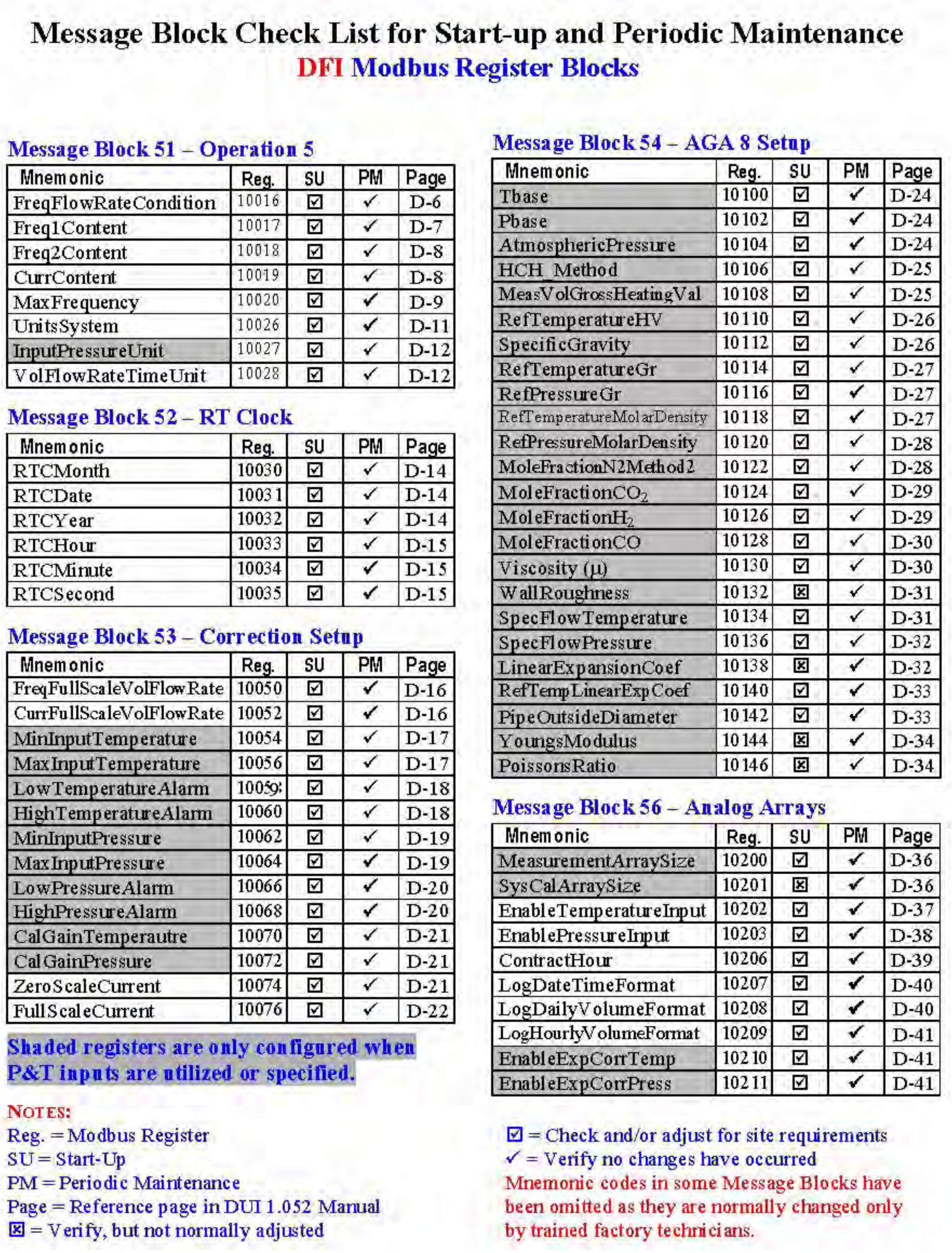
Mnemonic	Register	Start-Up	PM	Page
VelOffset	300	☒	✓	C-49
PipeDiam	302	☒	✓	C-49
XA	304	☒	✓	C-49
XB	306	☒	✓	C-49
XC	308	☒	✓	C-49
XD	310	☒	✓	C-50
LA	312	☒	✓	C-50
LB	314	☒	✓	C-50
LC	316	☒	✓	C-50
LD	318	☒	✓	C-50
WtA	320	☒	✓	C-50
WtB	322	☒	✓	C-51
WtC	324	☒	✓	C-51
WtD	326	☒	✓	C-51
MeterFctr	328	☒	✓	C-51
BGFctr	330	☒	✓	C-52
AvgDlyA	332	☒	✓	C-52
AvgDlyB	334	☒	✓	C-52
AvgDlyC	336	☒	✓	C-52
AvgDlyD	338	☒	✓	C-52
DltDlyA	340	☒	✓	C-52
DltDlyB	342	☒	✓	C-53
DltDlyC	344	☒	✓	C-53
DltDlyD	346	☒	✓	C-53
CableDly	348	☒	✓	C-53

NOTES:

Register = Modbus Register
PM = Periodic Maintenance
Page = Reference page in DUI 1.052 Manual
☒ = Verify, but not normally adjusted
☑ = Check and/or adjust for site requirements
✓ = Verify no changes have occurred

Mnemonic codes in some Message Blocks have been omitted as they are normally changed only by trained factory technicians.

Figure 3-8 CPU Modbus Register Blocks 1 of 2



Message Block Check List for Start-up and Periodic Maintenance

DFI Modbus Register Blocks

Message Block 51 – Operation 5

Mnemonic	Reg.	SU	PM	Page
FreqFlowRateCondition	10016	☑	✓	D-6
Freq1Content	10017	☑	✓	D-7
Freq2Content	10018	☑	✓	D-8
CurrContent	10019	☑	✓	D-8
MaxFrequency	10020	☑	✓	D-9
UnitsSystem	10026	☑	✓	D-11
InputPressureUnit	10027	☑	✓	D-12
VolFlowRateTimeUnit	10028	☑	✓	D-12

Message Block 52 – RT Clock

Mnemonic	Reg.	SU	PM	Page
RTCMonth	10030	☑	✓	D-14
RTCDate	10031	☑	✓	D-14
RTCYear	10032	☑	✓	D-14
RTCHour	10033	☑	✓	D-15
RTCMinute	10034	☑	✓	D-15
RTCSecond	10035	☑	✓	D-15

Message Block 53 – Correction Setup

Mnemonic	Reg.	SU	PM	Page
FreqFullScaleVolFlowRate	10050	☑	✓	D-16
CurrFullScaleVolFlowRate	10052	☑	✓	D-16
MinInputTemperature	10054	☑	✓	D-17
MaxInputTemperature	10056	☑	✓	D-17
LowTemperatureAlarm	10059:	☑	✓	D-18
HighTemperatureAlarm	10060	☑	✓	D-18
MinInputPressure	10062	☑	✓	D-19
MaxInputPressure	10064	☑	✓	D-19
LowPressureAlarm	10066	☑	✓	D-20
HighPressureAlarm	10068	☑	✓	D-20
CalGainTemperautre	10070	☑	✓	D-21
CalGainPressure	10072	☑	✓	D-21
ZeroScaleCurrent	10074	☑	✓	D-21
FullScaleCurrent	10076	☑	✓	D-22

Shaded registers are only configured when P&T inputs are utilized or specified.

NOTES:
Reg. = Modbus Register
SU = Start-Up
PM = Periodic Maintenance
Page = Reference page in DUI 1.052 Manual
☒ = Verify, but not normally adjusted

Message Block 54 – AGA 8 Setup

Mnemonic	Reg.	SU	PM	Page
Tbase	10100	☑	✓	D-24
Pbase	10102	☑	✓	D-24
AtmosphericPressure	10104	☑	✓	D-24
HCH_Method	10106	☑	✓	D-25
MeasVolGrossHeatingVal	10108	☑	✓	D-25
RefTemperatureHV	10110	☑	✓	D-26
SpecificGravity	10112	☑	✓	D-26
RefTemperatureGr	10114	☑	✓	D-27
RefPressureGr	10116	☑	✓	D-27
RefTemperatureMolarDensity	10118	☑	✓	D-27
RefPressureMolarDensity	10120	☑	✓	D-28
MoleFractionN2Method2	10122	☑	✓	D-28
MoleFractionCO_2	10124	☑	✓	D-29
MoleFractionH_2	10126	☑	✓	D-29
MoleFractionCO	10128	☑	✓	D-30
Viscosity (μ)	10130	☑	✓	D-30
WallRoughness	10132	☒	✓	D-31
SpecFlowTemperature	10134	☑	✓	D-31
SpecFlowPressure	10136	☑	✓	D-32
LinearExpansionCoef	10138	☒	✓	D-32
RefTempLinearExpCoef	10140	☑	✓	D-33
PipeOutsideDiameter	10142	☑	✓	D-33
YoungsModulus	10144	☒	✓	D-34
PoissonsRatio	10146	☒	✓	D-34

Message Block 56 – Analog Arrays

Mnemonic	Reg.	SU	PM	Page
MeasurementArraySize	10200	☑	✓	D-36
SysCalArraySize	10201	☒	✓	D-36
EnableTemperatureInput	10202	☑	✓	D-37
EnablePressureInput	10203	☑	✓	D-38
ContractHour	10206	☑	✓	D-39
LogDateTimeFormat	10207	☑	✓	D-40
LogDailyVolumeFormat	10208	☑	✓	D-40
LogHourlyVolumeFormat	10209	☑	✓	D-41
EnableExpCorrTemp	10210	☑	✓	D-41
EnableExpCorrPress	10211	☑	✓	D-41

☑ = Check and/or adjust for site requirements
✓ = Verify no changes have occurred
Mnemonic codes in some Message Blocks have been omitted as they are normally changed only by trained factory technicians.

Figure 3-9 CPU Modbus Register Blocks 2 of 2

METER CONFIGURATION, FIRMWARE

The purpose of this section is to provide instructions on the operation of the DFI.

4.1 CONFIGURING THE DFI

This section describes the steps involved in configuring the DFI via the Modbus registers. See APPENDIX D, for the Modbus register definitions. See Section 5 for detailed specifications regarding these configurations.

The DFI board jumper JP2 is used to prevent changes to DFI board parameter registers (Modbus Blocks 51, 53, 54, and 56) and to prevent analog input and current output calibrations. The jumper must be removed prior to configuring the DFI board. After the configuration is completed jumper JP2 can be inserted to prevent future changes to the DFI board parameters and calibration values.

4.1.1 Set Real-Time Clock

It is recommended that the real-time clock be set prior to changing any other Modbus registers so that event and data records are logged with the correct date and time. The Modbus Block 52 registers are used for reading and setting the real-time clock. See APPENDIX D, for register information.

These registers must be read from and written to as a complete block (including the spare registers).

First read the real-time clock by reading Modbus Block 52. If the date and/or time is incorrect, then write the correct date and time to the Block 52 registers.

Note that the real-time clock represents the year using only the last two year digits. For example, for the year 1998, the real-time clock stores the year as “98”. The DFI interprets the years “98” and “99” as 1998 and 1999, respectively, and all other years as being 20xx. The real-time clock recognizes the year “00” (i.e., the year 2000) correctly as being a leap year. Thus, the DFI date is valid from Jan. 1, 1998 through Dec. 31, 2097.

4.1.2 Set DFI General Parameters

Operating Mode

Select the DFI operating mode via the Mode Modbus register (Block 50). Upon power-on/reset, the DFI defaults to the Normal Mode (Mode=0). The DFI operational mode can be changed to the Test Mode (Mode=1), the Maintenance Mode (Mode=2), or the Current Calibration Mode (Mode=3).

Polling Period

Specify the period at which the DFI polls the Host TimeLapse register (for batch update detection) via the PollingPeriod Modbus register (Block 51). Shorter polling periods decrease the batch update latency (i.e., the time between the end of the batch and the frequency/current update) but may increase communication errors when accessing Host Modbus registers via the DFI.

Non-Normal Timeout

Specify the length of time that the DFI can remain in a non-Normal operating mode (i.e., the Test Mode, Maintenance Mode, or Current Calibration Mode) via the NonNormalModeTimeout Modbus register (Block 51). Setting the NonNormalModeTimeout register to zero disables the DFI non-Normal timeout feature (i.e., the DFI can remain in a non-Normal mode indefinitely).

Communication Timeout

Specify the maximum length of time the DFI has to begin transmission of a Modbus response message (after receipt of a Modbus request message) via the CommTimeoutSec Modbus register (Block 51). If no response is received within the time limit, no response will be sent.

Communication Response Delay

In some instances, an external computer (i.e., flow computer or diagnostic computer) requires that the DFI delay transmitting Modbus response messages a minimum length of time. Specify the minimum response delay time in milliseconds for each communication port via the CommARspDlyMillisec Modbus register (for port A) and CommBRspDlyMillisec Modbus register (for port B) (Block 56).

System Units

Select the system of units for accessing Modbus registers representing physical quantities via the UnitsSystem Modbus register (Block 51) as either U.S. Customary (0) or Metric (1). See Table 5-1 for a list of the pre-defined metric and U.S. Customary units.

Volumetric Flow Rate Time Unit

Select the time unit for the volumetric flow rate output via the VolFlowRateTimeUnit Modbus register (Block 51) as either volume per second (0), volume per hour (1), or volume per day (2). The volumetric flow rate unit indicated by DFI Modbus registers, the frequency outputs, and the current output is a function of the system of units (see above and Section 5.8) and VolFlowRateTimeUnit. For example, if metric units (UnitsSystem=1) and volume per hour (VolFlowRateTimeUnit=1) are selected, then the unit for Modbus registers such as QMeter, QFlow, and QBase and for frequency and current outputs is cubic meters per hour.

4.1.3 Set Temperature and Pressure Sampling

Analog Inputs

The flow condition temperature and pressure inputs can be independently disabled (0), enabled (1), or specified (2) via the Enable-TemperatureInput and EnablePressureInput Modbus registers (Block 56). If an input is enabled, then its value is determined by sampling an analog input signal once per second and optionally averaging a specified number of samples. If an input is specified, then its value is specified by a writable Modbus register (SpecFlowTemperature or SpecFlowPressure). If an input is neither enabled nor specified, then it is disabled.

Input Averaging

The enabled temperature and pressure inputs are sampled once per second. The measurements can be smoothed using sample averaging in which a specified number of samples are averaged to arrive at the temperature or pressure value to use for calculation. Specify the number of samples to be averaged via the MeasurementArraySize Modbus register (Block 56). Setting MeasurementArraySize to 1 disables the measurement smoothing. It is recommended that the number of samples to average be set to the number of seconds per batch. For example, the default batch time for a multi-path meter is approximately five seconds; in that case, the MeasurementArraySize register should be set to 5.

Temperature Input Range

The temperature input is expected to be a 4-20 mA or a 1-5 V signal, depending on which PFC board is installed. Specify the temperature represented by a 4 mA or 1 V input via the MinInputTemperature Modbus register (Block 53); specify the temperature represented by a 20 mA or 5 V input via the MaxInputTemperature Modbus register (Block 53). Refer to Section 5.8 for the units for these specifications based upon the selected system of units.

Flow Condition Temperature

If the temperature input is specified (i.e., the EnableTemperatureInput register is set to 2), then the flow condition temperature must be specified via the SpecFlowTemperature Modbus register (Block 54). Note that SpecFlowTemperature can be modified regardless of the memory protect jumper (JP2) position. The unit for this specification is determined by the selected system of units (refer to Section 5.8).

Temperature Alarm Limits

Specify the flow condition measured or specified temperature alarm limits via the LowTemperatureAlarm and HighTemperatureAlarm Modbus registers (Block 53). Temperature values which are outside of the alarm limits are flagged as being invalid. Refer to Section 5.8 (See List of Tables) for the units for these specifications based upon the selected system of units.

Pressure Input Unit and Atmospheric Pressure

Select the pressure input unit via the InputPressureUnit Modbus register (Block 51) as either gage (0) or absolute (1). If gage pressure is selected, then specify the atmospheric pressure via the AtmosphericPressure Modbus register (Block 54). Refer to Section 5.8 for the atmospheric pressure unit based upon the selected system of units.

Pressure Input Range

The pressure input is expected to be a 4-20 mA or a 1-5 V signal, depending on which PFC board is installed. Specify the pressure represented by a 4 mA or 1 V input via the MinInputPressure Modbus register (Block 53); specify the pressure represented by a 20 mA or 5 V input via the MaxInputPressure Modbus register (Block 53). The unit for these specifications is a function of the selected system of units (refer to Section 5.8) and pressure input unit (see above).

Flow Condition Pressure

If the pressure input is specified (i.e., the EnablePressureInput register is set to 2), then the flow condition pressure must be specified via the SpecFlowPressure Modbus register (Block 54). Note that SpecFlowTemperature can be modified regardless of the memory protect jumper (JP2) position. The unit for this specification is determined by the selected system of units (refer to Section 5.8) and the value of the InputPressureUnit register.

Pressure Alarm Limits

Specify the flow condition measured or specified pressure alarm limits via the LowPressureAlarm and HighPressureAlarm Modbus registers (Block 53). Pressure values which are outside of the alarm limits are flagged as being invalid. The unit for these specifications is a function of the selected system of units (refer to Section 5.8) and pressure input unit (see above).

4.1.4 Set AGA8 Parameters

The compressibility calculation parameters (AGA8 parameters) are required for flow-profile effect correction (for models 3410, 3420 and 3450) and for flow condition to base condition conversion.

Beginning with v3.62, the AGA8 calculations can be performed externally (such as in a flow computer) with the results (e.g., flow-condition mass density, flow-condition compressibility, and base-condition compressibility) specified to the DFI via Modbus registers. The base-condition temperature and pressure must be specified as described in the "Base Condition" paragraph below. The flow-condition temperature and pressure must be either input or specified as described in Section 4.1.3.

The HCH_Method register is used to specify external AGA8 calculations as described in the HCH Calculation Method paragraph below.

Base Condition

Specify the base (contract) temperature and pressure via the TBase and PBase Modbus registers (Block 54) respectively. The units for these specifications are determined by the selected system of units (refer to Section 5.8). The base pressure is expected to be absolute pressure.

HCH Calculation Method

Select the AGA8 gross characterization method (for calculating the equivalent hydrocarbon molar gross heating value) via the HCH_Method Modbus register (Block 54) as either the first gross characterization method (1) or the second gross characterization method (2).

Beginning with v3.62, if the AGA8 calculations are to be performed externally (with the results specified to the DFI), then set the HCH_Method Modbus register to 0. The DFI expects the flow-condition mass density, the flow-condition compressibility, and the base-condition compressibility to be specified as described below. The base-condition temperature and pressure must also be specified as described in the "Base Condition" paragraph above. The flow-condition temperature and pressure must be either input or specified as described in Section 4.1.3.

Measured Volumetric Gross Heating Value

If the first gross characterization method is selected (HCH_Method=1, see above), then specify the measured volumetric gross heating value and the reference temperature via the MeasVolGrossHeatingValue and RefTemperatureHV Modbus registers (Block 54), respectively. The units for these specifications are determined by the selected system of units (refer to Section 5.8).

Specific Gravity

Specify the specific gravity of the natural gas mixture via the SpecificGravity Modbus register (Block 54). Specify the reference condition (temperature and pressure) for the specific gravity via the RefTemperatureGr and RefPressureGr Modbus registers (Block 54). The units for these specifications are determined by the selected system of units (refer to Section 5.8). The reference pressure is expected to be absolute pressure.

Molar Density Reference Condition

If the first gross characterization method is selected (i.e., HCH_Method=1; see above), then specify the molar density reference condition (temperature and pressure) via the RefTemperatureMolarDensity and RefPressureMolarDensity Modbus registers (Block 54). The units for these specifications are determined by the selected system of units (refer to Section 5.8). The reference pressure is expected to be absolute pressure.

Gas Composition

Specify the gas composition in mole fractions of carbon dioxide, hydrogen, and carbon monoxide via the Modbus registers MoleFractionCO2, MoleFractionH2, and MoleFractionCO (Block 54), respectively. If the second gross characterization method is selected (HCH_Method=2, see above), then specify the mole fraction of nitrogen via the Modbus register MoleFractionN2Method2 (Block 54). (The mole fraction of nitrogen is calculated for the first gross characterization method.) Note that the gas composition is specified in terms of mole fractions not percentages. For example, if the gas is composed of 0.5956 percent carbon dioxide, then specify MoleFractionCO2=0.005956.

Ensure that you specify the gas composition in terms of mole fractions rather than percentages.

Flow-Condition Mass Density

If the AGA8 calculations are performed externally (HCH_Method=0, see above), then specify the flow-condition gas mass density via the SpecRhoMixFlow Modbus register (Block 53). The unit for this specification is determined by the selected system of units (refer to Section 5.8).

Flow-Condition Compressibility

If the AGA8 calculations are performed externally (HCH_Method=0, see above), then specify the flow-condition compressibility via the dimensionless SpecZFlow Modbus register (Block 53).

Base-Condition Compressibility

If the AGA8 calculations are performed externally (HCH_Method=0, see above), then specify the base-condition compressibility via the dimensionless SpecZBase Modbus register (Block 53).

4.1.5 Set Expansion Correction Parameters

Expansion Correction due to Temperature and Pressure

The volumetric flow rate can be corrected for expansion due to temperature and pressure effects upon the pipe. The corrections can be independently enabled (1) or disabled (0) via the EnableExpCorrTemp (for temperature) and EnableExpCorrPress (for pressure) registers (Block 56). The temperature effect expansion correction requires that the temperature input be enabled or specified (via EnableTemperatureInput); similarly, the pressure effect expansion correction requires that the pressure input be enabled or specified (via EnablePressureInput).

Linear Expansion Coefficient

The linear expansion coefficient is required for the calculation of the temperature-effect expansion correction factor. Specify the linear expansion coefficient via the LinearExpansionCoef register and the reference temperature for the coefficient via the RefTempLinearExpCoef register (both in Block 54). The units for these specifications are determined by the selected system of units (refer to Section 5.8).

Pipe Outside Diameter

The pipe outside diameter is required for the calculation of the pressure-effect expansion correction factor. Specify the pipe outside diameter via the PipeOutsideDiameter register (Block 54). The unit for this specification is determined by the selected system of units (refer to Section 5.8).

Pipe Inside Diameter

The pipe inside diameter is required for the calculation of the pressure-effect expansion correction factor. This value should already have been specified (via the CPU PipeDiam register in Block 11) as it is essential to the volumetric flow rate measurement.

Young's Modulus

The Young's Modulus value is required for the calculation of the pressure-effect expansion correction factor. Specify Young's Modulus via the YoungsModulus register (Block 54). The unit for this specification is determined by the selected system of units (refer to Section 5.8).

Poisson's Ratio

The Poisson's Ratio value is required for the calculation of the pressure-effect expansion correction factor. Specify Poisson's Ratio via the PoissonsRatio register (Block 54). The unit for this specification is determined by the selected system of units (refer to Section 5.8).

4.1.6 Reynolds Number and Flow-Profile-Effect Correction Parameters

Reynolds Number

This is a dimensionless value which represents the nature of the gas flow within the pipe. Although the primary reason for calculating Reynolds Number is for flow-profile-effect correction, it is calculated for all meter types regardless of whether the flow-profile-effect correction factor is calculated. The meter-reported volumetric flow rate must be valid in order for Reynolds Number to be calculated. In addition, the calculation requires the flow-condition gas mass density and the gas viscosity as discussed below. The Reynolds Number calculation is described in Section A.4.6.

Flow-Condition Gas Mass Density

If the AGA8 calculations are performed by the DFI (HCH_Method =1 or 2), then the flow-condition temperature and pressure must both be valid (specified or input) and the AGA8 base calculations must be valid in order for the flow-condition gas mass density to be calculated or estimated. If the AGA8 calculations are performed externally (HCH_Method=0), then specify the flow-condition gas mass density via the SpecRhoMixFlow Modbus register (Block 53) for calculating Reynolds Number. The unit for this specification is determined by the selected system of units (refer to SectionA.1).

Gas Viscosity

Specify the gas viscosity via the Viscosity Modbus register (Block 54). The unit for this specification is determined by the selected system of units (see Appendix A).

For meter models 3410, 3420, and 3450, the volumetric flow rate requires correction for flow-profile-effect due to the location of the transducers. This correction is not required by other meter models. For firmware prior to v3.73, this correction factor is either calculated (based upon a calculated Reynolds Number, see above) or set to a default value; for firmware v3.73 and later, the correction factor must either be specified (via the SpecCorrectionFactor register in Block 53), calculated (if SpecCorrectionFactor is equal to 0.0 and temperature and pressure are both enabled/specified) or set to the default (if SpecCorrectionFactor is equal to 0.0 and either temperature or pressure is disabled). The correction factor calculation is described in Appendix A.1.

SpecCorrectionFactor

If flow-profile-effect correction is required and the correction factor is to be specified (v3.73+), then specify the value via the SpecCorrectionFactor register (Block 53). (Note that pipe wall roughness does not need to be specified in this case. The gas viscosity is not required either but may be specified if the user wants Reynolds Number to be calculated.) Otherwise, the SpecCorrectionFactor register should be set to zero so that the correction factor is either calculated or set to the default.

Pipe Wall Roughness

If flow-profile-effect correction is required and the correction factor is to be calculated, then specify the pipe wall roughness via the WallRoughness Modbus register (Block 54). The unit for this specification is determined by the selected system of units (see Appendix A).

4.1.7 Set Frequency and Current Outputs

Flow Rate Condition

Select the flow rate condition indicated by the frequency and current outputs via the FreqFlowRateCondition Modbus register (Block 51). The outputs can indicate the volumetric flow rate at either the flow condition (0) or the base (contract) condition (1).

Frequency Flow Direction

Select the flow direction to be represented by the frequency outputs 1 and 2 via the Freq1Content and Freq2Content Modbus registers (Block 51) as either reverse flow (0), forward flow (1), or absolute flow (2).

For DFI boards with firmware prior to v3.73 or with an FPGA prior to v1.2, the "B" phase frequency outputs are set to zero whenever the frequency output is invalid (including when in the Test mode). For DFI boards with v3.73 or later firmware and a v1.2 or later FPGA, the user can elect to not zero the "B" phase frequencies when the frequency output is invalid. In that case, in addition to the three options for Freq1Content and Freq2Content (0, 1, and 2), the user has an additional three options: non-zero Phase B reverse flow (4), non-zero Phase B forward flow (5), and non-zero Phase B absolute flow (6).

Maximum Frequency Output

Select the maximum frequency output via the MaxFrequency Modbus register (Block 51) as either 1000 Hz (1000) or 5000 Hz (5000).

Frequency Output Full Scale Volumetric Flow Rate

Specify the volumetric flow rate represented by the maximum frequency output (specified above) via the FreqFullScaleVolFlowRate Modbus register (Block 53).

Frequency Feedback

Select the frequency feedback via the EnableFreqFeedback Modbus register (Block 51) as either enabled (1) or disabled (0). It is highly recommended that the frequency feedback always be enabled.

Frequency Feedback Correction

Specify the percentage of the frequency output correction indicated by the frequency feedback via the FreqFeedbackCorrectionPct Modbus register (Block 51). It is highly recommended that this parameter be set to the default value.

Current Flow Direction

Select the flow direction to be represented by the current output via the CurrContent Modbus register (Block 51) as either reverse flow (0), forward flow (1), or absolute flow (2).

Current Output Full Scale Volumetric Flow Rate

Specify the volumetric flow rate represented by the maximum current output (20 mA) via the CurrFullScaleVolFlowRate Modbus register (Block 53).

4.2 CALIBRATING TEMPERATURE AND PRESSURE INPUTS

The DFI uses a two-point calibration (offset and gain) for each of the enabled analog inputs (temperature and pressure). The system calibration values currently used by the DFI can be read via the Modbus registers TempOffsetValue, TempGainCoefficient, PressOffsetValue, and PressGainCoefficient in Block 66. The default offsets are 0 K for temperature and 0.0 MPa for pressure; the default gains are one. Note that the corresponding ADC is re-calibrated as part of the offset calibration. The ADC calibration values can be read via the Modbus registers TempADCZeroScaleCalReg, TempADCFullScaleCalReg, PressADCZeroScaleCalReg, and PressADCFullScaleCalReg in Block 65.

The procedure for performing an analog input signal calibration is outlined below. Note that only enabled analog input signals can be calibrated. If neither analog input signal is enabled, the Maintenance Mode cannot be entered. Enabled analog input signals cannot be calibrated if the memory protect jumper (JP2) is installed.

See Section 5 for additional detailed specifications regarding this operation.

For proper analog input calibration, the offset calibration must be performed before the gain calibration.

1. Enter the Maintenance Mode Read Inputs Submode by writing the value 2 to the Mode Modbus register and the value 0 to the MaintenanceSubmode Modbus register (Block 50). Note that if the NonNormalModeTimeout Modbus register (Block 51) is set to a non-zero value, the following steps must be completed in the number of minutes specified by this register.
2. Specify the number of readings to be averaged for calculating the calibration points via the SysCalArraySize Modbus register (Block 56). It is recommended that this register be set to the maximum value of 64 (the default value) for the most accurate calibration point calculation.
3. Perform the offset calibration as follows (assumes a calibrator is being used):
   (a) Set the analog input signal to be calibrated (temperature or pressure) to precisely 4 mA or 1 V, depending on which PFC board is installed.
   (b) Change the MaintenanceSubmode Modbus register (Block 51) to 1 if calibrating the temperature input offset or to 3 if calibrating the pressure input offset.
   (c) When the offset calibration is completed, the DFI automatically returns to the Read Inputs Submode. Verify the end of the offset calibration by repetitively reading the MaintenanceSubmode Modbus register until its value is 0 (indicating the Read Inputs Submode).
4. Perform the gain calibration as follows (assumes a calibrator is being used):
   (a) Set the analog input signal to be calibrated (temperature or pressure) to as close to 20 mA or 5 V as possible, depending on which PFC board is installed.

(b) Calculate the temperature or pressure indicated by the analog input current or input voltage set in the previous step using the appropriate equation below.

For Temperature Gain Calibration:

(1) $$\left(\left(\frac{InputCurrent - 4mA}{16mA}\right) \times (MaxInputTemperature - MinInputTemperature)\right) + MinInputTemperature$$

OR

(2) $$\left(\left(\frac{InputVoltage - 1V}{4V}\right) \times (MaxInputTemperature - MinInputTemperature)\right) + MinInputTemperature$$

For Pressure Gain Calibration:

(3) $$\left(\left(\frac{InputCurrent - 4mA}{16mA}\right) \times (MaxInputPressure - MinInputPressure)\right) + MinInputPressure$$

OR

(4) $$\left(\left(\frac{InputVoltage - 1V}{4V}\right) \times (MaxInputPressure - MinInputPressure)\right) + MinInputPressure$$

where InputCurrent (mA) or InputVoltage (V) is the value from the previous step and MinInputTemperature, MaxInputTemperature, MinInputPressure, and MaxInputPressure are the Modbus register values (Block 53).

(c) Write the value calculated above to the CalGainTemperature Modbus register if performing a temperature gain calibration or to the CalGainPressure Modbus register if performing a pressure gain calibration (Block 53).

(d) Change the MaintenanceSubmode Modbus register (Block 51) to 2 if calibrating the temperature input gain or to 4 if calibrating the pressure input gain.

(e) When the gain calibration is completed, the DFI automatically returns to the Read Inputs Submode. Verify the end of the gain calibration by repetitively reading the MaintenanceSubmode Modbus register until its value is 0 (indicating the Read Inputs Submode).

5. Return to the Normal Mode by writing 0 to the Mode Modbus register (Block 50).

To reset a calibration value to its default value, change to the Maintenance Mode (if not already in that mode) by writing 2 to the Mode Modbus register (Block 50). Next, write the appropriate value (see Table 4-1) to the MaintenanceSubmode Modbus register (Block 50). When the specified calibration value is reset, the DFI automatically returns to the Read Inputs Submode. Verify the end of the calibration reset by repetitively reading the MaintenanceSubmode Modbus register until its value is 0 (indicating the Read Inputs Submode). Finally, return to the Normal Mode by writing 0 to the Mode Modbus register (Block 50).

Table 4-1 Calibration Reset Submodes

Maintenance Submode Value	**Calibration Value to Reset**
101	Temperature Offset
102	Temperature Gain
103	Pressure Offset
104	Pressure Gain

While in the Maintenance Mode, the temperature and pressure inputs are considered invalid since they are not expected to represent the flow condition.

The compressibility (AGA8) and Reynolds number calculations use the last flow condition temperature and pressure values (prior to entering the Maintenance Mode). These values can be read via the Modbus registers FlowTemperature and FlowPressure in Block 62. While in the Maintenance Read Inputs Submode, the present temperature and pressure readings can be read via the Modbus registers MaintTemperature and MaintPressure in Block 64.

4.3 CALIBRATING CURRENT OUTPUT SIGNAL

See Section 5 for detailed specifications regarding this function.The procedure for performing the current output signal calibration is outlined below:

1. Enter the Current Calibration Mode Zero Scale Submode by writing the value 3 to the Mode Modbus register and the value 0 to the CurrentCalSubmode Modbus register (Block 50). Note that if the NonNormalModeTimeout Modbus register (Block 51) is set to a non-zero value, the following steps must be completed in the number of minutes specified by this register.
2. Measure the output current in mA and write the measurement value to the ZeroScaleCurrent Modbus register (Block 53). The calculated current offset value can be read from the CurrOffsetValue Modbus register (Block 66).

For proper current output calibration, the zero scale current value must be specified before the full scale current value.

3. Change to the Full Scale Submode by writing the value 1 to the CurrentCalSubmode Modbus register (Block 50).
4. Measure the output current in mA and write the measurement value to the FullScaleCurrent Modbus register (Block 53). The calculated current gain coefficient can be read from the CurrGainCoefficient Modbus register (Block 66).
5. Exit from the Current Calibration Mode to the Normal Mode by writing the value 0 to the Mode Modbus register (Block 50).

The zero-scale current can be reset to its default value (4.0 mA) while in the Current Calibration Mode either by setting the CurrentCalSubmode Modbus register to 100 or by setting the ZeroScaleCurrent Modbus register to 4.0. If the CurrentCalSubmode Modbus register is set to 100, then the DFI automatically returns to the Zero Scale Submode after the zero-scale current has been reset.

The full-scale current can be reset to its default value (20.0 mA) while in the Current Calibration Mode either by setting the CurrentCalSubmode

Modbus register to 101 or by setting the FullScaleCurrent Modbus register to 20.0. If the CurrentCalSubmode Modbus register is set to 101, then the DFI automatically returns to the Zero Scale Submode after the full-scale current has been reset.

4.4 CONFIGURING EVENT AND DATA LOGGING

Although the hourly and daily log records are not configurable, the format in which some of the record data is transmitted is configurable via Modbus registers. Also, the contract hour (i.e., the hour at which a daily record is to be logged) is specified via a Modbus register. See Section 5, Theory of Operation, for detailed specifications regarding this configuration.

4.4.1 Specifying the Contract Hour

Specify the contract hour in military format (0-23 hours) via the ContractHour Modbus register (Block 56).

4.4.2 Selecting the Log Date and Time Format

Select the format in which log record date and time information is to be transmitted via the LogDateTimeFormat Modbus register (Block 56). The encoding for this register is shown in Table 4-2 on page 4-18.

4.4.3 Selecting the Daily Log Volume Format

Select the format in which the daily log record volume information is to be transmitted via the LogDailyVolumeFormat Modbus register (Block 56) as either 32-bit floating point (0) or 32-bit integer (1). The default format is floating point. The 32-bit integer format should be selected if the daily volumes (flow-condition and base-condition) are expected to require more than seven digits of precision. The daily record volumes are reported in either cubic meters or cubic feet depending upon the units specified by the UnitsSystem register (see Section 4.1.2).

Table 4-2 Date and Time Formats per LogDataTimeFormat Value

LogDateTimeFormat Value	Data Type	Date		Time (HHMMSS, military format)
		Format	Example July 4, 1999	Example 3:45:30pm
0 (default)	32 bit, floating point	MMDDYY	70499.0	154530.0
1	32 bit, long integer	MMDDYYYY	7041999	154530
2	32 bit, floating point	DDMMYY	40799.0	154530.0
3	32 bit, long integer	DDMMYYYY	4071999	154530
4	32 bit, floating point	YYMMDD	990704.0	154530.0
5	32 bit, long integer	YYYYMMDD	19990704	154530

4.4.4 Selecting the Hourly Log Volume Format

Select the format in which the hourly log record volume information is to be transmitted via the LogHourlyVolumeFormat Modbus register (Block 56) as either 32-bit floating point (0) or 32-bit integer (1). The default format is floating point. The 32-bit integer format should be selected if the hourly volumes (flow-condition and base-condition) are expected to require more than seven digits of precision. The hourly record volumes are reported in either cubic meters or cubic feet depending upon the units specified by the UnitsSystem register (see Section 4.1.2).

4.5 TESTING THE FREQUENCY AND CURRENT OUTPUT SIGNALS

The DFI Test Mode is used to force the frequency and current output signals to a user-specified percentage of full scale. For the frequency output signals, full scale is determined by the value of the MaxFrequency Modbus register (Block 51).

While in the Test Mode, the frequency and current output signals are considered to be invalid since they do not represent flow information. The maximum length of time (in minutes) that the DFI can remain in the Test Mode is specified by the NonNormalModeTimeout Modbus register (Block 51); if NonNormalModeTimeout is set to zero, the DFI can remain in the Test Mode indefinitely.

The percentage of full scale (from 0 to 100 percent in 1 percent increments) is specified via the TestModeOutputPct Modbus register (Block 51). The Test Mode is selected by writing 1 to the Mode Modbus register (Block 50).

For example, if the maximum frequency is 5000 Hz (MaxFrequency=5000) and the test mode output percentage is 50 percent (TestModeOutputPct=50), then when in the Test Mode the frequency outputs would be at 2500 Hz and the current output would be at 12 mA.

See Section 5 for detailed specifications regarding this test.

4.6 TESTING THE AGA8 COMPRESSIBILITY CALCULATION

The AGA8 compressibility calculation can be tested using twenty test cases (listed in Table 5) which are a subset of the test cases listed in the AGA Transmission Measurement Committee Report No. 8 (Appendix B of [3]). The DFI must be in the Normal Mode (Mode=0) in order to perform AGA8 Test Case calculations. Specify the test case number (1 through 20) via the NormalDiagnosticMode register (Block 50); the currently specified AGA8 Gross Characterization Method (specified by the HCH_Method register) is used for the calculation.

The DFI indicates the completion of the AGA8 test case compressibility calculation by setting the NormalDiagnosticMode register back to zero. The status of the calculation is indicated by the AGA8TestCalcStatus register (Block 69); refer to Table D-17 for the listing of status values. The test case number, HCH method used, calculated compressibility, and percent error from the expected value are indicated by the registers ZTestCaseID, ZTestCaseHCHMethod, ZTest, and ZTestErr, respectively (Block 64). See Section 5 for detailed specifications regarding this test.

THEORY OF OPERATION

The purpose of this section is to give the reader a basic understanding of how the DFI board operates.

5.1 UNITS OF MEASUREMENT

Like the USM, the DFI stores measurements and performs calculations using metric units. However, the user can select to read/write DFI Modbus registers in either metric or U.S. Customary units which are pre-defined. These units are listed in Table 5-1. For all measurements except temperature, the Modbus access metric unit is the same as the storage unit; temperatures are stored in Kelvin but are accessed (in metric) in degrees Celsius. Also, the time base for volumetric flow rate information is user-selectable but the values are stored in units of cubic meters per hour.

CPU board Modbus registers (i.e., registers numbered below 10,000) read from or written to via the DFI use metric units

5.2 MEASUREMENT

5.2.1 Introduction

Since the Model 3400 SeniorSonic™ Gas Flow Meter uses four acoustic-signal paths (or ultrasonic paths) on two or four different planes to sample the gas flow, it can provide gas measurement accuracy not possible with single-path designs. This means that four mean velocities are continuously measured and appropriately averaged to determine the average gas velocity and flow rate through the meter. The four-path method insures measurement reliability because if one path fails, the other three paths will continue the measurement process and will substitute values for the failed path. An alarm will indicate any path failure.

The Model 3410 Single Path JuniorSonic™ and the Model 3420 Dual Path JuniorSonic™ Meters provide center chord measurements requiring velocity profile corrections. These units are appropriate for allocation metering and control, check metering and wet gas applications.

The Ultrasonic Gas Flow Meter's unique design creates no line obstruction or pressure loss and the need for unit maintenance is greatly reduced. In addition, the Ultrasonic Gas Flow Meter uses digital techniques to process the signals from the meter's transducers.

5.2.2 Noise Immunity

One of the more significant developments in the Ultrasonic Gas Flow Meter is the application of digital signal processing to extract measurements from the signals detected by the unit's four pairs of transducers. Automatic gain control circuitry compensates for the wide variation in signal amplitude caused by varying flow conditions such as pressure and flowrate.

After the signal has been digitized, signal-processing techniques are applied to provide accurate measurement of transit times. Checks are performed to verify signal integrity, and system setup allows selection of the most applicable signal-enhancement software for specific conditions. For example, the unit can be configured to handle flow-generated noise, which has an amplitude comparable to the flow measurement signal.

5.2.3 Measurement Independence

See Figure 5-1, and see Figure 5-2 for measurement independence details.

The Ultrasonic Gas Flow Meter precisely measures the transit time of an ultrasonic wave passing through the gas to determine the mean axial velocity of the gas through the unit. The measurement paths are angled to the pipe axis, and each path has two transducers acting alternately as transmitter and receiver. This permits the transit times to be measured both with and against the flow.

The transducers are mounted on the meter housing at accurately known locations for each pipe size so the distance L between opposing transducers and the angle are precisely defined for the measurement path.

The transit time of a signal traveling with the flow is less than that traveling against the flow. Both transit times are used to calculate the mean velocity of the flowing gas. Since the equations (see the following) are valid for gas flowing in either direction, the unit is inherently bi-directional in operation.

Consequently, the final equation (see the following) contains only physical dimensions of the unit body and the transit times, but it does NOT include the velocity of the sound of the flowing gas. This means that the measurement of gas velocity is independent of factors, such as temperature, pressure and gas composition, that affect the speed of sound in the gas.

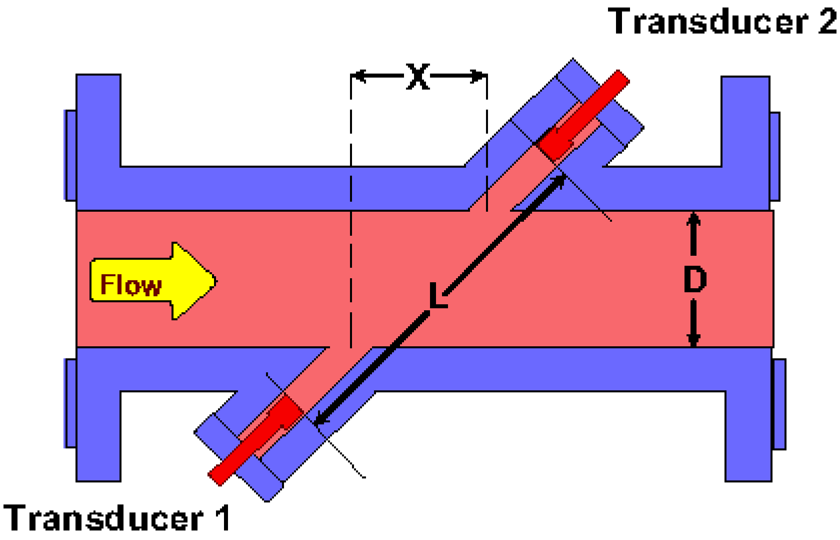


Figure 5-1 SeniorSonic™ Measurement Principle

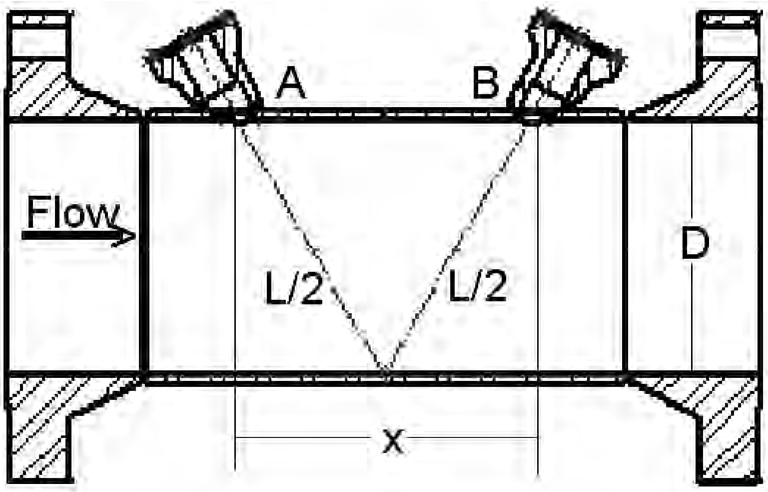


Figure 5-2 JuniorSonic^{TM} Principle

The following equations (Figure 5-3 and Figure 5-4) define flow rate using two transducers located at positions U (upstream) and D (downstream) along one plane of measurement across the bore of the meter.

$$C = \frac{L}{2} \cdot \left[\frac{t_{du} + t_{ud}}{t_{du} t_{ud}} \right]$$

Figure 5-3 Flow Rate Equation #1

$$V_i = \frac{L^2}{2X} \cdot \frac{t_{du} - t_{ud}}{(t_{du})(t_{ud})}$$

Figure 5-4 Flow Rate Equation #2

Refer to Figure 5-5 and Figure 5-6 for the actual volume flow rate for a multipath SeniorSonic™ Flow Meter.

$$V_m = \sum_{i=1}^{4} W_i V_i$$

Figure 5-5 Actual Volume Flow Rate Equation #1

$$Q = V_m \cdot \frac{\pi D^2}{4} = K \cdot \frac{t_{du} - t_{ud}}{(t_{ud})(t_{du})}$$

Figure 5-6 Actual volume flow Rate Equation #2

Where

t_{ud} = Transit time from transducer U to D

t_{du} = Transit time from transducer D to U

L = Distance between transducers U and D

C = Velocity of sound in the gas in still condition

V_i = Mean velocity of the flowing gas along a chord

V_m = Mean velocity of the flowing gas

W_i = Weighting factor for velocity

X_i = Axial distance between transducers U and D

D = Diameter of the meter bore

K = Constant for a specific meter

5.2.4 Volume Calculations

All calculations performed on the CPU board of Ultrasonic flow meters are metric. First calculate the individual chord velocities. From the individual chord velocities calculate the Average Weighted Flow Velocity using the respective weights for each chord.

Average Weighted Flow Velocity = (WeightA * FlowVelA) + (WeightB * FlowVelB) + (WeightC * FlowVelC) + (WeightD * FlowVelD) [m/s]

Next VEL is calculated as a product of the Average Weighted Flow Velocity and the BGFctr.

VEL = Average Weighted Flow Velocity * BGFctr. [m/s]

If **flow is in the forward direction** (VEL >= 0) then:

Determine whether to use the first or third order of calibration by looking at A0, A1, A2 and A3 values.

If the A0, A1, A2, and A3 values are 0,1,0,0 or 0,0,0,0 use the first order as follows:

Average Flow Velocity = (VEL - VelocityOffset)*MeterFctr.[m/s]

Else use the third order calibration,

Average Flow Velocity = FwdA0 + (VEL * FwdA1) + (VEL * VEL * FwdA2) + (VEL * VEL * VEL * FwdA3). [m/s]

Calculate uncorrected flow rate (register 388, blk #12),

UnCorrFlwRt = PipeArea * Average Flow Velocity * 3600.0. [m3]

Determine if 10-point curve fit linearization is desired (FwdFlwRt1 > 0). An "if" loop is used to determine between which two flowrates the current batch flowrate falls under, and that interval's corresponding m and b values are found. It uses the basic equation of straight line y = mX + c. A sample case of m and b calculations is provided.

m = (FwdMtrFctr1 - FwdMtrFctr2)/(FwdFlwRt1 - FwdFlwRt2)

b = FwdMtrFctr1 - m(FwdFlwRt1).

The correct LinearMtrFctr (register 390, blk #12) for that UnCorrFlwRt and FlowRate (register 392, blk #12) are determined.

LinearMtrFctr = m(UnCorrFlwRt) + b.

FlowRate = UnCorrFlwRt * LinearMtrFctr. [m3]

This will be converted to the corresponding corrected velocity using the following formula:

AvgFlow(register 360, blk #12) = corrected flowrate / (PipeArea * 3600). [m/s]

If no suitable interval is found, LinearMtrFctr is set to 1. Also if the UnCorrFlwRt is out of range, use the FwdMtrFctr corresponding to the FwdFlwRt closest to it.

Else if 10-point curve fit linearization is not desired, set LinearMtrFctr to 1, save UnCorrFlwRt as **FlowRate,** and **Average Flow Velocity** as **AvgFlow.**

Else if **flow is in the negative direction** (VEL < 0) then:

Determine whether to use first or third order of calibration by looking at A0, A1, A2 and A3 values. If the respective values are 0,1,0,0 or 0,0,0,0 then use first order,

Average Flow Velocity = (VEL - VelocityOffset) * MeterFctr.[m/s]

Else use third order calibration,

Average Flow Velocity = FwdA0 + (VEL * FwdA1) + (VEL * VEL * FwdA2) + (VEL * VEL * VEL * FwdA3).[m/s]

Calculate uncorrected flow rate (register 388, blk #12),

UnCorrFlwRt = PipeArea * Average Flow Velocity * 3600.0. [m3]

Determine if 10-point curve fit linearization is desired (RevFlwRt1 > 0). An "if" loop is used to determine between which two flowrates the current batch flowrate falls under, and that interval's corresponding m and b values are found. It uses the basic equation of straight line, y = mX + c. A sample case of m & b calculations is provided.

m = (RevMtrFctr1 - RevMtrFctr2)/(RevFlwRt1 - RevFlwRt2).

b = RevMtrFctr1 - m(RevFlwRt1).

The correct LinearMtrFctr (register 390, blk #12) for that UnCorrFlwRt and FlowRate (register 392, blk #12) are determined.

LinearMtrFctr = m(UnCorrFlwRt) + b.

Flowrate = UnCorrFlwRt * LinearMtrFctr. [m3]

This will be converted to the corresponding corrected velocity using the formula;

AvgFlow(register 360, blk #12) = corrected flowrate / (PipeArea * 3600). [m/s]

If no suitable interval is found, LinearMtrFctr is set to 1. Also if the UnCorrFlwRt is out of range, use the RevMtrFctr corresponding to the FwdFlwRt closest to it. Else if 10-point curve fit linearization is not desired, set LinearMtrFctr to 1, save UnCorrFlwRt as **FlowRate,** and **Average Flow Velocity** as **AvgFlow.**

The 10-point curve fit linearization process is implemented in Version 6.45 and later versions of CPU (DFI V3.83). If curve-fit is not desired, depending on the direction of flow, either FwdFlwRt1 or RevFlwRt1 should be set to 0. If the decision is to use less than 10 points, the FlwRt and MtrFctr values of unused points should be set to 0 and 1 respectively. The input flowrate coefficients should be entered in descending order (highest first) with their corresponding MtrFctrs. If these are entered in the wrong order, the meter would still work but the accuracy may be affected. The meter will not accept negative values, so only positive values should be entered for both forward and reverse flowrates. Only values between 0.98 and 1.02 are acceptable for MtrFctr coefficients.

5.2.5 Flow Profile Correction Factors for JuniorSonic™ Meters

Refer to Figure 5-7 for the flow-profile-effect correction factor equation for JuniorSonic™ meters.

$$CF = 1 + \frac{0.242}{\log\left[0.2703\left(\frac{25e^{-6}}{D}\right) + \frac{0.835}{\mathrm{Re}^{0.8}}\right]}$$

Figure 5-7 Flow-Profile Correction Factor for JuniorSonic™ Meter

Where

CF = Flow-profile-effect correction factor (dimensionless)

$25e^{-6}$ = Wall roughness (ft) (equivalent to 300 microinches)

D = Pipe inside diameter (ft)

Re = Reynolds Number (dimensionless)

The JuniorSonic™ Reynolds Number is approximated by taking 0.94 of the estimated Reynolds Number calculated using the raw average velocity from the meter. Refer to Figure 5-8.

$$\mathrm{Re} = 0.94\,\mathrm{Re}_{EST}$$

Figure 5-8 JuniorSonic™ Reynolds Number Equation

Where

Re = JuniorSonic™ Reynolds Number (dimensionless). Refer to Figure 5-9.

$$\mathrm{Re}_{EST} = 1488.164\frac{\rho V_{avg} D}{\mu}$$

Figure 5-9 JuniorSonic™ Reynolds Number (dimensionless)

$\mathrm{Re}_{\mathrm{EST}}$ = Estimated Reynolds Number (dimensionless)

1488.164 = Conversion factor for inputting viscosity in cPoise (cPoise ft s / lbm)

ρ = Flow-condition gas mass density (lbm/ft3)

V_{avg} = Uncorrected average gas velocity calculated by the JuniorSonic™ (ft/s)

D = Pipe inside diameter (ft)

μ = Absolute viscosity (cPoise)

Refer to Figure 5-10 for the uncorrected volumetric flow rate calculation.

$$Q_{Ultrasonic\ meter} = V_{avg}\frac{\pi}{4}D^2$$

Figure 5-10 Uncorrected Volumetric Flow Rate Calculation

Where

$Q_{\text{Ultrasonic meter}}$ = Volumetric flow rate calculated by the JuniorSonic™ (ft3/s)

V_{avg} = Uncorrected average gas velocity calculated by the JuniorSonic™ (ft/s)

π = pi, geometric constant, ratio of circumference of circle to its diameter (3.14159... dimensionless)

D = Pipe inside diameter (ft)

Combining the equations (see Figure 5-7, Figure 5-8, Figure 5-9, and Figure 5-10), the JuniorSonic™ Reynolds Number can be calculated alternatively as Figure 5-11.

$$\mathrm{Re} = (0.94)(1488.164)\left[\frac{4}{\pi}\right]\frac{Q_{Ultrasonic\ meter}\,\rho}{D\mu}$$

Figure 5-11 Alternative Combined JuniorSonic™ Reynolds Number Equation

Finally, the flow-profile-effect corrected volumetric flow rate is calculated (see Figure 5-12).

$$Q_{Corrected} = CF \cdot Q_{Ultrasonic\ meter}$$

Figure 5-12 Flow-Profile-Effect Corrected Volumetric Flow Rate Calculation

Also, the flow-profile-effect corrected volumetric flow rate calculation (Figure 5-13).

$$\rho_f = \rho_b \cdot \frac{P_f T_b Z_b}{P_b T_f Z_f}$$

Figure 5-13 Flow-Profile-Effect Calculation

Where

ρ = Density

P = Absolute pressure

T = Absolute temperature

Z = Compressibility

5.3 COMMUNICATIONS

5.3.1 Architecture Issues

The DFI board processor communicates with the Host processor via a dedicated serial port in order to obtain information such as meter type, flow rate, and batch duration. Thus, the Host processor serial communication interface (otherwise used for communication with an external flow computer) must be dedicated to communication with the DFI board processor. The DFI processor is the Modbus master and the Host processor is the Modbus slave. Since both processors have the same built-in serial communication interface, the two processors communicate directly (i.e., without a driver). This frees up the RS-232C and RS-485 drivers (on the PS board) for use by the DFI processor for external communication.

Table 5-1 Predefined Measurement Units (Sheet 1 of 2)

Measurement	Metric Unit	US. Customary Unit
Temperature	K (storage) C (Modbus access)	F
Pressure	MPa (gage or abs)	psig or psia
Length	m	ft
Volume	m^3	ft^3
Gross Heating Value	kJ/dm^3	Btu/ft^3
Viscosity	Pa s	cPoise
Molar Density	$g\text{-}mol/dm^3$	$lbm\text{-}mol/ft^3$
Volumetric Flow Rate (depends upon user-selected time unit)	m^3/s m^3/hr (storage) m^3/day	ft^3/sec ft^3/hr ft^3/day
KFactor	$pulses/m^3$	$pulses/ft^3$
Mass Density	kg/m^3	lbm/ft^3
Molar Gross Heating Value	kJ/g-mol	Btu/lbm-mol
Molar Mass	kg/kg-mol	lbm/lbm-mol

Table 5-1 Predefined Measurement Units (Sheet 2 of 2)

Measurement	Metric Unit	US. Customary Unit
Second Virial Coefficient	dm^{3}/g-mol	ft^{3}/lbm-mol
Third Virial Coefficient	dm^{6}/g-mol^{2}	ft^{6}/lbm-mol^{2}
Linear Expansion Coefficient	K-^{1} (storage) C-^{1} (Modbus access)	F-^{1}
Young's Modulus	MPa	10^{6} psi

The DFI processor handles all external communication and provides the same Modbus address, baud rate, and protocol options (via DFI board DIP switches) that were provided by the Host processor. For external communication, the external computer is the Modbus master and the DFI processor is the Modbus slave. The DFI Modbus registers are numbered beginning with 10000 so that there is no conflict with Host processor Modbus registers (numbered 1-9999). The DFI simply passes external Modbus requests related to Host registers to the Host processor and then passes the Host processor response back to the source of the request. For the DFI to pass these messages efficiently, all DFI communication (via the two external communication ports and the serial communication interface to the Host processor) uses the same Modbus address and protocol.

In order for the DFI processor to initially establish communication with the Host processor, the Host's communication parameters must be set (via CPU board jumpers) to the following default values: 9600 baud, ASCII Modbus protocol, and Modbus Address 32. Once the DFI processor has established communication with the Host processor (using the default parameters), the DFI processor then writes the desired communication Modbus address and protocol (parity and word length) to the Host processor and verifies that the Host processor has indeed changed its communication settings. When this verification is complete, the DFI processor can relay external Modbus requests to the Host processor.

See Section 3.2 for more information on switch and jumper settings.

5.3.2 External Communication

As discussed in the previous section, the DFI communicates with external computers the same way as the Host processor would if the DFI accessory were not used. The only exception is that the DFI processor has two external communication ports whereas the Host processor has only one external communication port. Thus, the external communication port expected to be used for communicating with a flow computer (Port A) offers the same Modbus address selections (1-32), Modbus protocol selections (RTU or ASCII), and baud rate selections (1200, 2400, 4800, or 9600) as the Host processor offered. The external communication port expected to be used for communicating with a diagnostic computer (Port B), is required to use the same Modbus address and protocol as Port A but has a more limited baud rate selection (2400 or 9600).

Due to a hardware problem with the device used for external communication, beginning with v3.62, the DFI, upon start-up, outputs at least one and as many as four characters via the diagnostic computer port (Port B) to properly configure the device.

The DFI processor handles the same Modbus functions as the Host processor: namely, function code 3 (read multiple registers), function code 6 (write single register), and function code 16 (write multiple registers). Refer to Appendix B for further information on the formats of the supported Modbus function codes.

The DFI Modbus registers are numbered beginning with 10000 so that there is no conflict with Host processor Modbus registers (numbered 1-9999). Refer to Appendix C Modbus Registers for the Host processor Modbus register definition. Refer to Appendix D Modbus Registers for the DFI Modbus register definition. The DFI duplicates a very small subset of Host processor registers for two reasons:

1. To provide time and cold-start information in the same block as the accumulated volumes so that when read as a block, the values are guaranteed to be from the same batch, and
2. To minimize the number of external flow computer accesses to Host processor Modbus registers which are slower than accesses to DFI Modbus registers and which cause extra communication “traffic” between the DFI and Host processors.

5.3.3 Host Communication

The purpose of this section is to discuss the communication between the DFI and Host processors originated by the DFI processor (i.e., not originated by an external computer).

Start-up communication

As previously discussed, if the Modbus protocol and address selected via DFI board DIP switches are not the same as the Host processor default communication Modbus protocol and address, then the initial communication from the DFI processor to the Host processor (using 9600 baud, ASCII Modbus, and Modbus Address 32) is a request for the Host to change its communication parameters to the selected values. All subsequent DFI processor Modbus requests use the DIP switch selected Modbus protocol and address at 9600 baud.

The DFI processor then requests to read the Host processor's Device (Model) Number (using the selected Modbus protocol and address at 9600 baud) so that the DFI processor can determine the meter type: single-path, dual-path, or multi-path. If the Host processor had been requested to change its communication parameters, this request also acts to verify that the Host had indeed made the change.

Beginning with version 3.00, the start-up communication also includes reading each of the CPU Modbus parameter Blocks (i.e., Blocks 2, 3, 9, 10, and 11) and storing the parameter values for audit logging purposes.

Batch cycle communication

The DFI processor takes advantage of the fact that the Host processor updates the TimeLapse Modbus register at the very end of its batch processing. Thus, the DFI processor can determine when a batch update has just been completed by polling the value of the Host TimeLapse register looking for a change. In order to prevent tying-up the DFI-Host communication path (which may also be used for passing requests from external communication sources to the Host), the DFI processor polls the Host TimeLapse register at regular intervals (set via the DFI PollingPeriod Modbus register).

When the DFI processor detects a change in the Host TimeLapse register (indicating that a batch update has just taken place), the DFI processor then sends a series of requests to the Host processor for the values needed for batch data processing. These data requests are discussed in further detail in the Batch Cycle Processing section.

5.4 MODES OF OPERATION

There are four primary DFI modes of operation: Normal, Test, Maintenance, and Current Calibration. As the name implies, the Normal mode is the usual mode of operation. The DFI operation in the Test, Maintenance, and Current Calibration modes is nearly the same as for the Normal mode but with some minor variations.

In the Normal mode, the flow condition temperature and pressure (either sampled analog inputs or specified via Modbus registers) are used to correct the volumetric flow rate (reported by the Host processor) for flow-profile effects (for single-path and dual-path meters) and for calculating the equivalent user-specified base condition volumetric flow rate. The frequency and current outputs are updated to reflect the volumetric flow rate at the user-specified condition (flow or base); the direction output is updated based upon the sign of the volumetric flow rate; and the validity output is updated based upon the meter status and the validity of the sampled input signals. Gas volumes are accumulated for both flow and base condition in each direction.

The multi-path meter, by design, does not require flow-profile effect correction.

The Test mode is used to set the frequency and current outputs to the user-specified percentage of full scale for testing purposes. Thus, the Test mode is the same as the Normal mode except the frequency and current outputs do not indicate the volumetric flow rate and the validity output indicates invalid output. All the Normal mode calculations are performed (except those for updating the frequency and current outputs) and the volume accumulators are updated.

The Maintenance mode is used to perform system calibration of the temperature and pressure input signals. All the Normal mode calculations are performed and volume accumulators are updated except that the flow condition temperature and pressure values used in the calculations are the last measurements taken prior to entering the

Maintenance mode. The temperature and pressure measurements are assumed to be invalid for the purpose of setting the validity output. For more details see Section 5.8.

The Current Calibration mode is used to calibrate the 4-20 mA current output signal. All the Normal mode calculations are performed and volume accumulators are updated except that the current output does not represent the volumetric flow rate: it is either the uncalibrated zero-scale value or the offset-calibrated full-scale value depending upon the selected submode.

The user can specify the maximum amount of time (in minutes) that the DFI can remain in a non-Normal mode (i.e., Test, Maintenance, or Current Calibration mode) via the Modbus Block 51 NonNormalModeTimeout register. When the DFI has been in any non-Normal mode for the specified maximum duration, the DFI automatically changes to the Normal mode. When the NonNormalModeTimeout register is set to zero, the time out feature is overridden and the DFI can remain in a non-Normal mode indefinitely.

5.5 BATCH CYCLE PROCESSING

5.5.1 Determining Meter Batch Completion

The DFI processor takes advantage of the fact that the Host processor updates the TimeLapse Modbus register at the very end of its batch processing. Thus, the DFI processor can determine when a batch update has just completed by polling the value of the Host TimeLapse register and looking for a change. The rate at which the DFI polls the TimeLapse register is controlled via the DFI PollingPeriod Modbus register.

5.5.2 Reading Host Processor Modbus Registers

Once a change in the TimeLapse register is detected (indicating the completion of a batch), the DFI processor then begins a series of data requests from the Host processor. The Host Modbus registers read by the DFI per batch cycle are listed in Table 5-2 (values grouped together are read as a block):

Table 5-2 Host Modbus Registers Read per Batch Cycle

Host Modbus Register Name	Modbus Register(s)
PipeDiam	302-303
FlowRate CutRate	392-393 394-395
StatusA StatusB StatusC StatusD SystemStatus	62 63 64 65 66
ColdStart DataQlty TimeLapse TimeOverflow Time	1504-1505 1506-1507 1512-1513 1514-1515 1516-1517

If the Host ColdStart register indicates that the meter has cold-started, then the DFI writes a zero to the Host ColdStart register as acknowledgement and to reset the register.

5.5.3 Flow Condition Temperature and Pressure

The flow condition temperature and pressure are used to correct the meter-reported volumetric flow rate (for single-path and dual-path meters) and to convert the volumetric flow rate at the flow condition to the equivalent volumetric flow rate at the user-specified base condition.

The flow condition temperature and pressure inputs can be independently disabled, enabled, or specified. If an input is enabled, its value is determined by sampling an analog input signal once per second and optionally averaging a specified number of samples. If an input is specified, its value is specified by a writable Modbus register. If either input is disabled, the AGA8 flow-condition calculations, Reynolds Number calculation, flow-profile-effect correction calculation (for single-path and dual-path meters only), and flow-condition-to-base-condition conversion factor calculation cannot be performed. In this case, Reynolds Number is set to its minimum value (1.0E4) and for single-path and dual-path meters, the flow-profile-effect correction factor is fixed at 0.95.

When the DFI is in the Normal or Test mode, each enabled analog input signal is sampled once per second. The sample is stored in a corresponding measurement array (queue) which stores up to the last 64 samples. The value used for the batch calculations is the average of the samples stored in the measurement array where the number of samples to average is specified by the user (via MeasurementArraySize). The temperature and pressure values used for the batch calculations are readable via the FlowTemperature and FlowPressure registers.

When the DFI is in the Maintenance mode, the enabled temperature and pressure input signals are expected to be set to some specific value for calibrating the analog input measurement system. Since the temperature and pressure signals do not reflect the actual gas temperature and pressure, the last known measurements (i.e., the last measurements prior to entering the Maintenance mode) which are saved in the FlowTemperature and FlowPressure registers are used for batch calculations.

5.5.4 Temperature and Pressure Effect Expansion Correction

The DFI is capable of correcting the meter-reported volumetric flow rate for the effect of pipe expansion due to temperature and pressure changes. The temperature-effect expansion correction and pressure-effect expansion correction are individually enabled or disabled via the EnableExpCorrTemp and EnableExpCorrPress Modbus registers in Block 56. Note that for a correction to be applied, the correction must be enabled and the corresponding input (flow-condition temperature or pressure) must be enabled or specified (via the EnableTemperatureInput and EnablePressureInput registers in Block 56). If the correction is disabled or the corresponding input is disabled, the corresponding correction factor is set to 1.0. The expansion correction factors and expansion-corrected volumetric flow rate are accessible via the Modbus registers ExpCorrTemperature, ExpCorrPressure, and QExpCorr in Block 62.

The calculation of the expansion correction factors and expansion-corrected volumetric flow rate are described below.

The expansion-corrected volumetric flow rate is calculated using the equation shown:

$$Q_{(ExpCorr,f)} = Q_{(UFM,f)} \times C_t \times C_p \tag{1}$$

Where

$Q_{ExpCorr,f}$ = expansion-corrected (flow-condition) vol-umetric flow rate (m^3/hr) (readable via QExpCorr Modbus register)

$Q_{UFM,f}$ = uncorrected flow-condition volumetric flow rate (m^3/s) (read from Host FlowRate Modbus register, readable via DFI QMeter Modbus register)

This value must be converted to m^3/s from the storage unit of m^3/hr.

C_t = expansion correction factor due to temperature (dimensionless) (readable via Exp-CorrTemperature Modbus register)

If expansion correction for temperature effects is disabled (via EnableExpCorrTemp) or the temperature input is disabled (via EnableTemperature), then this is set to 1.0; otherwise, this value is calculated per Equation 2 below.

C_p = expansion correction factor due to pressure (dimensionless) (readable via ExpCorr-Pressure Modbus register). If expansion correction for pressure effects is disabled (via EnableExpCorrPress) or the pressure input is disabled (via EnablePressure), then this is set to 1.0; otherwise, this value is calculated per Equation 3 below.

If the expansion correction for temperature effects is enabled or the temperature input is enabled, then C_t is calculated via this equation:

$$C_t = 1 + [3 \times \alpha \times (T_f - T_{ref})] \tag{2}$$

Where

α = pipe linear expansion coefficient due to temperature (K^{-1}) (user input via the LinearExpansionCoef Modbus register)

T_f = flow-condition absolute temperature (K)

This is either the sampled analog temperature input signal or the specified flow-condition temperature (readable via the FlowTemperature register).

T_{ref} = reference temperature for the pipe linear expansion coefficient (K) (user input and readable via the RefTempLinearExpCoef register)

If the expansion correction for pressure effects is enabled or the pressure input is enabled, then C_p is calculated via this equation:

(3) $$C_p = 1 + [3 \times \beta \times (P_f - 0.101325)]$$

Where

P_f = flow-condition absolute pressure (MPa)

This is either the sampled analog pressure input signal or the specified flow-condition pressure (plus the user input atmospheric pressure if the input is gage pressure) (readable via the AbsFlowPressure register).

β = pipe strain per unit stress (MPa^{-1}) (readable via the StrainPerUnitStress register); see Equation 4 below

Pipe strain per unit stress (β) is calculated via the following formula:

(4) $$\beta = \frac{D_{out}^2(1+\nu) + D_{in}^2(1-2\nu)}{E(D_{out}^2 - D_{in}^2)}$$

Where

D_{out} = outside diameter of the meter or pipe (m) (user input via the PipeOutsideDiameter register)

D_{in} = inside diameter of the meter or pipe (m) (user input via the CPU PipeDiam register)

ν = Poisson's Ratio (dimensionless) (user input via the PoissonsRatio register)

E = Young's modulus of elasticity (MPa) (user input via the YoungsModulus register)

5.5.5 AGA8 Flow-Condition Compressibility Calculation

The gas compressibility at the flow condition (i.e., at the temperature and pressure measured or specified as described above) is calculated as specified by AGA8 [3] using the Gross Characterization Method specified by the user. (The base-condition gas compressibility is calculated upon start-up and whenever any of the user-specified AGA8 parameters in Modbus Block 54 is changed.)

Beginning with v3.62, the compressibilities can be calculated externally (allowing the AGA8 Detail Method to be used) with the results specified to the DFI. Refer to Section 4.1.4 for further information.

The AGA8 Gross Characterization Method is recommended for calculations of natural gas compressibility factors and densities for temperatures from 32 to 130 °F (0 to 55 °C) and for pressures up to 1200 psia (8.3 MPa). If the DFI is used in conditions outside of these ranges, the volumetric flow rate flow-to-base conversation may not be available due to the inability of the AGA8 Gross Characterization Method to calculate compressibility at the flow condition.

Several intermediate calculation values are readable via Modbus registers in Block 63. Some of these intermediate values are used in the Reynolds Number calculation described below.

5.5.6 Reynolds Number Calculation

Reynolds Number is a dimensionless value which represents the nature of the gas flow within the pipe. Although the primary reason for calculating Reynolds Number is for flow-profile-effect correction, it is calculated for all meter types regardless of whether the flow-profile-effect correction factor is calculated.

Reynolds Number is calculated using the equation shown:

(5)

$$Re = (PathFactor)\left(\frac{4}{\pi}\right)\frac{Q_{ExpCorr,f} \times \rho_{(T_f,P_f)}}{d\mu}$$

Where

Re = Reynold's number (dimensionless)

$PathFactor$ = factor to (approximately) correct for velocity profile effects (0.94 for single-path and dual-path meters, 1.00 for multi-path meters; dimensionless)

π = geometric constant, ratio of circumference of circle to its diameter (3.14159... dimensionless)

$Q_{ExpCorr,f}$ = expansion-corrected (flow-condition) volumetric flow rate (m3/s) (readable via QExpCorr Modbus register)

This value must be converted to m^3/s from the storage unit of m^3/hr.

d = inside pipe diameter (m) (read from Host PipeDiam Modbus register)

μ = dynamic viscosity (Pa s) (user input via DFI Viscosity Modbus register)

$\rho_{(T_f,P_f)}$ = mass density of the natural gas mixture at the flow condition (kg/m3) (readable via DFI RhoMixFlow Modbus register); see below

If the AGA8 calculations are performed externally (i.e., HCH_Method=0) with the results specified to the DFI, then the value for $\rho_{(T_f,P_f)}$ is determined by the specified density at the flow-condition, SpecRhoMixFlow (Block 53, register 10078):

$$\rho_{(T_f,P_f)} = SpecRhoMixFlow$$

Otherwise, if the AGA8 flow-condition calculation is performed internally and is valid, then the value for $\rho_{(T_f,P_f)}$ is calculated as:

$$\rho_{(T_f,P_f)} = M_r d_{(T_f,P_f)} \tag{6}$$

Where

M_r = molar mass (molecular weight) of the natural gas mixture (kg/kg-mol) (calculated as part of the AGA8 Gross Method, readable via DFI Mr Modbus register)

$d_{(T_f,P_f)}$ = molar density of the natural gas mixture at the flow condition (kg-mol/m 3 or equivalently g-mol/dm^3) (calculated as part of the AGA8 Gross Method, readable via DFI dFlow Modbus register)

Otherwise, the value for $\rho_{(T_f,P_f)}$ is estimated via the Ideal Gas Law:

$$\rho_{(T_f,P_f)} = G_r \rho_{air(T_{G_r},P_{G_r})}\left(\frac{P_f}{P_{G_r}}\right)\left(\frac{T_{G_r}}{T_f}\right) \tag{7}$$

Where

G_r = natural gas mixture (dimensionless) (user specified via the DFI SpecificGravity Modbus register)

$\rho_{air(T_{G_r},P_{G_r})}$ = mass density of air at the specific gravity reference condition (T_{G_r},P_{G_r}) (kg/m^3) (calculated as part of the AGA8 Gross Method, readable via DFI RhoAir Modbus register)

P_f = flow-condition absolute pressure (MPa) (readable via DFI AbsFlowPressure Modbus register)

P_{G_r} = specific gravity reference absolute pressure (MPa) (user specified via DFI RefPressureGr Modbus register)

T_{G_r} = specific gravity reference temperature (K) (user specified via DFI RefTemperatureGr Modbus register)

T_f = flow-condition absolute temperature (K) (readable via the FlowTemperature register)

5.5.7 Flow Profile Effect Correction

For meter models 3410, 3420, Double Dual 3422, and 3450, the volumetric flow rate requires flow-profile-effect correction due to the location of the transducers. (All other meter models do not require this correction; for those models the correction factor is set to 1.)

Prior to firmware V3.73, if the flow-condition temperature and pressure were enabled/specified, then the correction factor was calculated (using the equation shown below). Otherwise, the correction factor was set to the default value (0.95). Beginning with firmware v3.73, the correction factor can also be specified (via the Block 53 SpecCorrectionFactor register). Also, beginning with firmware v3.73, the correction factor can be calculated even if the temperature and/or pressure is disabled as long as the AGA8 calculations are performed externally with the gas mass density specified (via the Block 53 SpecRhoMixFlow register) (since the gas mass density is required for the Reynolds Number calculation).

Thus, for models 3410, 3420, and 3450,

```
if (SpecCorrectionFactor ≠ 0), then
    $CF = SpecCorrectionFactor$
else if ((AGA8 calculations not performed externally) AND ((temperature is disabled) OR (pressure is disabled))), then
    $CF = 0.95$
else
```

(8)

$$CF = 1 + \frac{0.242}{LOG\left(0.2703\frac{WR}{d} + \frac{0.835}{\mathrm{Re}^{0.8}}\right)}$$

For all other models,

$$CF = 1.0$$

Where

CF =	correction factor (dimensionless)readable via DFI CorrectionFactor Modbus register
$SpecCorrectionFactor$ =	specified correction factor (dimensionless) (user specified via the DFI SpecCorrectionFactor Modbus register)
WR =	wall roughness (m) (user input via DFI WallRoughness Modbus register)
d =	inside pipe diameter (m) (read from Host PipeDiam Modbus register)
Re =	Reynolds number (dimensionless); see Equation 5

The expansion-corrected volumetric flow rate (at the flow condition) is flow-profile corrected using the equation shown:

(9) $$Q_{(DFI,f)} = CF \times Q_{(ExpCorr,f)}$$

Where

$QDFI_{,f}$ = corrected flow-condition volumetric flow rate (m^3/hr) (read from Host FlowRate Modbus register, readable via DFI QMeter Modbus register)

CF = flow-profile-effect correction factor (dimensionless) (refer to Equation 8, readable via DFI CorrectionFactor Modbus register)

$Q_{ExpCorr,f}$ = expansion-corrected (flow-condition) volumetric flow rate (m^3/hr) (readable via QExpCorr Modbus register)

If the corrected flow-condition volumetric flow rate is less than the volumetric flow rate cut-off (read from the Host CutRate Modbus register, readable via the DFI QCutOff register), then the corrected flow-condition volumetric flow rate, $Q\mathrm{DFI}_{,f}$, is set to zero.

5.5.8 Base-Condition Volumetric Flow Rate Calculation

The conversion of the corrected flow-condition volumetric flow rate to the equivalent base-condition volumetric flow rate is calculated according to AGA7 ([2] equation 16):

(10) $$Q_b = Q_{(DFI,f)}\left(\frac{P_f}{P_b}\right)\left(\frac{T_b}{T_f}\right)\left(\frac{Z_b}{Z_f}\right)$$

Where

Q_b base-condition volumetric flow rate (m^3/hr) (readable via DFI QBase Modbus register)

$QDFI_{,f}$ = corrected flow-condition volumetric flow rate (m^3/hr) (read from Host FlowRate Modbus register, readable via DFI QMeter Modbus register)

P_f = flow-condition absolute pressure (MPa) (readable via DFI AbsFlowPressure Modbus register)

If the input pressure signal unit is absolute, then this is either the sampled absolute analog pressure input signal or the specified absolute flow condition pressure. If the input pressure signal is gage, then this is the sum of the absolute atmospheric pressure, specified via the AtmosphericPressure register, and the gage flow-condition pressure, readable via the FlowPressure register (which is either the sampled gage analog pressure input signal or the specified gage flow-condition pressure).

P_b = base-condition absolute pressure (MPa) (user specified via DFI PBase Modbus register)

T_b = base-condition absolute temperature (K) (user specified via DFI TBase Modbus register)

T_f = flow-condition absolute temperature (K)

This is either the sampled analog temperature input signal or the specified flow-condition temperature (readable via the FlowTemperature register).

Z_b = base-condition compressibility factor (dimensionless) (calculated via the AGA8 Gross Method, readable via DFI ZBase Modbus register)

Z_f = compressibility factor at flowing conditions (dimensionless) (calculated via the AGA8 Gross Method, readable via DFI ZFlow Modbus register)

The product of the pressure, temperature, and compressibility terms in Equation 10 above is readable via the DFI AGA8FlowToBaseConversion Modbus register.

5.6 DATA VALIDITY DETERMINATION

The validity indicators discussed in this section are used in determining the validity output signal value. A live temperature input must be configured for this test to be active.

5.6.1 Temperature Measurement Validity

In the Normal mode, the flow condition temperature and pressure (either sampled analog input or specified via Modbus register) are used to correct the volumetric flow rate (reported by the Host processor) for flow-profile effect (for single-path and dual-path meters) and for calculating the equivalent user- specified base condition volumetric flow rate. The frequency and current output are updated to reflect the volumetric flowrate at the user- specified condition (flow or base); the direction output is updated based upon the sign of the volumetric flow rate; and the validity output is updated based upon the meter status and the validity of the sampled input signal. Gas volumes are accumulated for both flow and base condition in each direction.

TemperatureValidity =

(11) Valid if

(EnableTemperatureInput ≠ DISABLE_INPUT) and

(UFIMode ≠ Maintenance Mode) and

(LowTemperatureAlarm ≤ FlowTemperature ≤ HighTemperatureAlarm)

Invalid otherwise

5.6.2 Pressure Measurement Validity

PressureValidity =

(12) Valid if

(EnablePressureInput ≠ DISABLE_INPUT) and

(UFIMode ≠ Maintenance Mode) and

(LowPressureAlarm ≤ FlowPressure ≤ HighPressureAlarm)

Invalid otherwise

5.6.3 AGA8 Base Condition Compressibility Calculation Validity

The AGA8 base-condition compressibility calculation is valid if the compressibility was calculated without error and is invalid otherwise. The validity is readable via the DFI AGA8BaseCalcValidity Modbus register. Note that the base-condition gas compressibility is calculated upon startup and whenever any of the user-specified AGA8 parameters in Modbus Block 54 is changed.

This is a note regarding section 5.6.3 and 5.6.4

This test in not performed unless corrected volumes are being calculated.

5.6.4 AGA8 Flow Condition Compressibility Calculation Validity

The DFI attempts to calculate the AGA8 flow-condition compressibility if the temperature and pressure are valid and the AGA8 base-condition calculation is valid. The AGA8 flow-condition compressibility calculation is valid if the compressibility was calculated without error and is invalid otherwise. The validity is readable via the DFI AGA8FlowCalcValidity Modbus register.

5.6.5 Meter-Reported Flow Condition Volumetric Flow Rate Validity

The meter-reported flow-condition volumetric flow rate (QMeter) is valid if the meter is in the measurement mode (i.e., no active chords are in the acquire mode) and the number of working chords is acceptable ≥ min chord; the volumetric flow rate is invalid otherwise. The Host processor chord status Modbus registers (StatusA, StatusB, StatusC, and StatusD) are used to determine which chords are active and if the meter is in the measurement mode. The Host processor DataQlty register value is used to determine if the number of working chords is acceptable. The meter-reported flow-condition volumetric flow rate validity is readable via the DFI QMeterValidity Modbus register.

5.6.6 Corrected Flow Condition Volumetric Flow Rate Validity

The DFI corrects the meter-reported volumetric flow rate (QMeter) for the effect of pipe expansion due to temperature and pressure changes and, for single-path and dual-path meters, it also corrects for flow-profile effects. (Multi-path meters, by design, do not require flow-profile effect correction.) Thus, the validity of the corrected flow-condition volumetric flow rate (QFlow) depends upon the validity of the meter-reported volumetric flow rate and the validity of the pipe expansion corrections and flow-profile correction.

Pipe Expansion Corrections Validities

If the temperature-effect pipe expansion correction is disabled and/or the temperature input is disabled, then it is assumed that the temperature-effect pipe expansion correction is not desired. In that case, the corresponding correction factor is set to 1 and the correction is treated as being valid. Otherwise, (the temperature-effect pipe expansion correction is enabled and the temperature input is not disabled), the correction is valid if the temperature input is valid and is invalid if the temperature input is invalid. Thus, the temperature-effect expansion correction validity (readable via ExpCorrTempValidity in Block 60) is determined as shown:

ExpCorrTempValidity =

(13) Invalid if

(EnableExpCorrTemp = Enabled) and

(EnableTemperature ≠ Disabled) and

(TemperatureValidity = Invalid)

Valid otherwise

Similarly, if the pressure-effect pipe expansion correction is disabled and/or the pressure input is disabled, then it is assumed that the pressure-effect pipe expansion correction is not desired. In that case, the corresponding correction factor is set to 1 and the correction is treated as being valid. Otherwise (the pressure-effect pipe expansion correction is enabled and the pressure input is not disabled), the correction is valid if the pressure input is valid and is invalid if the pressure input is invalid. Thus, the pressure-effect expansion correction validity (readable via ExpCorrPressureValidity in Block 60) is determined as shown:

ExpCorrPressValidity =

(14) Invalid if

(EnableExpCorrPress = Enabled) and

(EnablePressure ≠ Disabled) and

(PressureValidity = Invalid)

Valid otherwise

Flow-Profile-Effect Correction Validity

For those meter types that require flow-profile-effect correction (models 3410, 3420, Double Dual 3422, and 3450), the validity of the correction factor depends upon whether the correction factor is calculated, set to the default, or specified.

If the correction factor is specified or set to the default, then it is considered to be valid. If the correction factor is calculated, then its validity depends upon the validity of the equation inputs (including those for the Reynolds Number calculation). If the AGA8 calculations are performed externally (indicated by the HCH_Method register set to 0.0), then the specified flow-condition gas mass density (specified via SpecRhoMixFlow) and meter-reported volumetric flow rate must be valid in order for Reynolds Number (and thus the correction factor) to be valid. Otherwise (the AGA8 calculations are performed by the DFI), the flow-condition temperature and pressure must both be valid, the meter-reported volumetric flow rate must be valid, and the AGA8 base-condition calculations must be valid in order for Reynolds Number (and thus the correction factor) to be valid.

For meter types that do not require flow-profile-effect correction, the correction factor is fixed at 1.0 and is valid.

Corrected Flow-Condition Volumetric Flow Rate Validity

Finally, the corrected flow-condition volumetric flow rate validity (QFlowValidity) can be expressed as a function of the above correction validities and the meter-reported volumetric flow rate validity as shown:

QFlowValidity =

(15) Valid if

(QMeterValidity = Valid) and

(ExpCorrTempValidity = Valid) and

(ExpCorrPressValidity = Valid) and

(FlowProfileCorrValidity = Valid)

Invalid otherwise

5.6.7 Base Condition Volumetric Flow Rate Validity

QBase Validity =

(16) Valid if

(QFlowValidity = Valid) and

(AGA8FlowCalcValidity = Valid)

Invalid otherwise

5.6.8 Frequency Data Validity

FrequencyDataValidity =

(17) Valid if

(UFIMode ≠ Test Mode) and

{(Output QFlow and QFlowValidity = Valid) and

or

(Output QBase and QBaseValidity = Valid)}

Invalid otherwise

The frequency data validity (FrequencyDataValidity) is used to determine the state of the validity output signal: the validity output signal is activated if FrequencyDataValidity=Valid and is not activated otherwise (FrequencyDataValidity=Invalid).

5.7 OUTPUT SIGNAL UPDATING

5.7.1 Output Volumetric Flow Rate Calculation

In order to maintain accuracy in the volumetric flow rate frequency outputs, a frequency pulse signal is fed back from the integrated circuit chip that generates the output frequency signals to the DFI processor. The frequency pulse signal which is fed back represents the absolute volumetric flow rate and is synchronized with the output frequency signals. The purpose of the frequency signal feedback is to correct the frequency volumetric flow rate outputs for small errors caused by (1) the asynchronous nature of the DFI volumetric flow rate updating relative to the meter updating, and (2) the small variation in batch duration from one batch to another. The algorithm for calculating the output volumetric flow rate is described below.

In general the volumetric flow rate to be output via the frequency outputs is the sum of the absolute volumetric flow rate plus the amount of volume error rate to correct for during the current cycle:

$$OutputVFR = |Q| + VFRErrorCompensation \tag{18}$$

If a large negative error rate would result in an output volumetric flow rate which indicates flow in the opposite direction of the actual flow, then the output volumetric flow rate is recalculated to be half the absolute volumetric flow rate:

$$OutputVFR = \frac{|Q|}{2} \tag{19}$$

The amount of the volume error rate to correct for during the current cycle is calculated as follows:

$$VFRErrorCompensation = TotalVFRError \times FreqFeedbackCorrectionPct \tag{20}$$

Where

$VFRErrorCompensation$ = amount of volume error rate to correct for during the current cycle (m^3/hr)

$TotalVFRError$ = (21)amount of volume error rate expected for during the current cycle (m^3/hr); see Equation 22

$FreqFeedbackCorrectionPct$ = percentage of the volume error rate to correct during a cycle (%) (specified via the FreqFeedbackCorrectionPct Modbus register

The volume error expected during the current cycle is calculated as follows:

(22)

$$TotalVFRError = \frac{(|Q| \times (BatchTimeHours - AvgBatchTimeHours)) + VolError}{AvgBatchTimeHours}$$

Where

$TotalVFRError$ = amount of volume error rate expected for during the current cycle (m^3/hr)

$|Q|$ = absolute value of the volumetric flow rate selected for output (i.e., absolute value of either QFlow or QBase) (m^3/hr)

$BatchTimeHours$ = time during which the current batch was measured (calculated below) (hr)

$AvgBatchTimeHours$ = average batch duration (calculated as the average BatchTimeHours value during the last 32 batches) (hr)

$VolError$ = previous cycle volume error (m^3); see Equation 24

The time during which the current batch was measured is calculated as follows:

(23) $$BatchTimeHours = \frac{TimeLapse_i - TimeLapse_{(i-1)}}{9.536743(counts/\sec ond) \times 3600(\sec onds/hr)}$$

Where

$BatchTimeHours$ = time during which the current batch was measured (calculated below) (hr)

$TimeLapse_i$ = value of the Host TimeLapse register for the current batch (time counts)

$TimeLapse_{(i-1)}$ = value of the Host TimeLapse register for the previous batch (time counts)

The volume error during the last output cycle is calculated as follows:

(24) $$VolError = PrevDesiredVol - FreqFeedbackVol$$

Where

$VolError$ = previous cycle volume error (m^3)

$PrevDesiredVol$ = desired volume to output during the previous cycle (m^3)

$FreqFeedbackVol$ = volume represented by the frequency pulses output since the last update (i.e., during the previous cycle) (m^3); see Equation 25

The volume represented by the frequency pulses output since the last update is calculated as follows:

(25) $$FreqFeedbackVol = FreqFeedbackPulseCnt \times VolPerPulse$$

Where

FreqFeedbackVol = volume represented by the frequency pulses output since the last update (m^3)

FreqFeedbackPulseCnt = number of pulses output since the last update (from the fed back signal) (pulses)

VolPerPulse = volume represented by each output pulse (m^3/pulses); see Equation 26

(26)
$$VolPerPulse = \frac{FreqFullScaleVolFlowRate}{MaxFrequency \times 3600(\sec onds/hour)}$$

Where

VolPerPulse = volume represented by each output pulse (m^3/pulses)

FreqFullScaleVolFlowRate = user-specified volumetric flow rate corresponding to the maximum frequency output (m^3/hr)

MaxFrequency = user-specified maximum frequency output (pulses/sec)

5.7.2 Frequency Signal Updating

The signal content of the frequency output signals is user-specified via the DFI Modbus registers Freq1Content and Freq2Content as either forward, reverse, or absolute. FREQ1B and FREQ2B are 90 degree phase-lagged copies of FREQ1A and FREQ2A respectively.

If the frequency signal content corresponds to the flow direction or is absolute, then the frequency of the output signal is calculated as follows:

(27)
$$VFRFreqX = \frac{OutputVFR}{FreqFullScaleVolFlowRate} \times MaxFrequency$$

Where

VFRFreqX = FreqX (Frequency1 or Frequency2) output frequency (Hz)

OutputVFR = volumetric flow rate to output; see Equation 18 (m^3/hr)

FreqFullScaleVolFlowRate = user-specified volumetric flow rate corresponding to the maximum frequency output (m^3/hr)

MaxFrequency = user-specified full-scale output frequency (Hz)

If the frequency signal content is the opposite of the flow direction, then the frequency of the output signal is 0 Hz.

Example:

If

Freq1Content = forward flow or absolute flow

Freq2Content = reverse flow

OutputVFR = 20000 m^3/hr

FlowDirection = forward flow

FreqFullScaleVolFlowRate = 50000 m^3/hr

MaxFrequency = 5000 Hz

Then

VFRFreq1= 2000 Hz

VFRFreq2= 0 Hz

5.7.3 Current Signal Updating

The current output signal indicates the volumetric flow rate based upon the user-specified signal content (forward, reverse, or absolute via the CurrContent register) and the user-specified current full-scale volumetric flow rate (via the CurrFullScaleVolFlowRate register).

The normal output range of the current signal is 4 mA (representing no flow) to 20 mA (representing the full scale volumetric flow rate); however, the current output can be as high as 24 mA (125% of full scale).

If the output volumetric flow rate is in the opposite direction of the selected current signal content (i.e., the flow is in the forward direction and CurrContent selects reverse flow, or the flow is in the reverse direction and CurrContent selects forward flow), then the current output signal is 4 mA (indicating no flow in the selected direction). Otherwise, (the output volumetric flow rate is in the same direction as the current signal content or the current signal content is absolute), the amount of current to output is calculated as follows:

$$VFRCurrentOutput = \left(\frac{|Q|}{CurrFullScaleVolFlowRate} \times (20 - 4)\right) + 4 \tag{28}$$

Where

$VFRCurrentOutput$ = current output (mA)

$|Q|$ = absolute value of the volumetric flow rate selected for output (i.e., absolute value of either QFlow or QBase) (m^3/hr)

$CurrFullScaleVolFlowRate$ = user-specified volumetric flow rate corresponding to the current full scale output (m^3/hr)

In order to achieve the desired current output (calculated above), the current calibration values (offset value and gain coefficient) must be applied to the desired current output to calculate the DAC command value as shown:

$$DACCommandCurrent = (((VFRCurrentOutput - 4) - CurrOffsetValue) \times CurrGainCoefficient) + 4 \tag{29}$$

Where

$DACCommandCurrent$ = current value to output to the DAC (mA)

$VFRCurrentOutput$ = desired current output (mA); see Equation 28

$CurrOffsetValue$ = current calibration offset value (mA) (readable via the CurrOffsetValue Modbus register)

$CurrGainCoefficient$ = current calibration gain coefficient (dimensionless) (readable via the CurrGainCoefficient Modbus register)

5.7.4 Direction and Validity Output Updating

The flow direction discrete output is high (> 3.5 V) when the flow is in the forward direction and is low (< 0.7 V) when the flow is in the reverse direction.

The validity discrete output is high (> 3.5 V) when the frequency signals contain valid volumetric flow rate data (as determined by FrequencyDataValidity defined in Equation 10) and is low (< 0.7 V) otherwise.

5.8 MAINTENANCE MODE (ANALOG INPUT SIGNAL)

The Maintenance mode is used to perform system calibration of the (enabled) temperature and pressure input signals.

All the Normal mode calculations are performed and volume accumulators are updated except that the flow condition temperature and pressure values used in the calculations are the last measurements taken prior to entering the Maintenance mode. The temperature and pressure measurements are assumed to be invalid for the purpose of setting the validity output.

A two-point system calibration (offset and gain) is available for each input (temperature and pressure). The calibration values (readable via Modbus Block 66) are stored in non-volatile memory so that they are retained when the DFI is not powered. The default temperature offset is 0.0 K and the default pressure offset is 0.0 MPa. The default temperature and pressure gain calibration values are 1.0 (dimensionless).

There are nine submodes within the Maintenance mode (selectable via the MaintenanceSubmode Modbus register):

- Read Inputs
- Temperature Offset Calibration
- Temperature Gain Calibration
- Pressure Offset Calibration
- Pressure Gain Calibration
- Reset Temperature Offset Calibration
- Reset Temperature Gain Calibration
- Reset Pressure Offset Calibration
- Reset Pressure Gain Calibration

5.8.1 Read Inputs Submode

The Read Inputs submode is the “default” Maintenance submode; all other Maintenance submodes automatically return to the Read Inputs submode when the particular calibration task is completed. The Read Inputs submode is exited only when either (a) another Maintenance submode is selected or, (b) the Maintenance mode is exited.

The Read Inputs submode allows the user to read the temperature and pressure input signal values via the Block 64 Modbus registers MaintTemperature and MaintPressure. The input signals are sampled once per main processing loop. The system offset and gain values are applied to the digitized input signal as follows:

$$Measurement = \left(\left(\left(\left(\frac{InputSignal - ZeroScaleSignal}{FullScaleSignal - ZeroScaleSignal}\right) \times (MaxInput - MinInput)\right) - SysOffset\right) \times SysGain\right) + MinInput \qquad (30)$$

Where

InputSignal = input signal current (mA) or voltage (V)

ZeroScaleSignal = zero-scale current (4 mA) or voltage (1 V)

FullScaleSignal = full-scale current (20 mA) or voltage (5 V)

MaxInput = maximum (full-scale) input (MaxInputTemperature (K) or MaxInputPressure (MPa))

MinInput = minimum (zero-scale) input (MinInputTemperature (K) or MinInputPressure (MPa))

SysOffset = system offset (TempOffsetValue (K) or PressOffsetValue (MPa))

SysGain = system gain (TempGainCoefficient or PressGainCoefficient, dimensionless)

Measurement = measurement (MaintTemperature (K) or MaintPressure (MPa))

5.8.2 Temperature and Pressure Offset Calibration Submodes

The Temperature Offset Calibration submode and Pressure Offset Calibration submode are used to determine the system offset value for the corresponding analog input signal. The default temperature offset is 0.0 K. The default pressure offset is 0.0 MPa.

When the submode is entered, the corresponding analog input signal is expected to be the zero-scale input value.

Upon entering an offset calibration submode, the corresponding ADC channel is self-calibrated and then the analog input signal is sampled SysCalArraySize times; the average of the readings is stored as the system offset value. For the SysCalArraySize number of readings, the offset is assumed to be 0.0 (Kelvin or MPa) and the gain is assumed to be 1.0. Following the offset value calculation, the DFI automatically returns to the Read Inputs submode.

5.8.3 Temperature and Pressure Gain Calibration Submodes

The Temperature Gain Calibration submode and Pressure Gain Calibration submode are used to determine the system gain value for the corresponding analog input signal. The default gain calibration value for both analog inputs is 1.0.

The analog input signal offset calibration should be done prior to performing a gain calibration.

When the submode is entered, the corresponding analog input signal is expected to be the value corresponding to the calibration gain temperature or pressure (Modbus Block 53). For best results, the calibration gain input should be as close to the maximum input value as possible.

Upon entering a gain calibration submode, the corresponding analog input signal is sampled SysCalArraySize times; the average of the readings is used to calculate the system gain value which is stored in either TempGainCoefficient or PressGainCoefficient in Block 66. For the SysCalArraySize number of readings, the gain is assumed to be 1.0. Following the gain value calculation, the DFI automatically returns to the Read Inputs submode.

5.8.4 Reset Calibration Submodes

The Reset Temperature Offset, Reset Temperature Gain, Reset Pressure Offset, and Reset Pressure Gain submodes are used to reset the corresponding calibration value to the default value. The default offset is 0.0 (Kelvin or MPa); the default gain is 1.0. Following the resetting of the corresponding calibration value, the DFI automatically returns to the Read Inputs submode.

5.9 CURRENT CALIBRATION MODE

The Current Calibration mode is used to perform system calibration of the current output signal. A digital ammeter or multi-meter is required for performing a current calibration. All the Normal mode calculations are performed and volume accumulators are updated except that the current output does not represent the volumetric flow rate: it is either the uncalibrated zero-scale value or the offset-calibrated full-scale value depending upon the selected submode.

A two-point system calibration (offset and gain) is used. The calibration values (readable via Modbus Block 66) are stored in non-volatile memory so that they are retained when the DFI is not powered. The default current offset is 0.0 mA and the default gain coefficient is 1.0 (dimensionless).

There are four submodes within the Current Calibration mode (selectable via the CurrentCalSubmode Modbus register):

- Zero Scale
- Full Scale
- Offset Reset
- Gain Reset

5.9.1 Zero Scale Submode

The Zero Scale submode forces the current output signal to the uncalibrated zero scale output. The user measures the current output (with a digital ammeter or multi-meter) and writes the value to the ZeroScaleCurrent Modbus register. When this register is written to, the current offset value is calculated as:

(31) $$CurrOffsetValue = ZeroCurrentScale - 4mA$$

5.9.2 Full Scale Submode

The Full Scale submode forces the current output signal to the offset-calibrated full scale output. The user measures the current output (with a digital ammeter or multi-meter) and writes the value to the FullScale-Current Modbus register. When this register is written to, the current gain coefficient is calculated as:

(32) $$CurrGainCoefficient = \frac{20 - 4mA}{FullScaleCurrent - 4mA - CurrOffsetValue}$$

5.9.3 Reset Offset Submode

The Reset Offset submode sets the ZeroScaleCurrent Modbus register to its default value of 4.0 mA thus setting CurrOffsetValue to zero. After the current offset is reset, the DFI reverts to the Zero Scale submode.

5.9.4 Reset Gain Submode

The Reset Gain submode sets the FullScaleCurrent Modbus register to its default value of 20.0 mA and the CurrGainCoefficient is re-calculated as shown above. If the current offset value is zero, then CurrGainCoefficient is set to one. After the current gain is reset, the DFI reverts to the Zero Scale submode.

5.10 EVENT AND DATA LOGGING

Beginning with firmware v3.00, the DFI implements event and data logging which meets the requirements set forth in the American Gas Association / American Petroleum Institute *Manual of Petroleum Measurement Standards*, Chapter 21, Flow Measurement Using Electronic Metering Systems (ref. [4]).

5.10.1 General

The implementation of the event and data logging for the DFI is consistent with other Daniel products with some minor differences.

The DFI board includes a real-time clock and 512K byte flash (non-volatile) memory for event and data logging use. The unit also uses a separate non-volatile memory (NOVRAM) for storing the various log pointers and indices.

The DFI stores four types of logs in the log memory:

- Hourly Logs – The DFI stores a log record in the Hourly Log memory once per hour on the hour. The Hourly Log has a readable semi-fixed configuration. The DFI can store 862 Hourly Log records (35 days, 22 hours). Refer to Table 5-4.
- Daily Logs – The DFI stores a log record in the Daily Log memory once per day at the user-specified contract hour. The Daily Log has a readable semi-fixed configuration. The DFI can store 862 Daily Log records. Refer to Table 5-4.
- Audit Logs – The DFI stores a log record in the Audit Log memory whenever any parameter affecting the gas flow measurement is modified. The parameters which affect the gas flow measurement are listed in Table 5-5. The DFI can store 2849 Audit Log records.
- Alarm Logs – The DFI stores a log record in the Alarm Log memory whenever an alarm or error condition becomes active or is cleared. The alarm and error conditions which are logged are listed in Table 5-6. The DFI can store 3640 Alarm Log records.

The 512K byte flash memory is arranged in eight 64K byte sectors in which individual bytes can be written to (programmed) but must be erased as a sector. Thus, two sectors are allocated to each log type. When the two sectors assigned to a log become full, the sector containing the oldest records is erased to make room for new log entries. The number of logs that can be stored for each type is a function of the record size and the memory sector size.

Since the log flash memory must be erased a sector at a time and during the erasure data cannot be written to the memory, each log record must be queued in external RAM until the record can be stored in the log memory. If power is lost while a record is being written to the log memory, the log record is lost and the partial record in the log memory contains invalid information. When power is restored, the unit clears the partially stored record to indicate that the record was corrupted by a power loss and the corresponding log memory pointers and indices are updated to skip over the corrupted record.

A record read as all zeroes indicates that the record was lost due to a power disruption.

Although Audit Log records and Alarm Log records are stored in separate log memory areas, they are combined into an Event Log for purposes of reading the log records.

The Hourly and Daily Log records have semi-fixed configurations: the data points to be logged are fixed but the format for transmitting volume data is configurable (via the LogHourlyVolumeFormat and LogDailyVolumeFormat registers) as either 32-bit floating point or 32-bit integer format. The configurations are readable so that any future changes to the configurations do not require changes to the host computer software.

The user can select the transmission format for record date and time information via the writable Modbus register LogDateTimeFormat as shown in Table 5-3 below. Both floating point and long integer formats are 32-bit formats.

With the floating point formats, only the last 2 digits of the year are transmitted; with the long integer formats, all four year digits are transmitted.

Time is always transmitted in military format (0-23 hours) as HHMMSS where HH is the hour, MM is the minutes, and SS is the seconds.

Table 5-3 Time and Date Formats per LogDateTimeFormat Value

LogData TimeFormat Value	**Data Type**	**Date**		**Time (HHMMSS) Military Format**
		Format	**Example** July 4, 1999	**Example** 3:45:30pm
0 (default)	32 bit. floating point	MMDDYY	70499.0	154530.0
1	32 bit, long integer	MMDDYYYY	7041999	154530
2	32 bit. floating point	DDMMYY	40799.0	154530.0
3	32 bit, long integer	DDMMYYYY	4071999	154530
4	32 bit. floating point	YYMMDD	990704.0	154530.0
5	32 bit, long integer	YYYYMMDD	19990704	154530

Table 5-4 Current Contents of Hourly and Daily Log Records (Sheet 1 of 2)

Data Point ID	**Data Point Label**	**Action**	**Note**
10550	PosVolFlow	totalize	
10554	NegVolFlow	totalize	
10558	PosVolBase	totalize	
10562	NegVolBase	totalize	
10600	FlowTemperature	average	
10602	FlowPressure	average	

Table 5-4 Current Contents of Hourly and Daily Log Records (Sheet 2 of 2)

Data Point ID	Data Point Label	Action	Note
10636	AbsFlowPressure	average	
10638 10640	HourlyFlowTime (Hourly Log) DailyFlowTime (Daily Log)	snapshot	
370	AvgSndVel	average	beginning with v3.34
10612	RhoMixFlow	average	beginning with v3.62
10604	ZFlow	average	beginning with v3.62
10606	ZBase	average	beginning with v3.62

STOP

This information pertains to firmware up to and including v3.62. External computers, prior to reading hourly and daily log records, should read the hourly and daily log configuration records to determine record content and NOT rely on the above table.

Table 5-5 Data Points Monitored for the Audit Log (Sheet 1 of 2)

Register Owner	Register Number(s)	Register Name or Block Number
CPU	16 - 30	Block 2
CPU	31 - 45	Block 3
CPU	51	ResetTrkParam
CPU	52	ResetProp
CPU	55	AckHMemErr
CPU	56	AckDMemErr

Table 5-5 Data Points Monitored for the Audit Log (Sheet 2 of 2)

Register Owner	**Register Number(s)**	**Register Name or Block Number**
CPU	200 - 249	Block 9
CPU	250 - 299	Block 10
CPU	300 - 349	Block 11
CPU	1504,1505	ColdStart (the DFI disallows all external requests to modify the CPU ColdStart, i.e., the CPU ColdStart can only be modified by the DFI upon power-up/warm boot)
DFI	10000	UFIMode
DFI	10015 - 10029	Block 51
DFI	10030 - 10044	Block 52
DFI	10050 - 10099	Block 53 (register numbers 78, 80, & 82 are not recorded in the audit log.)
DFI	10100 - 10133	Block 54 (except SpecFlowTemperature and SpecFlowPressure)
DFI	10200 - 10214	Block 56
DFI	10582,10583	ColdStart
DFI	10750 - 10757	Block 65 (ADC calibration values only)
DFI	10800 - 10811	Block 66 (temperature and pressure system calibration values and current output calibration values only)

Table 5-6 Data Points Monitored for the Alarm Log Sheet (Sheet 1 of 7)

Register Owner	Register Number(s)	Data Point ID*	Register Name or Block Number
DFI	10501	10501	FreqDataValidity
DFI	10502	10502	QMeterValidity
DFI	10503	10503	QFlowValidity
DFI	10504	10504	QBaseValidity
DFI	10505	10505	TemperatureValidity
DFI	10506	10506	PressureValidity
DFI	10507	10507	AGA8BaseCalcValidity
DFI	10508	10508	AGA8FlowCalcValidity
DFI	10584	30000-30031	DataQlty (copy of CPU register 1506, includes UFMSystemStatus bits) (19 bits used, 32 bits possible)
		30000	• Chord A failed
		30001	• Chord B failed
		30002	• Chord C failed
		30003	• Chord D failed
		30004-30007	• Reserved
		30008	• RS232 Communication error
		30009	• Pulse Accumulator error
		30010	• HC11 Ram Memory error
		30011	• HC11 Program Memory error
		30012	• EEPROM validation error
		30013	• DSP Program Memory error
		30014	• DSP Y-Memory error
		30015	• DSP X-Memory error
		30016	• Number of operating chords below desired amount
		30017	• Average flow velocity range error
		30018	• Pulses per batch range error

Table 5-6 Data Points Monitored for the Alarm Log Sheet (Sheet 2 of 7)

Register Owner	Register Number(s)	Data Point ID*	Register Name or Block Number
DFI	10950	30032-30047	DFISystemStatus1 (16 bits)
		30032	• DUART invalid interrupt
		30033	• Port A unexpected receive interrupt
		30034	• Port B unexpected receive interrupt
		30035	• Port A unexpected transmit interrupt
		30036	• Port B unexpected transmit interrupt
		30037	• Port A unexpected RTU Modbus timeout
		30038	• Port B unexpected RTU Modbus timeout
		30039	• Port A unexpected RTU Modbus timeout while using ASCII Modbus
		30040	• Port B unexpected RTU Modbus timeout while using ASCII Modbus
		30041	• DFI-Host port transmit error
		30042	• DFI-Host port receive error
		30043	• Error communicating with the analog-to-digital converter, digital-to-analog converter, or real-time clock (serial peripheral interface error)
DFI	10951	30048-30063	DFISystemStatus2 (16 bits)
		30048	• Error trying to program an EEPROM byte
		30049	• Modbus block 51 invalid checksum
		30050	• Modbus block 53 invalid checksum
		30051	• Modbus block 54 invalid checksum
		30052	• Modbus block 56 invalid checksum
		30053	• Modbus block 66 invalid checksum
		30054	• Modbus block 61 invalid checksum
		30055	• Temperature analog-to-digital converter communication error
		30056	• Pressure analog-to digital converter communication error
		30057	• Temperature analog-to-digital converter calibration error
		30058	• Pressure analog-to digital converter calibration error
		30059	• Reserved
		30060	• Program memory error
		30061	• Internal random access memory error
		30062	• External random access memory error
		30063	• Software error (invalid value)

Table 5-6 Data Points Monitored for the Alarm Log Sheet (Sheet 3 of 7)

Register Owner	Register Number(s)	Data Point ID*	Register Name or Block Number
DFI	10952	30064-30095	UFMCommChangeStatus (only flag if communication cannot be established)
		30064	• Awaiting UFM communication parameter change
		30065	• UFM communication parameters changed successfully
		30066	• DFI SCI not ready to transmit
		30067	• Invalid request message length
		30068	• DFI SCI transmit data register not empty
		30069	• SCI unknown error
		30070	• An error occurred while decoding the UFM response message
		30071	• An unknown error occurred while decoding the UFM response message
		30072	• A receiver overrun occurred while receiving the UFM response message
		30073	• A parity error was detected in the UFM response message
		30074	• The UFM response message was not received within the allotted time
		30075	• The UFM response message overflowed the receive buffer
		30076	• Unknown error during receipt of the UFM response message
		30077	• Unable to change the UFM communication (SCI) parameters

Table 5-6 Data Points Monitored for the Alarm Log Sheet (Sheet 4 of 7)

Register Owner	**Register Number(s)**	**Data Point ID***	**Register Name or Block Number**
DFI	10959	30096-30127 30096 30097 30098 30099 30100 30101 30102 30103-30105 30106 30107 30108 30109 30110	AGA8BaseCalcStatus (multiple values) • The AG8 calculation was performed successfully • (Applies to Method 1 only). H_CH could not be calculated due to conflicting user inputs • Bmix could not be calculated due to an attempt to take the square root of a negative number • H_CH could not be c calculated as the number of iterations for the selected gross method exceeded the limit • The virial coefficient for either the equivalent hydrocarbon or carbon dioxide is negative; the natural gas mixture third virial coefficient was not calculated • The molar density was not bounded (molar density estimate set to zero) • The iterativve algorithm to estimate the molar density did not converge; the molar density estimate was set to zero • Reserved • Attempt to divide by zero during the air mass density calculation • (Applies to Method 1 only.) Attempt to divide by zero during HN_GERG calculation • (Applies to Method 1 only.) Attempt to divide by zero during equivalent hydrocarbon mole fraction calculation • (Applies to Method 1 only.) Attempt to divide by zero during H_CH calculation • (Applies to Method 1 only.) Attempt to divide by zero during the calculation of the compressibility estimate at density reference conditions.

Table 5-6 Data Points Monitored for the Alarm Log Sheet (Sheet 5 of 7)

Register Owner	**Register Number(s)**	**Data Point ID***	**Register Name or Block Number**
			determining if the H_CH calculation can be exited
		30111	• Attempt to divide by zero during the calculation of the new compressibility estimate at specific gravity reference conditions
		30112	• Attempt to divide by zero during the calculation of the ratio for
		30113	• (Applies to Method 2 Only.) Attempt to divide by zero during the calculation of the equivalent hydrocarbon molar mass
		30114	• Attempt to divide by zero during the calculation of the mixture molar mass
		30115	• Attempt to divide by zero during the calculation of the new density estimate
		30116	• Attempt to divide by zero during the calculation of the density estimate
		30117	• (Applies to flow condition only.) Attempt to divide by zero during the calculation of the flow-to-base conversion factor

Table 5-6 Data Points Monitored for the Alarm Log Sheet (Sheet 6 of 7)

Register Owner	Register Number(s)	Data Point ID*	Register Name or Block Number
DFI	10960	30128-30159	AGA8FlowCalcStatus (multiple values)
		30128	• The AG8 calculation was performed successfully
		30129	• (Applies to Method 1 only). H_CH could not be calculated due to conflicting user inputs
		30130	• Bmix could not be calculated due to an attempt to take the square root of a negative number
		30131	• H_CH could not be c calculated as the number of iterations for the selected gross method exceeded the limit
		30132	• The virial coefficient for either the equivalent hydrocarbon or carbon dioxide is negative; the natural gas mixture third virial coefficient was not calculated
		30133	• The molar density was not bounded (molar density estimate set to zero)
		30134	• The iterativve algorithm to estimate the molar density did not converge; the molar density estimate was set to zero
		30135-30137	• Reserved
		30138	• Attempt to divide by zero during the air mass density calculation
		30139	• (Applies to Method 1 only.) Attempt to divide by zero during HN_GERG calculation
		30140	• (Applies to Method 1 only.) Attempt to divide by zero during equivalent hydrocarbon mole fraction calculation
		30141	• (Applies to Method 1 only.) Attempt to divide by zero during H_CH calculation
		30142	• (Applies to Method 1 only.) Attempt to divide by zero during the calculation of the compressibility estimate at density reference conditions.

Table 5-6 Data Points Monitored for the Alarm Log Sheet (Sheet 7 of 7)

Register Owner	Register Number(s)	Data Point ID*	Register Name or Block Number
			determining if the H_CH calculation can be exited
		30143	• Attempt to divide by zero during the calculation of the new compressibility estimate at specific gravity reference conditions
		30144	• Attempt to divide by zero during the calculation of the ratio for
		30145	• (Applies to Method 2 only.) Attempt to divide by zero during the calculation of the equivalent hydrocarbon molar mass
		30146	• Attempt to divide by zero during the calculation of the mixture molar mass
		30147	• Attempt to divide by zero during the calculation of the new density estimate
		30148	• Attempt to divide by zero during the calculation of the density estimate
		30149	• (Applies to flow condition only.) Attempt to divide by zero during the calculation of the flow-to-base conversion factor

For non-boolean registers (i.e., registers that do not have simply "valid" or "invalid" values), the register number could not be used as the data point ID. For these registers, data point IDvalues have been assigned. For bit-mapped registers, a data point ID is assigned for each bit; for example consider the DFISystemStatus2 register: bit 0 is assigned data point ID 30048, bit 1 is assigned data point ID 30049, and so on. For non-bitmapped, non-boolean registers, a data point ID is assigned for each register value; for example consider the AGA8BaseCalcStatus register: if the register value is 1, the data point ID is 30097, if the register value is 2, the data point ID is 30098, and so on.

5.10.2 Reading Log Configurations and Records

See Table 5-7 below and Table 5-8 for log configurations.

Hourly and Daily Log configuration information and log records are read using “Special Modbus Registers” as described in the following paragraphs. These Special Modbus Registers can be read using either ASCII or RTU Modbus.

Reading the Hourly Log Configuration

The Hourly Log configuration is fixed and thus cannot be modified. The DFI Hourly Log configuration is read using the Modbus format described below where N is the number of data points in the Hourly Log. The maximum number of Hourly Log data points is 13. (This limitation is due to the requirement that the unit must be able to store at least 35 days worth of Hourly Log records, the log record size, and the log memory sector size.)

Table 5-7 Read Hourly Log Configuration Request Message Content

Message Field	Description
Address	DFI Modbus address (1-32) expressed in hexadecimal
Function Code	Read multiple registers function code (3)
Data Start Register HO	Special Modbus register number 20002 (decimal) expressed in hexadecimal and divided into its high order and low order bytes
Data Start Register LO	
Data Number of Registers HO	The number of registers is always 1.
Data Number of Registers LO	

Table 5-8 Read Hourly Log Configuration Response Message Content

Message Field	**Description**
Address	DFI Modbus address (1-32) expressed in hexadecimal
Function Code	Read multiple registers function code (3)
Byte Count	Number of bytes (4 + (*N* * 8)) expressed as an 8-bit integer in hexadecimal
Time Interval	Time interval between logs in minutes (60) expressed as a 16-bit integer in hexadecimal
Number of Hourly Log Data Points	Number of hourly log data points (*N*) expressed as a 16-bit integer in hexadecimal. The maximum number of hourly log data points is 13.
Value *1* Action	Value *1* action type: snapshot (0), average over the hour (1), or totalize over the hour (2) as a 16-bit integer in hexadecimal
Value *1* Data Point	Value *1* data point number (Modbus register number of the data point) expressed as a 16-bit integer in hexadecimal
Value *1* Type	Value *1* data type: 32-bit integer (0) or 32-bit floating point (1) expressed as a 16-bit integer. For volume data, this is determined by the LogHourlyVolumeFormat Modbus register value.
Value *1* Unit	Value *1* units system: U.S. Customary (0) or metric (1) expressed as a 16-bit integer
. . .	. . .
Value *N* Action	Value *N* action type
Value *N* Data Point	Value *N* data point number
Value *N* Type	Value *N* data type
Value *N* Unit	Value *N* units system

Reading the Daily Log Configuration

The Daily Log configuration is fixed and thus cannot be modified. The DFI Daily Log configuration is read using the Modbus format described below where N is the number of data points in the Daily Log. The maximum number of Daily Log data points is 13 (see Table 5-9 below and Table 5-10).

Table 5-9 Read Daily Log Configuration Request Message Content

Message Field	**Description**
Address	DFI Modbus address (1-32) expressed in hexadecimal
Function Code	Read multiple registers function code (3)
Data Start Register HO	Special Modbus register number 20001 (decimal) expressed in hexadecimal and divided into its high order and low order bytes
Data Start Register LO	
Data Number of Registers HO	The number of registers is always 1.
Data Number of Registers LO	

Table 5-10 Read Daily Log Configuration Response Message Content

Message Field	**Description**
Address	DFI Modbus address (1-32) expressed in hexadecimal
Function Code	Read multiple registers function code (3)
Byte Count	Number of bytes (6 + (*N* * 8)) expressed as an 8-bit integer in hexadecimal
Contract Hour	Contract hour (0-23) expressed as a 16-bit integer in hexadecimal
Contract Interval	Contract interval of 24 hours expressed as a 16-bit integer in hexadecimal
Number of Hourly Log Data Points	Number of hourly log data points (*N*) expressed as a 16-bit integer in hexadecimal. The maximum number of hourly log data points is 13.
Value *1* Action	Value *1* action type: snapshot (0), average over the day (1), or totalize over the day (2) as a 16-bit integer in hexadecimal
Value *1* Data Point	Value *1* data point number (Modbus register number of the data point) expressed as a 16-bit integer in hexadecimal
Value *1* Type	Value *1* data type: 32-bit integer (0) or 32-bit floating point (1) expressed as a 16-bit integer. For volume data, this is determined by the LogDailyVolumeFormat Modbus register value
Value *1* Unit	Value *1* units system: U.S. Customary (0) or metric (1) expressed as a 16-bit integer
. . .	. . .
Value *N* Action	Value *N* action type
Value *N* Data Point	Value *N* data point number
Value *N* Type	Value *N* data type
Value *N* Unit	Value *N* units system

Reading an Hourly or Daily Log Record

See Table 5-11 and Table 5-12. The DFI includes two read-only Modbus registers, LastHourlyLogRecIndex and LastDailyLogRecIndex, that indicate (respectively) the indices of the last Hourly Log record and Daily Log record.

The LastHourlyLogRecIndex and LastDailyLogRecIndex registers are read as zero when the DFI is first put into service indicating that the corresponding log is empty (i.e., when the DFI has been in operation less than one hour and when the DFI has been in operation less than one contract day).

The maximum number of Hourly Log records is 862. If the DFI has been operating for more than 862 hours, the index of the oldest available Hourly Log record is LastHourlyLogRecIndex+1. If a host computer wanted to read all 862 Hourly Log records in chronological order, it would request Hourly Log record LastHourlyLogRecIndex+1 to 862, 1 to LastHourlyLogRecIndex. If the DFI has been operating for less than 862 hours, then requests to read Hourly Log records from LastHourlyLogRecIndex+1 to 862 are responded to with illegal data exception errors.

The maximum number of Daily Log records is 862. If the DFI has been operating for more than 862 days, the index of the oldest available Daily Log record is LastDailyLogRecIndex+1. If a host computer wanted to read all 862 Daily Log records in chronological order, it would request Daily Log record LastDailyLogRecIndex+1 to 862, 1 to LastDailyLogRecIndex. If the DFI has been operating for less than 862 days, then requests to read Daily Log records from LastDailyLogRecIndex+1 to 862 are responded to with illegal data exception errors.

A single DFI Hourly Log record or Daily Log record is read using the Modbus format described below where N is the number of data points in the hourly or Daily Log record. The maximum number of data points (for both log types) is 13.

Table 5-11 Read Daily or Hourly Log Record Request Message Content

Message Field	Description
Address	DFI Modbus address (1-32) expressed in hexadecimal
Function Code	Read multiple registers function code (3)
Data Start Register HO	Special Modbus register number 20003 (to read a daily log record) or 20004 (to read an hourly log record) expressed in hexadecimal and divided into its high order and low order bytes
Data Start Register LO	
Data Number of Registers HO	The number of the record to be read: 1-862 for daily log records or 1-862 for hourly log records.
Data Number of Registers LO	

Table 5-12 Read Daily or Hourly Log Record Response Message Content

Message Field	Description
Address	DFI Modbus address (1-32) expressed in hexadecimal
Function Code	Read multiple registers function code (3)
Byte Count	Number of bytes (8 + (*N* x 4)) expressed as an 8-bit integer in hexadecimal
Long/Float Date*	Log record date
Long/Float Time*	Log record time
Long/Float Value *1*	Log value *1*
Long/Float Value *2*	Log value *2*
⋮	⋮
Long/Float Value *N*	Log value *N* where *N* = <13 for hourly log records and *N* = <13 for daily log records

* The date and time data format is specified by the Modbus register LogDateTimeFormat. See Section A.9.1 for more information.

Reading Event Log Records

To read the DFI Event Log, the host computer sends an “Event Log Read” request message (see Table 5-13). The DFI response message contains from 0 to as many Audit and/or Alarm Log records as can be sent within a Modbus message with a maximum size of 255 bytes. The maximum number of Audit and/or Alarm Log records that may be read in a single Modbus response message is 12. The response message format is detailed in Table 5-13.

The host computer should then send a “Clear Event Log” request message (see Table 5-13) so that the previously sent Event Log records are cleared. If the “Clear Event Log” request message is not sent to the DFI, then the DFI response to the next “Event Log Read” request message is to repeat the previously sent response message. The DFI response to a “Clear Event Log” request message is to return a copy of the message to the host computer after decrementing the NumAvailAuditRecords and/or NumAvailAlarmRecords Modbus registers based upon the number of records read by the last “Read Event Log” request.

The host computer should send “Event Log Read” request messages and “Clear Event Log” request messages until the DFI responds with a message with 0 events indicating that all Event Log records have been read.

When the host computer has completed reading Event Log records, it has the option of sending a “Reset Event Log” request message (see Table 5-13) which forces the DFI to respond to the next “Event Log Read” request message with the oldest available Event Log record. The DFI response to a “Reset Event Log” request message is to return a copy of the message to the host computer after resetting the NumAvailAuditRecords and/or NumAvailAlarmRecords Modbus registers.

Beginning with v3.62, the Event Log access via the two external communication ports is independent. That is, resetting the Event Log via Port A does not cause the Event Log access via Port B to be reset as well. Thus, several Block 67 registers such as NumAvailAuditRecords and NumAvailAlarmRecords may have different values when read via Port A than when read via Port B.

Also, see Table 5-14, and Table 5-15.

Table 5-13 Read Event Log Request Message Content

Message Field	**Description**
Address	DFI Modbus address (1-32) expressed in hexadecimal
Function Code	Read multiple registers function code (3)
Data Start Register HO	Special Modbus register number 20005 expressed in hexadecimal and divided into its high order and low order bytes
Data Start Register LO	
Data Number of Registers HO	These message fields are ignored by the DFI.
Data Number of Registers LO	

Table 5-14 Read Event Log Response Message Content (Sheet 1 of 3)

Message Field	**Description**
Address	DFI Modbus address (1-32) expressed in hexadecimal
Function Code	Read multiple registers function code (3)
Byte Count	Number of bytes (*N* x 20) expressed as an 8-bit integer in hexadecimal where *N* is the number of records in the message
Bitmap *1*	First record bitmap (16-bits) in which bit 9 indicates whether the record is an Audit Log record (bit 9=1) or an Alarm Log record (bit 9=0). If the record is an Alarm Log record, bit 15 indicates whether the alarm was activated (bit 15=1) or cleared (bit 15=0).

Table 5-14 Read Event Log Response Message Content (Sheet 2 of 3)

Message Field	**Description**
Data Point ID *1*	First record data point identifier (16-bit integer). For Audit Log records, this is the number of the Modbus register which was modified. For Alarm Log records, this indicates which alarm was activated or cleared; the relationship between the Alarm Log Data Point ID and the alarm Modbus register number/bit number is shown in Table 6.
Long/Float Date *1**	First record date. For Audit Log records, this is the date when the modification was made, for Alarm Log records, this is the date when the alarm became active or was cleared.
Long/Float Time *1**	First record time. For Audit Log records, this is the time when the modification was made, for Alarm Log records, this is the time when the alarm became active or was cleared.
Float Value 1_A	First record floating point value *A*. For Audit Log records, this is the old data point value converted to a floating point value from the internal data type. *The unit of measurement is the storage unit.* Refer to the Modbus Registers Appendix D, and the Block List Appendix D of this manual for the storage unit information. For Alarm Log records, this field only has meaning in the case of a chord failure; in that case this field is the corresponding chord status at the time of the failure. For all other alarm cases, this field has no meaning and is set to 0.0.
Float Value 1_B	First record floating point value *B*. For Audit Log records, this is the new data point value converted to a floating point value from the internal data type. *The unit of measurement is the storage unit.* This field has no meaning for Alarm Log records and is set to 0.0.
. . .	. . .
Bitmap *N*	N^{th} record bitmap
Data Point ID *N*	N^{th} record data point identifier
Long/Float Date *N**	N^{th} record date

Table 5-14 Read Event Log Response Message Content (Sheet 3 of 3)

Message Field	**Description**
Long/Float Time *N**	N^{th} record time
Float Value N_A	N^{th} record floating point value *A*
Float Value $N_{\mathbf{B}}$	N^{th} record floating point value *B*

* The date and time data format is specified by the Modbus register LogDateTimeFormat. See Section A.9.1 for more information.

Table 5-15 Clear and Reset Event Log Request/Response Message Content

Message Field for Clear Event Log	**Description**
Address	DFI Modbus address (1-32) expressed in hexadecimal
Function Code	Force single coil function code (5)
Data Start Register HO	Special Modbus register number 20005 expressed in hexadecimal and divided into its high order and low order bytes
Data Start Register LO	
Data Coil Number HO	The Data Coil Number high order byte must be set to 0xFF and the low order byte must be set to 0x00.
Data Coil Number LO	

The “Data On/Off/Ind” and “Data” fields which are normally part of a function code 5 request message are not included.

Message Field for Reset Event Log	**Description**
Address	DFI Modbus address (1-32) expressed in hexadecimal
Function Code	Force single coil function code (5)
Data Start Register HO	Special Modbus register number 20005 expressed in hexadecimal and divided into its high order and low order bytes
Data Start Register LO	
Data Coil Number HO	The Data Coil Number high order and low order bytes must be set to 0x00.
Data Coil Number LO	

Logging Error Indication

The DFI provides a Modbus register for each of the four logs for indicating logging errors: DailyLogStatus, HourlyLogStatus, AuditLogStatus, and AlarmLogStatus. These registers are located in Modbus Block 67. Refer to the Modbus Register Definition (Appendix D) for further information about these registers.

5.11 SELF TESTS

The DFI self-tests are described below.

5.11.1 Internal RAM Integrity

The integrity of the internal RAM is tested upon power-on/reset using the “checkerboard” test. In this test each internal RAM location is written the value 0x55 (a pattern of alternating 1s and 0s). Next each internal RAM location is read and compared to the value written. If any internal RAM location does not equal the expected value, then the test is stopped and the failure is flagged. If no errors are detected, then the test is repeated with the alternate pattern 0xAA. If a failure is detected, the location of the failure is stored in a specific location in external RAM and a bit is set in the SystemStatus2 register.

5.11.2 External RAM Address Line

Upon power-on/reset, if the internal RAM integrity test is passed, then the external RAM address lines are tested using the “walking ones” test described below.

- First write to all the external RAM locations: write 0 to the first location, 1 to the second location, and so on. (The value to write wraps from 255 to 0.)
- Next read all the external RAM locations sequentially beginning with the first location and compare the value read with the expected value. If the value read is not equal to the expected value, stop the test and store the address at which the failure occurred in a specific location in internal RAM.

5.11.3 External RAM Integrity

The integrity of the external RAM is tested periodically during DFI operation using the 'checkerboard' test. One external RAM location is tested each main loop cycle. Interrupts are disabled during the test so that the location to be tested is not inadvertently changed. The value of the location to be tested is first saved in a dedicated internal RAM location. Next the value 0x55 (a pattern of alternating 1's and 0's) is written to the test location and then the value of the test location is read. If the value read is not the same as the value written, then an error is declared. Otherwise, the write/read test is repeated with the alternate pattern 0xAA. The original test location value (saved in internal RAM) is then written to the test location and interrupts are re-enabled. If an error is detected, the external RAM error bit is set in the SystemStatus2 register.

5.11.4 Program Memory Validity

The DFI program code is stored in FLASH memory in a banked memory system. The DFI architecture allows up to 256K of program code divided into eight banks (32K per bank). During FLASH memory programming, a 16-bit checksum is calculated for each bank and is stored in the first two bytes of the bank. The program memory validity is determined by calculating a checksum for each of the eight banks and comparing the calculated checksums against the stored checksums. If a calculated checksum and the stored checksum for a bank do not agree, the program memory error bit is set in the SystemStatus2 register.

The entire program memory is checked upon power-on/reset and then a portion of the program memory is checked during each main loop cycle (typically, the entire program memory is checked about twice per minute during DFI operation).

5.11.5 Software Error Detection

The DFI firmware includes checks of many variables for invalid values (indicative of a software error). If an invalid value is detected, the address at which the error was detected is stored in NOVRAM memory for assistance in locating the software error.

5.11.6 Normal Diagnostic Mode (AGA8 Test Cases)

See Table 5-16 for AGA8 test Case details.

The AGA8 Test Cases allow the user to verify the AGA8 compressibility calculation. The software uses the same function to calculate the test case compressibility as it does for the base-condition and flow-condition compressibility values. The twenty available test cases are listed in Table 5-16. They are a subset of the test cases listed in the AGA Transmission Measurement Committee Report No. 8 (see Section 1.3). The DFI must be in the Normal Mode in order to perform AGA8 Test Case calculations. The user specifies the test case via the NormalDiagnosticMode register; the currently specified AGA8 Gross Characterization Method (specified by the HCH_Method register) is used for the calculation.

The DFI indicates the completion of the AGA8 test case compressibility calculation by setting the NormalDiagnosticMode register back to zero. The status of the calculation is indicated by the AGA8TestCalcStatus register (Modbus Block 69). The test case number, HCH method used, calculated compressibility, and percent error from the expected value are indicated by the Modbus Block 64 registers ZTestCaseID, ZTestCaseHCHMethod, ZTest, and ZTestErr, respectively.

Table 5-16 Normal Mode Diagnostic Test Cases

Normal Mode Diagnostic Test Cases								
Test Case ID	(K)	(MPa)	(kJ/dm^3)	(--)	(---)	(---)	(---)	
							Method 1	Method 2
1	273.1500	0.101560	38.6022	0.581078	0.002595	0.005956	0.997407	0.997408
2			38.5574	0.608657	0.031284	0.004676	0.997309	0.997310
3			41.2871	0.649521	0.010068	0.014954	0.996792	0.996794
4			33.7797	0.644869	0.134650	0.009850	0.997681	0.997682
5			34.7672	0.686002	0.057021	0.075851	0.997220	0.997222
6	273.1500	8.273708	38.6022	0.581078	0.002595	0.005956	0.795719	0.795840
7			38.5574	0.608657	0.031284	0.004676	0.787317	0.787484
8			41.2871	0.649521	0.010068	0.014954	0.733805	0.734024
9			33.7797	0.644869	0.134650	0.009850	0.824302	0.824432
10			34.7672	0.686002	0.057021	0.075851	0.777024	0.777179
11	327.5944	0.101560	38.6022	0.581078	0.002595	0.005956	0.998652	0.998653
12			38.5574	0.608657	0.031284	0.004676	0.998598	0.998599
13			41.2871	0.649521	0.010068	0.014954	0.998299	0.998300
14			33.7797	0.644869	0.134650	0.009850	0.998822	0.998822
15			34.7672	0.686002	0.057021	0.075851	0.998549	0.998550
16	327.5944	8.273708	38.6022	0.581078	0.002595	0.005956	0.905682	0.905742
17			38.5574	0.608657	0.031284	0.004676	0.901743	0.901825
18			41.2871	0.649521	0.010068	0.014954	0.876792	0.876893
19			33.7797	0.644869	0.134650	0.009850	0.920727	0.920793
20			34.7672	0.686002	0.057021	0.075851	0.897561	0.897635

Note that, for all test cases,

$$T_{HV} = T_d = T_{G_r} = 288.7056K(60°F)$$

$$P_{HV} = P_d = P_{G_r} = 0.101560MPa(14.73psia)$$

$$x_{N_2} = 0$$

$$X_{CO_2} = 0$$

Temperature and pressure values have been converted to the expected SI units. See reference [3].

5.12 ADC SELF-CALIBRATION

Internal self-calibration is performed on the enabled temperature and pressure analog-to-digital converters (ADCs) upon power-on/reset, and then once per hour. Each ADC is also self-calibrated during the respective Maintenance Mode system offset calibration.

The temperature and pressure ADC zero scale and full scale register values are readable via Modbus Block 65.

5.13 NON-VOLATILE DATA PROTECTION

The DFI operational parameters (accessed via Modbus Blocks 51, 53, 54, and 56) and the flow volume data are stored in non-volatile memory so that the data is preserved when the DFI is not powered.

The DFI board includes a jumper (JP2) for protecting the value of the DFI operational parameters. When the jumper is closed, the DFI operational parameters cannot be modified. Beginning with firmware V3.62, the DFI JP2 jumper, when closed, also protects the CPU board operation and calibration parameters (Modbus Blocks 2, 3, 9, 10, and 11).

MAINTENANCE

Daniel Ultrasonic Flow Meters are supplied with T-Slot transducer assemblies which are extractable while the line is pressurized.

T-Slot transducer assemblies are available on 4 inch and larger meters for the Model 3400 units. The T-Slot assemblies are available on all meter sizes for the JuniorSonic™ (Models 3410 and 3420). The T-Slot transducer assemblies are extractable while the line is pressurized. See Section 2.2.6 for the types of Transducers available.

6.1 FIELD HYDROSTATIC PRESSURE TESTING PROCEDURES

6.1.1 T-Slot Transducer Assembly and Mount

1. Slowly vent all line pressure on the Daniel Ultrasonic Meter to atmosphere.
2. Disconnect transducer cabling from the transducer holders.
3. If installed, remove the mount cover by loosening the two mount cover screws. These screws are captive.
4. Loosen the T-Slot transducer assembly with a 1 1/4 wrench or socket. Carefully remove the T-Slot transducer assembly.
5. Place a label on the transducer assembly to marks its location (i.e., A1, A2, B1, B2, C1, C2, D1, or D2). Port locations are marked on the meter housings that are cast, as well as, on the transducer cable.
6. Ensure the transducer mount threads are clean and free of debris.
7. Apply a small amount of Nickel antiseize compound (P/N 3-9960-134) to the threads of the hydro-test plug (from kit P/N 1-360-01-220) and install it into the mount.
8. Repeat Steps 3 through 7 for the other transducer(s) being careful to note the location of each transducer in the meter assembly.
9. Run the field hydrostatic test.
10. Reverse the steps above to re-install the transducers into their appropriate ports. Before reinstalling the transducer assemblies, ensure the transducer ports, mounts, and transducer holders are clean and free of debris. Apply a small amount of Nickel antiseize compound to the outer threads of the transducer holders before installing into the mounts.

6.2 T-SLOT TRANSDUCER REMOVAL AND INSTALLATION PROCEDURES

The T-Slot transducer assembly is an improvement to the direct mount transducer. It offers improved transducer alignment and superior acoustic isolation between the transducer and the meter housing. The net result is improved performance and stability. The assembly is used on both SeniorSonic™ and JuniorSonic™ Meters and is line pressure vented.

Figure 6-1 J-Mount Transducer Assembly

Figure 6-2 J-Mount Transducer Assembly

.

Figure 6-3 J-Mount Transducer Assembly

Figure 6-4 J-Mount Transducer Disassembly

Figure 6-5 M-Mount Transducer Disassembly

Figure 6-6 M-Mount Transducer Disassembly

6.2.1 Removal With Extractor Tool

To replace transducers under pressure, refer to the *Daniel Ultrasonic Extractor Tool Operation Manual* (Daniel P/N 3-9000-729) for installation and removal of the older style transducers (e.g. M-Mount, P-Mount, and Q-Mount). For J-Mount and K-Mount transducers, refer to *Ultrasonic Split Clamp Extractor Tool Operation Manual* (Daniel P/N 3-9000-744).

6.2.2 Removel Without Extractor Tool

The following instructions are for transducer removal and installation without the use of an extractor tool. It is recommended that one work on one transducer assembly at a time to reduce the possibility of improper assembly with respect to transducer lengths and location.

- Transducers are always replaced in pairs.
- Update the calibration parameters for every chord when replacing a pair of transducers.

1. Slowly vent all line pressure on the Daniel Ultrasonic Meter to atmosphere.
2. Disconnect transducer cabling from the transducer holders.
3. If installed, remove the mount cover by loosening the two mount cover screws. These screws are captive.
4. Loosen the T-Slot transducer assembly with a 1 1/4 wrench or socket. Carefully remove the T-Slot transducer assembly.
5. If removing the T-17 one-piece transducer, skip to Step 9.
6. Loosen the three setscrews holding the transducer in place. Carefully remove the old transducer by pulling it from the T-Slot transducer assembly without rotating.
7. Insert the new transducer (parts are keyed and can only be assembled one way).

   Ensure that the transducers identified as belonging to end 1 are installed on end 1 of the meter housing and those identified as belonging to end 2 are installed on end 2 of the meter housing.

   Equally tighten the three setscrews to secure the new transducer assembly.
8. Replace the O rings and Back Up rings on the transducer holder. It is highly recommended that the O rings be replaced when the transducer is removed from the holder/stalk. Replacing the O rings at this point minimizes the chances of damaging the transducer by dropping it. Lubricate with Dow Corning 111 Silicone Grease or equivalent.

9. Ensure that the Daniel Ultrasonic Meter transducer port, mount, and T-Slot transducer assembly are clean and free of debris.

10. Apply a small amount of Nickel antiseize compound (P/N 3-9960-134) to the outer threads of the transducer holder or T-17 one-piece transducers.

11. Carefully replace the T-Slot transducer assembly in the Daniel Ultrasonic Meter transducer port. Tighten to securely seat the assembly in the mount. Do not over tighten.

For the T-17 one-piece transducers, ensure that the transducers identified as belonging to end 1 are installed on end 1 of the meter housing and those identified as belonging to end 2 are installed on end 2 of the meter housing.

12. Repeat Steps 2 through 11 for all transducer assemblies to be replaced.

13. Check that the Daniel Ultrasonic Meter is pressure tight. Pressurize the meter to line pressure. Check for leaks around all Mounts and Transducer Holders, which were removed, using soapy water or other recognized leak detector. If leaks are found, the meter must be vented to atmosphere and the problem corrected. Check for leaks again. Continue the process until there are no leaks.

14. If applicable, replace the mount cover by rotating the tag and sliding the mount cover over the 1 1/4 hex head screw of the transducer holder. Align the two screws with their respective screw holes and tighten. The screw holes can be located as they are marked with an arrowhead, "V", on the mount rim.

15. Reconnect the transducer cabling to the transducer holders. The internal connector of the transducer cable is keyed and will only go on one way. Secure the transducer cabling.

16. Repeat steps 13 and 14 for the remaining transducer assemblies which were replaced.

6.2.3 Modifying the Calibration Parameters

For Accurate operation it is necessary to modify the calibration parameters for the chord(s) in which the transducer were exchanged. This means modifying "L", Average Delay Time, and Delta Delay time for the affected chord(s).

Average Delay Time and Delta Delay Time Modifications

Located on a Calibration Sheet with each transducer pair, these values should be downloaded to the appropriate Modbus registers in the Ultrasonic Meter. The lengths of the transducers are included on the above Calibration Sheet as well as being etched on the transducers. Likewise the lengths of the Stalk Assemblies, Transducer Holders, and Mounts are also etched on the individual components. The length of the meter housing is found on the original Calibration Sheet supplied with the meter.

Determining the “L” Value

The value "L" is determined by adding the length of the meter housing to the lengths of the two mounts and subtracting the lengths of the transducer holders, stalk assemblies, and transducers. This value should be downloaded to the appropriate Modbus register in the Ultrasonic Meter for each chord that received new transducers.

6.3 REPAIRING THE UFM

In the event the Daniel Model 3400 Ultrasonic Gas Flow Meter needs repair, the user is advised to contact Daniel Field Services, Customer Service.

Customer Service contact information is located in the rear portion of this manual.

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APPENDIX A, CONVERSION FACTORS

A.1 CONVERSION FACTORS PER UNIT OF MEASUREMENT

The following table includes several conversion factors that may be useful. Exact conversion factors are distinguished with boldface type.

Table A-1 Conversion Factors per Unit of Measurement

Conversion Factors	**Unit Of Measurement**
(°F-32)x(5/9)–>°C (°C+273.15)–>K	
1	K/°C
5/9	°C/°F
10^{-6}	MPa/Pa
0.006894757	MPa/psi
0.1	MPa/bar
0.101325	MPa/atm
0.000133322	MPa/mmHg
0.3048	m/ft
0.0254	m/in
10^{3}	dm^3/m^3
10^{-6}	m^3/cc (=m^3/cm^3)
$(0.3048)^3$	m^3/ft^3
$(0.0254)^3$	m^3/in^3
3600	s/hr
86400	s/day
10^{3}	g/kg
0.45359237	kg/lbm
4.1840	kJ/kcaltc
1.055056	kJ/ BtuIT
$10^{-}3$	Pa•s/cPoise
1.488	Pa•s/(lb/(ft•s))

APPENDIX B, MODBUS COMMUNICATIONS

B.1 INTRODUCTION TO MODBUS COMMUNICATION

This appendix describes the standard Gould Modbus communication protocol (ASCII mode and RTU mode) implemented by the DFI for communicating with an external flow computer and/or diagnostic computer. Refer to the Gould Modbus Protocol Reference Guide [1] for further information.

This appendix does not apply to Modbus communication for accessing log configurations and records. Refer to the section "Reading Log Configurations and Records" for further information on this topic.

The DFI uses the same Modbus communication conventions as the Host processor. The communication between the DFI and an external computer is half-duplex with the external computer as the Master and the DFI as the Slave.

All DFI parameters and data are accessed via registers which are grouped into blocks. All registers within a block have the same data format; the available data formats are 16-bit integer, 32-bit long integer, and 32-bit IEEE-format floating point. Each Modbus register is 16 bits in length; thus, two Modbus registers are required for each long integer and floating point value. Integer data blocks contain 15 registers; long integer data blocks and floating point data blocks each contains 50 registers (25 values times 2 registers per value).

All registers within a block also have the same accessibility: read-only or read-write. The DFI supports only Modbus functions 3 (read multiple registers), 6 (write to a single register), and 16 (write to multiple registers). When accessing multiple registers, all the registers must be within the same block. It is not necessary to access the entire block. Attempting to access multiple registers from more than one block results in an illegal data address error. Attempts to write to a read-only register are ignored without generating an error.

Modbus registers numbered below 10000 reside in the Host processor but can be accessed via the DFI. Modbus registers numbered 10000 and above reside in the DFI.

See Section C.2 Modbus Regsisters provides the Host processor Modbus register definitions (see Section D.2 Modbus Registers) of this manual provides the DFI Modbus register definitions.

Blocks which contain writable registers for meter operation can be protected from being changed via jumpers on the CPU and DFI boards. CPU board (Rev. C and later) jumper JP9 protects Blocks 2, 3, 9, 10, and 11. DFI board jumper JP2 protects Blocks 51, 53, 54, and 56.

The supported exception codes are as follows:

01	illegal function
02	illegal data address
03	illegal data value
06	busy (not used at this time)

B.2 MESSAGE FORMATS

The abbreviations used to describe the Modbus message formats are:

Table B-1 Modbus Message Format Abbreviations

Abbreviation	**Description**
ADDR	Modbus ADDRESS (Device Identification)
BYTE_CNT	number of bytes in the frame
CR	ASCII carriage return character (ASCII Modbus only)
CRC_LOW	low byte of the 16-bit Cyclic Redundancy Check (RTU Modbus only)
CRC_HI	high byte of the 16-bit Cyclic Redundancy Check (RTU Modbus only)
DATA	the data to be transmitted
FC	MOdbus function code (3, 6, or 16)
LF	ASCII line feed character (ASCII Modbus only)
LRC	8-bit Longitudinal Redundancy Check (ASCII Modbus only)
LSB	least-significant byte
MSB	most-significant byte
REG_CNT	register count
START_REG	starting register number
T_{FRAME}	three and one-half character time delay (RTU Modbus only)

The format of the register data depends upon the register data type is:

Table B-2 Modbus Register Data per Format Type

Format Type	**Register Data**
Integer	MSB, LSB (1 Modbus register)
(IEEE) Floating Point	EXP,MAN,MAN,MAN (one exponent byte, three mantissa bytes) (2 Modbus registers)
Long Integer	MSB, MIDH, MIDL, LSB (2 Modbus registers)

B.3 ASCII MODBUS FORMAT

Framing in ASCII transmission mode is accomplished by the use of the colon (:) character to indicate the beginning of a frame and the carriage return/linefeed pair (CR/LF) to indicate the end of a frame. The communication parameters for ASCII Modbus are 7 data bits, even parity, and one stop bit.

The ASCII Modbus 8-bit Longitudinal Redundancy Check (LRC) is produced by converting the hex characters to binary, adding the binary characters without wrap-around carry, and two's complementing the result. The colon, carriage return and line feed characters are not included in the LRC calculation.

The ASCII Modbus formats for the supported Modbus functions are described below.

B.3.1 Function Code 3 – Read Multiple Registers

Send Format:

:, ADDR, FC, START_REG MSB, START_REG LSB, REG_CNT MSB, REG_CNT LSB, LRC, CR, LF

Response Format:

:, ADDR, FC, BYTE_CNT, ...DATA... , LRC, CR, LF

B.3.2 Function Code 6 – Write Single Register

Send Format:

:, ADDR, FC, START_REG MSB, START_REG LSB, DATA MSB, DATA LSB, LRC, CR, LF

Response Format:

:,ADDR, FC, START_REG MSB, START_REG LSB, DATA MSB, DATA LSB, LRC, CR, LF

B.3.3 Function Code 16 – Write Multiple Registers

Send Format:

:, ADDR, FC, START_REG MSB, START_REG LSB, REG_CNT MSB, REG_CNT LSB, BYTE_CNT, ...DATA..., LRC, CR, LF

Response Format:

:, ADDR, FC, START_REG MSB, START_REG LSB, REG_CNT MSB, REG_CNT LSB, LRC, CR, LF

B.4 RTU MODBUS FORMAT

RTU Modbus uses the timing between character transmission to frame a message. The receiving device monitors the elapsed time between receipt of characters. If three and one-half character times elapse without receipt of a new character, then the received message is completed. Thus, the time between transmitting characters within a message must not be longer than three and one-half character times otherwise the receiving device will prematurely declare the message complete.

The communication parameters for RTU Modbus are 8 data bits, no parity, and one stop bit.

The RTU Modbus formats for the supported Modbus functions are described below.

B.4.1 Function Code 3 – Read Multiple Registers

Send Format:

TFRAME, ADDR, FC, START_REG MSB, START_REG LSB, REG_CNT MSB, REG_CNT LSB, CRC_LOW, CRC_HI, TFRAME

Response Format:

TFRAME, ADDR, FC, BYTE_CNT, ...DATA..., CRC_LOW, CRC_HI, TFRAME

B.4.2 Function Code 6 – Write Single Register

Send Format:

TFRAME, ADDR, FC, START_REG MSB, START_REG LSB, DATA MSB, DATA LSB, CRC_LOW, CRC_HI, TFRAME

Response Format:

TFRAME, ADDR, FC, START_REG MSB, START_REG LSB, DATA MSB, DATA LSB, CRC_LOW, CRC_HI, TFRAME

B.4.3 Function Code 16 – Write Multiple Registers

Send Format:

TFRAME, ADDR, FC, START_REG MSB, START_REG LSB, REG_CNT MSB, REG_CNT LSB, BYTE_CNT, ...DATA..., CRC_LOW, CRC_HI, TFRAME

Response Format:

TFRAME, ADDR, FC, START_REG MSB, START_REG LSB, REG_CNT MSB, REG_CNT LSB, CRC_LOW, CRC_HI, TFRAME

APPENDIX C, BLOCK LIST

C.1 SPECIFIC MESSAGE BLOCKS AND REGISTERS

For more information about UFM Modbus registers, click on the Help button to access the online help.

The following sections provide the Modbus register names, descriptions, and values per Message Block for the Daniel Ultrasonic Flow Meter (UFM). This appendix also includes configuration options (such as appropriate value ranges and units of measurement), default settings, discussions of related functions, and other important information.

To look up specific message Blocks, refer to the list below. To look up specific registers, see Section C.2.

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APPENDIX C, UFM MODBUS REGISTERS

C.2 MODBUS REGISTER VALUES MESSAGE BLOCKS

Table C-1 Modbus Register Values Message Block 1 (Communications) (Sheet 1 of 2)

Number	Name	Description	Unit(s)	Default Value	Type	Access[a]
1	Spare	This register number is not used.	n/a	n/a	INT	R/W
2	Parity	set communication parity 0 = no parity (RTU MODBUS) 1 = odd parity (ASCII MODBUS) 2 = even parity (ASCII MODBUS)	n/a	2	INT	R/W
3	BaudRate	set communications baud rate Acceptable rates: 1200, 2400, 4800, 9600 {start up baud rate = 1200, 2400, 4800, 9600}	bits/second	9600	INT	R/W
4	WdLength	set number of data bits 7 = 7 data bits (ASCII MODBUS) 8 = 8 data bits (RTU MODBUS)	bits/word	7	INT	R/W
5	StopBits	set number of stop bit(s) Note that only 1 stop bit is supported.	bits	1	INT	R/W

Table C-1 Modbus Register Values Message Block 1 (Communications) (Sheet 2 of 2)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**[a]
6	ModbusID	Device Modbus ID Range: 1 to 32	n/a	32	INT	R/W
7	CommRspDly	Minimum length of time for a communication response message to be delayed after receipt of a request message. When the DFI option is used, this register should be set to 0 milliseconds and the corresponding DFI registers should be used. Range: 0 to 100	ms	0	INT	R/W
8-15	Spare	These register numbers are not used.	n/a	n/a	INT	R/W

[a] For Rev. C (and later) CPU boards programmed with firmware version 5.62 (and later), Modbus Register Blocks containing operation and calibration parameters (i.e., Blocks 2, 3, 9, 10, 11) are only writable if the memory-protect jumper (JP9 on the CPU board) is *not* installed. Jumper JP9 should *never* be installed on Rev. A and Rev. B CPU boards.

Table C-2 Modbus Register Values Message Block 2 (Operation) (Sheet 1 of 8)

Number	Name	Description	Unit(s)	Default Value	Type	Access
16	Spare	This register number is not used.	n/a	n/a	INT	R/W
17	Mode	DSP Operation Mode 0 = Measurement Mode 1 = Diagnostic Mode Note that only Measurement Mode is currently supported.	n/a	0	INT	R/W
18	VelHold	Hold the last operating velocity constant for this number of batches when the ultrasonic flow meter is in the Acquisition Mode. Range: 0 to 100 batches	batches	0	INT	R/W

Table C-2 Modbus Register Values Message Block 2 (Operation) (Sheet 2 of 8)

Number	Name	Description	Unit(s)	Default Value	Type	Access
19	StackSize	stack size This parameter is used to employ ‘stacking’ as a means of noise reduction. Stacking simply averages the specified number of signals prior to measuring transit time. The number of signals ‘stacked’ to average can be 2, 4, 8, 16, or 32. Not: the more signals ‘stacked’ to average, the less frequent the flow rate is updated. There are two different firing sequences for stacking that override the sequence set by FireSeq; they are stacking-by-chord and stacking-by-path. Let N be the number of signals to average. For stacking-by-chord, the two transducers for a chord are alternately fired N times. The order of the chords to fire is taken from the chord sequence (not path sequence) specified by FireSeq. For stacking-by-path, each transducer is fired N consecutive times. The order of paths to fire is taken from the path sequence specified by FireSeq. (continued on next page)	count	0	INT	R/W

Table C-2 Modbus Register Values Message Block 2 (Operation) (Sheet 3 of 8)

Number	Name	Description	Unit(s)	Default Value	Type	Access
19 (cont.)	StackSize	To select stacking-by-chord, set StackSize to the desired number of signals to average (2, 4, 8, 16, or 32). To select stacking-by-path, set StackSize to 128 plus the desired number of signals to average (130, 132, 136, 144, or 160). For example, StackSize equal to 136 specifies stacking-by-path 8 (136-128) signals. It is recommended that for the Digital Master Board (a.k.a. DUK board), if stacking is desired, stacking-by-chord should be selected. Setting StackSize to 0 or 1 disables stacking. Range: 0, 1, 2, 4, 8, 16, 32, 128, 129, 130, 132, 136, 144, 160	count	0	INT	R/W
20	Pk1Thrsh	first peak threshold (i.e., the amplitude threshold of the first peak after signal quality) Range: 0 to 30 Note: This register is not used in V6.45 of the CPU	n/a	10	INT	R/W

Table C-2 Modbus Register Values Message Block 2 (Operation) (Sheet 4 of 8)

Number	Name	Description	Unit(s)	Default Value	Type	Access
21	MinChord	Minimum number of operating chords allowed. If the number of operating chords is less than MinChord, then bit 8 of SystemStatus is set as a warning. Range: 1 for single-path meters (models 3410, 3450) 1,2 for dual-path (model 3420) and single-dual (model 3412) meters; 1…4 for multi-path (model 3400) and double-dual (model 3422) meters	n/a	1 <=6.34 4 >=6.42	INT	R/W
22	Filter	filter select switch 0 = off 1 = apply default filter	n/a	0	INT	R/W

Table C-2 Modbus Register Values Message Block 2 (Operation) (Sheet 5 of 8)

Number	Name	Description	Unit(s)	Default Value	Type	Access
23	FireSeq	transducer firing sequence 0 = {Bup, Bdown, Cup, Cdown, Aup, Adown, Dup, Ddown} 1 = {Aup, Adown, Bup, Bdown, Cup, Cdown, Dup, Ddown} Note that: • Firing sequence #2 has been deleted (beginning with Version 5.40). • Chords manually set as inactive are not fired (beginning with Version 5.40); see ChordInactv (register 34). Note: This register is not used since V6.45 of the CPU	n/a	0	INT	R/W
24	SNRatio	acceptable signal-to-noise ratio If the ratio of the maximum signal level to the maximum noise level is less than SNRatio, then the error is flagged via bit 1 of the chord status register (StatusA to StatusD). Range: 5 to 30	n/a	10	INT	R/W

Table C-2 Modbus Register Values Message Block 2 (Operation) (Sheet 6 of 8)

Number	Name	Description	Unit(s)	Default Value	Type	Access
25	MaxNoise	maximum acceptable noise level If the noise level exceeds MaxNoise, then the error is flagged via bit 0 of the chord status register (StatusA to StatusD). Range: 512 to 8192	n/a	4096	INT	R/W

Table C-2 Modbus Register Values Message Block 2 (Operation) (Sheet 7 of 8)

Number	Name	Description	Unit(s)	Default Value	Type	Access

26	Profile	Select flow-profile check.
		0 = no flow-profile check
		1 = symmetric flow-profile check
		Range: 0 for single-path (3410, 3450), dual-path (3420), and single-dual (3412) meters;
		0,1 for multi-path (3400) and doubledual (3422) meters
		Note: This register is not used since V6.45 of the CPU (ADDITIONAL NOTE: Profile check will only be done if delta time for the chord to be tested is greater than 0.000002 seconds.)
		Symmetric Flow Profile Check:
		if (A/B ratio is out of range) then
		if ((B/C ratio is out of range) AND (A/D ratio is within range)) then mark chord B failed
		if ((B/C ratio is within range) AND (A/D ratio is out of range)) then mark chord A failed
		else if (D/C ratio is out of range) then
		if ((B/C ratio is out of range) AND (A/D ratio is within range)) then mark chord C failed
		if ((B/C ratio is within range) AND (A/D ratio is out of range)) then mark chord D failed
		• All ratios are delta time ratios between chords.
		• A/B range = (RABLo, RABHi)
		• D/C range = (RDCLo, RDCHi)
		• A/D range = (RADLo, RADHi)
		• B/C range = (RBCLo, RBDHi)
			n/a	0	INT	R/W

Table C-2 Modbus Register Values Message Block 2 (Operation) (Sheet 8 of 8)

Number	Name	Description	Unit(s)	Default Value	Type	Access
27	PkMatch	reset peak tracking parameters threshold • Check the ratio between the upstream and down stream tracked amplitude percentage. • Check the ratio between the target and tracked amplitude percentage. Range: 0 to 100 percent 0% = reset peak tracking parameters all the time 100% = do not reset peak tracking parameters	percentage	60	INT	R/W
28	GainLowLmt	Minimum gain. Range: 40…120 Firmware <= V6.24; 0…GainHighLmt Firmware >= V6.30	n/a	50	INT	R/W
29	FltrThrsh	filter threshold Note: This register is not used since V6.45 of the CPU	n/a	512	INT	R/W
30	GainHighLmt	maximum gain (CPU V6.30+, previously Spare). Range: 0 Firmware <= V6.24; GainLowLmt…200 Firmware >= V6.30	n/a	180	INT	R/W

Table C-3 Modbus Register Values Message Block 3 (Operation) (Sheet 1 of 4)

Number	Name	Description	Unit(s)	Default Value	Type	Access
31	NumVals	number of values used when updating flow profile This number is used to determine how rapidly the historical flow profile is updated. Range: 10 to 1000	n/a	10	INT	R/W
32	LowFlowLmt	low flow limit Proportions are not updated below this point. Range: 1 to 30 m/s	m/s	1	INT	R/W
33	FlowDir	flow direction 0 = positive flow direction 1 = negative flow direction	n/a	0	INT	R/W

Table C-3 Modbus Register Values Message Block 3 (Operation) (Sheet 2 of 4)

Number	Name	Description	Unit(s)	Default Value	Type	Access
34	ChordInactv	Set chords to be inactive. Use substituted velocity for inactive chords. Up to three chords may be disabled. Range: 14 for single-path meters (models 3410, 3450) 12,13,14 for dual-path (model 3420) and single-dual (model 3412) meters 0…14 for multi-path (model 3400) and double-dual (model 3422) meters Examples: 0 = all chords active 1 = set Chord A inactive 2 = set Chord B inactive 4 = set Chord C inactive 8 = set Chord D inactive 12 = set chords C and D inactive 13 = set Chords A, C, and D inactive 14 = set Chords B, C, and D inactive Default: 14 for single-path meters (models 3410, 3450) (only ChordA active) 12 for dual-path (model3420) and single-dual (model3412) meters (only ChordsA and B active) 0 for multi-path (model3400) and doubledual (model3422) meters (all chords active)	n/a	depends on model	INT	R/W

Table C-3 Modbus Register Values Message Block 3 (Operation) (Sheet 3 of 4)

Number	Name	Description	Unit(s)	Default Value	Type	Access
35	CalFlag	calibration function switch Upon turning on the calibration function switch, the flow meter resets the CalVol and the CalTime registers to zero and starts to accumulate volume and time for a calibration run. The accumulation stops when the calibration function switch is set to off. 0 = calibration off 1 = calibration on	n/a	0	INT	R/W
36	BatchSize	batch size; number of measurements per path, per calculation cycle Range: 10 to 30	count	20	INT	R/W

Table C-3 Modbus Register Values Message Block 3 (Operation) (Sheet 4 of 4)

Number	Name	Description	Unit(s)	Default Value	Type	Access
37	AlarmDef	alarm regulator This register is used to keep intermittent chord failures from showing up in the DataQlty register and from corrupting flow profile values. A chord must fail at least AlarmDef consecutive times for its corresponding bit in the DataQlty register to be set; the bit is cleared after a batch in which the chord is not failed. Flow profiles are updated only if all available chords have not failed during the previous AlarmDef consecutive batches (and the flow rate is above LowFlowLmt). Range: 1 to 1000	n/a	24	INT	R/W
38-45	Spare	This register number is not used.	n/a	n/a	INT	R/W

NOTE: For Rev. C (and later) CPU boards programmed with firmware version 5.62 (and later), Modbus Register Blocks containing operation and calibration parameters (i.e., Blocks 2, 3, 9, 10, 11) are only writable if the memory-protect jumper (JP9 on the CPU board) is *not* installed. Jumper JP9 should *never* be installed on Rev. A and Rev. B CPU boards.

Table C-4 Modbus Register Values Message Block 4 (Diagnostics) (Sheet 1 of 3)

Number	Name	Description	Unit(s)	Default Value	Type	Access
46	Spare	This register number is not used.	n/a	n/a	INT	R/W
47	DiagFn	Diagnostic function request register. This register is used to request that diagnostic information be sent from the DSP to the Host. This register should be read as zero prior to writing a non-zero value to it and should be read as zero before reading the corresponding diagnostic data block (indicating that the requested data is ready). The setting of the register is as follows: 0 = no diagnostic function in progress/data ready 1 = read gain, hold-off time, window pointer (updates Blocks 6,15) 2 = read signal identification parameters (updates Blocks 6,16,21,22) 3 = read first four zero crossing's landing position and amplitude percentage data (updates Blocks 23,24,25) 4 = read tracked target spans and amplitudes (updates Block 26) 5 = read fuzzy calculation results (updates Blocks 16,21,23,24,25,27,28) 6 = read tracked minimum and maximum span parameters (updates Blocks 19,20)	n/a	0	INT	R/W

Table C-4 Modbus Register Values Message Block 4 (Diagnostics) (Sheet 2 of 3)

Number	Name	Description	Unit(s)	Default Value	Type	Access
48	HAddr	display host memory Enter HC11 memory starting address in hexadecimal notation.	n/a	0	INT	R/W
49	DSel	display DSP memory / log wave form value (decimal) 0 = off 81 = log Chord A waveform 82 = log Chord B waveform 83 = log Chord C waveform 84 = log Chord D waveform 88 = log compressed waveform (all 4 chords) 91 = log dual signal for Chord A 92 = log dual signal for Chord B 93 = log dual signal for Chord C 94 = log dual signal for Chord D	n/a	0	INT	R/W
50	DAddr	display DSP memory	n/a	0	INT	R/W
51	ResetTrkParam	reset tracked parameters switch	n/a	0	INT	R/W
52	ResetProp	used to reset the proportions to their default values	n/a	0	INT	R/W

Table C-4 Modbus Register Values Message Block 4 (Diagnostics) (Sheet 3 of 3)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
53	FFT	FFT switch 0 = off 1 = frequency spectrum for Chord A 2 = frequency spectrum for Chord B 3 = frequency spectrum for Chord C 4 = frequency spectrum for Chord D	n/a	0	INT	R/W
54	Spare	This register number is not used.	n/a	n/a	INT	R/W
55	AckHMemErr	acknowledge Host Module error status flag 0 = off 1 = acknowledged; clear SystemStatus error bits for Host Module	n/a	0	INT	R/W
56	AckDMemErr	acknowledge DSP Module error status flag 0 = off 1 = acknowledged; clear SystemStatus error bits for DSP Module	n/a	0	INT	R/W
57-60	Spare	This register number is not used.	n/a	n/a	INT	R/W

Table C-5 Modbus Register Values Message Block 5 (Status) (Sheet 1 of 4)

Number	Name	Description	Unit(s)	Default Value	Type	Access
61	Spare	This register number is not used.	n/a	n/a	INT	R
62	StatusA	system status for Chord A See Note1. on Page 26 for chord status definitions.	n/a	0	INT	R
63	StatusB	system status for Chord B See Note1. on Page 26 for chord status definitions.	n/a	0	INT	R
64	StatusC	system status for Chord C See Note1. on Page 26 for chord status definitions.	n/a	0	INT	R
65	StatusD	system status for Chord D See Note1. on Page 26 for chord status definitions.	n/a	0	INT	R

Table C-5 Modbus Register Values Message Block 5 (Status) (Sheet 2 of 4)

Number	Name	Description	Unit(s)	Default Value	Type	Access
66	SystemStatus	general system status System status definition: 0 = no error bit 0 set = reserved bit 1 set = Pulse Accumulator error bit 2 set = HC11 RAM Memory error bit 3 set = HC11 Program Memory error bit 4 set = EEPROM CRC check failed * bit 5 set = DSP Program Memory error bit 6 set = DSP Y-Memory error bit 7 set = DSP X-Memory error bit 8 set = too few operating chords bit 9 set = average flow velocity out of range bit 10 set = batch number of time pulses out of range *EEPROM CRC check failure may be caused by the following events: 1. A new software update was installed (the sizes of the parameters to be saved in the EEPROM are different between the two software revisions). 2. EEPROM was erased by the utility software. 3. EEPROM failed.	n/a	0	INT	R

(continued on next page)

Table C-5 Modbus Register Values Message Block 5 (Status) (Sheet 3 of 4)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
66 (cont.)	SystemStatus	In cases (1) and (2), default parameters are used. User should enter desired parameters accordingly. After all the parameters are updated, toggle the power, and this flag should be cleared. If case (1) or case (2) did not happen, this flag indicates parameters in the EEPROM are corrupted.	n/a	0	INT	R
67	FailCntA1	number of failures per batch for Chord A in the upstream direction Range: 0 to BatchSize	count	0	INT	R
68	FailCntB1	number of failures per batch for Chord B in the upstream direction Range: 0 to BatchSize	count	0	INT	R
69	FailCntC1	number of failures per batch for Chord C in the upstream direction Range: 0 to BatchSize	count	0	INT	R

Table C-5 Modbus Register Values Message Block 5 (Status) (Sheet 4 of 4)

Number	Name	Description	Unit(s)	Default Value	Type	Access
70	FailCntD1	number of failures per batch for Chord D in the upstream direction Range: 0 to BatchSize	count	0	INT	R
71	FailCntA2	number of failures per batch for Chord A in the down stream direction Range: 0 to BatchSize	count	0	INT	R
72	FailCntB2	number of failures per batch for Chord B in the down stream direction Range: 0 to BatchSize	count	0	INT	R
73	FailCntC2	number of failures per batch for Chord C in the down stream direction Range: 0 to BatchSize	count	0	INT	R
74	FailCntD2	number of failures per batch for Chord D in the down stream direction Range: 0 to BatchSize	count	0	INT	R
75	Spare	This register number is not used.	n/a	n/a	INT	R

1. Note: Chord Status definitions are:

0 = no error
bit 0 set = reject signal due to noise level (see MaxNoise)
bit 1 set = reject signal due to Signal-to-Noise Ratio (see SNRatio)
bit 2 set = reject signal if measurement quality check failed
bit 3 set = reject signal if speed of sound out of range (see SSMax & SSMin)
bit 4 set = reject signal if delta time check failed
bit 5 set = reject signal for span check failure
bit 6 set = spare
bit 7 set = reject chord if flow profile check failed
bit 8 set = reject signal if peak pulse width exceeds limit
bit 9 set = reject signal due to signal quality
bit 10 set = flow change indicator
bit 11 set = reject chord if intra-chord quality check out of range
bit 12 set = reject chord if speed of sound deviation out of range
bit 13 set = chord is manually set to be inactive (see ChordInactv)
bit 14 set = chord failed
bit 15 set = acquisition mode

Table C-6 Modbus Register Values Message Block 6 (Diagnostics) (Sheet 1 of 5)

Number	Name	Description	Unit(s)	Default Value	Type	Access
76	Spare	This register number is not used.	n/a	n/a	INT	R
77	GainA1	Gain when Transducer A1 is receiving a signal. Beginning with CPU firmware V6.31, this value is updated every batch (i.e., it no longer requires use of the DiagFn register although the DiagFn register can still be used to force an update of this register). Range: 50…180 CPU Firmware <= V6.24 GainLowLmt … GainHighLmt CPU Firmware >= V6.30	n/a	0	INT	R
78	GainA2	Gain when Transducer A2 is receiving a signal. Beginning with CPU firmware V6.31, this value is updated every batch (i.e., it no longer requires use of the DiagFn register although the DiagFn register can still be used to force an update of this register). Range: 50…180 CPU Firmware <= V6.24 GainLowLmt … GainHighLmt CPU Firmware >= V6.30	n/a	0	INT	R

Table C-6 Modbus Register Values Message Block 6 (Diagnostics) (Sheet 2 of 5)

Number	Name	Description	Unit(s)	Default Value	Type	Access
79	GainB1	Gain when Transducer B1 is receiving a signal. Beginning with CPU firmware V6.31, this value is updated every batch (i.e., it no longer requires use of the DiagFn register although the DiagFn register can still be used to force an update of this register). Range: 50…180 CPU Firmware <= V6.24 GainLowLmt … GainHighLmt CPU Firmware >= V6.30	n/a	0	INT	R
80	GainB2	Gain when Transducer B2 is receiving a signal. Beginning with CPU firmware V6.31, this value is updated every batch (i.e., it no longer requires use of the DiagFn register although the DiagFn register can still be used to force an update of this register). Range: 50…180 CPU Firmware <= V6.24 GainLowLmt … GainHighLmt CPU Firmware >= V6.30	n/a	0	INT	R

Table C-6 Modbus Register Values Message Block 6 (Diagnostics) (Sheet 3 of 5)

Number	Name	Description	Unit(s)	Default Value	Type	Access
81	GainC1	Gain when Transducer C1 is receiving a signal. Beginning with CPU firmware V6.31, this value is updated every batch (i.e., it no longer requires use of the DiagFn register although the DiagFn register can still be used to force an update of this register). Range: 50…180 CPU Firmware <= V6.24 GainLowLmt … CPU Firmware >= V6.30 GainHighLmt	n/a	0	INT	R
82	GainC2	Gain when Transducer C2 is receiving a signal. Beginning with CPU firmware V6.31, this value is updated every batch (i.e., it no longer requires use of the DiagFn register although the DiagFn register can still be used to force an update of this register). Range: 50…180 CPU Firmware <= V6.24 GainLowLmt … CPU Firmware >= V6.30 GainHighLmt	n/a	0	INT	R

Table C-6 Modbus Register Values Message Block 6 (Diagnostics) (Sheet 4 of 5)

Number	Name	Description	Unit(s)	Default Value	Type	Access
83	GainD1	Gain when Transducer D1 is receiving a signal. Beginning with CPU firmware V6.31, this value is updated every batch (i.e., it no longer requires use of the DiagFn register although the DiagFn register can still be used to force an update of this register). Range: 50…180 CPU Firmware <= V6.24 GainLowLmt … GainHighLmt CPU Firmware >= V6.30	n/a	0	INT	R
84	GainD2	Gain when Transducer D2 is receiving a signal. Beginning with CPU firmware V6.31, this value is updated every batch (i.e., it no longer requires use of the DiagFn register although the DiagFn register can still be used to force an update of this register). Range: 50…180 CPU Firmware <= V6.24 GainLowLmt … GainHighLmt CPU Firmware >= V6.30	n/a	0	INT	R
85	Reserved	Reserved (formerly AutoCtrlA, CPU Firmware <= V6.24).	n/a	0	INT	R

Table C-6 Modbus Register Values Message Block 6 (Diagnostics) (Sheet 5 of 5)

Number	Name	Description	Unit(s)	Default Value	Type	Access
86	Reserved	Reserved (formerly AutoCtrlB, CPU Firmware <= V6.24).	n/a	0	INT	R
87	Reserved	Reserved (formerly AutoCtrlC, CPU Firmware <= V6.24).	n/a	0	INT	R
88	Reserved	Reserved (formerly AutoCtrlD, CPU Firmware <= V6.24).	n/a	0	INT	R
89-90	Spare	This register number is not used.	n/a	n/a	INT	R

Table C-7 Modbus Register Values Message Block 7 (Memory Display)

Number	Name	Description	Unit(s)	Default Value	Type	Access
91-105	HMem00 to HMem14	Host module memory display from (HSADDR+0) to (HSADDR+14)	n/a	0	INT	R

Table C-8 Modbus Register Values Message Block 8 (Diagnostics)

Number	Name	Description	Unit(s)	Default Value	Type	Access
106-120	Spare	This register number is not used.	n/a	n/a	INT	R

Table C-9 Modbus Register Values Message Block 9 (Operation) (Sheet 1 of 10)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
200	ZeroCut	Volume cut-off threshold If the magnitude of the average flow velocity (AvgFlow) is less than ZeroCut, then the batch volume is zero (i.e., no volume is accumulated for the batch). Range: 0 to 1 m/s	m/s	0.1 firmware <=V6.30 0.03048 firmware >= V6.31	FP	R/W
202	SSMax	maximum speed of sound (corresponds to bit 3 of the chord status register, StatusA to StatusD) Range: 20 to 2000 m/s	m/s	450	FP	R/W
204	SSMin	minimum speed of sound (corresponds to bit 3 of the chord status register, StatusA to StatusD) Range: 20 to 2000 m/s	m/s	300	FP	R/W
206	EmRate	emission rate If stacking is used, see StackEmRate (register 248). Range: 0.008 to 0.100 seconds	seconds	0.032	FP	R/W

Table C-9 Modbus Register Values Message Block 9 (Operation) (Sheet 2 of 10)

Number	Name	Description	Unit(s)	Default Value	Type	Access
208	SampRate	Sample rate Range: 0.625 (V6.30+), 1.25, 2.50, 5.0 (V6.30+) MHz	MHz	1.25	FP	R/W
210	PulseWidth	transducer driver pulse width Range: 0.0000010 to 0.0000255 seconds	seconds	0.000004	FP	R/W
212	PctFail	percentage failure allowed before a chord is flagged as being failed Range: 10 to 100 percent	percentage	40 firmware <=V6.30 75 firmware >= V6.31	FP	R/W
214	MinHoldTime	minimum hold-off time Range: 0.000050 to 0.006000 seconds	seconds	0.000208	FP	R/W
216	Pk1Pct	percentage of the maximum peak amplitude used to identify the first peak Range: 40, 50, 60, 70 percent Note: This register is not used since V6.45 of the CPU	percentage	60	FP	R/W

Table C-9 Modbus Register Values Message Block 9 (Operation) (Sheet 3 of 10)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
218	MinSigQlty	acceptable signal quality If signal quality falls below the minimum threshold (i.e., signal quality < MinSigQlty), then an error is flagged. The corresponding status bit is bit 9 of the chord status (StatusA to StatusD). Range: 5 to 30	n/a	8	FP	R/W
220	DltChk	maximum time difference between the upstream and down stream (PF-P1) span Note that the corresponding status bit is bit 4 of the chord status (StatusA to StatusD). Range: 0.0000032 to 0.0000320 seconds	seconds	0.0000056 firmware <=V6.30 0.0000072 firmware >= V6.31	FP	R/W
222	Spare	This register number is not used. Note: This register is not used since V6.45 of the CPU	n/a	n/a	FP	R/W

Table C-9 Modbus Register Values Message Block 9 (Operation) (Sheet 4 of 10)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
224	NegSpan	signal must be negative for this amount of time before P1 Note that the corresponding status bit is bit 5 of the chord status (StatusA to StatusD). Range: 0.000001 to 0.000010 seconds	seconds	0.0000024	FP	R/W
226	PosSpan	signal must be positive for this amount of time before P1 Note that the corresponding status bit is bit 5 of the chord status (StatusA to StatusD). Range: 0.000001 to 0.000010 seconds	seconds	0.0000032	FP	R/W
228	TmDevLow1	measurement quality (sigma) check #1 on transmit time If sigma is greater than TmDevLow1, then check the deviation. Note that the corresponding status bit is bit 2 of the chord status (StatusA to StatusD). Range: 0 to 0.000005 seconds	seconds	0.000001 firmware <=V6.30 0.000002 firmware >= V6.31	FP	R/W

Table C-9 Modbus Register Values Message Block 9 (Operation) (Sheet 5 of 10)

Number	Name	Description	Unit(s)	Default Value	Type	Access
230	TmDevLow2	measurement quality (sigma) check #2 on transit time If sigma is greater than TmDevLow2, then check the deviation. Note that the corresponding status bit is bit 2 of the chord status (StatusA to StatusD). Range: 0 to 0.000005 seconds Note: This register is not used in V6.45 of the CPU	seconds	0.000002	FP	R/W
232	CRange	percentage of deviation allowed on speed of sound check Note that the corresponding status bit is bit 12 of the chord status (StatusA to StatusD). Range: 0 to 10 percent	percentage	1.5	FP	R/W

Table C-9 Modbus Register Values Message Block 9 (Operation) (Sheet 6 of 10)

Number	Name	Description	Unit(s)	Default Value	Type	Access
234	SDevLow	intrachord quality check performed if S1 or S2 or S3 (defined below) is less than SDevLow S1 is sigma on upstream transit time; S2 is sigma on down stream transit time; S3 is sigma on delta time. An error is flagged if |(S1-S2) / MIN(S1,S2)| > SDevFctr |(S1-S3) / MIN(S1,S3)| > SDevFctr |(S2-S3) / MIN(S2,S3)| > SDevFctr Note that the corresponding status bit is bit 11 of the chord status (StatusA to StatusD). Range: 0.000001 to 0.000010 seconds Note: This register is not used since V6.45 of the CPU	seconds	0.000001 firmware <=V6.30 0.000010 firmware >= V6.31	FP	R/W
236	SDevFctr	range factor for deviation check on standard deviation Note that the corresponding status bit is bit 11 of the chord status (StatusA to StatusD). Range: 1 to 100 Note: This register is not used since V6.45 of the CPU	n/a	2	FP	R/W

Table C-9 Modbus Register Values Message Block 9 (Operation) (Sheet 7 of 10)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
238	Pk1Wdth	acceptable selected peak maximum pulse width Note that the corresponding status bit is bit 8 of the chord status (StatusA to StatusD). Range: 0.000001 to 0.000010 seconds	seconds	0.0000056	FP	R/W
240	TmDevFctr1	range factor for sigma check #1 Note that the corresponding status bit is bit 2 of the chord status (StatusA to StatusD). Range: 1 to 100	n/a	2	FP	R/W
242	TmDevFctr2	range factor for sigma check #2 Note that the corresponding status bit is bit 2 of the chord status (StatusA to StatusD). Range: 1 to 100 Note: This register is not used in V6.45 of The CPU	n/a	2	FP	R/W

Table C-9 Modbus Register Values Message Block 9 (Operation) (Sheet 8 of 10)

Number	Name	Description	Unit(s)	Default Value	Type	Access
244	FlwChgThrsh	flow change threshold For example: let X be Chord A, B, C, or D; let DEV_RATIO = (SDevTm1X + SDevTm2X)/ SDevDltTmX. If {SDevTm1X > TmDevLow1} and {SDevTm2X > TmDevLow1} and {(1 – FCTHRD) < DEV_RATIO < (1 + FCTHRD)} then check for flow change. Range: 0 to 25 percent Note: This register is not used since V6.45 of the CPU	percentage	5	FP	R/W

Table C-9 Modbus Register Values Message Block 9 (Operation) (Sheet 9 of 10)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
246	FlwChgDtctr	flow change detector DTUP = Tavg_now – Tavg_last on up stream DTDN = Tavg_now – Tavg_last on down stream If (DTUP + DTDN < FlwChgDtctr) then flow has changed. If flow has change, then the transit time deviation check is not done. Note that the corresponding status bit is bit 10 of the chord status (StatusA to StatusD). Range: 0.000001 to 0.000010 seconds Note: This register is not changed since V6.45 of The CPU	seconds	0.000002	FP	R/W

Table C-9 Modbus Register Values Message Block 9 (Operation) (Sheet 10 of 10)

Number	Name	Description	Unit(s)	Default Value	Type	Access
248	StackEmRate	stacking emission rate This emission rate is used between firings until the StackSize number of firings has been completed for the path (if stacking-by-path) or for the chord (if stacking-by-chord). The emission rate, EmRate, is used after the last StackSize firing has been completed to allow for the extra time required for end-of-stacking computations. EmRate should be greater than or equal to Stack-EmRate. Range: 0.004 to 0.100 seconds Note: This register is not used in V6.45 of The CPU	seconds	0.008	FP	R/W

NOTE: For Rev. C (and later) CPU boards programmed with firmware version 5.62 (and later), Modbus Register Blocks containing operation and calibration parameters (i.e., Blocks 2, 3, 9, 10, 11) are only writable if the memory-protect jumper (JP9 on the CPU board) is *not* installed. Jumper JP9 should *never* be installed on Rev. A and Rev. B CPU boards.

Table C-10 Modbus Register Values Message Block 10 (Operation) (Sheet 1 of 5)

Number	Name	Description	Unit(s)	Default Value	Type	Access
250	TampLo	Tamp absolute low range Range: 0 to 100 percent Note: This register is not used since V6.45 of The CPU	percentage	30	FP	R/W
252	TspfLo	Tspf low range Range: 0 to 37 sample intervals (si) Note: This register is not used since V6.45 of The CPU	si	8	FP	R/W
254	TspeLo	Tspe low range Range: -25 to +25 sample intervals (si) Note: This register is not used since V6.45 of The CPU	si	-8	FP	R/W
256	Tspf	target span away from the critical point To correct, enter a value other than the current value.	si	15	FP	R/W
258	Tspe	target span away from the energy arrival point To correct, enter a value other than the current value.	si	8	FP	R/W

Table C-10 Modbus Register Values Message Block 10 (Operation) (Sheet 2 of 5)

Number	Name	Description	Unit(s)	Default Value	Type	Access
260	Tamp	target amplitude percentage To correct, enter a value other than the current value. Range: -100 to +100 percent	percentage	-80	FP	R/W
262	TspfSen	sensitivity of Tspf Range: 6 to 37 sample intervals (si) Note: This register is not used since V6.45 of The CPU	si	10	FP	R/W
264	TspeSen	sensitivity of Tspe Range: 6 to 37 sample intervals (si) Note: This register is not used since V6.45 of The CPU	si	18	FP	R/W
266	TampSen	sensitivity of Tamp Range: 5 to 100 percent Note: This register is not used since V6.45 of The CPU	percentage	30	FP	R/W
268	TspfWt	weighting factor of Tspf Range: 0 to 3	n/a	2	FP	R/W

Table C-10 Modbus Register Values Message Block 10 (Operation) (Sheet 3 of 5)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
270	TspeWt	weighting factor of Tspe Range: 0 to 3	n/a	1	FP	R/W
272	TampWt	weighting factor of Tamp Range: 0 to 3	n/a	2	FP	R/W

274	TspeLmt	Pe-Pf limit
		If ((Pe-Pf) > TspeLmt), then Pe is not used in the calculation.
		If ((Pf-Pe) > TspeLmt), then Pf is not used in the calculation.
		Range: 0 to 30 si
		Note: This register is not used since V6.45 of The CPU
			si	25	FP	R/W

276	TampHi	Tamp absolute high range Range: 0 to 100 percent Note: This register is not used in V6.45 of The CPU	percentage	90	FP	R/W

Table C-10 Modbus Register Values Message Block 10 (Operation) (Sheet 4 of 5)

Number	Name	Description	Unit(s)	Default Value	Type	Access
278	TspfHi	Tspf high range Range: 0 to 37 si Note: This register is not used since V6.45 of The CPU	si	20	FP	R/W
280	TspeHi	Tspe high range Range: -25 to +25 si Note: This register is not used since V6.45 of The CPU	si	15	FP	R/W
282	Reserved	This register number is reserved for future use. Note: This register is not used since V6.45 of The CPU	n/a	n/a	FP	R/W
284	FwdA0	forward flow zeroth calibration coefficient if third-order calibration is used Range: -1.0 to 1.0 m/s	m/s	0	FP	R/W
286	FwdA1	forward flow first calibration coefficient if third-order calibration is used Range: 0.95 to 1.05	n/a	1	FP	R/W
288	FwdA2	forward flow second calibration coefficient if third-order calibration is used Range: -0.1 to 0.1 s/m	s/m	0	FP	R/W

Table C-10 Modbus Register Values Message Block 10 (Operation) (Sheet 5 of 5)

Number	Name	Description	Unit(s)	Default Value	Type	Access
290	FwdA3	forward flow third calibration coefficient if third-order calibration is used Range: -0.1 to 0.1 s^2/m^2	s^2/m^2	0	FP	R/W
292	RevA0	reverse flow zeroth calibration coefficient if third-order calibration is used Range: -1.0 to 1.0 m/s	m/s	0	FP	R/W
294	RevA1	reverse flow first calibration coefficient if third-order calibration is used Range: 0.95 to 1.05	n/a	1	FP	R/W
296	RevA2	reverse flow second calibration coefficient if third-order calibration is used Range: -0.1 to 0.1 s/m	s/m	0	FP	R/W
298	RevA3	reverse flow third calibration coefficient if third-order calibration is used Range: -0.1 to 0.1 s^2/m^2	s^2/m^2	0	FP	R/W

NOTE: For Rev. C (and later) CPU boards programmed with firmware version 5.62 (and later), Modbus Register Blocks containing operation and calibration parameters (i.e., Blocks 2, 3, 9, 10, 11) are only writable if the memory-protect jumper (JP9 on the CPU board) is *not* installed. Jumper JP9 should *never* be installed on Rev. A and Rev. B CPU boards.

Table C-11 Modbus Register Values Message Block 11 (Calibration) (Sheet 1 of 5)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
300	VelOffset	average velocity offset constant Range: -1 to 1 m/s	m/s	0	FP	R/W
302	PipeDiam	internal pipe diameter Range: 0 to 2 m	m	0.1524	FP	R/W
304	XA	component of L in the direction of flow (X) for Chord A within the meter bore Range: 0 to 2 m	m	0.1524	FP	R/W
306	XB	component of L in the direction of flow (X) for Chord B within the meter bore Range: 0 to 2 m	m	0.1524	FP	R/W
308	XC	component of L in the direction of flow (X) for Chord C within the meter bore Range: 0 to 2 m	m	0.1524	FP	R/W

Table C-11 Modbus Register Values Message Block 11 (Calibration) (Sheet 2 of 5)

<table>
<tr><th>Number</th><th>Name</th><th>Description</th><th>Unit(s)</th><th>Default Value</th><th>Type</th><th>Access</th></tr>
<tr><td>310</td><td>XD</td><td>component of L in the direction of flow (X) for Chord D within the meter bore
Range: 0 to 2 m</td><td>m</td><td>0.1524</td><td>FP</td><td>R/W</td></tr>
<tr><td>312</td><td>LA</td><td>measured chord length (L) for Chord A
Range: 0 to 5 m</td><td>m</td><td>0.3048</td><td>FP</td><td>R/W</td></tr>
<tr><td>314</td><td>LB</td><td>measured chord length (L) for Chord B
Range: 0 to 5 m</td><td>m</td><td>0.3048</td><td>FP</td><td>R/W</td></tr>
<tr><td>316</td><td>LC</td><td>measured chord length (L) for Chord C
Range: 0 to 5 m</td><td>m</td><td>0.3048</td><td>FP</td><td>R/W</td></tr>
<tr><td>318</td><td>LD</td><td>measured chord length (L) for Chord D
Range: 0 to 5 m</td><td>m</td><td>0.3048</td><td>FP</td><td>R/W</td></tr>
<tr><td>320</td><td>WtA</td><td>Weight of Chord A, for calculating average weighted flow velocity
<table>
<tr><th></th><th>single-path
(3410, 3450)</th><th>dual-path
(3412, 3420)</th><th>double-dual
(3422)</th><th>multi-path
(3400)</th></tr>
<tr><td>WtA range</td><td>1.0</td><td>0.0 to 1.0</td><td>0.0 to 1.0</td><td>0.0 to 1.0</td></tr>
<tr><td>Default</td><td>1.0</td><td>0.5</td><td>0.25</td><td>0.1382</td></tr>
</table></td><td>n/a</td><td>depends on model</td><td>FP</td><td>R/W</td></tr>
</table>

Table C-11 Modbus Register Values Message Block 11 (Calibration) (Sheet 3 of 5)

<table>
<tr><th>Number</th><th>Name</th><th>Description</th><th>Unit(s)</th><th>Default Value</th><th>Type</th><th>Access</th></tr>
<tr><td>322</td><td>WtB</td><td>Weight of Chord B, for calculating average weighted flow velocity
<table>
<tr><th></th><th>single-path
(3410, 3450)</th><th>dual-path
(3412, 3420)</th><th>double-dual
(3422)</th><th>multi-path
(3400)</th></tr>
<tr><td>WtB range</td><td>0.0</td><td>0.0 to 1.0</td><td>0.0 to 1.0</td><td>0.0 to 1.0</td></tr>
<tr><td>Default</td><td>0.0</td><td>0.5</td><td>0.25</td><td>0.3618</td></tr>
</table></td><td>n/a</td><td>depends on model</td><td>FP</td><td>R/W</td></tr>
<tr><td>324</td><td>WtC</td><td>Weight of Chord C, for calculating average weighted flow velocity
<table>
<tr><th></th><th>single-path
(3410, 3450)</th><th>dual-path
(3412, 3420)</th><th>double-dual
(3422)</th><th>multi-path
(3400)</th></tr>
<tr><td>WtC range</td><td>0.0</td><td>0.0</td><td>0.0 to 1.0</td><td>0.0 to 1.0</td></tr>
<tr><td>Default</td><td>0.0</td><td>0.0</td><td>0.25</td><td>0.3618</td></tr>
</table></td><td>n/a</td><td>depends on model</td><td>FP</td><td>R/W</td></tr>
<tr><td>326</td><td>WtD</td><td>Weight of Chord D, for calculating average weighted flow velocity
<table>
<tr><th></th><th>single-path
(3410, 3450)</th><th>dual-path
(3412, 3420)</th><th>double-dual
(3422)</th><th>multi-path
(3400)</th></tr>
<tr><td>WtD range</td><td>0.0</td><td>0.0</td><td>0.0 to 1.0</td><td>0.0 to 1.0</td></tr>
<tr><td>Default</td><td>0.0</td><td>0.0</td><td>0.25</td><td>0.1382</td></tr>
</table></td><td>n/a</td><td>depends on model</td><td>FP</td><td>R/W</td></tr>
<tr><td>328</td><td>MeterFctr</td><td>meter factor
Range: 0.95 to 1.05</td><td>n/a</td><td>1.0</td><td>FP</td><td>R/W</td></tr>
</table>

Table C-11 Modbus Register Values Message Block 11 (Calibration) (Sheet 4 of 5)

Number	Name	Description	Unit(s)	Default Value	Type	Access
330	BGFctr	Correction factor determined by British Gas. Range: 0.95 - 1.05 single-path, single-dual, double-dual multi-path dual-path (3412,3422) (3400) (3410, 3450,3420) (varies by size) Default 1.000	n/a	depends on model	FP	R/W
332	AvgDlyA	average delay time for Chord A Range: 0 to 50 µs	seconds	0	FP	R/W
334	AvgDlyB	average delay time for Chord B Range: 0 to 50 µs	seconds	0	FP	R/W
336	AvgDlyC	average delay time for Chord C Range: 0 to 50 µs	seconds	0	FP	R/W
338	AvgDlyD	average delay time for Chord D Range: 0 to 50 µs	seconds	0	FP	R/W
340	DltDlyA	difference in upstream and down stream delay times for Chord A Range: -1 to 1 µs	seconds	0	FP	R/W

Table C-11 Modbus Register Values Message Block 11 (Calibration) (Sheet 5 of 5)

Number	Name	Description	Unit(s)	Default Value	Type	Access
342	DltDlyB	difference in upstream and down stream delay times for Chord B Range: -1 to 1 µs	seconds	0	FP	R/W
344	DltDlyC	difference in upstream and down stream delay times for Chord C Range: -1 to 1 µs	seconds	0	FP	R/W
346	DltDlyD	difference in upstream and down stream delay times for Chord D Range: -1 to 1 µs	seconds	0	FP	R/W
348	CableDly	systematic delay time introduced by the length of the cable and/or by the electronics Range: 0 to 10 µs for Rev. A CPU boards 1.5 to 10 µs for Rev. C CPU boards Defaults = 0 for Rev. A CPU boards 0.0000015 for Rev. C CPU boards	seconds	depends on CPU board rev level	FP	R/W

NOTE: For Rev. C (and later) CPU boards programmed with firmware version 5.62 (and later), Modbus Register Blocks containing operation and calibration parameters (i.e., Blocks 2, 3, 9, 10, 11) are only writable if the memory-protect jumper (JP9 on the CPU board) is *not* installed. Jumper JP9 should *never* be installed on Rev. A and Rev. B CPU boards.

Table C-12 Modbus Register Values Message Block 12 (Calculation Results CPU R Registers) (Sheet 1 of 3)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
350	Spare	This register number is not used.	n/a	n/a	FP	R
352	FlowVelA	flow velocity for Chord A	m/s	0	FP	R
354	FlowVelB	flow velocity for Chord B	m/s	0	FP	R
356	FlowVelC	flow velocity for Chord C	m/s	0	FP	R
358	FlowVelD	flow velocity for Chord D	m/s	0	FP	R
360	AvgFlow	corrected flow velocity after linearization	m/s	0	FP	R
362	SndVelA	sound velocity for Chord A	m/s	0	FP	R
364	SndVelB	sound velocity for Chord B	m/s	0	FP	R
366	SndVelC	sound velocity for Chord C	m/s	0	FP	R
368	SndVelD	sound velocity for Chord D	m/s	0	FP	R
370	AvgSndVel	average sound velocity	m/s	0	FP	R
372	CalVol	volume accumulated during the calibration function	m^3	0	FP	R
374	CalTime	time accumulated during the calibration function	pulses	0	FP	R

Table C-12 Modbus Register Values Message Block 12 (Calculation Results CPU R Registers) (Sheet 2 of 3)

Number	Name	Description	Unit(s)	Default Value	Type	Access
376	SDevVelA	standard deviation for velocity for Chord A Note that this register is not implemented.	m/s	0	FP	R
378	SDevVelB	standard deviation for velocity for Chord B Note that this register is not implemented.	m/s	0	FP	R
380	SDevVelC	standard deviation for velocity for Chord C Note that this register is not implemented.	m/s	0	FP	R
382	SDevVelD	standard deviation for velocity for Chord D Note that this register is not implemented.	m/s	0	FP	R
384	SDevSndA	standard deviation for speed of sound for Chord A Note that this register is not used since V6.45 of the CPU.	m/s	0	FP	R
386	SDevSndB	standard deviation for speed of sound for Chord B Note that this register is not used since V6.45 of the CPU.	m/s	0	FP	R

Table C-12 Modbus Register Values Message Block 12 (Calculation Results CPU R Registers) (Sheet 3 of 3)

Number	Name	Description	Unit(s)	Default Value	Type	Access
388	UnCorrFlwRt	Uncorrected flowrate before linearization Note that this register is used since V6.45 of the CPU.	m^3/h	0	FP	R
390	LinearMtrFctr	Piece-wise linear factor being used Note that this register is used since V6.45 of the CPU.	n/a	1	FP	R
392	FlowRate	corrected flow velocity after linearization	acmh	0	FP	R
394	CutRate	flow rate cutoff threshold in ACMH If ABS(FlowRate) < CutRate, then Volume is not accumulated.	acmh	0	FP	R
396	CalVolA	volume accumulated due to Chord A only during the calibration function (for testing only)	m^3	0	FP	R
398	CalVolB	volume accumulated due to Chord B only during the calibration function (for testing only)	m^3	0	FP	R

Table C-13 Modbus Register Values Message Block 13 (Calculation Results) (Sheet 1 of 2)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
400	Spare	This register number is not used.	n/a	n/a	FP	R
402	MaxTmA1	maximum transit time up stream for Chord A	seconds	0	FP	R
404	MaxTmB1	maximum transit time up stream for Chord B	seconds	0	FP	R
406	MaxTmC1	maximum transit time up stream for Chord C	seconds	0	FP	R
408	MaxTmD1	maximum transit time up stream for Chord D	seconds	0	FP	R
410	MaxTmA2	maximum transit time down stream for Chord A	seconds	0	FP	R
412	MaxTmB2	maximum transit time down stream for Chord A	seconds	0	FP	R
414	MaxTmC2	maximum transit time down stream for Chord A	seconds	0	FP	R
416	MaxTmD2	maximum transit time down stream for Chord A	seconds	0	FP	R
418	MinTmA1	minimum transit time up stream for Chord A	seconds	0	FP	R
420	MinTmB1	minimum transit time up stream for Chord B	seconds	0	FP	R
422	MinTmC1	minimum transit time up stream for Chord C	seconds	0	FP	R
424	MinTmD1	minimum transit time up stream for Chord D	seconds	0	FP	R

Table C-13 Modbus Register Values Message Block 13 (Calculation Results) (Sheet 2 of 2)

Number	Name	Description	Unit(s)	Default Value	Type	Access
426	MinTmA2	minimum transit time down stream for Chord A	seconds	0	FP	R
428	MinTmB2	minimum transit time down stream for Chord A	seconds	0	FP	R
430	MinTmC2	minimum transit time down stream for Chord A	seconds	0	FP	R
432	MinTmD2	minimum transit time down stream for Chord A	seconds	0	FP	R
434	MeanTmA1	average transit time up stream for Chord A	seconds	0	FP	R
436	MeanTmB1	average transit time up stream for Chord B	seconds	0	FP	R
438	MeanTmC1	average transit time up stream for Chord C	seconds	0	FP	R
440	MeanTmD1	average transit time up stream for Chord D	seconds	0	FP	R
442	MeanTmA2	average transit time down stream for Chord A	seconds	0	FP	R
444	MeanTmB2	average transit time down stream for Chord A	seconds	0	FP	R
446	MeanTmC2	average transit time down stream for Chord A	seconds	0	FP	R
448	MeanTmD2	average transit time down stream for Chord A	seconds	0	FP	R

Table C-14 Modbus Register Values Message Block 14 (Calculation Results) (Sheet 1 of 3)

Number	Name	Description	Unit(s)	Default Value	Type	Access
450	Spare	This register number is not used.	n/a	n/a	FP	R
452	DltTmA	delta times (T1 minus T2) for Chord A	seconds	0	FP	R
454	DltTmB	delta times (T1 minus T2) for Chord B	seconds	0	FP	R
456	DltTmC	delta times (T1 minus T2) for Chord C	seconds	0	FP	R
458	DltTmD	delta times (T1 minus T2) for Chord D	seconds	0	FP	R
460	SDevTmA1	standard deviation of transit times for Chord A, up stream	ns	0	FP	R
462	SDevTmB1	standard deviation of transit times for Chord B, up stream	ns	0	FP	R
464	SDevTmC1	standard deviation of transit times for Chord C, up stream	ns	0	FP	R
466	SDevTmD1	standard deviation of transit times for Chord D, up stream	ns	0	FP	R
468	SDevTmA2	standard deviation of transit times for Chord A, down stream	ns	0	FP	R

Table C-14 Modbus Register Values Message Block 14 (Calculation Results) (Sheet 2 of 3)

Number	Name	Description	Unit(s)	Default Value	Type	Access
470	SDevTmB2	standard deviation of transit times for Chord B, down stream	ns	0	FP	R
472	SDevTmC2	standard deviation of transit times for Chord C, down stream	ns	0	FP	R
474	SDevTmD2	standard deviation of transit times for Chord D, down stream	ns	0	FP	R
476	SDevDltTmA	standard deviation of delta times for Chord A	ns	0	FP	R
478	SDevDltTmB	standard deviation of delta times for Chord B	ns	0	FP	R
480	SDevDltTmC	standard deviation of delta times for Chord C	ns	0	FP	R
482	SDevDltTmD	standard deviation of delta times for Chord D	ns	0	FP	R
484	MaxDltTmA	maximum delta times for Chord A	seconds	0	FP	R
486	MaxDltTmB	maximum delta times for Chord B	seconds	0	FP	R
488	MaxDltTmC	maximum delta times for Chord C	seconds	0	FP	R
490	MaxDltTmD	maximum delta times for Chord D	seconds	0	FP	R
492	MinDltTmA	minimum delta times for Chord A	seconds	0	FP	R
494	MinDltTmB	minimum delta times for Chord B	seconds	0	FP	R

Table C-14 Modbus Register Values Message Block 14 (Calculation Results) (Sheet 3 of 3)

Number	Name	Description	Unit(s)	Default Value	Type	Access
496	MinDltTmC	minimum delta times for Chord C	seconds	0	FP	R
498	MinDltTmD	minimum delta times for Chord D	seconds	0	FP	R

Table C-15 Modbus Register Values Message Block 15 (Diagnostics) (Sheet 1 of 2)

Number	Name	Description	Unit(s)	Default Value	Type	Access
500	Spare	This register number is not used.	n/a	n/a	FP	R
502	HoldTmA1	hold-off times used for Chord A, up stream	seconds	0	FP	R
504	HoldTmA2	hold-off times used for Chord A, down stream	seconds	0	FP	R
506	HoldTmB1	hold-off times used for Chord B, up stream	seconds	0	FP	R
508	HoldTmB2	hold-off times used for Chord B, down stream	seconds	0	FP	R
510	HoldTmC1	hold-off times used for Chord C, up stream	seconds	0	FP	R
512	HoldTmC2	hold-off times used for Chord C, down stream	seconds	0	FP	R
514	HoldTmD1	hold-off times used for Chord D, up stream	seconds	0	FP	R

Table C-15 Modbus Register Values Message Block 15 (Diagnostics) (Sheet 2 of 2)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
516	HoldTmD2	hold-off times used for Chord D, down stream	seconds	0	FP	R
518	WdwPtrA1	window pointers used for Chord A, up stream	si	0	FP	R
520	WdwPtrA2	window pointers used for Chord A, down stream	si	0	FP	R
522	WdwPtrB1	window pointers used for Chord B, up stream	si	0	FP	R
524	WdwPtrB2	window pointers used for Chord B, down stream	si	0	FP	R
526	WdwPtrC1	window pointers used for Chords A -D, down stream	si	0	FP	R
528	WdwPtrC2	window pointers used for Chord C, up stream down	si	0	FP	R
530	WdwPtrD1	window pointers used for Chord C, down stream	si	0	FP	R
532	WdwPtrD2	window pointers used for Chord D, up stream down	si	0	FP	R
534-548	Spare	This register number is not used.	n/a	n/a	FP	R

Table C-16 Modbus Register Values Message Block 16 (Diagnostics) (Sheet 1 of 2)

Number	Name	Description	Unit(s)	Default Value	Type	Access
550	PfA1	critical point position for path A (up)	si	0	FP	R
552	PfA2	critical point position for path A (down)	si	0	FP	R
554	PfB1	critical point position for path B (up)	si	0	FP	R
556	PfB2	critical point position for path B (down)	si	0	FP	R
558	PfC1	critical point position for path C (up)	si	0	FP	R
560	PfC2	critical point position for path C (down)	si	0	FP	R
562	PfD1	critical point position for path D (up)	si	0	FP	R
564	PfD2	critical point position for path D (down)	si	0	FP	R
566	PlA1	measured point landing position for path A (up)	si	0	FP	R
568	PlA2	measured point landing position for path A (down)	si	0	FP	R
570	PlB1	measured point landing position for path B (up)	si	0	FP	R
572	PlB2	measured point landing position for path B (down)	si	0	FP	R
574	PlC1	measured point landing position for path C (up)	si	0	FP	R

Table C-16 Modbus Register Values Message Block 16 (Diagnostics) (Sheet 2 of 2)

Number	Name	Description	Unit(s)	Default Value	Type	Access
576	PlC2	measured point landing position for path C (down)	si	0	FP	R
578	PlD1	measured point landing position for path D (up)	si	0	FP	R
580	PlD2	measured point landing position for path D (down)	si	0	FP	R
582	PwA1	{P2-P1} for path A (up)	si	0	FP	R
584	PwA2	{P2-P1} for path A (down)	si	0	FP	R
586	PwB1	{P2-P1} for path B (up)	si	0	FP	R
588	PwB2	{P2-P1} for path B (down)	si	0	FP	R
590	PwC1	{P2-P1} for path C (up)	si	0	FP	R
592	PwC2	{P2-P1} for path C (down)	si	0	FP	R
594	PwD1	{P2-P1} for path D (up)	si	0	FP	R
596	PwD2	{P2-P1} for path D (down)	si	0	FP	R
598	Spare	This register number is not used.	n/a	n/a	FP	R

Table C-17 Modbus Register Values Message Block 17 (Calculation Results) (Sheet 1 of 3)

Number	Name	Description	Unit(s)	Default Value	Type	Access
600	PropA	Proportion used for calculating substituted Chord A positive flow velocity. single-path dual-path, double-dual multi-path (3410, 3450) single-dual (3422) (3400) (3412, 3420) Default 1.000 1.000 1.000 0.890	n/a	depends on model	FP	R
602	PropB	Proportion used for calculating substituted Chord B positive flow velocity. single-path dual-path, double-dual multi-path (3410, 3450) single-dual (3422) (3400) (3412, 3420) Default 0.000 1.000 1.000 1.042	n/a	depends on model	FP	R
604	PropC	Proportion used for calculating substituted Chord C positive flow velocity. single-path dual-path, double-dual multi-path (3410, 3450) single-dual (3422) (3400) (3412, 3420) Default 0.000 0.000 1.000 1.042	n/a	depends on model	FP	R
606	PropD	Proportion used for calculating substituted Chord D positive flow velocity. single-path dual-path, double-dual multi-path (3410, 3450) single-dual (3422) (3400) (3412, 3420) Default 0.000 0.000 1.000 0.890	n/a	depends on model	FP	R

Table C-17 Modbus Register Values Message Block 17 (Calculation Results) (Sheet 2 of 3)

Number	Name	Description	Unit(s)	Default Value	Type	Access
608	RPropA	Proportion used for calculating substituted Chord A negative flow velocity. single-path dual-path, double-dual multi-path (3410, 3450) single-dual (3422) (3400) (3412, 3420) Default 1.000 1.000 1.000 0.890	n/a	depends on model	FP	R
610	RPropB	Proportion used for calculating substituted Chord B negative flow velocity. single-path dual-path, double-dual multi-path (3410, 3450) single-dual (3422) (3400) (3412, 3420) Default 0.000 1.000 1.000 1.042	n/a	depends on model	FP	R
612	RPropC	Proportion used for calculating substituted Chord C negative flow velocity. single-path dual-path, double-dual multi-path (3410, 3450) single-dual (3422) (3400) (3412, 3420) Default 0.000 0.000 1.000 1.042	n/a	depends on model	FP	R
614	RPropD	Proportion used for calculating substituted Chord D negative flow velocity. single-path dual-path, double-dual multi-path (3410, 3450) single-dual (3422) (3400) (3412, 3420) Default 0.000 0.000 1.000 0.890	n/a	depends on model	FP	R

Table C-17 Modbus Register Values Message Block 17 (Calculation Results) (Sheet 3 of 3)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
616	RABLo	delta time ratio low limit (Chord A/B) (PropA*XA/PropB*XB)*(1–0.5)	n/a	0	FP	R
418	RABHi	delta time ratio high limit (Chord A/B) (PropA*XA/PropB*XB)*(1+0.5)	n/a	0	FP	R
420	RDCLo	delta time ratio low limit (Chord D/C) (PropD*XD/PropC*XC)*(1–0.5)	n/a	0	FP	R
422	RDCHi	delta time ratio high limit (Chord D/C) (PropD*XD/PropC*XC)*(1+0.5)	n/a	0	FP	R
424	RADLo	delta time ratio low limit (Chord A/D) (PropA*XA/PropD*XD)*(1–0.1)	n/a	0	FP	R
426	RADHi	delta time ratio high limit (Chord A/D) (PropA*XA/PropD*XD)*(1+0.1)	n/a	0	FP	R
428	RBCLo	delta time ratio low limit (Chord B/C) (PropB*XB/PropC*XC)*(1–0.1)	n/a	0	FP	R
430	RBCHi	delta time ratio high limit (Chord B/C) (PropB*XB/PropC*XC)*(1+0.1)	n/a	0	FP	R
632-648	Spare	This register number is not used.	n/a	n/a	FP	R

Table C-18 Modbus Register Values Message Block 18 (Diagnostics)

Number	Name	Description	Unit(s)	Default Value	Type	Access
650-698	Spare	This register number is not used.	n/a	n/a	INT	R

Table C-19 Modbus Register Values Message Block 19 (Diagnostics) (Sheet 1 of 3)

Number	Name	Description	Unit(s)	Default Value	Type	Access
700	Wdw1A1	acquisition mode status for window #1, path A (up); see Note for status indicator values	n/a	0	FP	R
702	Wdw1A2	acquisition mode status for window #1, path A (down); see Note for status indicator values	n/a	0	FP	R
704	Wdw1B1	acquisition mode status for window #1, path B (up); see Note for status indicator values	n/a	0	FP	R
706	Wdw1B2	acquisition mode status for window #1, path B (down); see Note for status indicator values	n/a	0	FP	R
708	Wdw1C1	acquisition mode status for window #1, path C (up); see Note for status indicator values	n/a	0	FP	R

Table C-19 Modbus Register Values Message Block 19 (Diagnostics) (Sheet 2 of 3)

Number	Name	Description	Unit(s)	Default Value	Type	Access
710	Wdw1C2	acquisition mode status for window #1, path C (down); see Note for status indicator values	n/a	0	FP	R
712	Wdw1D1	acquisition mode status for window #1, path D (up); see Note for status indicator values	n/a	0	FP	R
714	Wdw1D2	acquisition mode status for window #1, path D (down); see Note for status indicator values	n/a	0	FP	R
716	Wdw2A1	acquisition mode status for window #2, path A (up); see Note for status indicator values	n/a	0	FP	R
718	Wdw2A2	acquisition mode status for window #2, path A (down); see Note for status indicator values	n/a	0	FP	R
720	Wdw2B1	acquisition mode status for window #2, path B (up); see Note for status indicator values	n/a	0	FP	R
722	Wdw2B2	acquisition mode status for window #2, path B (down); see Note for status indicator values	n/a	0	FP	R
724	Wdw2C1	acquisition mode status for window #2, path C (up); see Note for status indicator values	n/a	0	FP	R
726	Wdw2C2	acquisition mode status for window #2, path C (down); see Note for status indicator values	n/a	0	FP	R

Table C-19 Modbus Register Values Message Block 19 (Diagnostics) (Sheet 3 of 3)

Number	Name	Description	Unit(s)	Default Value	Type	Access
728	Wdw2D1	acquisition mode status for window #2, path D (up); see Note for status indicator values	n/a	0	FP	R
730	Wdw2D2	acquisition mode status for window #2, path D (down); see Note for status indicator values	n/a	0	FP	R
732-748	Spare	This register number is not used.	n/a	n/a	FP	R

NOTE: The acquisition mode status indicators are:
0: OK
81: failed signal to noise ratio check (SNRatio)
82: failed noise check (MaxNoise)
83: failed signal quality check (MinSigQlty)
89: failed speed of sound test (SSMin, SSMax)

Table C-20 Modbus Register Values Message Block 20 (Diagnostics) (Sheet 1 of 2)

Number	Name	Description	Unit(s)	Default Value	Type	Access
750	Wdw3A1	acquisition mode status for window #3, path A (up); see Note for status indicator values	n/a	0	FP	R
752	Wdw3A2	acquisition mode status for window #3, path A (down); see Note for status indicator values	n/a	0	FP	R
754	Wdw3B1	acquisition mode status for window #3, path B (up); see Note for status indicator values	n/a	0	FP	R
756	Wdw3B2	acquisition mode status for window #3, path B (down); see Note for status indicator values	n/a	0	FP	R
758	Wdw3C1	acquisition mode status for window #3, path C (up); see Note for status indicator values	n/a	0	FP	R
760	Wdw3C2	acquisition mode status for window #3, path C (down); see Note for status indicator values	n/a	0	FP	R
762	Wdw3D1	acquisition mode status for window #3, path D (up); see Note for status indicator values	n/a	0	FP	R
764	Wdw3D2	acquisition mode status for window #3, path D (down); see Note for status indicator values	n/a	0	FP	R
766	Wdw4A1	acquisition mode status for window #4, path A (up); see Note for status indicator values	n/a	0	FP	R

Table C-20 Modbus Register Values Message Block 20 (Diagnostics) (Sheet 2 of 2)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
768	Wdw4A2	acquisition mode status for window #4, path A (down); see Note for status indicator values	n/a	0	FP	R
770	Wdw4B1	acquisition mode status for window #4, path B (up); see Note for status indicator values	n/a	0	FP	R
772	Wdw4B2	acquisition mode status for window #4, path B (down); see Note for status indicator values	n/a	0	FP	R
774	Wdw4C1	acquisition mode status for window #4, path C (up); see Note for status indicator values	n/a	0	FP	R
776	Wdw4C2	acquisition mode status for window #4, path C (down); see Note for status indicator values	n/a	0	FP	R
778	Wdw4D1	acquisition mode status for window #4, path D (up); see Note for status indicator values	n/a	0	FP	R
780	Wdw4D2	acquisition mode status for window #4, path D (down); see Note for status indicator values	n/a	0	FP	R
782-798	Spare	This register number is not used.	n/a	n/a	FP	R

NOTE: The acquisition mode status indicators are:
0: OK
81: failed signal to noise ratio check (SNRatio)
82: failed noise check (MaxNoise)
83: failed signal quality check (MinSigQlty)
89: failed speed of sound test (SSMin, SSMax)

Table C-21 Modbus Register Values Message Block 21 (Diagnostics) (Sheet 1 of 4)

Number	Name	Description	Unit(s)	Default Value	Type	Access
800	SpecMaxA1	maximum frequency spectrum for path A (up)	n/a	0	FP	R
802	SpecMaxA2	maximum frequency spectrum for path A (down)	n/a	0	FP	R
804	SpecMaxB1	maximum frequency spectrum for path B (up)	n/a	0	FP	R
806	SpecMaxB2	maximum frequency spectrum for path B (down)	n/a	0	FP	R
808	SpecMaxC1	maximum frequency spectrum for path C (up)	n/a	0	FP	R
810	SpecMaxC2	maximum frequency spectrum for path C (down)	n/a	0	FP	R
812	SpecMaxD1	maximum frequency spectrum for path D (up)	n/a	0	FP	R
814	SpecMaxD2	maximum frequency spectrum for path D (down)	n/a	0	FP	R

Table C-21 Modbus Register Values Message Block 21 (Diagnostics) (Sheet 2 of 4)

Number	Name	Description	Unit(s)	Default Value	Type	Access
816	MaxNEA1	maximum Chord A up stream noise energy Beginning with CPU firmware V6.31, this value is updated every batch (i.e., it no longer requires use of the DiagFn register although the DiagFn register can still be used to force an update of this register).	n/a	0	FP	R
818	MaxNEA2	maximum Chord A down stream noise energy Beginning with CPU firmware V6.31, this value is updated every batch (i.e., it no longer requires use of the DiagFn register although the DiagFn register can still be used to force an update of this register).	n/a	0	FP	R
820	MaxNEB1	maximum Chord B up stream noise energy Beginning with CPU firmware V6.31, this value is updated every batch (i.e., it no longer requires use of the DiagFn register although the DiagFn register can still be used to force an update of this register).	n/a	0	FP	R
822	MaxNEB2	maximum Chord B down stream noise energy Beginning with CPU firmware V6.31, this value is updated every batch (i.e., it no longer requires use of the DiagFn register although the DiagFn register can still be used to force an update of this register).	n/a	0	FP	R

Table C-21 Modbus Register Values Message Block 21 (Diagnostics) (Sheet 3 of 4)

Number	Name	Description	Unit(s)	Default Value	Type	Access
824	MaxNEC1	maximum Chord C up stream noise energy Beginning with CPU firmware V6.31, this value is updated every batch (i.e., it no longer requires use of the DiagFn register although the DiagFn register can still be used to force an update of this register).	n/a	0	FP	R
826	MaxNEC2	maximum Chord C down stream noise energy Beginning with CPU firmware V6.31, this value is updated every batch (i.e., it no longer requires use of the DiagFn register although the DiagFn register can still be used to force an update of this register).	n/a	0	FP	R
828	MaxNED1	maximum Chord D up stream noise energy Beginning with CPU firmware V6.31, this value is updated every batch (i.e., it no longer requires use of the DiagFn register although the DiagFn register can still be used to force an update of this register).	n/a	0	FP	R
830	MaxNED2	maximum Chord D down stream noise energy Beginning with CPU firmware V6.31, this value is updated every batch (i.e., it no longer requires use of the DiagFn register although the DiagFn register can still be used to force an update of this register).	n/a	0	FP	R

Table C-21 Modbus Register Values Message Block 21 (Diagnostics) (Sheet 4 of 4)

Number	Name	Description	Unit(s)	Default Value	Type	Access
832	QpefA1	energy arrival position for path A (up stream)	n/a	0	FP	R
834	QpefA2	energy arrival position for path A (down stream)	n/a	0	FP	R
836	QpefB1	energy arrival position for path B (up stream)	n/a	0	FP	R
838	QpefB2	energy arrival position for path B (down stream)	n/a	0	FP	R
840	QpefC1	energy arrival position for path C (up stream)	n/a	0	FP	R
842	QpefC2	energy arrival position for path C (down stream)	n/a	0	FP	R
844	QpefD1	energy arrival position for path D (up stream)	n/a	0	FP	R
846	QpefD2	energy arrival position for path D (down)	n/a	0	FP	R
848	Spare	This register number is not used.	n/a	n/a	FP	R

Table C-22 Modbus Register Values Message Block 22 (Diagnostics) (Sheet 1 of 2)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
850	MsqvA1	maximum signal quality value for path A (up)	n/a	0	FP	R
852	MsqvA2	maximum signal quality value for path A (down)	n/a	0	FP	R
854	MsqvB1	maximum signal quality value for path B (up)	n/a	0	FP	R
856	MsqvB2	maximum signal quality value for path B (down)	n/a	0	FP	R
858	MsqvC1	maximum signal quality value for path C (up)	n/a	0	FP	R
860	MsqvC2	maximum signal quality value for path C (down)	n/a	0	FP	R
862	MsqvD1	maximum signal quality value for path D (up)	n/a	0	FP	R
864	MsqvD2	maximum signal quality value for path D (down)	n/a	0	FP	R
866	MsqpA1	maximum signal quality position for path A (up)	n/a	0	FP	R
868	MsqpA2	maximum signal quality position for path A (down)	n/a	0	FP	R
870	MsqpB1	maximum signal quality position for path B (up)	n/a	0	FP	R
872	MsqpB2	maximum signal quality position for path B (down)	n/a	0	FP	R
874	MsqpC1	maximum signal quality position for path C (up)	n/a	0	FP	R
876	MsqpC2	maximum signal quality position for path C (down)	n/a	0	FP	R

Table C-22 Modbus Register Values Message Block 22 (Diagnostics) (Sheet 2 of 2)

Number	Name	Description	Unit(s)	Default Value	Type	Access
878	MsqpD1	maximum signal quality position for path D (up)	n/a	0	FP	R
880	MsqpD2	maximum signal quality position for path D (down)	n/a	0	FP	R
882	PfvA1	critical point value for path A (up)	n/a	0	FP	R
884	PfvA2	critical point value for path A (down)	n/a	0	FP	R
886	PfvB1	critical point value for path B (up)	n/a	0	FP	R
888	PfvB2	critical point value for path B (down)	n/a	0	FP	R
890	PfvC1	critical point value for path C (up)	n/a	0	FP	R
892	PfvC2	critical point value for path C (down)	n/a	0	FP	R
894	PfvD1	critical point value for path D (up)	n/a	0	FP	R
896	PfvD2	critical point value for path D (down)	n/a	0	FP	R
898	Spare	This register number is not used.	n/a	n/a	FP	R

Table C-23 Modbus Register Values Message Block 23 (Diagnostics) (Sheet 1 of 2)

Number	Name	Description	Unit(s)	Default Value	Type	Access
900	Pp1A1	first zero crossing after critical point for path A (up)	si	0	FP	R
902	Pp1A2	first zero crossing after critical point for path A (down)	si	0	FP	R
904	Pp1B1	first zero crossing after critical point for path B (up)	si	0	FP	R
906	Pp1B2	first zero crossing after critical point for path B (down)	si	0	FP	R
908	Pp1C1	first zero crossing after critical point for path C (up)	si	0	FP	R
910	Pp1C2	first zero crossing after critical point for path C (down)	si	0	FP	R
912	Pp1D1	first zero crossing after critical point for path D (up)	si	0	FP	R
914	Pp1D2	first zero crossing after critical point for path D (down)	si	0	FP	R
916	Pp2A1	second zero crossing after critical point for path A (up)	si	0	FP	R
918	Pp2A2	second zero crossing after critical point for path A (down)	si	0	FP	R
920	Pp2B1	second zero crossing after critical point for path B (up)	si	0	FP	R
922	Pp2B2	second zero crossing after critical point for path B (down)	si	0	FP	R

Table C-23 Modbus Register Values Message Block 23 (Diagnostics) (Sheet 2 of 2)

Number	Name	Description	Unit(s)	Default Value	Type	Access
924	Pp2C1	second zero crossing after critical point for path C (up)	si	0	FP	R
926	Pp2C2	second zero crossing after critical point for path C (down)	si	0	FP	R
928	Pp2D1	second zero crossing after critical point for path D (up)	si	0	FP	R
930	Pp2D2	second zero crossing after critical point for path D (down)	si	0	FP	R
932	Pp3A1	third zero crossing after critical point for path A (up)	si	0	FP	R
934	Pp3A2	third zero crossing after critical point for path A (down)	si	0	FP	R
936	Pp3B1	third zero crossing after critical point for path B (up)	si	0	FP	R
938	Pp3B2	third zero crossing after critical point for path B (down)	si	0	FP	R
940	Pp3C1	third zero crossing after critical point for path C (up)	si	0	FP	R
942	Pp3C2	third zero crossing after critical point for path C (down)	si	0	FP	R
944	Pp3D1	third zero crossing after critical point for path D (up)	si	0	FP	R
946	Pp3D2	third zero crossing after critical point for path D (down)	si	0	FP	R
948	Spare	This register number is not used.	n/a	n/a	FP	R

Table C-24 Modbus Register Values Message Block 24 (Diagnostics) (Sheet 1 of 2)

Number	Name	Description	Unit(s)	Default Value	Type	Access
950	Pp4A1	fourth zero crossing after critical point for path A (up)	si	0	FP	R
952	Pp4A2	fourth zero crossing after critical point for path A (down)	si	0	FP	R
954	Pp4B1	fourth zero crossing after critical point for path B (up)	si	0	FP	R
956	Pp4B2	fourth zero crossing after critical point for path B (down)	si	0	FP	R
958	Pp4C1	fourth zero crossing after critical point for path C (up)	si	0	FP	R
960	Pp4C2	fourth zero crossing after critical point for path C (down)	si	0	FP	R
962	Pp4D1	fourth zero crossing after critical point for path D (up)	si	0	FP	R
964	Pp4D2	fourth zero crossing after critical point for path D (down)	si	0	FP	R
966	Ap1A1	PP1 associated amplitude percentage for path A (up)	percentage	0	FP	R
968	Ap1A2	PP1 associated amplitude percentage for path A (down)	percentage	0	FP	R
970	Ap1B1	PP1 associated amplitude percentage for path B (up)	percentage	0	FP	R

Table C-24 Modbus Register Values Message Block 24 (Diagnostics) (Sheet 2 of 2)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
972	Ap1B2	PP1 associated amplitude percentage for path B (down)	percentage	0	FP	R
974	Ap1C1	PP1 associated amplitude percentage for path C (up)	percentage	0	FP	R
976	Ap1C2	PP1 associated amplitude percentage for path C (down)	percentage	0	FP	R
978	Ap1D1	PP1 associated amplitude percentage for path D (up)	percentage	0	FP	R
980	Ap1D2	PP1 associated amplitude percentage for path D (down)	percentage	0	FP	R
982	Ap2A1	PP2 associated amplitude percentage for path A (up)	percentage	0	FP	R
984	Ap2A2	PP2 associated amplitude percentage for path A (down)	percentage	0	FP	R
986	Ap2B1	PP2 associated amplitude percentage for path B (up)	percentage	0	FP	R
988	Ap2B2	PP2 associated amplitude percentage for path B (down)	percentage	0	FP	R
990	Ap2C1	PP2 associated amplitude percentage for path C (up)	percentage	0	FP	R
992	Ap2C2	PP2 associated amplitude percentage for path C (down)	percentage	0	FP	R
994	Ap2D1	PP2 associated amplitude percentage for path D (up)	percentage	0	FP	R
996	Ap2D2	PP2 associated amplitude percentage for path D (down)	percentage	0	FP	R
998	Spare	This register number is not used.	n/a	n/a	FP	R

Table C-25 Modbus Register Values Message Block 25 (Diagnostics) (Sheet 1 of 2)

Number	Name	Description	Unit(s)	Default Value	Type	Access
1000	Ap3A1	PP3 associated amplitude percentage for path A (up)	percentage	0	FP	R
1002	Ap3A2	PP3 associated amplitude percentage for path A (down)	percentage	0	FP	R
1004	Ap3B1	PP3 associated amplitude percentage for path B (up)	percentage	0	FP	R
1006	Ap3B2	PP3 associated amplitude percentage for path B (down)	percentage	0	FP	R
1008	Ap3C1	PP3 associated amplitude percentage for path C (up)	percentage	0	FP	R
1010	Ap3C2	PP3 associated amplitude percentage for path C (down)	percentage	0	FP	R
1012	Ap3D1	PP3 associated amplitude percentage for path D (up)	percentage	0	FP	R
1014	Ap3D2	PP3 associated amplitude percentage for path D (down)	percentage	0	FP	R
1016	Ap4A1	PP4 associated amplitude percentage for path A (up)	percentage	0	FP	R

Table C-25 Modbus Register Values Message Block 25 (Diagnostics) (Sheet 2 of 2)

Number	Name	Description	Unit(s)	Default Value	Type	Access
1018	Ap4A2	PP4 associated amplitude percentage for path A (down)	percentage	0	FP	R
1020	Ap4B1	PP4 associated amplitude percentage for path B (up)	percentage	0	FP	R
1022	Ap4B2	PP4 associated amplitude percentage for path B (down)	percentage	0	FP	R
1024	Ap4C1	PP4 associated amplitude percentage for path C (up)	percentage	0	FP	R
1026	Ap4C2	PP4 associated amplitude percentage for path C (down)	percentage	0	FP	R
1028	Ap4D1	PP4 associated amplitude percentage for path D (up)	percentage	0	FP	R
1030	Ap4D2	PP4 associated amplitude percentage for path D (down)	percentage	0	FP	R
1032	Spare	This register number is not used.	n/a	n/a	FP	R

Table C-26 Modbus Register Values Message Block 26 (Diagnostics) (Sheet 1 of 5)

Number	Name	Description	Unit(s)	Default Value	Type	Access
1050	TspfA1	tracked target span away from the critical point for path A (up) This value is tracked if DLTMTHD=2.	si	0	FP	R
1052	TspfA2	tracked target span away from the critical point for path A (down) This value is tracked if DLTMTHD=2.	si	0	FP	R
1054	TspfB1	tracked target span away from the critical point for path B (up) This value is tracked if DLTMTHD=2.	si	0	FP	R
1056	TspfB2	tracked target span away from the critical point for path B (down) This value is tracked if DLTMTHD=2.	si	0	FP	R
1058	TspfC1	tracked target span away from the critical point for path C (up) This value is tracked if DLTMTHD=2.	si	0	FP	R

Table C-26 Modbus Register Values Message Block 26 (Diagnostics) (Sheet 2 of 5)

Number	Name	Description	Unit(s)	Default Value	Type	Access
1060	TspfC2	tracked target span away from the critical point for path C (down) This value is tracked if DLTMTHD=2.	si	0	FP	R
1062	TspfD1	tracked target span away from the critical point for path D (up) This value is tracked if DLTMTHD=2.	si	0	FP	R
1064	TspfD2	tracked target span away from the critical point for path D (down) This value is tracked if DLTMTHD=2.	si	0	FP	R
1066	TspeA1	tracked target span away from the energy arrival for path A (up) This value is tracked if DLTMTHD=2.	si	0	FP	R
1068	TspeA2	tracked target span away from the energy arrival for path A (down) This value is tracked if DLTMTHD=2.	si	0	FP	R

Table C-26 Modbus Register Values Message Block 26 (Diagnostics) (Sheet 3 of 5)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
1070	TspeB1	tracked target span away from the energy arrival for path B (up) This value is tracked if DLTMTHD=2.	si	0	FP	R
1072	TspeB2	tracked target span away from the energy arrival for path B (down) This value is tracked if DLTMTHD=2.	si	0	FP	R
1074	TspeC1	tracked target span away from the energy arrival for path C (up) This value is tracked if DLTMTHD=2.	si	0	FP	R
1076	TspeC2	tracked target span away from the energy arrival for path C (down) This value is tracked if DLTMTHD=2.	si	0	FP	R
1078	TspeD1	tracked target span away from the energy arrival for path D (up) This value is tracked if DLTMTHD=2.	si	0	FP	R

Table C-26 Modbus Register Values Message Block 26 (Diagnostics) (Sheet 4 of 5)

Number	Name	Description	Unit(s)	Default Value	Type	Access
1080	TspeD2	tracked target span away from the energy arrival for path D (down) This value is tracked if DLTMTHD=2.	si	0	FP	R
1082	TampA1	tracked target amplitude percentage for path A (up) This value is tracked if DLTMTHD=2.	si	0	FP	R
1084	TampA2	tracked target amplitude percentage for path A (down) This value is tracked if DLTMTHD=2.	si	0	FP	R
1086	TampB1	tracked target amplitude percentage for path B (up) This value is tracked if DLTMTHD=2.	si	0	FP	R
1088	TampB2	tracked target amplitude percentage for path B (down) This value is tracked if DLTMTHD=2.	si	0	FP	R
1090	TampC1	tracked target amplitude percentage for path C (up) This value is tracked if DLTMTHD=2.	si	0	FP	R

Table C-26 Modbus Register Values Message Block 26 (Diagnostics) (Sheet 5 of 5)

Number	Name	Description	Unit(s)	Default Value	Type	Access
1092	TampC2	tracked target amplitude percentage for path C (down) This value is tracked if DLTMTHD=2.	si	0	FP	R
1094	TampD1	tracked target amplitude percentage for path D (up) This value is tracked if DLTMTHD=2.	si	0	FP	R
1096	TampD2	tracked target amplitude percentage for path D (down) This value is tracked if DLTMTHD=2.	si	0	FP	R
1098	Spare	This register number is not used.	n/a	n/a	FP	R

Table C-27 Modbus Register Values Message Block 27 (Diagnostics) (Sheet 1 of 3)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
1100	Ff1A1	calculated fuzzy function of the first zero crossing after the critical point for path A (up)	n/a	0	FP	R
1102	Ff1A2	calculated fuzzy function of the first zero crossing after the critical point for path A (down)	n/a	0	FP	R
1104	Ff1B1	calculated fuzzy function of the first zero crossing after the critical point for path B (up)	n/a	0	FP	R
1106	Ff1B2	calculated fuzzy function of the first zero crossing after the critical point for path B (down)	n/a	0	FP	R
1108	Ff1C1	calculated fuzzy function of the first zero crossing after the critical point for path C (up)	n/a	0	FP	R
1110	Ff1C2	calculated fuzzy function of the first zero crossing after the critical point for path C (down)	n/a	0	FP	R
1112	Ff1D1	calculated fuzzy function of the first zero crossing after the critical point for path D (up)	n/a	0	FP	R
1114	Ff1D2	calculated fuzzy function of the first zero crossing after the critical point for path D (down)	n/a	0	FP	R
1116	Ff2A1	calculated fuzzy function of the second zero crossing after the critical point for path A (up)	n/a	0	FP	R

Table C-27 Modbus Register Values Message Block 27 (Diagnostics) (Sheet 2 of 3)

Number	Name	Description	Unit(s)	Default Value	Type	Access
1118	Ff2A2	calculated fuzzy function of the second zero crossing after the critical point for path A (down)	n/a	0	FP	R
1120	Ff2B1	calculated fuzzy function of the second zero crossing after the critical point for path B (up)	n/a	0	FP	R
1122	Ff2B2	calculated fuzzy function of the second zero crossing after the critical point for path B (down)	n/a	0	FP	R
1124	Ff2C1	calculated fuzzy function of the second zero crossing after the critical point for path C (up)	n/a	0	FP	R
1126	Ff2C2	calculated fuzzy function of the second zero crossing after the critical point for path C (down)	n/a	0	FP	R
1128	Ff2D1	calculated fuzzy function of the second zero crossing after the critical point for path D (up)	n/a	0	FP	R
1130	Ff2D2	calculated fuzzy function of the second zero crossing after the critical point for path D (down)	n/a	0	FP	R
1132	Ff3A1	calculated fuzzy function of the third zero crossing after the critical point for path A (up)	n/a	0	FP	R
1134	Ff3A2	calculated fuzzy function of the third zero crossing after the critical point for path A (down)	n/a	0	FP	R

Table C-27 Modbus Register Values Message Block 27 (Diagnostics) (Sheet 3 of 3)

Number	Name	Description	Unit(s)	Default Value	Type	Access
1136	Ff3B1	calculated fuzzy function of the third zero crossing after the critical point for path B (up)	n/a	0	FP	R
1138	Ff3B2	calculated fuzzy function of the third zero crossing after the critical point for path B (down)	n/a	0	FP	R
1140	Ff3C1	calculated fuzzy function of the third zero crossing after the critical point for path C (up)	n/a	0	FP	R
1142	Ff3C2	calculated fuzzy function of the third zero crossing after the critical point for path C (down)	n/a	0	FP	R
1144	Ff3D1	calculated fuzzy function of the third zero crossing after the critical point for path D (up)	n/a	0	FP	R
1146	Ff3D2	calculated fuzzy function of the third zero crossing after the critical point for path D (down)	n/a	0	FP	R
1148	Spare	This register number is not used.	n/a	n/a	FP	R

Table C-28 Modbus Register Values Message Block 28 (Diagnostics) (Sheet 1 of 4)

Number	Name	Description	Unit(s)	Default Value	Type	Access
1150	Ff4A1	calculated fuzzy function of the fourth zero crossing after the critical point for path A (up)	n/a	0	FP	R
1152	Ff4A2	calculated fuzzy function of the fourth zero crossing after the critical point for path A (down)	n/a	0	FP	R
1154	Ff4B1	calculated fuzzy function of the fourth zero crossing after the critical point for path B (up)	n/a	0	FP	R
1156	Ff4B2	calculated fuzzy function of the fourth zero crossing after the critical point for path B (down)	n/a	0	FP	R
1158	Ff4C1	calculated fuzzy function of the fourth zero crossing after the critical point for path C (up)	n/a	0	FP	R
1160	Ff4C2	calculated fuzzy function of the fourth zero crossing after the critical point for path C (down)	n/a	0	FP	R
1162	Ff4D1	calculated fuzzy function of the fourth zero crossing after the critical point for path D (up)	n/a	0	FP	R
1164	Ff4D2	calculated fuzzy function of the fourth zero crossing after the critical point for path D (down)	n/a	0	FP	R
1166	Ff5A1	calculated fuzzy function of the fifth zero crossing after the critical point for path A (up)	n/a	0	FP	R

Table C-28 Modbus Register Values Message Block 28 (Diagnostics) (Sheet 2 of 4)

Number	Name	Description	Unit(s)	Default Value	Type	Access
1168	Ff5A2	calculated fuzzy function of the fifth zero crossing after the critical point for path A (down)	n/a	0	FP	R
1170	Ff5B1	calculated fuzzy function of the fifth zero crossing after the critical point for path B (up)	n/a	0	FP	R
1172	Ff5B2	calculated fuzzy function of the fifth zero crossing after the critical point for path B (down)	n/a	0	FP	R
1174	Ff5C1	calculated fuzzy function of the fifth zero crossing after the critical point for path C (up)	n/a	0	FP	R
1176	Ff5C2	calculated fuzzy function of the fifth zero crossing after the critical point for path C (down)	n/a	0	FP	R
1178	Ff5D1	calculated fuzzy function of the fifth zero crossing after the critical point for path D (up)	n/a	0	FP	R
1180	Ff5D2	calculated fuzzy function of the fifth zero crossing after the critical point for path D (down)	n/a	0	FP	R
1182	SelPkA1	fuzzy function result for path A (up), calculated only when DLTMTHD=2 Selected peak will be the maximum of the first four fuzzy.	n/a	0	FP	R

Table C-28 Modbus Register Values Message Block 28 (Diagnostics) (Sheet 3 of 4)

Number	Name	Description	Unit(s)	Default Value	Type	Access
1184	SelPkA2	fuzzy function result for path A (down), calculated only when DLTMTHD=2 Selected peak will be the maximum of the first four fuzzy.	n/a	0	FP	R
1186	SelPkB1	fuzzy function result for path B (up), calculated only when DLTMTHD=2 Selected peak will be the maximum of the first four fuzzy.	n/a	0	FP	R
1188	SelPkB2	fuzzy function result for path B (down), calculated only when DLTMTHD=2 Selected peak will be the maximum of the first four fuzzy.	n/a	0	FP	R
1190	SelPkC1	fuzzy function result for path C (up), calculated only when DLTMTHD=2 Selected peak will be the maximum of the first four fuzzy.	n/a	0	FP	R

Table C-28 Modbus Register Values Message Block 28 (Diagnostics) (Sheet 4 of 4)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
1192	SelPkC2	fuzzy function result for path C (down), calculated only when DLTMTHD=2 Selected peak will be the maximum of the first four fuzzy.	n/a	0	FP	R
1194	SelPkD1	fuzzy function result for path D (up), calculated only when DLTMTHD=2 Selected peak will be the maximum of the first four fuzzy.	n/a	0	FP	R
1196	SelPkD2	fuzzy function result for path D (down), calculated only when DLTMTHD=2 Selected peak will be the maximum of the first four fuzzy.	n/a	0	FP	R
1198	Spare	This register number is not used.	n/a	n/a	FP	R

Table C-29 Modbus Register Values Message Block 29 (Calculation Results) (Sheet 1 of 8)

Number	Name	Description	Unit(s)	Default Value	Type	Access
1500	UnCorrVol	uncorrected positive volume This value 'rolls over' at 1,000,000,000 cubic meters. The number of roll-overs is counted in VolOFlow. Total Uncorrected Positive Volume = (VolOFlow × 10^9) + UnCorrVol + (UnCorrVolFrac × 10^{-3})	m^3	0	LINT	R
1502	NUnCorrVol	uncorrected negative volume This value 'rolls over' at 1,000,000,000 cubic meters. The number of roll-overs is counted in NVolOFlow. Total Uncorrected Negative Volume = (NVolOFlow × 10^9) + NUnCorrVol + (NUnCorrVolFrac × 10^{-3})	m^3	0	LINT	R

Table C-29 Modbus Register Values Message Block 29 (Calculation Results) (Sheet 2 of 8)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
1504	ColdStart	meter cold start flag (1=cold started, 0=cleared) Upon system cold start, this value is set to one by the system. If the DFI option is not used, then the user should acknowledge this flag after the system has cold started by writing a zero to this register (only a zero value can be written to this register to clear the flag). Otherwise (if the DFI option is used), this register should not be written to by the user; the user should acknowledge the system cold start by clearing the corresponding DFI ColdStart register (see DFI register 10582).	n/a	0	LINT	R

Table C-29 Modbus Register Values Message Block 29 (Calculation Results) (Sheet 3 of 8)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
1506	DataQlty	flow data quality indicator 0 = all four chords working bit 0 set = Chord A failed bit 1 set = Chord B failed bit 2 set = Chord C failed bit 3 set = Chord D failed bit 4 to 7 = reserved bit 8 to 16 = maps to SystemStatus bits 0 to 8 bit 8 set = reserved bit 9 set = Pulse Accumulator error bit 10 set = HC11 Ram Memory error bit 11 set = HC11 Program Memory error bit 12 set = EEPROM CRC check failed bit 13 set = DSP Program Memory error bit 14 set = DSP Y-Memory error bit 15 set = DSP X-Memory error bit 16 set = number of operating chords below desired amount bit 17 set = average flow velocity range error bit 18 set = pulses per batch range error	n/a	0	LINT	R
1508	VolOFlow	positive volume overflow count Each count indicates 1,000,000,000 cubic meters.	count	0	LINT	R

Table C-29 Modbus Register Values Message Block 29 (Calculation Results) (Sheet 4 of 8)

Number	Name	Description	Unit(s)	Default Value	Type	Access
1510	NVolOFlow	negative volume overflow count Each count indicates 1,000,000,000 cubic meters.	count	0	LINT	R
1512	TimeLapse	number of pulses accumulated to generate the actual volume There are 9.536743 pulses per second.	pulses	0	LINT	R
1514	TimeOFlow	time overflow count Each count indicates 1,000,000,000 pulses.	count	0	LINT	R
1516	Time	number of seconds to generate the actual volume (TimeLapse/pulses per seconds, rounded up)	seconds	0	LINT	R
1518	MaxSEA1	maximum Chord A upstream signal energy Beginning with CPU firmware V6.31, this value is updated every batch (i.e., it no longer requires use of the DiagFn register although the DiagFn register can still be used to force an update of this register).	n/a	0	LINT	R

Table C-29 Modbus Register Values Message Block 29 (Calculation Results) (Sheet 5 of 8)

Number	Name	Description	Unit(s)	Default Value	Type	Access
1520	MaxSEA2	maximum Chord A down stream signal energy Beginning with CPU firmware V6.31, this value is updated every batch (i.e., it no longer requires use of the DiagFn register although the DiagFn register can still be used to force an update of this register).	n/a	0	LINT	R
1522	MaxSEB1	maximum Chord B upstream signal energy Beginning with CPU firmware V6.31, this value is updated every batch (i.e., it no longer requires use of the DiagFn register although the DiagFn register can still be used to force an update of this register).	n/a	0	LINT	R
1524	MaxSEB2	maximum Chord B down stream signal energy Beginning with CPU firmware V6.31, this value is updated every batch (i.e., it no longer requires use of the DiagFn register although the DiagFn register can still be used to force an update of this register).	n/a	0	LINT	R

Table C-29 Modbus Register Values Message Block 29 (Calculation Results) (Sheet 6 of 8)

Number	Name	Description	Unit(s)	Default Value	Type	Access
1526	MaxSEC1	maximum Chord C upstream signal energy. Beginning with CPU firmware V6.31, this value is updated every batch (i.e., it no longer requires use of the DiagFn register although the DiagFn register can still be used to force an update of this register).	n/a	0	LINT	R
1528	MaxSEC2	maximum Chord C down stream signal energy. Beginning with CPU firmware V6.31, this value is updated every batch (i.e., it no longer requires use of the DiagFn register although the DiagFn register can still be used to force an update of this register).	n/a	0	LINT	R
1530	MaxSED1	maximum Chord D upstream signal energy. Beginning with CPU firmware V6.31, this value is updated every batch (i.e., it no longer requires use of the DiagFn register although the DiagFn register can still be used to force an update of this register).	n/a	0	LINT	R

Table C-29 Modbus Register Values Message Block 29 (Calculation Results) (Sheet 7 of 8)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
1532	MaxSED2	maximum Chord D down stream signal energy Beginning with CPU firmware V6.31, this value is updated every batch (i.e., it no longer requires use of the DiagFn register although the DiagFn register can still be used to force an update of this register).	n/a	0	LINT	R
1534	UnCorrVol	uncorrected positive volume This value 'rolls over' at 1,000,000,000 cubic meters. The number of roll-overs is counted in VolOFlow. Total Uncorrected Positive Volume = (VolOFlow × 10^9) + UnCorrVol + (UnCorrVolFrac × 10^{-3})	m^3	0	LINT	R
1536	UnCorrVolFrac	Fractional portion of positive uncorrected volume in thousandths of cubic meters. For example, if UnCorrVol is equal to 4 and UnCorrVolFrac is equal to 742 then the uncorrected positive volume would be 4.742 cubic meters. Total Uncorrected Positive Volume = (VolOFlow × 10^9) + UnCorrVol + (UnCorrVolFrac × 10^{-3})	10^{-3} m^3	0	LINT	R

Table C-29 Modbus Register Values Message Block 29 (Calculation Results) (Sheet 8 of 8)

Number	Name	Description	Unit(s)	Default Value	Type	Access
1538	NUnCorrVol	uncorrected negative volume This value ‘rolls-over’ at 1,000,000,000 cubic meters. The number of roll-overs is counted in NVolOFlow. Total Uncorrected Negative Volume = (NVolOFlow × 10^9) + NUnCorrVol + (NUnCorrVolFrac × 10^{-3})	m^3	0	LINT	R
1540	NUnCorrVol-Frac	fractional portion of negative uncorrected volume in thousandths of cubic meters For example, if NUnCorrVol is equal to 4 and NUnCorrVolFrac is equal to 742 then the uncorrected negative volume would be 4.742 cubic meters. Total Uncorrected Negative Volume = (NVolOFlow × 10^9) + NUnCorrVol + (NUnCorrVolFrac × 10^{-3})	10^{-3} m^3	0	LINT	R
1542-1548	Spare	This register number is not used.	n/a	n/a	LINT	R

Table C-30 Modbus Register Values Message Block 30 (Memory Display)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
1550-1598	DMemY00 to DMemY24	DSP module Y-memory contents from (DAddr+0) to (DAddr+24)	n/a	n/a	INT	R

Table C-31 Modbus Register Values Message Block 31 (Waveform)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
2000-2119	Sig0 to Sig119	DSP module wave form capture	n/a	n/a	LINT	R

Table C-32 Modbus Register Values Message Block 32 (Diagnostics) (Sheet 1 of 3)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
9001-9003	DeviceNum	device Model Number (left justified with trailing blanks, hexadecimal) 3400 spool-piece multi-path meter 3410 spool-piece single-path meter (V5.62+) 3412 spool-piece single-dual meter (V6.31+) 3420 spool-piece dual-path meter (V5.62+) 3422 spool-piece double-dual meter (V6.31+) 3450 hot-tap, single-path meter (V5.50+)	n/a	depends on model	ASCII	R
9004-9005	Revision	software revision number (N.NN) Registers 9004 (R_REVISION) and 9005, two 16-bit integers 0xN.NN Note: Registers in message block 32 cannot be read individually. You must start with register 9001. (The meter is hard-coded...) (e.g. 36 2E 33 32 hex= ’6’ ’.’ ‘3’ ‘2’ = version 6.32)	n/a	depends on model	ASCII	R
9006	Month	month of the software revision (1 to 12)	n/a	depends on model	INT	R
9007	Day	day of the software revision (1 to 31)	n/a	depends on model	INT	R

Table C-32 Modbus Register Values Message Block 32 (Diagnostics) (Sheet 2 of 3)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
9008	Year	year of software revision (1990 or greater)	n/a	depends on model	INT	R
9009	Hour	hour of the software revision (0 to 23)	n/a	depends on model	INT	R
9010	Minutes	minutes of the software revision (0 to 59)	n/a	depends on model	INT	R
9011	Seconds	seconds of the software revision (00 to 59)	n/a	depends on model	INT	R
9012	DayOfWeek	day of the week of the software revision (1 to 7)	n/a	depends on model	INT	R
9013	Reserved	This register number is reserved for future use.	n/a	0	INT	R
9014	ModbusID	device Modbus ID (1 to 32)	n/a	32	INT	R
9015	Reserved	This register number is reserved for future use.	n/a	n/a	INT	R
9016-9020	SerialNum	device Serial Number (left justified with trailing blanks; 6 digits allowed)	n/a	n/a	ASCII	R
9021	RevBOrLater	used to indicate if the CPU board is Rev. B or later: 0 for Rev. A CPU boards; 1 for Rev. B and later CPU boards	n/a	n/a	INT	R

Table C-32 Modbus Register Values Message Block 32 (Diagnostics) (Sheet 3 of 3)

Number	Name	Description	Unit(s)	Default Value	Type	Access
9022	BoardRevision	CPU board revision (1 for rev. A, 2 for rev. B, etc.) (two digits, right-justified, leading zero). V6.30+	n/a	n/a	INT	R
9023	FPGARevision	CPU board FPGA revision number (without the decimal point). For example, if the FPGA revision is 1.0, then this register reads 10; if the revision is 1.1, the register reads 11, etc. (two digits, right-justified). V6.30+	n/a	n/a	INT	R
9024-9050	Spare	These registers are not used.	n/a	0	INT	R

Note: Registers in this block cannot be read individually. You must start with register 9001

Table C-33 Modbus Register Values Message Block 33 (CPU R/W Registers) (Sheet 1 of 5)

Number	Name	Description	Unit(s)	Default Value	Type	Access
9100	FwdMtrFctr1	Forward-flow meter linearization factor 1 Range: 0.98 to 1.02 Note: This register is used in V6.45 and later of the CPU.	n/a	1	FP	R/W
9102	FwdMtrFctr2	Forward-flow meter linearization factor 2 Range: 0.98 to 1.02 Note: This register is used in V6.45 and later of the CPU.	n/a	1	FP	R/W
9104	FwdMtrFctr3	Forward-flow meter linearization factor 3 Range: 0.98 to 1.02 Note: This register is used in V6.45 and later of the CPU.	n/a	1	FP	R/W
9106	FwdMtrFctr4	Forward-flow meter linearization factor 4 Range: 0.98 to 1.02 Note: This register is used in V6.45 and later of the CPU.	n/a	1	FP	R/W

Table C-33 Modbus Register Values Message Block 33 (CPU R/W Registers) (Sheet 2 of 5)

Number	Name	Description	Unit(s)	Default Value	Type	Access
9108	FwdMtrFctr5	Forward-flow meter linearization factor 5 Range: 0.98 to 1.02 Note: This register is used in V6.45 and later of the CPU.	n/a	1	FP	R/W
9110	FwdMtrFctr6	Forward-flow meter linearization factor 6 Range: 0.98 to 1.02 Note: This register is used in V6.45 and later of the CPU.	n/a	1	FP	R/W
9112	FwdMtrFctr7	Forward-flow meter linearization factor 7 Range: 0.98 to 1.02 Note: This register is used in V6.45 and later of the CPU.	n/a	1	FP	R/W
9114	FwdMtrFctr8	Forward-flow meter linearization factor 8 Range: 0.98 to 1.02 Note: This register is used in V6.45 and later of the CPU.	n/a	1	FP	R/W

Table C-33 Modbus Register Values Message Block 33 (CPU R/W Registers) (Sheet 3 of 5)

Number	Name	Description	Unit(s)	Default Value	Type	Access
9116	FwdMtrFctr9	Forward-flow meter linearization factor 9 Range: 0.98 to 1.02 Note: This register is used in V6.45 and later of the CPU.	n/a	1	FP	R/W
9118	FwdMtrFctr10	Forward-flow meter linearization factor 10 Range: 0.98 to 1.02 Note: This register is used in V6.45 and later of the CPU.	n/a	1	FP	R/W
9120	FwdFlwRt1	Forward flow rate 1 Range: >= 0 m^3/h Note: This register is used in V6.45 and later of the CPU.	m^3/h	0	FP	R/W
9122	FwdFlwRt2	Forward flow rate 2 Range: >= 0 m^3/h Note: This register is used in V6.45 and later of the CPU.	m^3/h	0	FP	R/W

Table C-33 Modbus Register Values Message Block 33 (CPU R/W Registers) (Sheet 4 of 5)

Number	Name	Description	Unit(s)	Default Value	Type	Access
9124	FwdFlwRt3	Forward flow rate 3 Range: >= 0 m^3/h Note: This register is used in V6.45 and later of the CPU.	m^3/h	0	FP	R/W
9126	FwdFlwRt4	Forward flow rate 4 Range: >= 0 m^3/h Note: This register is used in V6.45 and later of the CPU.	m^3/h	0	FP	R/W
9128	FwdFlwRt5	Forward flow rate 5 Range: >= 0 m^3/h Note: This register is used in V6.45 and later of the CPU.	m^3/h	0	FP	R/W
9130	FwdFlwRt6	Forward flow rate 6 Range: >= 0 m^3/h Note: This register is used in V6.45 and later of the CPU.	m^3/h	0	FP	R/W

Table C-33 Modbus Register Values Message Block 33 (CPU R/W Registers) (Sheet 5 of 5)

Number	Name	Description	Unit(s)	Default Value	Type	Access
9132	FwdFlwRt7	Forward flow rate 7 Range: >= 0 m^3/h Note: This register is used in V6.45 and later of the CPU.	m^3/h	0	FP	R/W
9134	FwdFlwRt8	Forward flow rate 8 Range: >= 0 m^3/h Note: This register is used in V6.45 and later of the CPU.	m^3/h	0	FP	R/W
9136	FwdFlwRt9	Forward flow rate 9 Range: >= 0 m^3/h Note: This register is used in V6.45 and later of the CPU.	m^3/h	0	FP	R/W
9138	FwdFlwRt10	Forward flow rate10 Range: >= 0 m^3/h Note: This register is used in V6.45 and later of the CPU.	m^3/h	0	FP	R/W
9140-9148	Spare	These registers are not used.	n/a	0	INT	R/W

Table C-34 Modbus Register Values Message Block 34 (CPU R/W Registers) (Sheet 1 of 5)

Number	Name	Description	Unit(s)	Default Value	Type	Access
9150	RevMtrFctr1	Reverse-flow meter linearization factor 1 Range: 0.98 to 1.02 Note: This register is used in V6.45 and later of the CPU.	n/a	1	FP	R/W
9152	RevMtrFctr2	Reverse-flow meter linearization factor 2 Range: 0.98 to 1.02 This register is used in V6.45 and later of the CPU.	n/a	1	FP	R/W
9154	RevMtrFctr3	Reverse-flow meter linearization factor 3 Range: 0.98 to 1.02 Note: This register is used in V6.45 and later of the CPU.	n/a	1	FP	R/W
9156	RevMtrFctr4	Reverse-flow meter linearization factor 4 Range: 0.98 to 1.02 Note: This register is used in V6.45 and later of the CPU.	n/a	1	FP	R/W

Table C-34 Modbus Register Values Message Block 34 (CPU R/W Registers) (Sheet 2 of 5)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
9158	RevMtrFctr5	Reverse-flow meter linearization factor 5 Range: 0.98 to 1.02 Note: This register is used in V6.45 and later of the CPU.	n/a	1	FP	R/W
9160	RevMtrFctr6	Reverse-flow meter linearization factor 6 Range: 0.98 to 1.02 Note: This register is used in V6.45 and later of the CPU.	n/a	1	FP	R/W
9162	RevMtrFctr7	Reverse-flow meter linearization factor 7 Range: 0.98 to 1.02 Note: This register is used in V6.45 and later of the CPU.	n/a	1	FP	R/W
9164	RevMtrFctr8	Reverse-flow meter linearization factor 8 Range: 0.98 to 1.02 Note: This register is used in V6.45 and later of the CPU.	n/a	1	FP	R/W

Table C-34 Modbus Register Values Message Block 34 (CPU R/W Registers) (Sheet 3 of 5)

Number	Name	Description	Unit(s)	Default Value	Type	Access
9166	RevMtrFctr9	Reverse-flow meter linearization factor 9 Range: 0.98 to 1.02 Note: This register is used in V6.45 and later of the CPU.	n/a	1	FP	R/W
9168	RevMtrFctr10	Reverse-flow meter linearization factor 10 Range: 0.98 to 1.02 Note: This register is used in V6.45 and later of the CPU.	n/a	1	FP	R/W
9170	RevFlwRt1	Reverse flow rate 1 Range: >= 0 m^3/h Note: This register is used in V6.45 and later of the CPU.	m^3/h	0	FP	R/W
9172	RevFlwRt2	Reverse flow rate 2 Range: >= 0 m^3/h Note: This register is used in V6.45 and later of the CPU.	m^3/h	0	FP	R/W

Table C-34 Modbus Register Values Message Block 34 (CPU R/W Registers) (Sheet 4 of 5)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
9174	RevFlwRt3	Reverse flow rate 3 Range: >= 0 m^3/h Note: This register is used in V6.45 and later of the CPU.	m^3/h	0	FP	R/W
9176	RevFlwRt4	Reverse flow rate 4 Range: >= 0 m^3/h Note: This register is used in V6.45 and later of the CPU.	m^3/h	0	FP	R/W
9178	RevFlwRt5	Reverse flow rate 5 Range: >= 0 m^3/h Note: This register is used in V6.45 and later of the CPU.	m^3/h	0	FP	R/W
9180	RevFlwRt6	Reverse flow rate 6 Range: >= 0 m^3/h Note: This register is used in V6.45 and later of the CPU.	m^3/h	0	FP	R/W

Table C-34 Modbus Register Values Message Block 34 (CPU R/W Registers) (Sheet 5 of 5)

Number	**Name**	**Description**	**Unit(s)**	**Default Value**	**Type**	**Access**
9182	RevFlwRt7	Reverse flow rate 7 Range: >= 0 m^3/h Note: This register is used in V6.45 and later of the CPU.	m^3/h	0	FP	R/W
9184	RevFlwRt8	Reverse flow rate 8 Range: >= 0 m^3/h Note: This register is used in V6.45 and later of the CPU.	m^3/h	0	FP	R/W
9186	RevFlwRt9	Reverse flow rate 9 Range: >= 0 m^3/h Note: This register is used in V6.45 and later of the CPU.	m^3/h	0	FP	R/W
9188	RevFlwRt10	Reverse flow rate 10 Range: >= 0 m^3/h Note: This register is used in V6.45 and later of the CPU.	m^3/h	0	FP	R/W
9190-9198	Spare	These registers are not used.	n/a	0	INT	R/W

APPENDIX D, BLOCK LIST

D.1 SPECIFIC MESSAGE BLOCKS AND REGISTERS

For more information about DFI Modbus registers, click on the Help button to access the online help.

The following sections provide the Modbus register names, descriptions, and values per message block for the Diagnostic and Frequency Interface (DFI) board.This appendix also includes configuration options (such as appropriate value ranges and units of measurement), default settings, discussions of related functions, and other important information.

To look up specific message Blocks, refer to the list below. To look up specific registers, refer to INDEX OF REGISTERS.

See Table D-1, Modbus Register Values Message Block 50 (Operating Mode), Page D-3

See Table D-2, Modbus Register Values Message Block 51 (Operation Parameters), Page D-6

See Table D-3, Modbus Register Values Message Block 52 (Real-time Clock Settings/Status), Page D-14

See Table D-4, Modbus Register Values Message Block 53 (Correction Setup Parameters), Page D-16

See Table D-5, Modbus Register Values Message Block 54 (AGA8 Setup Parameters), Page D-24

See Table D-6, Modbus Register Values Message Block 55 (Diagnostics), Page D-35

See Table D-7, Modbus Register Values Message Block 56 (Analog Enable / Logging Parameters), Page D-36

See Table D-8, Modbus Register Values Message Block 60 (Frequency Status), Page D-42

See Table D-9, Modbus Register Values Message Block 61 (ACCUMULATED VOLUMES), Page D-46

See Table D-10, Modbus Register Values Message Block 62 (CALCULATION RESULTS 1), Page D-52

See Table D-11, Modbus Register Values Message Block 63 (CALCULATION RESULTS 2), Page D-61

See Table D-12, Modbus Register Values Message Block 64 (MAINTENANCE/TEST VALUES), Page D-66

See Table D-13, Modbus Register Values Message Block 65 (ADC CALIBRATION), Page D-68

See Table D-14, Modbus Register Values Message Block 66 (SYSTEM CALIBRATION), Page D-69

See Table D-15, Modbus Register Values Message Block 67 (LOG STATUS), Page D-70

See Table D-16, Modbus Register Values Message Block 68 (RESERVED), Page D-76

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See Table D-18, Modbus Register Values Message Block 70 (DEVICE INFORMATION), Page D-80

See Table D-19, Modbus Register Values Message Block 71 (INTEGER MEMORY CONTENTS), Page D-82

See Table D-20, Modbus Register Values Message Block 72 (FLOATING POINT MEMORY CONTENTS), Page D-82

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APPENDIX D, DFI MODBUS REGISTERS

D.2 MODBUS REGISTER VALUES MESSAGE BLOCKS

Table D-1 Modbus Register Values Message Block 50 (Operating Mode) (Sheet 1 of 3)

Number	Name and Description	Unit(s)	Default Value	Type	Access
10000	**Mode** DFI Operating Mode Range: 0 (Normal Mode); 1 (Test Mode); 2 (Maintenance Mode); 3 (Current Calibration Mode)	n/a	0	INT	R/W
10001	**NormalDiagnosticMode** normal Mode diagnostics enable/disable control This is used to verify the AGA8 Gross Method calculations. The test cases are listed in Table 5-16. Range: 0 (normal diagnostic mode disabled); 1 (AGA8 test case 1) to 20 (AGA8 test case 20)	n/a	0	INT	R/W

Table D-1 Modbus Register Values Message Block 50 (Operating Mode) (Sheet 2 of 3)

Number	Name and Description	Unit(s)	Default Value	Type	Access
10002	**MaintenanceSubMode** specifies the Maintenance submode defaults to 0, Read Inputs submode, upon Maintenance Mode entry. All other submodes exit to Read Inputs submode upon completion. Possible values are: 0 (Read Inputs) 1 (Temperature Offset Calibration) 2 (Temperature Gain Calibration) 3 (Pressure Offset Calibration) 4 (Pressure Gain Calibration) 101 (Reset Temperature Offset Calibration) 102 (Reset Temperature Gain Calibration) 103 (Reset Pressure Offset Calibration) 104 (Reset Pressure Gain Calibration)	n/a	0	INT	R/W

Table D-1 Modbus Register Values Message Block 50 (Operating Mode) (Sheet 3 of 3)

Number	Name and Description	Unit(s)	Default Value	Type	Access
10003	**CurrentCalSubMode** specifies the Current Calibration submode defaults to 0, Zero Scale Calibration submode, upon Current Calibration Mode entry. Reset submodes (100 and 101) exit to Zero Scale Calibration submode upon completion. Possible values are: 0 (Zero Scale Calibration) 1 (Full Scale Calibration) 100 (Reset Zero Scale and Current Offset) 101 (Reset Full Scale and Current Gain)	n/a	0	INT	R/W
10004 – 10014	**Spare** This register number is not used.	n/a	n/a	INT	R/W

Table D-2 Modbus Register Values Message Block 51 (Operation Parameters) (Sheet 1 of 8)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
10015	**PollingPeriod** time between polls of the UFM to look for new data Range: 3 to 10	ds	5	INT	R/W
10016	**FreqFlowRateCondition** specifies which temperature and pressure condition to use for outputting the flow rate The flow rate at the base condition can be output only if flow profile correction is enabled. Range: 0 (output flow rate at the flow condition); 1 (output flow rate at the base condition)	n/a	0	INT	R/W

Table D-2 Modbus Register Values Message Block 51 (Operation Parameters) (Sheet 2 of 8)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
10017	**Freq1Content** frequency 1 information content Range: 0 (reverse flow rate) 1 (forward flow rate) 2 (absolute flow rate) 3 (non-zero Phase B, reverse flow rate) (V3.73+and FPGA V1.2+) 4 (non-zero Phase B, forward flow rate) (V3.73+and FPGA V1.2+) 5 (non-zero Phase B, absolute flow rate)(V3.73+and FPGA V1.2+)	n/a	1	INT	R/W

These register values are stored in EEPROM.

Table D-2 Modbus Register Values Message Block 51 (Operation Parameters) (Sheet 3 of 8)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
10018	**Freq2Content** frequency 2 information content Range: 0 (reverse flow rate) 1 (forward flow rate) 2 (absolute flow rate) 3 (non-zero Phase B, reverse flow rate) (V3.73+ and FPGA V1.2+) 4 (non-zero Phase B, forward flow rate) (V3.73+ and FPGA V1.2+) 5 (non-zero Phase B, absolute flow rate) (V3.73+ and FPGA V1.2+)	n/a	1	INT	R/W
10019	**CurrContent** current output information content Range: 0 (reverse flow rate); 1 (forward flow rate); 2 (absolute flow rate)	n/a	1	INT	R/W

Table D-2 Modbus Register Values Message Block 51 (Operation Parameters) (Sheet 4 of 8)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
10020	**MaxFrequency** maximum frequency for all frequency output signals Range: 1000; 5000 Hz	Hz	1000	INT	R/W
	These register values are stored in EEPROM.				
10021	**TestModeOutputPct** test mode output percentage of full scale (for frequency and current) Range: 0 to 100 percent	percentage	50	INT	R/W
10022	**EnableFreqFeedback** enable/disable the frequency feedback adjustment It is recommended that frequency feedback is always enabled. Range: 0 (disable feedback adjustment); 1 (enable feedback adjustment)	n/a	1	INT	R/W

Table D-2 Modbus Register Values Message Block 51 (Operation Parameters) (Sheet 5 of 8)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
10023	**FreqFeedbackCorrectionPct** percentage of error (determined by frequency feedback) to adjust for per batch Range: 0 to 100 percent	percentage	25	INT	R/W
	These register values are stored in EEPROM.				
10024	**NonNormalModeTimeout** non-normal mode time-out value If the DFI is in a non-Normal Mode longer than this limit, it will automatically change to the Normal Mode. Setting this register to zero disables the non-Normal Mode time-out feature. Range: 0 to 60 minutes	minutes	30	INT	R/W

Table D-2 Modbus Register Values Message Block 51 (Operation Parameters) (Sheet 6 of 8)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
10025	**CommTimeoutSec** communication time-out value The DFI must respond to request messages within this time limit; if it cannot, it will not respond at all. Range: 3 to 30 seconds	seconds	4	INT	R/W
	These register values are stored in EEPROM.				
10026	**UnitsSystem** specifies the units system for reading from and writing to Modbus registers which represent physical quantities Range: 0 (U.S. Customary); 1 (Metric)	n/a	1 <= V3.62 0 >= V3.73	INT	R/W

Table D-2 Modbus Register Values Message Block 51 (Operation Parameters) (Sheet 7 of 8)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
10027	**InputPressureUnit** specifies whether the pressure input (sampled analog signal or specified via SpecFlowPressure) represents gauge pressure or absolute pressure If gauge pressure, then the absolute gas pressure is calculated as the sum of the (sampled or specified) gauge pressure and the atmospheric pressure specified via the AtmosphericPressure Modbus register. Range: 0 (gauge); 1 (Absolute)	n/a	1	INT	R/W
	These register values are stored in EEPROM.				
10028	**VolFlowRateTimeUnit** specifies the unit of time measurement of the volumetric flow rate frequency and current outputs and Modbus register reading/writing Range: 0 (vol/sec); 1 (vol/hr); 2 (vol/day)	n/a	1	INT	R/W

Table D-2 Modbus Register Values Message Block 51 (Operation Parameters) (Sheet 8 of 8)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
10029	**Spare** This register number is not used.	n/a	n/a	INT	R/W

These register values are stored in EEPROM.

Table D-3 Modbus Register Values Message Block 52 (Real-time Clock Settings/Status) (Sheet 1 of 2)

Number	Name and Description[1,3]	Unit(s)	Default Value	Type	Access
10030	**RTCMonth** Real-Time Clock month value Range: 1 (January) to 12 (December)	n/a	n/a	INT	R/W
10031	**RTCDate** Real-Time Clock date (day of month) Range: 1 to 31	n/a	n/a	INT	R/W
10032	**RTCYear** Real-Time Clock year (last two digits only) For example: for 1998, RTCYear=98. For RTCYear values of 98 and 99, the years are assumed to be 1998 and 1999. For all other RTCYear values, the years are assumed to be 20xx. Range: 00 to 99	n/a	n/a	INT	R/W

STOP **Message Block 52 must be read from and written to as an entire block (including Spare registers).**

Table D-3 Modbus Register Values Message Block 52 (Real-time Clock Settings/Status) (Sheet 2 of 2)

Number	Name and Description[1,3]	Unit(s)	Default Value	Type	Access
10033	**RTCHour** Real-Time Clock hour of the day (24-hour format) Range: 0 to 23	n/a	n/a	INT	R/W
10034	**RTCMinute** Real-Time Clock minutes past the hour Range: 0 to 59	n/a	n/a	INT	R/W
10035	**RTCSecond** Real-Time Clock seconds value Range: 0 to 59	n/a	n/a	INT	R/W
10036 – 10044	**Spare** This register number is not used.	n/a	n/a	INT	R/W

STOP **Message Block 52 must be read from and written to as an entire block (including Spare registers).**

Table D-4 Modbus Register Values Message Block 53 (Correction Setup Parameters) (Sheet 1 of 8)

Number	Name and Description[1]	Unit(s)[2]	Default Value	Type	Access
10050	**FreqFullScaleVolFlowRate** full scale volumetric flow rate used with the frequency outputs Note that 0 Hz output corresponds to zero flow, MaxFrequency output corresponds to this specified flow rate. Range: greater than 0	s: m^3/hr m: Note 4. on Page D-86 us: Note 4. on Page D-86	200,000 m^3/hr	FLOAT	R/W
10052	**CurrFullScaleVolFlowRate** full scale volumetric flow rate used with the current output Note that 4 mA output corresponds to zero flow, 20 mA output corresponds to this specified flow rate. Range: greater than 0	s: m^3/hr m: Note 4. on Page D-86 us: Note 4. on Page D-86	200,000 m^3/hr	FLOAT	R/W

These register values are stored in EEPROM (v1.00 through v3.34) or NOVRAM (v3.62 or later).

Table D-4 Modbus Register Values Message Block 53 (Correction Setup Parameters) (Sheet 2 of 8)

Number	Name and Description[1]	Unit(s)[2]	Default Value	Type	Access
10054	**MinInputTemperature** minimum input flow-condition temperature If the flow-condition temperature is enabled (i.e., input via an analog signal), then this value corresponds to a 4 mA input signal. Range: 233.15 K (-40 °C or -40 °F) to MaxInputTemperature	s: K m: °C us: °F	233.15 K -40 °C -40 °F	FLOAT	R/W
10056	**MaxInputTemperature** maximum input flow-condition temperature If the flow-condition temperature is enabled (i.e., input via an analog signal), then this value corresponds to a 20 mA input signal. Range: MinInputTemperature to 473.15 K (200 °C or 392 °F)	s: K m: °C us: °F	473.15 K 200 °C 392 °F	FLOAT	R/W

These register values are stored in EEPROM (v1.00 through v3.34) or NOVRAM (v3.62 or later).

Table D-4 Modbus Register Values Message Block 53 (Correction Setup Parameters) (Sheet 3 of 8)

Number	Name and Description[1]	Unit(s)[2]	Default Value	Type	Access
10058	**LowTemperatureAlarm** temperature alarm lower limit A flow-condition temperature value (sampled analog signal or specified via SpecFlowTemperature) is considered to be invalid if it is below this limit. Range: 233.15 K (-40 °C or -40 °F) to MaxInputTemperature	s: K m: °C us: °F	273.15 K 0 °C 32 °F	FLOAT	R/W
10060	**HighTemperatureAlarm** temperature alarm upper limit A flow-condition temperature value (sampled analog signal or specified via SpecFlowTemperature) is considered to be invalid if it is above this limit. Range: MinInputTemperature to 473.15 °K (200 °C or 392 °F)	s: K m: °C us: °F	328.15 K 55 °C 131 °F	FLOAT	R/W

These register values are stored in EEPROM (v1.00 through v3.34) or NOVRAM (v3.62 or later).

Table D-4 Modbus Register Values Message Block 53 (Correction Setup Parameters) (Sheet 4 of 8)

Number	Name and Description[1]	Unit(s)[2]	Default Value	Type	Access
10062	**MinInputPressure** minimum input flow-condition pressure If the flow-condition pressure is enabled (i.e., input via an analog signal), then this value corresponds to a 4 mA input signal. Note 5. on Page D-86 Range: 0 MPa (0 psi) to MaxInputPressure	s: MPa m: MPa us: psi	0 MPa 0 psi	FLOAT	R/W
10064	**MaxInputPressure** maximum input flow-condition pressure If the flow-condition pressure is enabled (i.e., input via an analog signal), then this value corresponds to a 20 mA input signal. Note 5. on Page D-86 Range: MinInputPressure to 100 MPa (14503.77 psi)	s: MPa m: MPa us: psi	10 MPa 1450.377 psi	FLOAT	R/W

These register values are stored in EEPROM (v1.00 through v3.34) or NOVRAM (v3.62 or later).

Table D-4 Modbus Register Values Message Block 53 (Correction Setup Parameters) (Sheet 5 of 8)

Number	Name and Description[1]	Unit(s)[2]	Default Value	Type	Access
10066	**LowPressureAlarm** pressure alarm lower limit A flow-condition pressure value (sampled analog signal or specified via SpecFlowPressure) is considered to be invalid if it is below this limit. Note 5. on Page D-86 Range: 0 MPa (0 psi) to HighPressureAlarm	s: MPa m: MPa us: psi	0 MPa 0 psi	FLOAT	R/W
10068	**HighPressureAlarm** pressure alarm upper limit A flow-condition pressure value (sampled analog signal or specified via SpecFlowPressure) is considered to be invalid if it is above this limit. Note 5. on Page D-86 Range: LowPressureAlarm to 100 MPa (14503.77 psi)	s: MPa m: MPa us: psi	8.3 MPa 1203.8 psi	FLOAT	R/W

These register values are stored in EEPROM (v1.00 through v3.34) or NOVRAM (v3.62 or later).

Table D-4 Modbus Register Values Message Block 53 (Correction Setup Parameters) (Sheet 6 of 8)

Number	Name and Description[1]	Unit(s)[2]	Default Value	Type	Access
10070	**CalGainTemperature** temperature input value for system gain calibration (for System Gain Calibration submode) Range: MinInputTemperature to MaxInputTemperature	s: K m: °C us: °F	328.15 K 55 °C 131 °F	FLOAT	R/W
10072	**CalGainPressure** pressure input value for system gain calibration (for Pressure Gain Calibration submode) Note 5. on Page D-86 Range: MinInputPressure to MaxInputPressure	s: MPa m: MPa us: psi	8.3 MPa 1203.8 psi	FLOAT	R/W
10074	**ZeroScaleCurrent** zero scale current value for use in calibrating the current output Range: 3.0 to 5.0	mA	4	FLOAT	R/W

These register values are stored in EEPROM (v1.00 through v3.34) or NOVRAM (v3.62 or later).

Table D-4 Modbus Register Values Message Block 53 (Correction Setup Parameters) (Sheet 7 of 8)

Number	Name and Description[1]	Unit(s)[2]	Default Value	Type	Access
10076	**FullScaleCurrent** full scale current value for use in calibrating the current output Range: 19.0 to 21.0	mA	20	FLOAT	R/W
10078	**SpecRhoMixFlow** flow-condition gas mass density (must be specified if HCH_Method = 0.0) Range: 0.0 to 500.0 kg/m^3	s: kg/m^3 m: kg/m^3 us: lbm/ft^3	0.0	FLOAT	R/W
10080	**SpecZFlow** flow-condition gas compressibility (must be specified if HCH_Method = 0.0) Range: 0.0 to 2.0	n/a	0.0	FLOAT	R/W
10082	**SpecZBase** base-condition gas compressibility (must be specified if HCH_Method = 0.0) Range: 0.0 to 2.0	n/a	0.0	FLOAT	R/W

Table D-4 Modbus Register Values Message Block 53 (Correction Setup Parameters) (Sheet 8 of 8)

Number	Name and Description[1]	Unit(s)[2]	Default Value	Type	Access
10084	**SpecCorrectionFactor** used for specifying a fixed flow-profile-effect correction Range: 0.0 indicates that the flow-profile-effect correction factor is to be calculated or set to the default 0.9-1.0 range for specifying a fixed flow-profile-effect correction factor (models 3410, 3420, and 3450 only)	n/a	0.0	FLOAT	R/W
10086 - 10099	**Spare** These register numbers are not used.	n/a	n/a	FLOAT	R/W

These register values are stored in EEPROM (v1.00 through v3.34) or NOVRAM (v3.62 or later).

Table D-5 Modbus Register Values Message Block 54 (AGA8 Setup Parameters) (Sheet 1 of 11)

Number	Description[1]	Unit(s)[2]	Default Value	Type	Access
10100	**Tbase** (T_b) base (contract) temperature Range: 0 to 328.15 K (-273.15 to 55 °C, or -459.67 to 131 °F)	s K : °C m °F : u s :	273.15 K <= V3.62 0 °C <= V3.62 32 °F <= V3.62 288.7056 K >= V3.73 15.5556 °C >= V3.73 60 °F >= V3.73	FLOAT	R/W
10102	**Pbase**)(P_b) base (contract) absolute pressure Range: 0 to 8.3 abs MPa (1203.8 psia)	s abs MPa : abs MPa m psia : u s :	0.101560 abs MPa 14.73 psia	FLOAT	R/W
10104	**AtmosphericPressure** (P_{atm}) If the pressure input is gauge pressure, then this register is used to specify the atmospheric pressure to be added to the gauge pressure to obtain absolute pressure. Range: 0 to 8.3 abs MPa (1203.8 psia)	s abs MPa : abs MPa m psia : psia u s :	0 abs MPa <=3.73 1.101560 >=3.82 0 psia <=3.73 14.73 >=3.82	FLOAT	R/W

Table D-5 Modbus Register Values Message Block 54 (AGA8 Setup Parameters) (Sheet 2 of 11)

These register values are stored in NOVRAM.

Number	Description[1]	Unit(s)[2]	Default Value	Type	Access
10106	**HCH_Method** AGA8 Gross Characterization Method for calculating the molar gross heating value of the equivalent hydrocarbon Range: 0 (calculations performed externally); 1 (Method 1); 2 (Method 2)	n/a	2	FLOAT	R/W
10108	**MeasVolGrossHeatingVal** *(HV)* volumetric gross heating value; used as input to the AGA8 Gross Method 1 calculation Range: 15 to 50 kJ/dm^3 (402.589 to 1341.959 Btu/ft^3)	s: kJ/dm^3 m: kJ/dm^3 us: Btu/ft^3	38.6022 kJ/dm^3 1036.0516 Btu/ft^3	FLOAT	R/W

Table D-5 Modbus Register Values Message Block 54 (AGA8 Setup Parameters) (Sheet 3 of 11)

Number	Description[1]	Unit(s)[2]	Default Value	Type	Access
10110	**RefTemperatureHV** (T_{HV}) reference temperature for the volumetric gross heating value; used as input to the AGA8 Gross Method 1 calculation Range: 0 to 328.15 K (-273.15 to 55 °C, or -459.67 to 131 °F)	s K : °C m °F : u s :	288.7056 K 15.5556 °C 60 °F	FLOAT	R/W
	These register values are stored in NOVRAM.				
10112	**SpecificGravity** (G_r) relative density; used as input to the AGA8 Gross Methods 1 and 2 calculations Range: 0 to 2	n/a	0.581078	FLOAT	R/W

Table D-5 Modbus Register Values Message Block 54 (AGA8 Setup Parameters) (Sheet 4 of 11)

Number	Description[1]	Unit(s)[2]		Default Value	Type	Access
10114	**RefTemperatureGr** (T_{G_r}) reference temperature for the specific gravity; used as input to the AGA8 Gross Methods 1 and 2 calculations Range: 0 to 328.15 K (-273.15 to 55 °C, or -459.67 to 131 °F)	s: m: us:	K °C °F	288.7056 K 15.5556 °C 60 °F	FLOAT	R/W
10116	**RefPressureGr** (P_{G_r}) reference pressure for the specific gravity; used as input to the AGA8 Gross Methods 1 and 2 calculations Range: 0 to 8.3 abs MPa (1203.8 psia)	s: m: us:	abs MPa abs MPa psia	0.101560 abs MPa 14.73 psia	FLOAT	R/W
	These register values are stored in NOVRAM.					
10118	**RefTemperatureMolarDensity** (T_d) reference temperature for the molar density; used as input to the AGA8 Gross Method 1 calculation Range: 0 to 328.15 K (-273.15 to 55 °C, or -459.67 to 131 °F)	s: m: us:	K °C °F	288.7056 K 15.5556 °C 60 °F	FLOAT	R/W

Table D-5 Modbus Register Values Message Block 54 (AGA8 Setup Parameters) (Sheet 5 of 11)

Number	Description[1]	Unit(s)[2]	Default Value	Type	Access
10120	**RefPressureMolarDensity** reference pressure for the molar density; used as input to the AGA8 Gross Method 1 calculation Range: 0 to 8.3 abs MPa (1203.8 psia)	s abs MPa : abs MPa m psia : u s :	0.101560 abs MPa 14.73 psia	FLOAT	R/W
These register values are stored in NOVRAM.					
10122	**MoleFractionN2Method2** (x_{N_2}) mole fraction of nitrogen in the natural gas mixture; used as input to the AGA8 Gross Method 2 calculation Note that this is a mole fraction, not a mole percentage. A 0.26 mole percentage is equivalent to a 0.0026 mole fraction. Range: 0 to 0.5	n/a	0.002595	FLOAT	R/W

Table D-5 Modbus Register Values Message Block 54 (AGA8 Setup Parameters) (Sheet 6 of 11)

Number	Description[1]	Unit(s)[2]	Default Value	Type	Access
10124	**MoleFractionCO2** (x_{CO_2}) mole fraction of carbon dioxide in the natural gas mixture; used as input to the AGA8 Gross Methods 1 and 2 calculations Range: 0 to 0.3	n/a	0.005956	FLOAT	R/W
	These register values are stored in NOVRAM.				
10126	**MoleFractionH2** (x_{H_2}) mole fraction of hydrogen in the natural gas mixture; used as input to the AGA8 Gross Methods 1 and 2 calculations Range: 0 to 0.1	n/a	0	FLOAT	R/W

Table D-5 Modbus Register Values Message Block 54 (AGA8 Setup Parameters) (Sheet 7 of 11)

Number	Description[1]	Unit(s)[2]	Default Value	Type	Access
10128	**MoleFractionCO** (x_{CO}) mole fraction of carbon monoxide in the natural gas mixture; used as input to the AGA8 Gross Methods 1 and 2 calculations Range: 0 to 0.03	n/a	0	FLOAT	R/W
10130	**Viscosity** (μ) natural gas mixture dynamic viscosity Range: 0 to 0.000050 Pa·s (0 to 0.050 cPoise)	s Pa·s : Pa·s m cPoise : u s :	0.000012 Pa·s 0.012 cPoise	FLOAT	R/W

These register values are stored in NOVRAM.

Table D-5 Modbus Register Values Message Block 54 (AGA8 Setup Parameters) (Sheet 8 of 11)

Number	Description[1]	Unit(s)[2]		Default Value	Type	Access
10132	**WallRoughness** (WR) pipe wall roughness Range: 0 to 10^{-4} m (0 to 0.0003281 ft)	s : m : u s :	m m ft	$7.62x10^{-6}$ m 0.000025 ft	FLOAT	R/W
10134	**SpecFlowTemperature** specified flow-condition temperature In order to specify the flow-condition temperature, the register EnableTemperatureInput must be equal to 2. Note that this register is not protected by the memory protect jumper (JP2). Changes to this register are not recorded in the Audit Log. Range: 233.15 to 473.15 K (-40 to 200 °C, or -40 to 392 °F)	s : m : u s :	K °C °F	273.15 K 0 °C 32 °F	FLOAT	R/W

These register values are stored in NOVRAM.

Table D-5 Modbus Register Values Message Block 54 (AGA8 Setup Parameters) (Sheet 9 of 11)

Number	Description[1]	Unit(s)[2]	Default Value	Type	Access
10136	**SpecFlowPressure** specified flow-condition pressure In order to specify the flow-condition pressure, the register EnablePressureInput must be equal to 2. Note 5. on Page D-86 Note that this register is not protected by the memory protect jumper (JP2). Changes to this register are not recorded in the Audit Log. Range: 0 to 100 abs MPa (14503.77 psia)	s: abs MPa m: abs MPa us: psia	0.101560 abs MPa 14.73 psia	FLOAT	R/W
10138	**LinearExpansionCoef** linear expansion coefficient of the pipe material This value is used for correcting the volumetric flow rate for expansion due to temperature changes. Range: 10E-6 to 18E-6 K^{-1} (10E-6 to 18E-6 $°C^{-1}$ or 5.55E-6 to 10E-6 $°F^{-1}$)	s: K^{-1} m: $°C^{-1}$ us: $°F^{-1}$	15.12E-6 K^{-1} 15.12E-6 $°C^{-1}$ 8.40E-6 $°F^{-1}$	FLOAT	R/W

Table D-5 Modbus Register Values Message Block 54 (AGA8 Setup Parameters) (Sheet 10 of 11)

These register values are stored in NOVRAM.

Number	Description[1]	Unit(s)[2]	Default Value	Type	Access
10140	**RefTempLinearExpCoef** linear expansion coefficient reference temperature Range: 233.15 to 473.15 K (-40 to 200 °C, or -40 to 392 °F)	s K : °C m °F : u s :	293.15 K 20 °C 68 °F	FLOAT	R/W
10142	**PipeOutsideDiameter** pipe outside diameter This value is used for correcting the volumetric flow rate for expansion due to pressure changes. The PipeOutsideDiameter value must be greater than the Host PipeDiam value. Range: 0.00635 to 2.0 m (0.02083 to 6.5 ft)	s m : m m ft : u s :	2.0 m 6.5 ft	FLOAT	R/W

These register values are stored in NOVRAM.

Table D-5 Modbus Register Values Message Block 54 (AGA8 Setup Parameters) (Sheet 11 of 11)

Number	Description[1]	Unit(s)[2]	Default Value	Type	Access
10144	**YoungsModulus** Young's Modulus value (ratio of tensile stress to tensile strain) This value is used for correcting the volumetric flow rate for expansion due to pressure changes. Range: 137895 to 310264 MPa (20E6 to 45E6 psi)	s MPa : MPa m psi : u s :	206842.71 MPa 30E6 psi	FLOAT	R/W
10146	**PoissonsRatio** Poisson's Ratio value (the absolute ratio of the pipe material lateral strain over axial strain) This value is used for correcting the volumetric flow rate for expansion due to pressure changes. Range: 0.2 to 0.4	n / a	0.3	FLOAT	R/W
10148	**Spare** This register number is not used.	n/a	n/a	FLOAT	R/W

These register values are stored in NOVRAM.

Table D-6 Modbus Register Values Message Block 55 (Diagnostics)

Number	Name and Description	Unit(s)	Default Value	Type	Access
10150	**DFIMemStartAddr** DFI memory starting address for analysis	n/a	0	INT	R/W
10151	**Reserved** This register number is reserved for future use.	n/a	0	INT	R/W
10152 – 10164	**Spare** This register number is not used.	n/a	n/a	INT	R/W

Table D-7 Modbus Register Values Message Block 56 (Analog Enable / Logging Parameters) (Sheet 1 of 7)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
10200	**MeasurementArraySize** number of analog input measurements (one per second) to average Range: 1 to 64	n/a	5	INT	R/W
10201	**SysCalArraySize** number of consecutive analog input measurements to average for system calibration measurements Range: 4 to 64	n/a	64	INT	R/W

These register values are stored in EEPROM.

Table D-7 Modbus Register Values Message Block 56 (Analog Enable / Logging Parameters) (Sheet 2 of 7)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
10202	**EnableTemperatureInput** allows the user to disable, enable, or specify the flow condition temperature input If the input is enabled, the flow-condition temperature is input via an analog signal. If the input is specified, the flow condition temperature is input via the SpecFlowTemperature register. This register cannot be changed while in the Maintenance Mode. Range: 0 (disable temperature input); 1 (enable temperature input); 2 (specify temperature input)	n/a	1 <= V3.62 0 >= V3.73	INT	R/W

This register value is stored in EEPROM.

Table D-7 Modbus Register Values Message Block 56 (Analog Enable / Logging Parameters) (Sheet 3 of 7)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
10203	**EnablePressureInput** allows the user to disable, enable, or specify the flow-condition pressure input If the input is enabled, the flow-condition pressure is input via an analog signal. If the input is specified, the flow-condition pressure is input via the SpecFlowPressure register. This register cannot be changed while in the Maintenance Mode. Range: 0 (disable pressure input); 1 (enable pressure input); 2 (specify pressure input)	n/a	1 <= V3.62 0 >= V3.73	INT	R/W
10204	**CommARspDlyMillisec** minimum time for communication response message to be delayed after receipt of a request message (Port A) Range: 0 to 100 ms	ms	0	INT	R/W

These register values are stored in EEPROM.

Table D-7 Modbus Register Values Message Block 56 (Analog Enable / Logging Parameters) (Sheet 4 of 7)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
10205	**CommBRspDlyMillisec** minimum time for communication response message to be delayed after receipt of a request message (Port B) Range: 0 to 100 ms	ms	0	INT	R/W
10206	**ContractHour** hour of day when a daily record is to be logged Range: 0 to 23 hours	hour (military time)	0	INT	R/W

These register values are stored in EEPROM.

Table D-7 Modbus Register Values Message Block 56 (Analog Enable / Logging Parameters) (Sheet 5 of 7)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
10207	**LogDateTimeFormat** specifies the format for transmitting log record date and time information Dates are transmitted according to the selected format. Times are transmitted in military time format (0-23 hours) as HHMMSS. Range: 0 (32-bit floating point, date format mmddyy) 1 (32-bit long integer, date format mmddyyyy) 2 (32-bit floating point, date format ddmmyy) 3 (32-bit long integer, date format ddmmyyyy) 4 (32-bit floating point, date format yymmdd) 5 (32-bit long integer, date format yyyymmdd)	n/a	0	INT	R/W
10208	**LogDailyVolumeFormat** specifies the format for transmitting daily record volume information Range: 0 (32-bit floating point); 1 (32-bit integer)	n/a	0	INT	R/W

These register values are stored in EEPROM.

Table D-7 Modbus Register Values Message Block 56 (Analog Enable / Logging Parameters) (Sheet 6 of 7)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
10209	**LogHourlyVolumeFormat** specifies the format for transmitting hourly record volume information Range: 0 (32-bit floating point); 1 (32-bit integer)	n/a	0	INT	R/W
10210	**EnableExpCorrTemp** allows the user to enable or disable the volumetric flow rate correction due to thermal expansion If enabled, the temperature must be input or specified. Range: 0 (disable correction); 1 (enable correction)	n/a	1 <= V3.62 0 >= V3.73	INT	R/W
10211	**EnableExpCorrPress** allows the user to enable or disable the volumetric flow rate correction due to pressure expansion If enabled, the pressure must be input or specified. Range: 0 (disable correction); 1 (enable correction)	n/a	1 <= V3.62 0 >= V3.73	INT	R/W

Table D-7 Modbus Register Values Message Block 56 (Analog Enable / Logging Parameters) (Sheet 7 of 7)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
	These register values are stored in EEPROM.				
10212 – 10214	**Spare** This register number is not used.	n/a	n/a	INT	R/W
	These register values are stored in EEPROM.				

Table D-8 Modbus Register Values Message Block 60 (Frequency Status) (Sheet 1 of 4)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
10500	**FlowDirection** flow direction indicator Range: 0 (reverse); 1 (forward)	n/a	n/a	INT	R

Table D-8 Modbus Register Values Message Block 60 (Frequency Status) (Sheet 2 of 4)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
10501	**FreqDataValidity** frequency data validity indicator Range: 0 (frequency data invalid); 1 (frequency data valid)	n/a	n/a	INT	R
10502	**QMeterValidity** UFM volumetric flow rate validity indicator Range: 0 (UFM volumetric flow rate invalid); 1 (UFM volumetric flow rate valid)	n/a	n/a	INT	R
10503	**QFlowValidity** low-condition volumetric flow rate validity indicator Range: 0 (flow-condition volumetric flow rate invalid); 1 (flow-condition volumetric flow rate valid)	n/a	n/a	INT	R
10504	**QBaseValidity** base-condition volumetric flow rate validity indicator Range: 0 (base-condition volumetric flow rate invalid); 1 (base-condition volumetric flow rate valid)	n/a	n/a	INT	R

Table D-8 Modbus Register Values Message Block 60 (Frequency Status) (Sheet 3 of 4)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
10505	**TemperatureValidity** temperature validity indicator Range: 0 (temperature invalid); 1 (temperature valid)	n/a	n/a	INT	R
10506	**PressureValidity** pressure validity indicator Range: 0 (pressure invalid); 1 (pressure valid)	n/a	n/a	INT	R
10507	**AGA8BaseCalcValidity** AGA8 base-condition compressibility calculation validity indicator Range: 0 (AGA8 Base Calculation invalid); 1 (AGA8 Base Calculation valid)	n/a	n/a	INT	R
10508	**AGA8FlowCalcValidity** AGA8 flow-condition compressibility calculation validity indicator Range: 0 (AGA8 Flow Calculation invalid); 1 (AGA8 Flow Calculation valid)	n/a	n/a	INT	R

Table D-8 Modbus Register Values Message Block 60 (Frequency Status) (Sheet 4 of 4)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
10509	**ExpCorrTempValidity** temperature-effect expansion correction validity indicator Range: 0 (correction invalid); 1 (correction valid)	n/a	n/a	INT	R
10510	**ExpCorrPressValidity** pressure-effect expansion correction validity indicator Range: 0 (correction invalid); 1 (correction valid)	n/a	n/a	INT	R
10511	**FlowProfileCorrValidity** flow-profile effect correction validity indicator Range: 0 (correction invalid); 1 (correction valid)	n/a	n/a	INT	R
10512 – 10514	**Spare** This register number is not used.	n/a	n/a	INT	R

Table D-9 Modbus Register Values Message Block 61 (Accumulated Volumes) (Sheet 1 of 6)

Number	Name and Description[1]	Unit(s)[4]	Default Value	Type	Access
10550	**PosVolFlow** ($PosVol_f$) total flow-profile corrected positive volume at the flow condition Range: 0 to 999,999,999	s: m^3 m: m^3 us: ft^3	n/a	LINT	R
10552	**PosVolFlowOverflow** ($PosVolOverflow_f$) overflow for corrected positive volume at the flow condition Range: 0 to 2,147,483,647	s: 1E9 m^3 m: 1E9 m^3 us: 1E9 ft^3	n/a	LINT	R
10554	**NegVolFlow** ($NegVol_f$) total flow-profile corrected negative volume at the flow condition Range: 0 to 999,999,999	s: m^3 m: m^3 us: ft^3	n/a	LINT	R

These register values are stored in NOVRAM.

Table D-9 Modbus Register Values Message Block 61 (Accumulated Volumes) (Sheet 2 of 6)

Number	Name and Description[1]	Unit(s)[4]	Default Value	Type	Access
10556	**NegVolFlowOverflow** ($NegVolOverflow_f$) overflow for corrected negative volume at the flow condition Range: 0 to 2,147,483,647	s: 1E9 m^3 m: 1E9 m^3 us: 1E9 ft^3	n/a	LINT	R
10558	**PosVolBase** ($PosVol_b$) total flow-profile corrected positive volume at the base condition Range: 0 to 999,999,999	s: m^3 m: m^3 us: ft^3	n/a	LINT	R
10560	**PosVolBaseOverflow** ($PosVolOverflow_b$) overflow for corrected positive volume at the base condition Range: 0 to 2,147,483,647	s: 1E9 m^3 m: 1E9 m^3 us: 1E9 ft^3	n/a	LINT	R

These register values are stored in NOVRAM.

Table D-9 Modbus Register Values Message Block 61 (Accumulated Volumes) (Sheet 3 of 6)

Number	Name and Description[1]	Unit(s)[4]	Default Value	Type	Access
10562	**NegVolBase** $(NegVol_b)$ total flow-profile corrected negative volume at the base condition Range: 0 to 999,999,999	s: m^3 m: m^3 us: ft^3	n/a	LINT	R
10564	**NegVolBaseOverflow** $(NegVolOverflow_b)$ overflow for corrected negative volume at the base condition Range: 0 to 2,147,483,647	s: 1E9 m^3 m: 1E9 m^3 us: 1E9 ft^3	n/a	LINT	R
10566 to 10580	**Reserved** This register number is reserved for future use.	n/a	n/a	LINT	R

These register values are stored in NOVRAM.

Table D-9 Modbus Register Values Message Block 61 (Accumulated Volumes) (Sheet 4 of 6)

Number	Name and Description[1]	Unit(s)[4]	Default Value	Type	Access
10582	**ColdStart** cold start indicator This value is set to 1 when the system is cold-started. The user should acknowledge this flag after the system is cold-started by writing a zero to this register. It is not necessary to write to the corresponding UFM register; the DFI writes a zero to the UFM ColdStart register upon start-up. Range: 0 (cold start acknowledged); 1 (system cold-started)	n/a	1	LINT	R/W
10584	**DataQlty** UFM data quality indicator Note 12. on Page D-91	n/a	n/a	LINT	R

These register values are stored in NOVRAM.

Table D-9 Modbus Register Values Message Block 61 (Accumulated Volumes) (Sheet 5 of 6)

Number	Name and Description[1]	Unit(s)[4]	Default Value	Type	Access
10586	**TimeLapse** number of pulses accumulated to generate the actual volume There are exactly 0.1048576 seconds per pulse. Beginning with v3.62, this register is cumulative. Range: 0 to 2,147,483,647	pulses	n/a	LINT	R
10588	**TimeOverflow** timeLapse overflow Beginning with v3.62, this register is cumulative. Range: 0 to 2,147,483,647	1E10 pulses	n/a	LINT	R

These register values are stored in NOVRAM.

Table D-9 Modbus Register Values Message Block 61 (Accumulated Volumes) (Sheet 6 of 6)

Number	Name and Description[1]	Unit(s)[4]	Default Value	Type	Access
10590	**Time** number of seconds to generate the actual volume This is equal to TimeLapse multiplied by 0.1048576 seconds per pulse, rounded up. Beginning with v3.62, this register is cumulative. Range: 0 to 225,179,986	seconds	n/a	LINT	R
10592 – 10599	**Spare** This register number is not used.	n/a	n/a	LINT	R

These register values are stored in NOVRAM.

Table D-10 Modbus Register Values Message Block 62 (Calculation Results 1) (Sheet 1 of 9)

Number	Name and Description[1]	Unit(s)[2]	Default Value	Type	Access
10600	**FlowTemperature** (T_f) flow-condition temperature (sampled analog signal or specified via SpecFlowTemperature) Note that this register is fixed at 0 K (-273.15 °C or -459.67 °F) if the temperature input is disabled. Range: MinInputTemperature to MaxInputTemperature	s: K m: °C us: °F	n/a	FLOAT	R
10602	**FlowPressure** (P_f) flow-condition pressure (gauge or absolute); sampled analog signal or specified via SpecFlowPressure Note that this register is fixed at 0 MPa if the pressure input is disabled. Note 5. on Page D-86 Range: MinInputPressure to MaxInputPressure	s: MPa m: MPa us: psi	n/a	FLOAT	R

Table D-10 Modbus Register Values Message Block 62 (Calculation Results 1) (Sheet 2 of 9)

Number	Name and Description[1]	Unit(s)[2]	Default Value	Type	Access
10604	**ZFlow** (Z_f) compressibility factor of the natural gas mixture at the flow condition Range: 0 to 1	n/a	n/a	FLOAT	R
10606	**ZBase** (Z_b) compressibility factor of the natural gas mixture at the base condition Range: 0 to 1	n/a	n/a	FLOAT	R
10608	**dFlow** (d_f) molar density of the natural gas mixture at the flow condition Range: 0.04 to 0.05 g-mol/dm^3 (0.0025 to 0.0031 lbm-mol/ft^3)	s: g-mol/dm^3 m: g-mol/dm^3 us: lbm-mol/ft^3	n/a	FLOAT	R

Table D-10 Modbus Register Values Message Block 62 (Calculation Results 1) (Sheet 3 of 9)

Number	Name and Description[1]	Unit(s)[2]	Default Value	Type	Access
10610	**dBase** (d_b) molar density of the natural gas mixture at the base condition Range: 0.04 to 0.05 g-mol/dm^3 (0.0025 to 0.0031 lbm-mol/ft^3)	s: g-mol/dm^3 m: g-mol/dm^3 us: lbm-mol/ft^3	n/a	FLOAT	R
10612	**RhoMixFlow** mass density of the natural gas mixture at the flow condition	s: kg/m^3 m: kg/m^3 us: lbm/ft^3	n/a	FLOAT	R
10614	**ReynoldsNumber** (Re) Reynolds number (measure of turbulence) Range: 1E4 to 1E8	n/a	n/a	FLOAT	R

Table D-10 Modbus Register Values Message Block 62 (Calculation Results 1) (Sheet 4 of 9)

Number	Name and Description[1]	Unit(s)[2]	Default Value	Type	Access
10616	**CorrectionFactor** (CF) volumetric flow rate flow-profile-effect correction factor Meter models 3410, 3420, and 3450 require flow-profile-effect correction. For these meters, the Correction Factor can be calculated (refer to section A.4.7), set to a default value (0.95), or, beginning with firmware V3.73, set to a specified value (via the SpecCorrectionFactor register). For all other meter models, no correction is necessary and this value is fixed at 1.0. Range: 0.9-1.0 meter models 3410, 3420, 3450; 1.0 other meter models	n/a	see below	FLOAT	R
10618	**AGA8FlowToBaseConversion** AGA8-calculated flow-condition to base-condition volumetric flow rate conversion factor	n/a	n/a	FLOAT	R

Table D-10 Modbus Register Values Message Block 62 (Calculation Results 1) (Sheet 5 of 9)

Number	Name and Description[1]	Unit(s)[2]	Default Value	Type	Access
10620	**QCutOff** volumetric flow rate cut-off value (equivalent to the Host Modbus register 394, CutRate)	s: m^3/hr m: Note 4. on Page D-86 us: Note 4. on Page D-86	n/a	FLOAT	R
10622	**QMeter** (Q_{UFM}) volumetric flow rate reported by the meter (equivalent to the Host Modbus register 392, FlowRate) Range: -100 to 100 m^3/s	s: m^3/hr m: Note 4. on Page D-86 us: Note 4. on Page D-86	n/a	FLOAT	R
10624	**QFlow** ($Q_{UFI,f}$) corrected volumetric flow rate at flow conditions (this includes the temperature-effect and pressure-effect expansion corrections and flow-profile-effect correction) Range: -100 to 100 m^3/s	s: m^3/hr m: Note 4. on Page D-86 us: Note 4. on Page D-86	n/a	FLOAT	R

Table D-10 Modbus Register Values Message Block 62 (Calculation Results 1) (Sheet 6 of 9)

Number	Name and Description[1]	Unit(s)[2]	Default Value	Type	Access
10626	**QBase** (Q_b) volumetric flow rate at base conditions Range: -100 to 100 m^3/s	s: m^3/hr m: Note 4. on Page D-86 us: Note 4. on Page D-86	n/a	FLOAT	R
10628	**VFRFreq1** frequency of the Frequency 1 output Range: 0 to MaxFrequency	Hz	0	FLOAT	R
10630	**VFRFreq2** frequency of the Frequency 2 output Range: 0 to MaxFrequency	Hz	0	FLOAT	R
10632	**VFRCurrentOutput** value of the volumetric flow rate current output Range: 4 to 20 mA	mA	n/a	FLOAT	R

Table D-10 Modbus Register Values Message Block 62 (Calculation Results 1) (Sheet 7 of 9)

Number	Name and Description[1]	Unit(s)[2]	Default Value	Type	Access
10634	**KFactor** frequency output K factor (number of pulses to represent one cubic meter of the natural gas mixture) This value is the inverse of register 11160, VolPerPulse.	s: pulses/m^3 m: pulses/m^3 us: pulses/ft^3	n/a	FLOAT	R
10636	**AbsFlowPressure** (P_f) flow-condition absolute pressure If the input pressure unit is gauge, then this is the sum of the measured or specified gauge pressure and the atmospheric pressure. If the input pressure unit is absolute, then this is equal to FlowPressure. Note that this register is fixed at 0 MPa if the pressure input is disabled. Range: 0 to 100 abs MPa (14503.77 psia)	s: abs MPa m: abs MPa us: psia	n/a	FLOAT	R
10638	**HourlyFlowTime** number of minutes during the current hour that the flow is above the cutoff value Range: 0 to 60 minutes (0 to 3600 seconds)	s: seconds m: minutes us: minutes	n/a	FLOAT	R

Table D-10 Modbus Register Values Message Block 62 (Calculation Results 1) (Sheet 8 of 9)

Number	Name and Description[1]	Unit(s)[2]	Default Value	Type	Access
10640	**DailyFlowTime** number of minutes during the current day that the flow is above the cutoff value Range: 0 to 1440 minutes (0 to 86400 seconds)	s: seconds m: minutes us: minutes	n/a	FLOAT	R
10642	**StrainPerUnitStress** calculated strain per unit stress due to pressure This value is used in the calculation of the expansion correction factor due to pressure.	s: MPa^{-1} m: MPa^{-1} us: psi^{-1}	n/a	FLOAT	R
10644	**ExpCorrPressure** volumetric flow rate correction factor for expansion due to pressure This value is equal to 1.0 if pressure is disabled (via Enable-PressureInput) or pressure expansion correction is disabled (via EnableExpCorrPress).	n/a	n/a	FLOAT	R

Table D-10 Modbus Register Values Message Block 62 (Calculation Results 1) (Sheet 9 of 9)

Number	Name and Description[1]	Unit(s)[2]	Default Value	Type	Access
10646	**ExpCorrTemperature** volumetric flow rate correction factor for expansion due to temperature This value is equal to 1.0 if temperature is disabled (via EnableTemperatureInput) or temperature expansion correction is disabled (via EnableExpCorrTemp).	n/a	n/a	FLOAT	R
10648	**QExpCorr** ($Q_{ExpCorr,f}$) expansion-corrected volumetric flow rate This is equal to the meter-reported volumetric flow rate multiplied by the temperature expansion and pressure expansion correction factors.	s: m^3/hr m: Note 4. on Page D-86 us: Note 4. on Page D-86	n/a	FLOAT	R

Table D-11 Modbus Register Values Message Block 63 (Calculation Results 2) (Sheet 1 of 5)

Number	Name and Description[1]	Unit(s)[2]	Default Value	Type	Access
10650	**RhoAir** $\rho_{air(T_{G_r}, P_{G_r})}$ mass density of air at the specific gravity reference condition; output is calculated from AGA8 Gross Methods 1 and 2 Range: 0 to 10 kg/m^3 (0 to 0.62428 lbm/ft^3)	s: kg/m^3 m: kg/m^3 us: lbm/ft^3	n/a	FLOAT	R
10652	**HNGERG** (HN_{UGERG}) molar ideal gross heating value at the GERG condition; this value is only calculated if AGA8 Gross Method 1 is selected (it is read as “0.0” if Gross Method 2 is selected) Range: 0 to 500 kJ/g-mol (0 to 214,961 Btu/lbm-mol)	s: kJ/g-mol m: kJ/g-mol us: Btu/lbm-mol	n/a	FLOAT	R
10654	**Mr** (M_r) molar mass of the natural gas mixture; output is calculated from AGA8 Gross Methods 1 and 2 Range: 0 to 200 kg/kg-mol (0 to 200 lbm/lbm-mol)	s: kg/kg-mol m: kg/kg-mol us: lbm/lbm-mol	n/a	FLOAT	R

Table D-11 Modbus Register Values Message Block 63 (Calculation Results 2) (Sheet 2 of 5)

Number	Name and Description[1]	Unit(s)[2]	Default Value	Type	Access
10656	**MoleFractionCH** (x_{CH}) mole fraction of the equivalent hydrocarbon; output is calculated from AGA8 Gross Methods 1 and 2 Range: 0 to 1	n/a	n/a	FLOAT	R
10658	**MoleFractionN2Method1** (x_{N_2}) mole fraction of nitrogen; if AGA8 Gross Method 1 is selected, this value is calculated; if AGA8 Gross Method 2 is selected, it is a copy of input register 10122, MoleFractionN2Method2 Range: 0 to 1	n/a	n/a	FLOAT	R
10660	**HCH** (H_{CH}) molar gross heating value of the equivalent hydrocarbon; output is calculated from AGA8 Gross Methods 1 and 2 Range: 300 to 1250 kJ/g-mol (128,977 to 537,403 Btu/lbm-mol)	s: kJ/g-mol m: kJ/g-mol us: Btu/lbm-mol	n/a	FLOAT	R

Table D-11 Modbus Register Values Message Block 63 (Calculation Results 2) (Sheet 3 of 5)

Number	Name and Description[1]	Unit(s)[2]	Default Value	Type	Access
10662	**MrCH** (M_{rCH}) molar mass of the equivalent hydrocarbon; output is calculated from AGA8 Gross Methods 1 and 2 Range: 1 to 200 kg/kg-mol (0 to 441 lbm/lbm-mol)	s: kg/kg-mol m: kg/kg-mol us: lbm/lbm-mol	n/a	FLOAT	R
10664	**B-CH-CH_Flow** $(B_{CH-CH(T_f)})$ second virial coefficient of the equivalent hydrocarbon at the flow condition; output is calculated from AGA8 Gross Methods 1 and 2 Range: -1 to 1 dm^3/g-mol (-16.0184 to 16.0184 ft^3/lbm-mol)	s: dm^3/g-mol m: dm^3/g-mol us: ft^3/lbm-mol	n/a	FLOAT	R

Table D-11 Modbus Register Values Message Block 63 (Calculation Results 2) (Sheet 4 of 5)

Number	Name and Description[1]	Unit(s)[2]	Default Value	Type	Access
10666	**BmixFlow** $(B_{mix(T_f)})$ second virial coefficient of the natural gas mixture at the flow condition; output is calculated from AGA8 Gross Methods 1 and 2 Range: -1 to 1 dm^3/g-mol (-16.0184 to 16.0184 ft^3/lbm-mol)	s: dm^3/g-mol m: dm^3/g-mol us: ft^3/lbm-mol	n/a	FLOAT	R
10668	**CmixFlow** $(C_{mix(T_f)})$ third virial coefficient of the natural gas mixture at the flow condition; output is calculated from AGA8 Gross Methods 1 and 2 Range: -1 to 1 dm^6/g-mol^2 (-256.591 to 256.591 ft^6/lbm-mol^2)	s: dm^6/g-mol^2 m: dm^6/g-mol^2 us: ft^6/lbm-mol^2	n/a	FLOAT	R
10670	**B-CH-CH_Base** second virial coefficient of the equivalent hydrocarbon at the base temperature; output is calculated from AGA8 Gross Methods 1 and 2 Range: -1 to 1 dm^3/g-mol (-16.0184 to 16.0184 ft^3/lbm-mol)	s: dm^3/g-mol m: dm^3/g-mol us: ft^3/lbm-mol	n/a	FLOAT	R

Table D-11 Modbus Register Values Message Block 63 (Calculation Results 2) (Sheet 5 of 5)

Number	Name and Description[1]	Unit(s)[2]	Default Value	Type	Access
10672	**BmixBase** $(B_{mix(T_b)})$ second virial coefficient of the natural gas mixture at the base temperature; output is calculated from AGA8 Gross Methods 1 and 2 Range: -1 to 1 dm^3/g-mol (-16.0184 to 16.0184 ft^3/lbm-mol)	s: dm^3/g-mol m: dm^3/g-mol us: ft^3/lbm-mol	n/a	FLOAT	R
10674	**CmixBase** $(C_{mix(T_b)})$ third virial coefficient of the natural gas mixture at the base condition; output is calculated from AGA8 Gross Methods 1 and 2 Range: -1 to 1 dm^6/g-mol^2 (-256.591 to 256.591 ft^6/lbm-mol^2)	s: dm^6/g-mol^2 m: dm^6/g-mol^2 us: ft^6/lbm-mol^2	n/a	FLOAT	R
10676 – 10699	**Spare** This register number is not used.	n/a	n/a	FLOAT	R

Table D-12 Modbus Register Values Message Block 64 (Maintenance/Test Values) (Sheet 1 of 2)

Number	Name and Description[1]	Unit(s)[2]	Default Value	Type	Access
10700	**MaintTemperature** maintenance Mode A/D temperature reading (Read Inputs submode) Note that this register is fixed at 0 K if the temperature input is disabled or specified. Range: 0 to MaxTemperature value	s: K m: °C us: °F	n/a	FLOAT	R
10702	**MaintPressure** maintenance Mode A/D pressure reading (Read Inputs submode) Note that this register is fixed at 0 MPa if the pressure is disabled or specified. Note 5. on Page D-86 Range: 0 to MaxPressure value	s: MPa m: MPa us: psi	n/a	FLOAT	R
10704	**ZTestCaseID** compressibility test case ID number for the following test results Range: 0 to 20	n/a	n/a	FLOAT	R

Table D-12 Modbus Register Values Message Block 64 (Maintenance/Test Values) (Sheet 2 of 2)

Number	Name and Description[1]	Unit(s)[2]	Default Value	Type	Access
10706	**ZTestCaseHCHMethod** compressibility test case HCH calculation method for the following test results Range: 1; 2	n/a	n/a	FLOAT	R
10708	**ZTest** normal Mode compressibility factor test result Range: 0 to 1	n/a	n/a	FLOAT	R
10710	**ZTestErr** normal Mode test compressibility factor result error (percentage of desired test result) Range: 0 to 100 percent	percentage	n/a	FLOAT	R
10712 – 10749	**Spare** This register number is not used.	n/a	n/a	FLOAT	R

Table D-13 Modbus Register Values Message Block 65 (ADC Calibration)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
10750	**TempADCZeroScaleCalReg** temperature ADC zero-scale calibration register value Range: 0 to 0xFFFFFF	n/a	n/a	LINT	R
10752	**TempADCFullScaleCalReg** temperature ADC full-scale calibration register value Range: 0 to 0xFFFFFF	n/a	n/a	LINT	R
10754	**PressADCZeroScaleCalReg** pressure ADC zero-scale calibration register value Range: 0 to 0xFFFFFF	n/a	n/a	LINT	R
10756	**PressADCFullScaleCalReg** pressure ADC full-scale calibration register value Range: 0 to 0xFFFFFF	n/a	n/a	LINT	R
10758 – 10799	**Spare** This register number is not used.	n/a	n/a	LINT	R

Table D-14 Modbus Register Values Message Block 66 (System Calibration) (Sheet 1 of 2)

Number	Name and Description	Unit(s)[2]	Default Value	Type	Access
10800	**TempOffsetValue** temperature offset value (from Temperature Offset Calibration submode)	s: K m: °C us: °F	0 K -273.15 °C -459.67 °F	FLOAT	R
10802	**TempGainCoefficient** temperature gain coefficient (from Temperature Gain Calibration submode)	n/a	1	FLOAT	R
10804	**PressOffsetValue** pressure offset value (from Pressure Offset Calibration submode) Note 5. on Page D-86	s: MPa m: MPa us: psi	0 MPa 0 psi	FLOAT	R
10806	**PressGainCoefficient** pressure gain coefficient (from Pressure Gain Calibration submode)	n/a	1	FLOAT	R
10808	**CurrOffsetValue** current output offset value (calculated from ZeroScaleCurrent value)	mA	0	FLOAT	R

Table D-14 Modbus Register Values Message Block 66 (System Calibration) (Sheet 2 of 2)

Number	Name and Description	Unit(s)[2]	Default Value	Type	Access
10810	**CurrGainCoefficient** current output gain coefficient (calculated from ZeroScale-Current and FullScaleCurrent values)	n/a	1	FLOAT	R
10812 – 10849	**Spare** This register number is not used.	n/a	n/a	FLOAT	R

Table D-15 Modbus Register Values Message Block 67 (Log Status) (Sheet 1 of 6)

Number	Name and Description[1,3]	Unit(s)	Default Value	Type	Access
10850	**LastDailyLogRecIndex** index of the last stored daily log record A zero value indicates that no daily log record is available (i.e., the DFI has been in operation for less than one contract day). Range: 0 to 862	n/a	n/a	INT	R

Table D-15 Modbus Register Values Message Block 67 (Log Status) (Sheet 2 of 6)

These register values are stored in NOVRAM.

Number	Name and Description[1,3]	Unit(s)	Default Value	Type	Access
10851	**LastHourlyLogRecIndex** index of the last stored hourly log record A zero value indicates that no hourly log record is available (i.e., the DFI has been in operation for less than one hour). Range: 0 to 862	n/a	n/a	INT	R
10852	**NumAvailAuditLogRecords** number of available audit log records Beginning with v3.62, the value of this register is specific to the port that is reading it. Range: 0 to 2849	n/a	n/a	INT	R

These register values are stored in NOVRAM.

Table D-15 Modbus Register Values Message Block 67 (Log Status) (Sheet 3 of 6)

Number	Name and Description[1,3]	Unit(s)	Default Value	Type	Access
10853	**NumAvailAlarmLogRecords** number of available alarm log records Beginning with v3.62, the value of this register is specific to the port that is reading it. Range: 0 to 3640	n/a	n/a	INT	R
10854	**DailyLogStatus** daily log status; see Note 11. on Page D-90	n/a	n/a	INT	R
10855	**HourlyLogStatus** hourly log status; see Note 11. on Page D-90	n/a	n/a	INT	R
10856	**AuditLogStatus** audit log status; see Note 11. on Page D-90	n/a	n/a	INT	R
10857	**AlarmLogStatus** alarm log status; see Note 11. on Page D-90	n/a	n/a	INT	R

Table D-15 Modbus Register Values Message Block 67 (Log Status) (Sheet 4 of 6)

Number	Name and Description[1,3]	Unit(s)	Default Value	Type	Access
	These register values are stored in NOVRAM.				
10858	**LastAuditLogRecIndex** index of the last stored audit log record A zero value indicates that no audit log record is available.	n/a	n/a	INT	R
10859	**LastAlarmLogRecIndex** index of the last stored alarm log record A zero value indicates that no alarm log record is available.	n/a	n/a	INT	R
10860	**PendingLastSentAuditIndex** index of the last sent (read) audit record This register is updated each time the event log is read. Beginning with v3.62, the value of this register is specific to the port that is reading it. Range: 1 to 2849	n/a	n/a	INT	R

Table D-15 Modbus Register Values Message Block 67 (Log Status) (Sheet 5 of 6)

Number	Name and Description[1,3]	Unit(s)	Default Value	Type	Access
	These register values are stored in NOVRAM.				
10861	**CurrentLastSentAuditIndex** latched index of the last sent (read) audit record This register is updated each time a "Clear Event Log" request is received. Beginning with v3.62, the value of this register is specific to the port that is reading it. Range: 1 to 2849	n/a	n/a	INT	R
10862	**PendingLastSentAlarmIndex** index of the last sent (read) alarm record This register is updated each time the event log is read. Beginning with v3.62, the value of this register is specific to the port that is reading it. Range: 1 to 3460	n/a	n/a	INT	R

Table D-15 Modbus Register Values Message Block 67 (Log Status) (Sheet 6 of 6)

Number	Name and Description[1,3]	Unit(s)	Default Value	Type	Access
	These register values are stored in NOVRAM.				
10863	**CurrentLastSentAlarmIndex** latched index of the last sent (read) alarm record This register is updated each time a "Clear Event Log" request is received. Beginning with v3.62, the value of this register is specific to the port that is reading it. Range: 1 to 3460	n/a	n/a	INT	R
10864	**Spare** This register number is not used.	n/a	n/a	INT	R
	These register values are stored in NOVRAM.				

Table D-16 Modbus Register Values Message Block 68 (Reserved)

Number	Name and Description	Unit(s)	Default Value	Type	Access
10900 – 10949	**Reserved** This register number is reserved for future use.	n/a	n/a	n/a	n/a

Table D-17 Modbus Register Values Message Block 69 (Device Status) (Sheet 1 of 4)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
10950	**DFISystemStatus1** DFI status register 1 Note 9. on Page D-89	n/a	n/a	INT	R
10951	**DFISystemStatus2** DFI status register 2 Note 10. on Page D-89	n/a	n/a	INT	R

Table D-17 Modbus Register Values Message Block 69 (Device Status) (Sheet 2 of 4)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
10952	**UFMCommChangeStatus** UFM communication change status Note 6. on Page D-87	n/a	n/a	INT	R
10953	**UFMSystemStatus** UFM system status (equivalent to UFM Modbus register 66, SystemStatus) Range: 0 to 65535 (0xFFFF)	n/a	n/a	INT	R
10954	**ChordAStatus** UFM Chord A status (equivalent to UFM Modbus register 62, StatusA) Range: 0 to 65535 (0xFFFF)	n/a	n/a	INT	R
10955	**ChordBStatus** UFM Chord B status (equivalent to UFM Modbus register 63, StatusB) Range: 0 to 65535 (0xFFFF)	n/a	n/a	INT	R

Table D-17 Modbus Register Values Message Block 69 (Device Status) (Sheet 3 of 4)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
10956	**ChordCStatus** UFM Chord C status (equivalent to UFM Modbus register 64, StatusC) Range: 0 to 65535 (0xFFFF)	n/a	n/a	INT	R
10957	**ChordDStatus** UFM Chord D status (equivalent to UFM Modbus register 65, StatusD) Range: 0 to 65535 (0xFFFF)	n/a	n/a	INT	R
10958	**SysCalStatus** DFI system calibration status register Note 7. on Page D-87	n/a	n/a	INT	R
10959	**AGA8BaseCalcStatus** AGA8 base-condition compressibility calculation status Note 8. on Page D-88	n/a	n/a	INT	R

Table D-17 Modbus Register Values Message Block 69 (Device Status) (Sheet 4 of 4)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
10960	**AGA8FlowCalcStatus** AGA8 flow-condition compressibility calculation status Note 8. on Page D-88	n/a	n/a	INT	R
10961	**AGA8TestCalcStatus** AGA8 compressibility test case calculation status **Note 8. on Page D-88**	n/a	n/a	INT	R
10962 – 10964	**Spare** This register number is not used.	n/a	n/a	INT	R

Table D-18 Modbus Register Values Message Block 70 (Device Information) (Sheet 1 of 2)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
11000	**Version** software version (without the decimal point) For example, 100 would indicate version 1.00 and 310 would indicate version 3.10. Register 11000, 32-bit integer, interpreted as four 8-bit characters. (e.g. 00 00 01 75 hex = 373 decimal = version 3.73.)	n/a	n/a	LINT	R
11002	**Date** software compilation date (mmddyy) For example, 71697 would indicate July 16, 1997 (leading zeros are suppressed).	n/a	n/a	LINT	R
11004	**DeviceNumber** CPU device number (read from the Host processor upon start-up)	n/a	n/a	LINT	R
11006	**SerialNumber** serial number (without the hyphen)	n/a	n/a	LINT	R

Table D-18 Modbus Register Values Message Block 70 (Device Information) (Sheet 2 of 2)

Number	Name and Description[1]	Unit(s)	Default Value	Type	Access
11008	**BoardRevision** DFI board revision number For example, 1 would indicate revision A, 2 would indicate revision B, etc.	n/a	n/a	LINT	R
11010	**FPGARevision** FPGA revision number For example, 10 would indicate revision 1.0, 11 would indicate revision 1.1, etc.	n/a	n/a	LINT	R
11012 – 11049	**Spare** This register number is not used.	n/a	n/a	LINT	R

Table D-19 Modbus Register Values Message Block 71 (Integer Memory Contents)

Number	Name and Description	Unit(s)	Default Value	Type	Access
11050 – 11064	**IntMem** DFI memory starting at address DFIMemStartAddr (Message Block #55) in integer format	n/a	n/a	INT	R

Table D-20 Modbus Register Values Message Block 72 (Floating Point Memory Contents)

Number	Name and Description	Unit(s)	Default Value	Type	Access
11100 – 11149	**FloatMem** DFI memory starting at address DFIMemStartAddr (Message Block #55) in floating point format	n/a	n/a	FLOAT	R

Table D-21 Modbus Register Values Message Block 73 (Frequency Feedback Information) (Sheet 1 of 4)

Number	Name and Description	Unit(s)^2	Default Value	Type	Access
11150	**BatchTimeSec** duration of the last completed batch expressed in seconds	seconds	n/a	FLOAT	R
11152	**BatchTimeHours** duration of the last completed batch expressed in hours	hours	n/a	FLOAT	R
11154	**AvgBatchTimeHours** average duration of the previous 8 batches expressed in hours	hours	n/a	FLOAT	R
11156	**FeedbackStatus** Feedback status value encoded as follows: 0 = forward flow 1 = reverse flow	n/a	n/a	FLOAT	R
11158	**FreqFeedbackPulseCnt** number of frequency pulses fed-back since the last frequency compensation	pulses	n/a	FLOAT	R

Table D-21 Modbus Register Values Message Block 73 (Frequency Feedback Information) (Sheet 2 of 4)

Number	Name and Description	Unit(s)[2]	Default Value	Type	Access
11160	**VolPerPulse** volume represented by one frequency output pulse	s: m^3/pulse m: m^3/pulse us: ft^3/pulse	n/a	FLOAT	R
11162	**FreqFeedbackVol** volume represented by the fed-back frequency pulses since the last frequency compensation	s: m^3 m: m^3 us: ft^3	n/a	FLOAT	R
11164	**PrevDesiredVol** volume desired to be output since the last frequency compensation	s: m^3 m: m^3 us: ft^3	n/a	FLOAT	R
11166	**VolError** error in the volume output since the last frequency compensation Equal to (PrevDesiredVol minus FreqFeedbackVol).	s: m^3 m: m^3 us: ft^3	n/a	FLOAT	R
11168	**DesiredVol** volume desired to be output during the current frequency output	s: m^3 m: m^3 us: ft^3	n/a	FLOAT	R

Table D-21 Modbus Register Values Message Block 73 (Frequency Feedback Information) (Sheet 3 of 4)

Number	Name and Description	Unit(s)^2	Default Value	Type	Access
11170	**TotalVFRError** total volumetric flow rate error	s: m^3/hr m: Note 4. on Page D-86 us: Note 4. on Page D-86	n/a	FLOAT	R
11172	**VFRErrorCompensation** amount of total volumetric flow rate error to be compensated for in the current frequency output Equal to (TotalVFRError Þ FreqFeedbackCorrectionPct). See Modbus Message Block 51. Note 5. on Page D-86	s: m^3/hr m: Note 4. on Page D-86 us: Note 4. on Page D-86	n/a	FLOAT	R
11174	**AbsVFR** absolute value of the uncorrected volumetric flow rate Note 5. on Page D-86	s: m^3/hr m: Note 4. on Page D-86 us: Note 4. on Page D-86	n/a	FLOAT	R
11176	**OutputVFR** flow rate Equal to (AbsVFR + VFRErrorCompensation). Note 5. on Page D-86	s: m^3/hr m: Note 4. on Page D-86 us: Note 4. on Page D-86	n/a	FLOAT	R

Table D-21 Modbus Register Values Message Block 73 (Frequency Feedback Information) (Sheet 4 of 4)

Number	Name and Description	Unit(s)[2]	Default Value	Type	Access
11178 – 11199	**Spare** This register number is not used.	n/a	n/a	FLOAT	R

NOTES:

1. Input values are clipped according to the acceptable values listed. Output values are not clipped; acceptable values are only included to indicate expected values under normal circumstances.
2. s = value stored
   m = Metric value
   us = U.S. Customary value
3. This is accessible beginning with firmware version 3.00.
4. Unit is determined by the value of the UnitsSystem and VolFlowRateTimeUnit registers as follows:

UnitsSystem	*VolFlowRateTimeUnit*	*Resulting Unit*
U.S. Customary	vol/sec	ft^3/sec
U.S. Customary	vol/hr	ft^3/hr
U.S. Customary	vol/day	ft^3/day
Metric	vol/sec	m^3/sec
Metric	vol/hr	m^3/hr
Metric	vol/day	m^3/day

5. Pressure is either absolute or gauge depending upon the value of the InputPressureUnit register.

6. UFMCommChangeStatus encoding:

0	Awaiting UFM communication parameter change.
1	UFM communication parameters changed successfully.
2	DFI SCI not ready to transmit.
3	Invalid request message length.
4	DFI SCI transmit data register not empty.
5	SCI unknown error.
6	An error occurred while decoding the UFM response message.
7	An unknown error occurred while decoding the UFM response message
8	A receiver overrun occurred while receiving the UFM response message.
9	A parity error was detected in the UFM response message.
10	The UFM response message was not received within the allotted time.
11	The UFM response message overflowed the receive buffer.
12	Unknown error during receipt of the UFM response message.
13	Unable to change the UFM communication (SCI) parameters.

7. The SysCalStatus register contains four nibbles (where a nibble is a 4-bit value). Each nibble contains the status value for a calibration submode as listed below:

Bits 0 - 3, System Temperature Offset Calibration Status
Bits 4 - 7, System Temperature Gain Calibration Status
Bits 8 - 11, System Pressure Offset Calibration Status
Bits 12 - 15, System Pressure Gain Calibration Status

The encoding for each nibble (in hexadecimal) is as follows:

Hex	*Value Status*
0x0	System calibration not requested.
0x1	System calibration in progress.
0xB	Error during system calibration. This may be due to the user forcing the calibration submode by changing the Mode or MaintenanceSubmode, errors communicating with the Analog-to-Digital Converter (ADC) during the system calibration, inability to successfully perform an ADC self-calibration, etc.
0xC	System calibration value cleared (reset to the default value).

0xD System calibration done (completed successfully).

8. AGA8 calculation status encoding is as follows:

0 The AGA8 calculation was performed successfully.
1 (Applies to Method 1 only.) H_CH could not be calculated due to conflicting user inputs.
2 Bmix could not be calculated due to an attempt to take the square root of a negative number.
3 H_CH could not be calculated as the number of iterations for the selected gross method exceeded the limit.
4 The virial coefficient for either the equivalent hydrocarbon or carbon dioxide is negative; the natural gas mixture third virial coefficient was not calculated.
5 The molar density was not bounded (molar density estimate set to zero).
6 The iterative algorithm to estimate the molar density did not converge; the molar density estimate was set to zero.
10 Attempt to divide by zero during the air mass density calculation.
11 (Applies to Method 1 only.) Attempt to divide by zero during HN_GERG calculation.
12 (Applies to Method 1 only.) Attempt to divide by zero during equivalent hydrocarbon mole fraction calculation.
13 (Applies to Method 1 only.) Attempt to divide by zero during H_CH calculation.
14 (Applies to Method 1 only.) Attempt to divide by zero during the calculation of the compressibility estimate at density reference conditions.
15 Attempt to divide by zero during the calculation of the new compressibility estimate at specific gravity reference conditions.
16 Attempt to divide by zero during the calculation of the ratio for determining if the H_CH calculation iterative loop can be exited.
17 (Applies to Method 2 only.) Attempt to divide by zero during the calculation of the equivalent hydrocarbon molar mass.
18 Attempt to divide by zero during the calculation of the mixture molar mass.
19 Attempt to divide by zero during the calculation of the new density estimate.
20 Attempt to divide by zero during the calculation of the density estimate.
21 (Applies to flow condition only.) Attempt to divide by zero during the calculation of the flow-to-base conversion factor.

9. The DFI System Status 1 register is encoded bitwise as follows:

Bit 0, DUART invalid interrupt (this situation may occur but does not adversely affect DFI operation)
Bit 1, Port A unexpected receive interrupt
Bit 2, Port B unexpected receive interrupt
Bit 3, Port A unexpected transmit interrupt
Bit 4, Port B unexpected transmit interrupt
Bit 5, Port A unexpected RTU Modbus time-out
Bit 6, Port B unexpected RTU Modbus time-out
Bit 7, Port A unexpected RTU Modbus time-out while using ASCII Modbus
Bit 8, Port B unexpected RTU Modbus time-out while using ASCII Modbus
Bit 9, DFI-Host port transmit error
Bit 10, DFI-Host port receive error
Bit 11, Error communicating with the analog-to-digital converter, digital-to-analog converter, or real-time clock (serial peripheral interface error)

10. The DFI System Status 2 register is encoded bitwise as follows:

Bit 0, Error trying to program an EEPROM byte
Bit 1, Modbus block 51 invalid checksum
Bit 2, Modbus block 53 invalid checksum
Bit 3, Modbus block 54 invalid checksum
Bit 4, Modbus block 56 invalid checksum
Bit 5, Modbus block 66 invalid checksum
Bit 6, Modbus block 61 invalid checksum
Bit 7, Temperature analog-to-digital converter communication error
Bit 8, Pressure analog-to-digital converter communication error
Bit 9, Temperature analog-to-digital converter calibration error
Bit 10, Pressure analog-to-digital converter calibration error
Bit 11, Reserved
Bit 12, Program memory error
Bit 13, Internal random access memory error

Bit 14, External random access memory error
Bit 15, Software error (invalid value)

11. The log status registers encoding is as follows:

Bit 0, A record could not be queued due to the queue being full. (Due to the log memory architecture, log records must be queued in RAM until the record can be written to the non-volatile log memory.)
Bit 1, The log could not be read due to the inability to suspend a log sector erasure in progress.
Bit 2, Not used.
Bit 3, Not used.
Bit 4, Sector A - error initiating a sector erasure.
Bit 5, Sector A - a byte to be programmed was not previously erased.
Bit 6, Sector A - the log memory indicated a time out while attempting to program a byte.
Bit 7, Sector A - a system time-out occurred while attempting to program a byte.
Bit 8, Sector A - a time-out error occurred while attempting to erase a sector.
Bit 9, Sector A - not used.
Bit 10, Sector B - error initiating a sector erasure.
Bit 11, Sector B - a byte to be programmed was not previously erased.
Bit 12, Sector B - the log memory indicated a time out while attempting to program a byte.
Bit 13, Sector B - a system time-out occurred while attempting to program a byte.
Bit 14, Sector B - a time-out error occurred while attempting to erase a sector.
Bit 15, Sector B - not used.

12. The UFM data quality indicators are as follows:

0 = all four chords working
bit 0 set = Chord A failed
bit 1 set = Chord B failed
bit 2 set = Chord C failed
bit 3 set = Chord D failed
bit 4 to 7 = reserved
bit 8 to 16 = maps to SystemStatus bits 0 to 8
bit 8 set = reserved
bit 9 set = Pulse Accumulator error
bit 10 set = HC11 Ram Memory error
bit 11 set = HC11 Program Memory error
bit 12 set = EEPROM CRC check failed
bit 13 set = DSP Program Memory error
bit 14 set = DSP Y-Memory error
bit 15 set = DSP X-Memory error
bit 16 set = number of operating chords below desired amount
bit 17 set = average flow velocity range error
bit 18 set = pulses per batch range error

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INDEX OF REGISTERS

APPENDIX E, SYSTEM SET-UP

E.1 SYSTEM SET-UP FLOW CHARTS

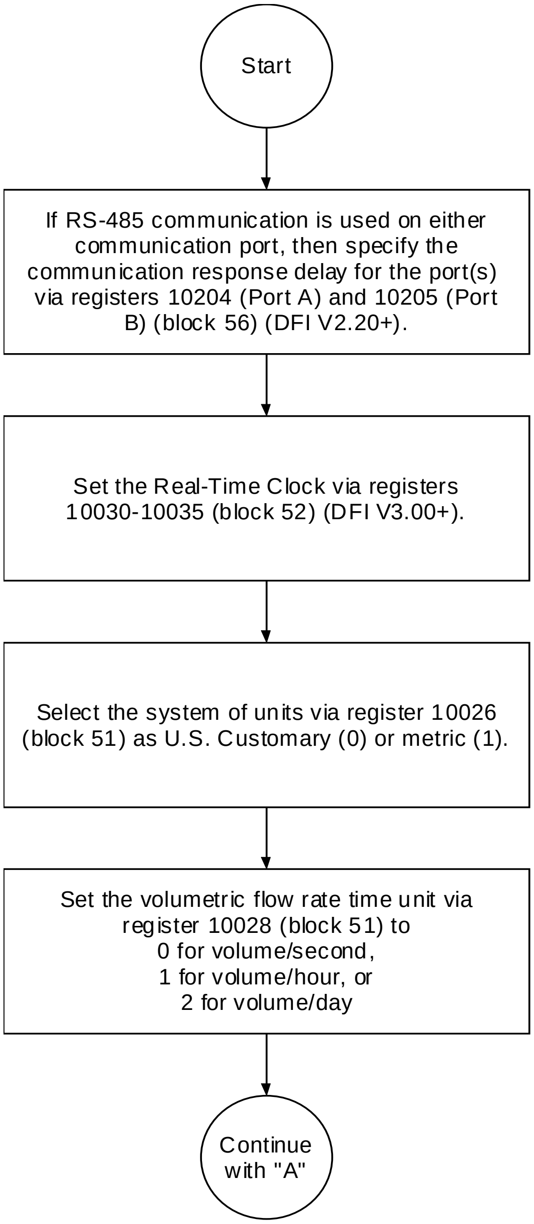


Figure E-1 Start Flow Chart

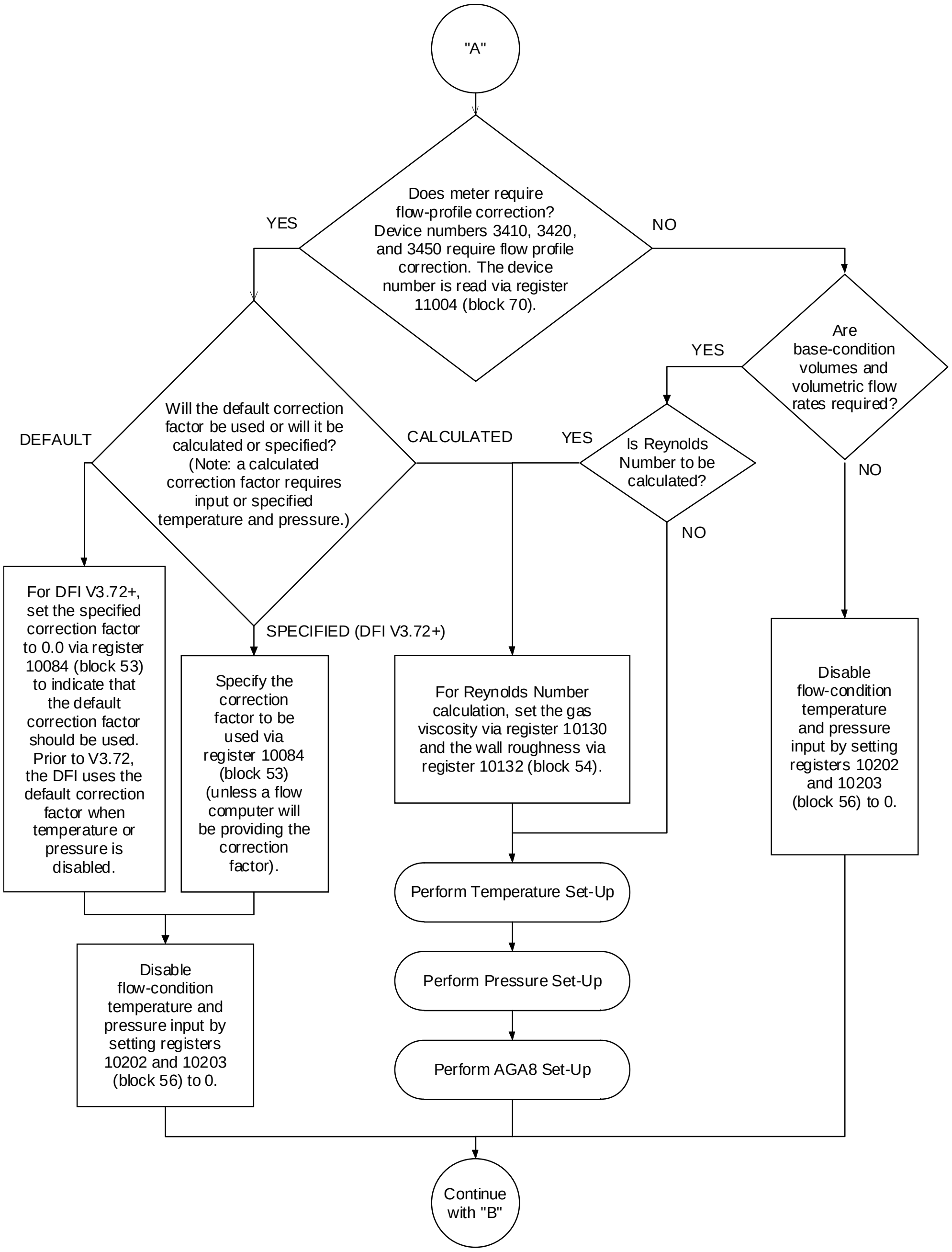


Figure E-2 "A" Flow Chart

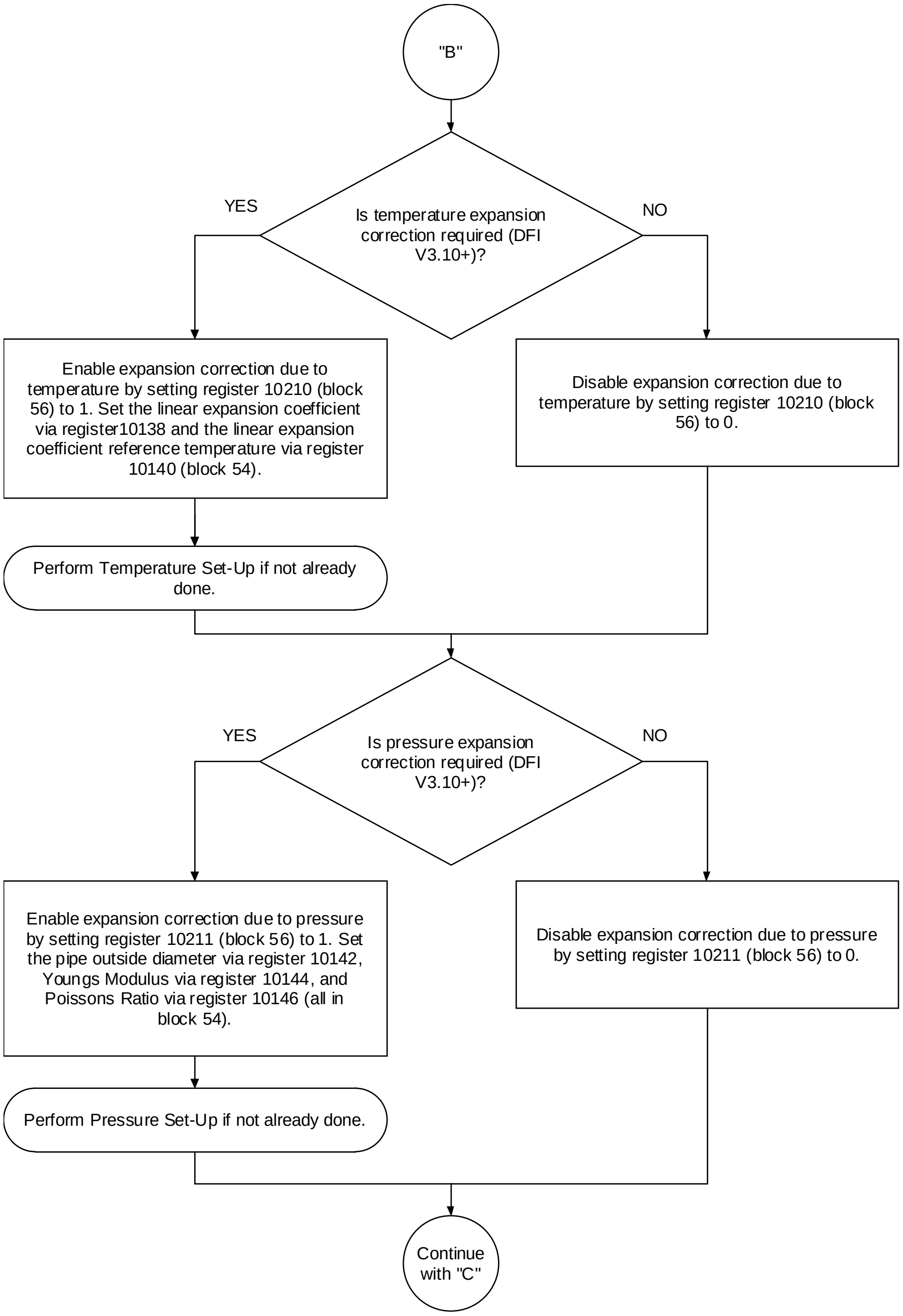


Figure E-3 "B" Flow Chart

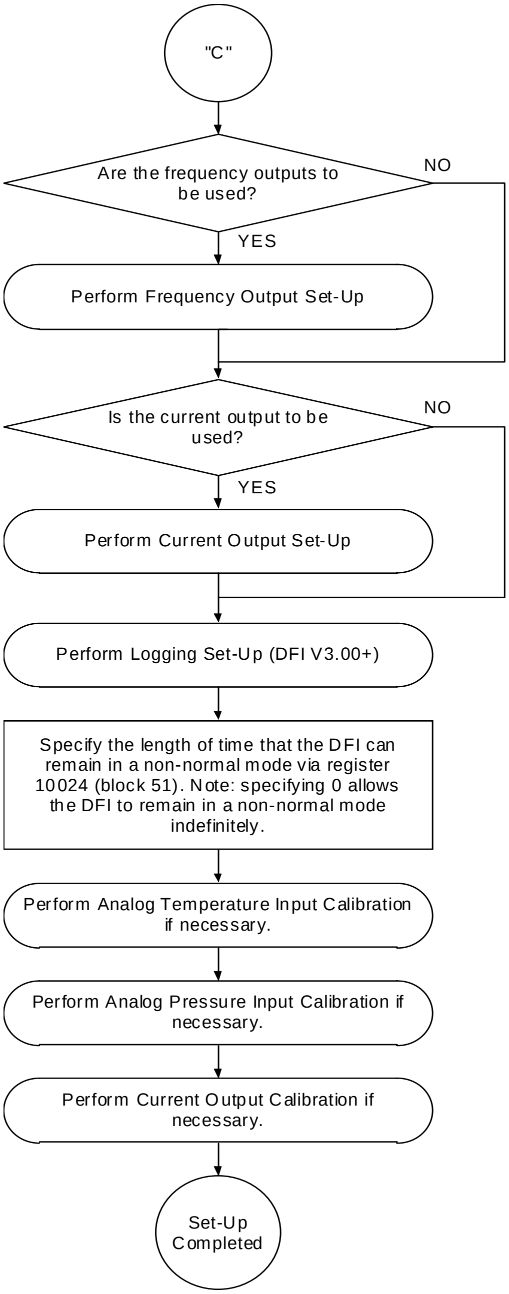


Figure E-4 "C" Flow Chart

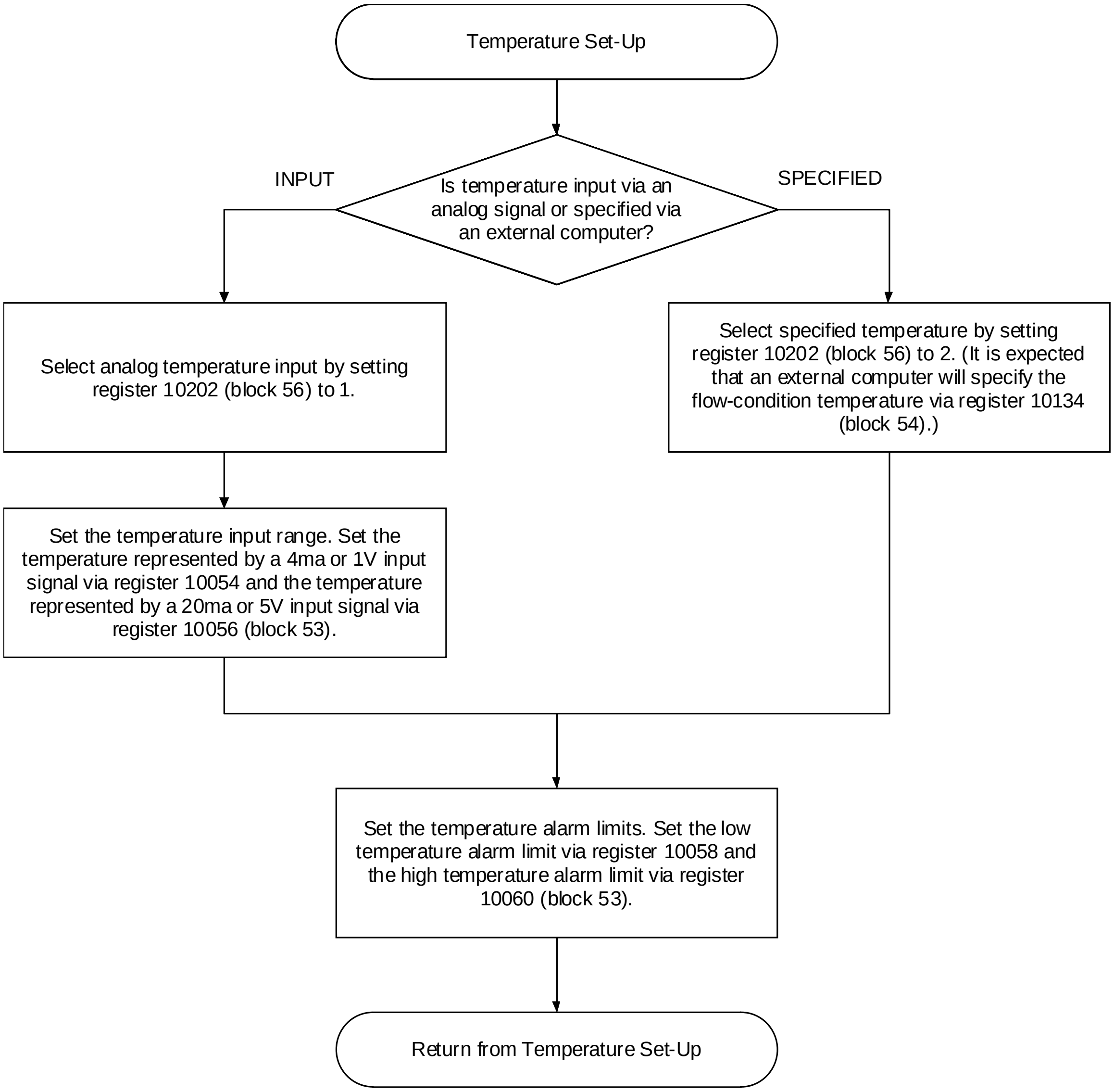


Figure E-5 Temperature Set-Up Flow Chart

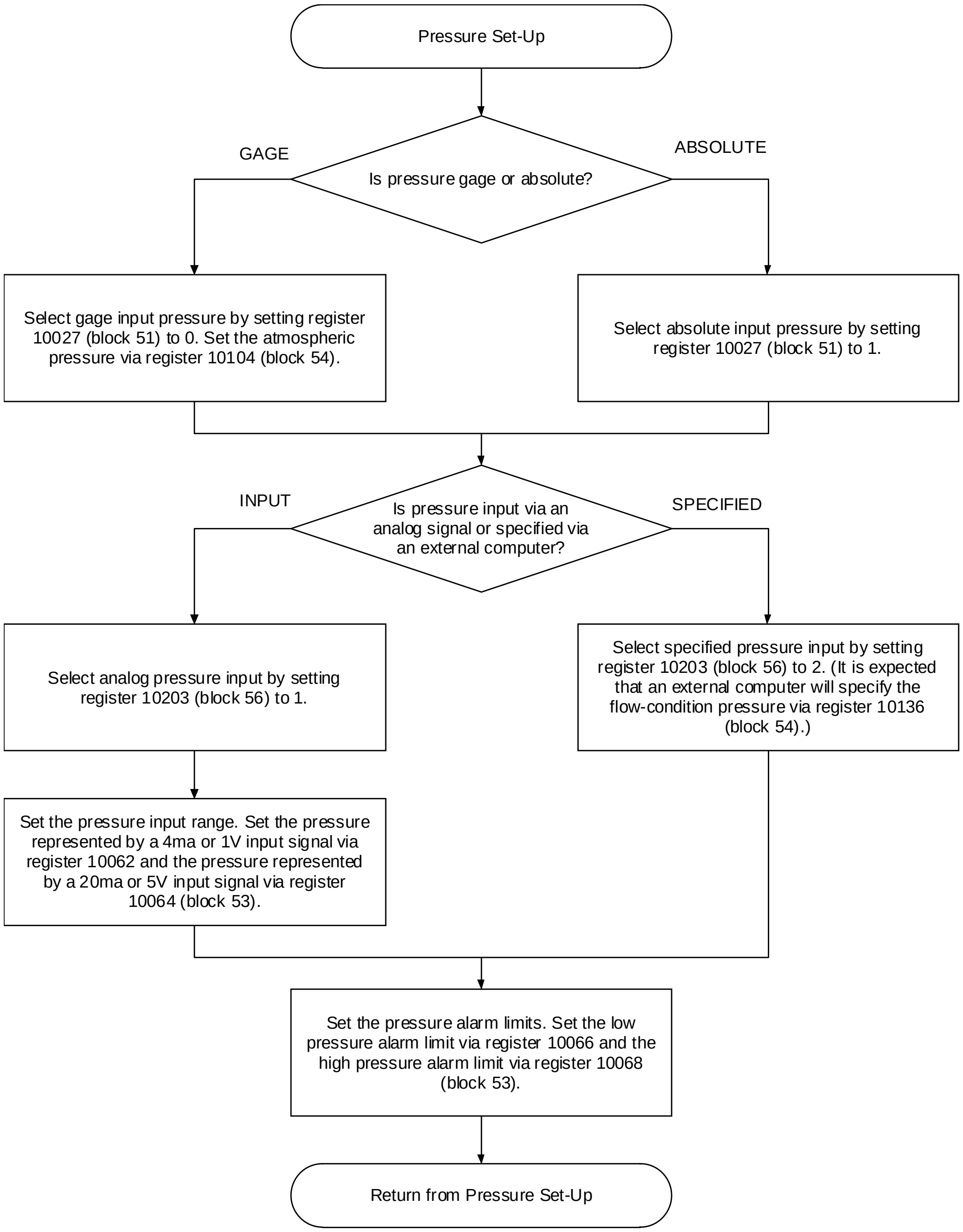


Figure E-6 Pressure Set-Up Flow Chart

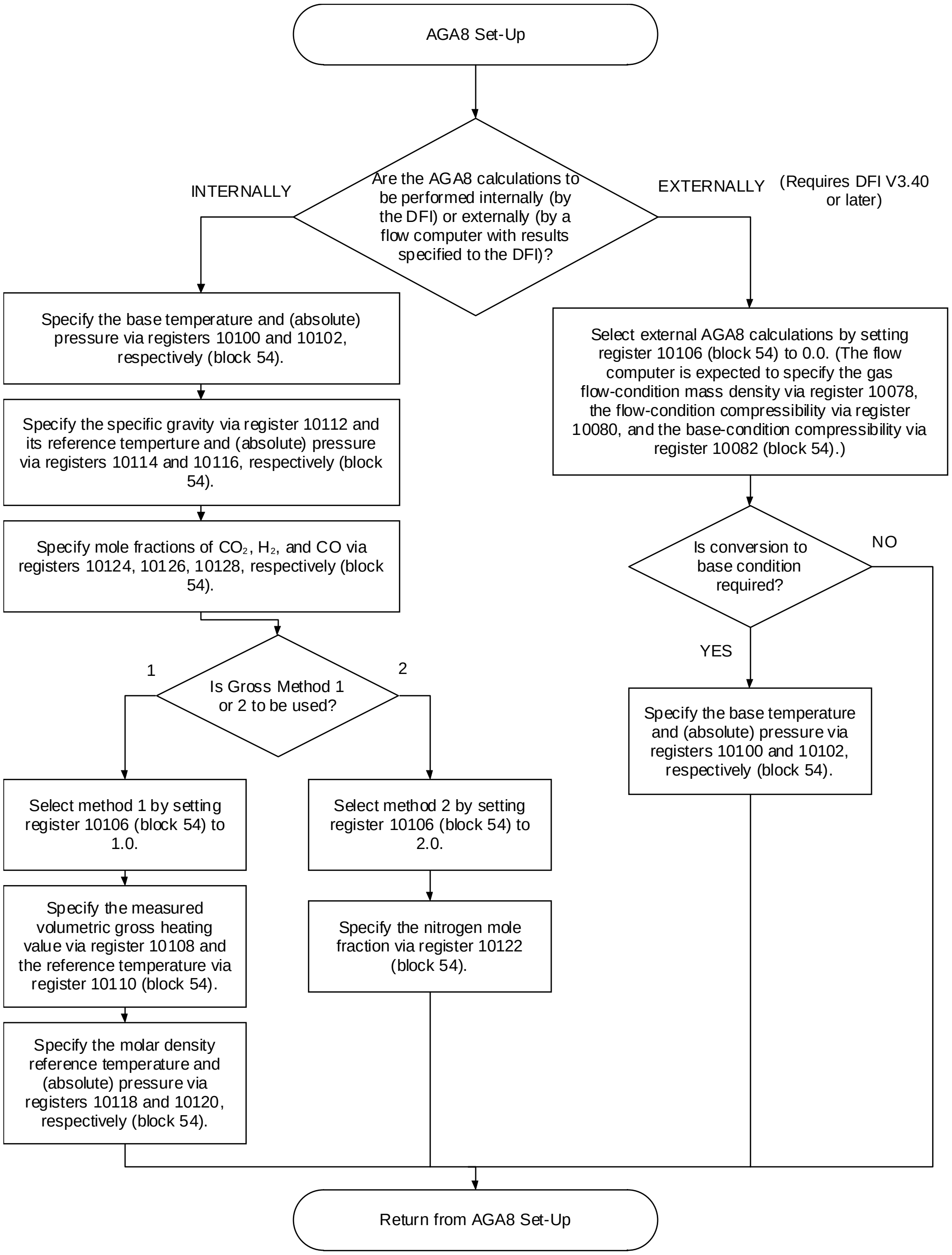
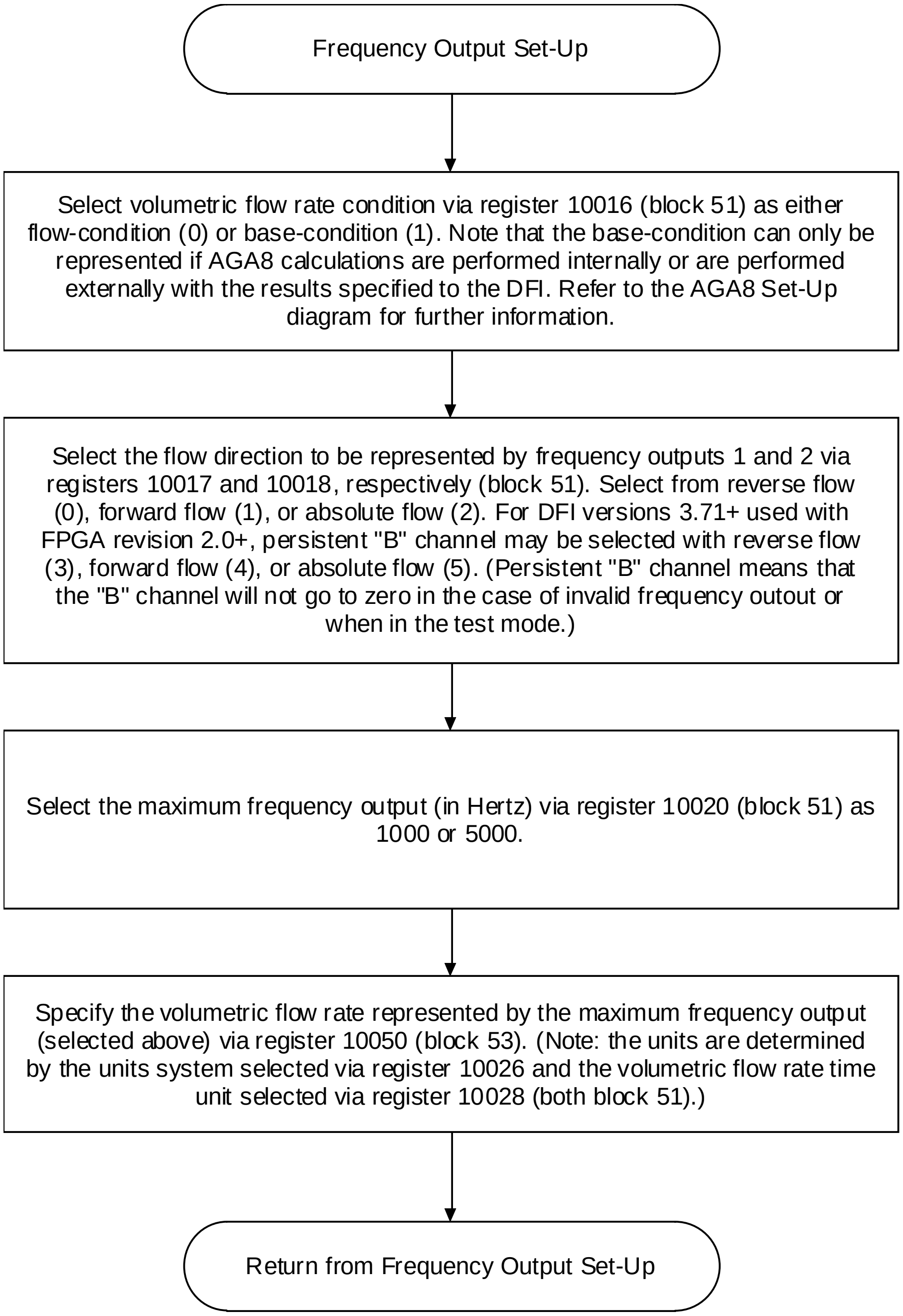


Figure E-7 AGA8 Set-Up Flow Chart



Frequency Output Set-Up

Select volumetric flow rate condition via register 10016 (block 51) as either flow-condition (0) or base-condition (1). Note that the base-condition can only be represented if AGA8 calculations are performed internally or are performed externally with the results specified to the DFI. Refer to the AGA8 Set-Up diagram for further information.

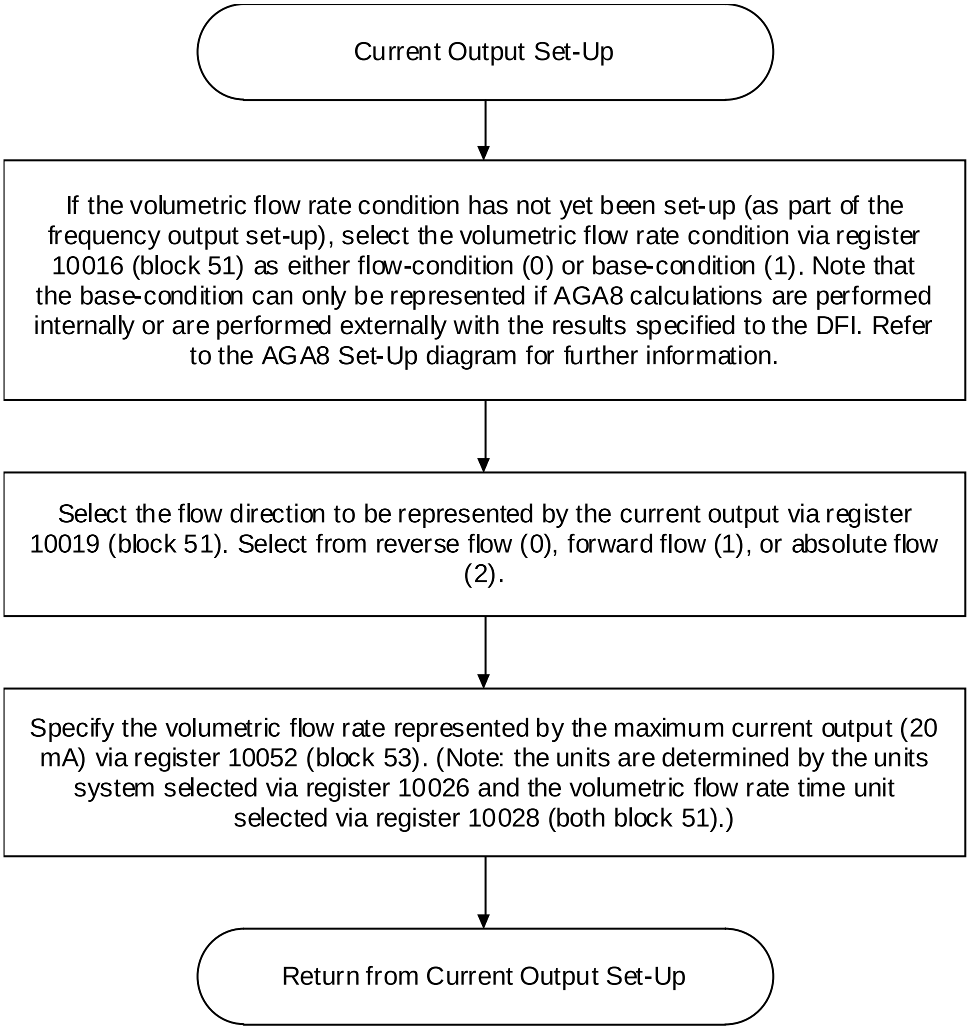
Select the flow direction to be represented by frequency outputs 1 and 2 via registers 10017 and 10018, respectively (block 51). Select from reverse flow (0), forward flow (1), or absolute flow (2). For DFI versions 3.71+ used with FPGA revision 2.0+, persistent "B" channel may be selected with reverse flow (3), forward flow (4), or absolute flow (5). (Persistent "B" channel means that the "B" channel will not go to zero in the case of invalid frequency outout or when in the test mode.)

Select the maximum frequency output (in Hertz) via register 10020 (block 51) as 1000 or 5000.

Specify the volumetric flow rate represented by the maximum frequency output (selected above) via register 10050 (block 53). (Note: the units are determined by the units system selected via register 10026 and the volumetric flow rate time unit selected via register 10028 (both block 51).)

Return from Frequency Output Set-Up

Figure E-8 Frequency Output Set-Up Flow Chart



Current Output Set-Up

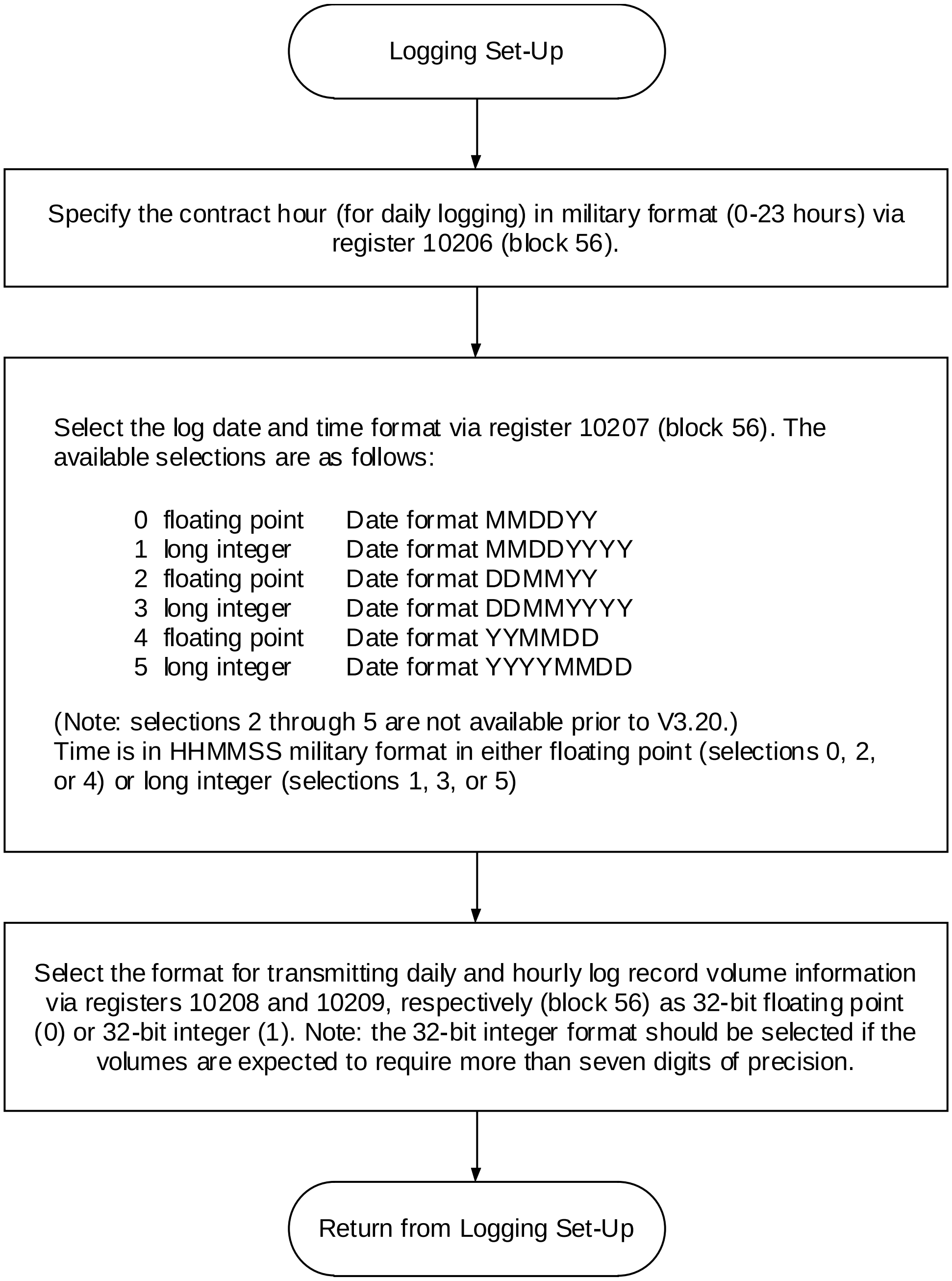
If the volumetric flow rate condition has not yet been set-up (as part of the frequency output set-up), select the volumetric flow rate condition via register 10016 (block 51) as either flow-condition (0) or base-condition (1). Note that the base-condition can only be represented if AGA8 calculations are performed internally or are performed externally with the results specified to the DFI. Refer to the AGA8 Set-Up diagram for further information.

Select the flow direction to be represented by the current output via register 10019 (block 51). Select from reverse flow (0), forward flow (1), or absolute flow (2).

Specify the volumetric flow rate represented by the maximum current output (20 mA) via register 10052 (block 53). (Note: the units are determined by the units system selected via register 10026 and the volumetric flow rate time unit selected via register 10028 (both block 51).)

Return from Current Output Set-Up

Figure E-9 Current Output Set-UP Flow Chart



Specify the contract hour (for daily logging) in military format (0-23 hours) via register 10206 (block 56).

Select the log date and time format via register 10207 (block 56). The available selections are as follows:

0	floating point	Date format MMDDYY
1	long integer	Date format MMDDYYYY
2	floating point	Date format DDMMYY
3	long integer	Date format DDMMYYYY
4	floating point	Date format YYMMDD
5	long integer	Date format YYYYMMDD

(Note: selections 2 through 5 are not available prior to V3.20.)
Time is in HHMMSS military format in either floating point (selections 0, 2, or 4) or long integer (selections 1, 3, or 5)

Select the format for transmitting daily and hourly log record volume information via registers 10208 and 10209, respectively (block 56) as 32-bit floating point (0) or 32-bit integer (1). Note: the 32-bit integer format should be selected if the volumes are expected to require more than seven digits of precision.

Figure E-10 Logging Set-Up Flow Chart

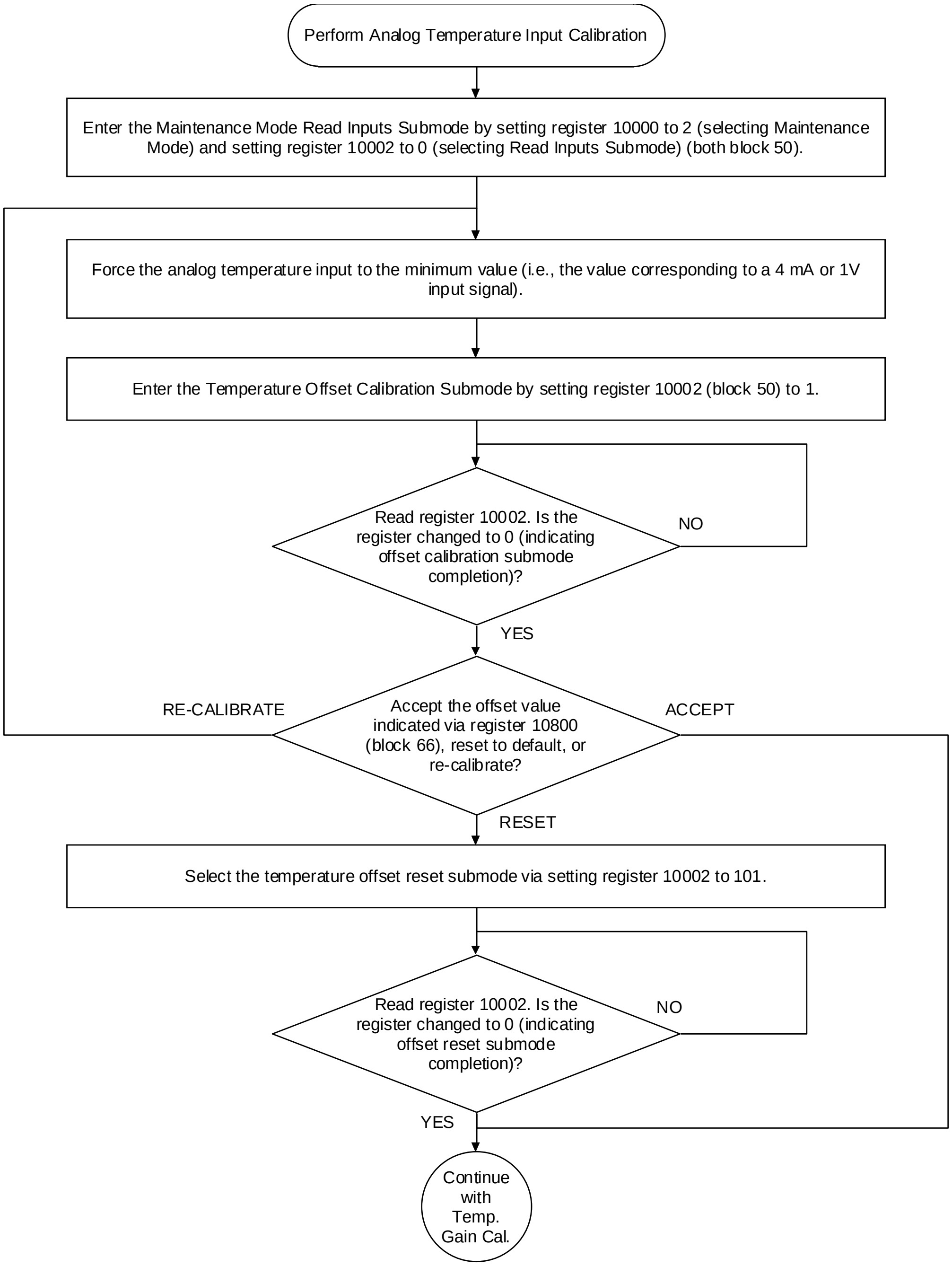


Figure E-11 Perform Analog Temperature Input Calibration Flow Chart

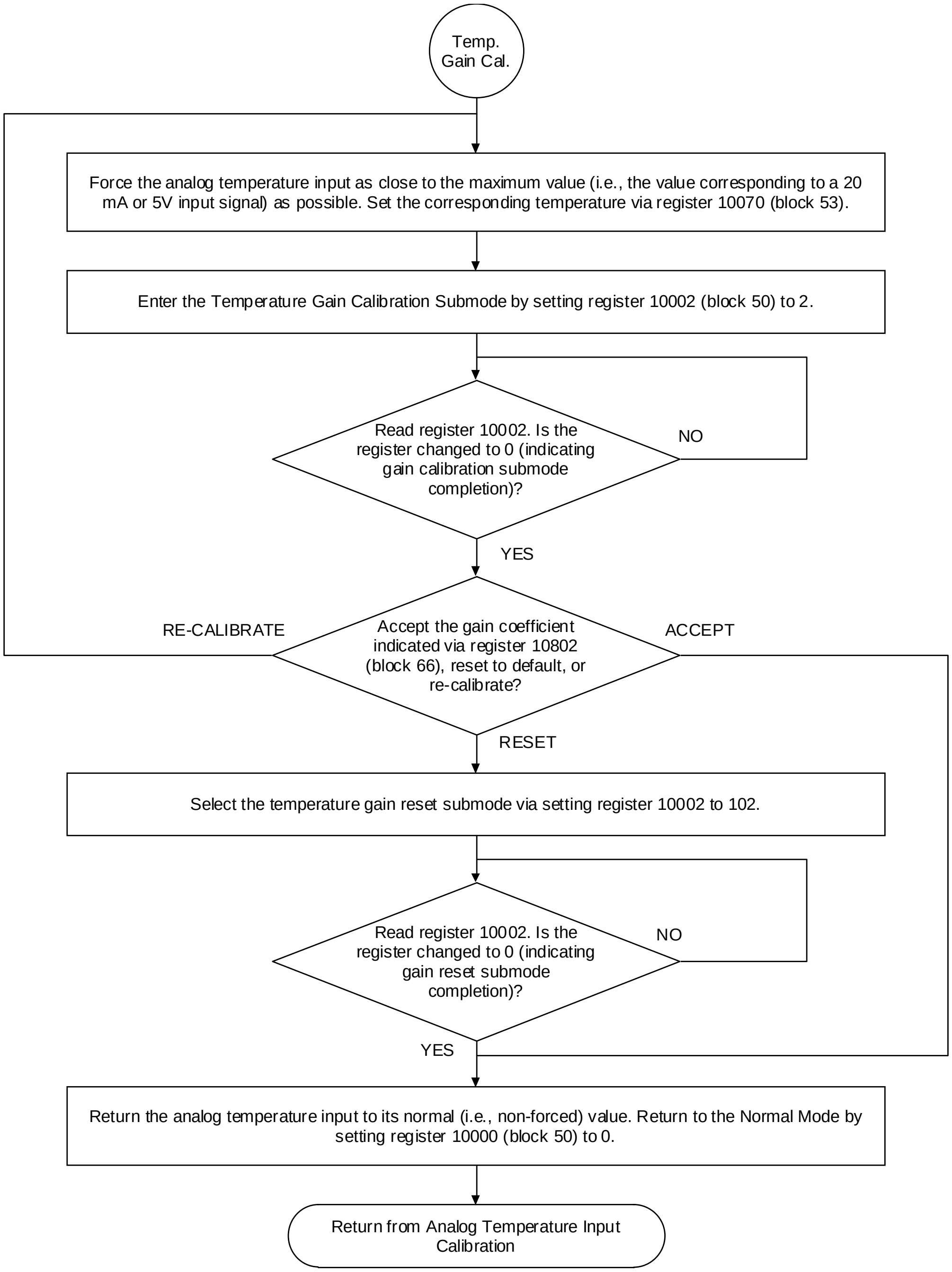


Figure E-12 Temperature Gain Cal. Flow Chart

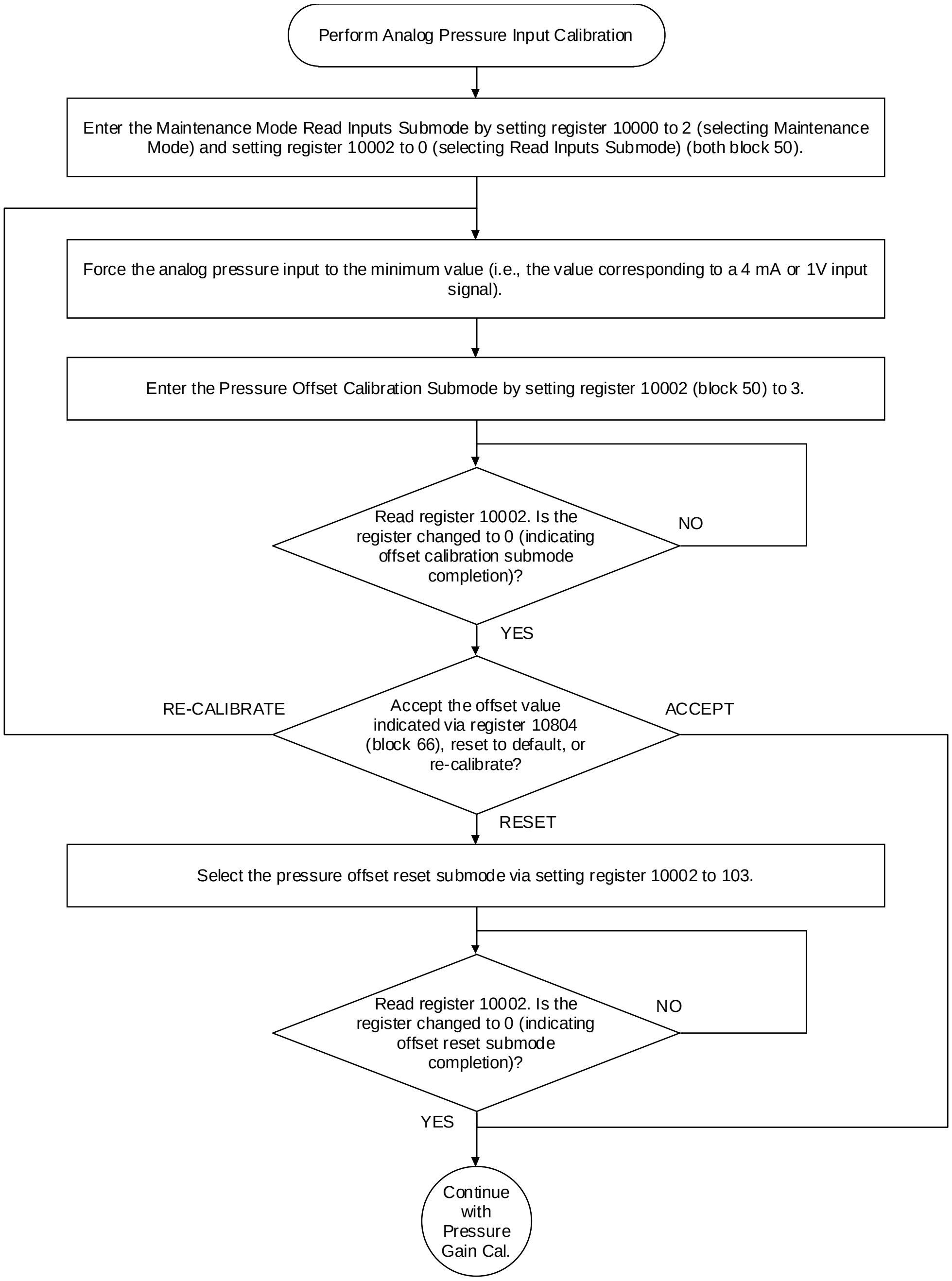


Figure E-13 Perform Analog Pressure Input Calibration Flow Chart

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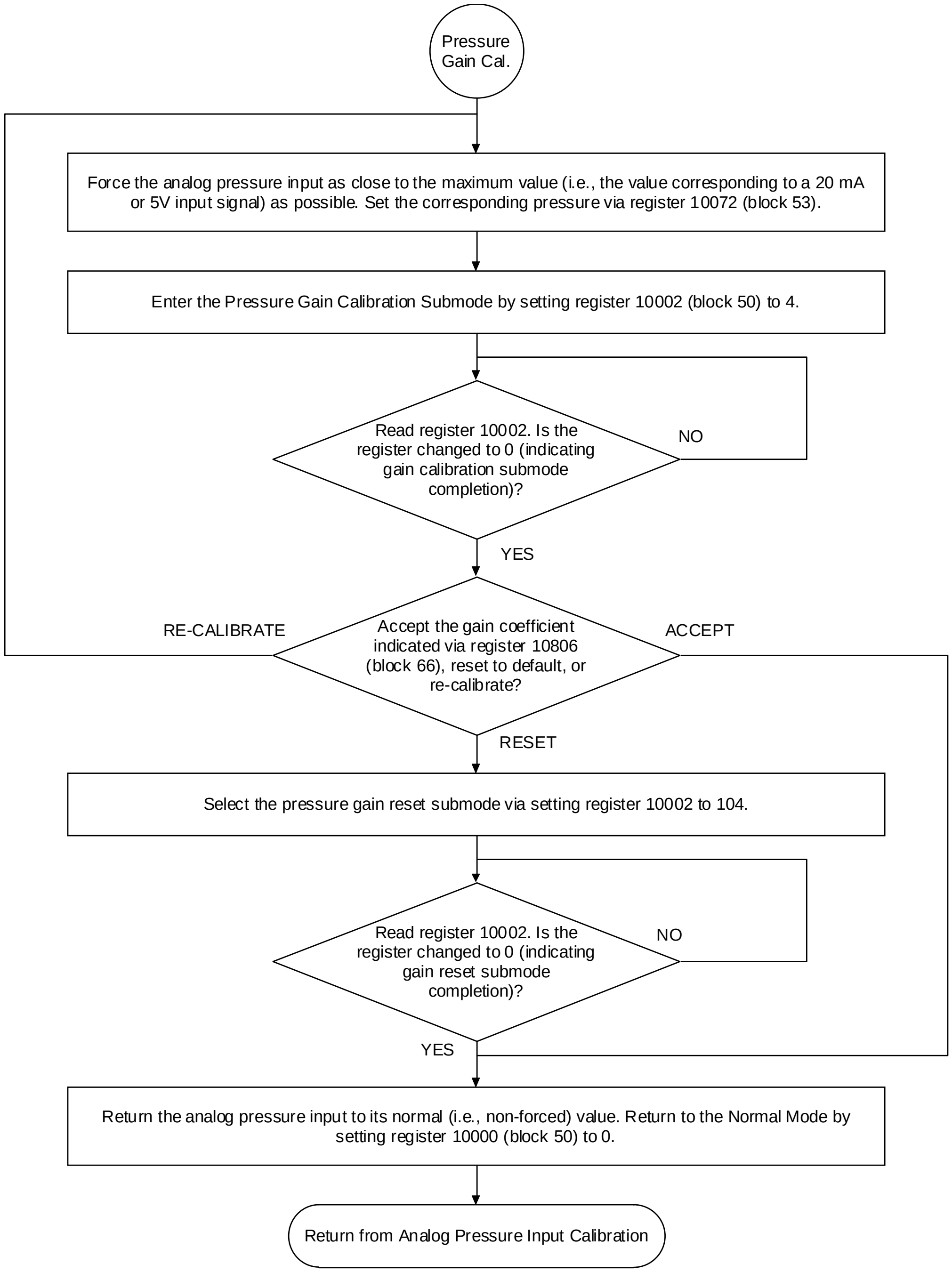

Figure E-14 Pressure Gain Cal. Flow Chart

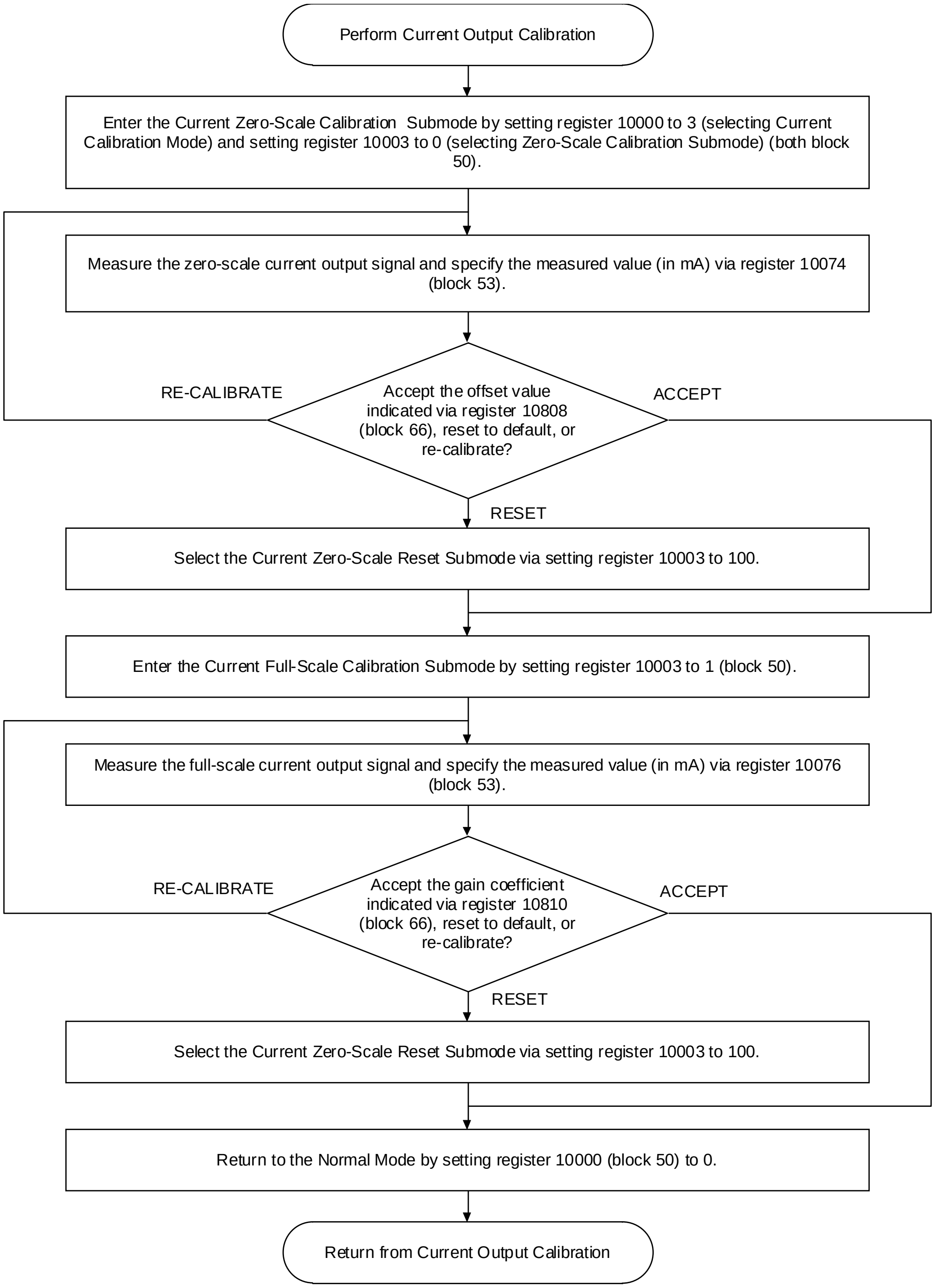

Figure E-15 Perform Current Output Calibration Flow Chart

E.2 VOLUME CALCULATIONS

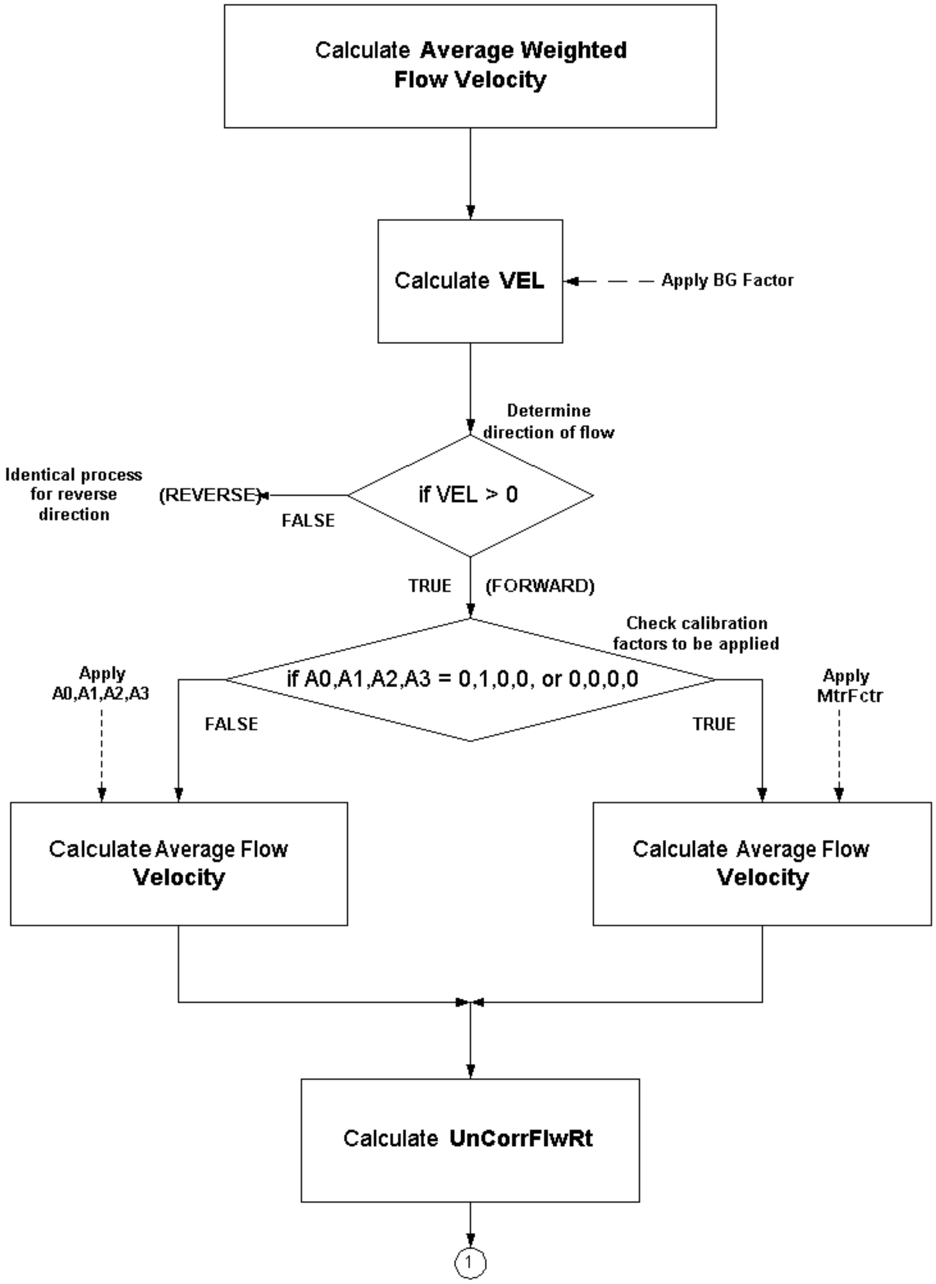

Figure E-16 Volume Calculations (Sheet 1 of 2)

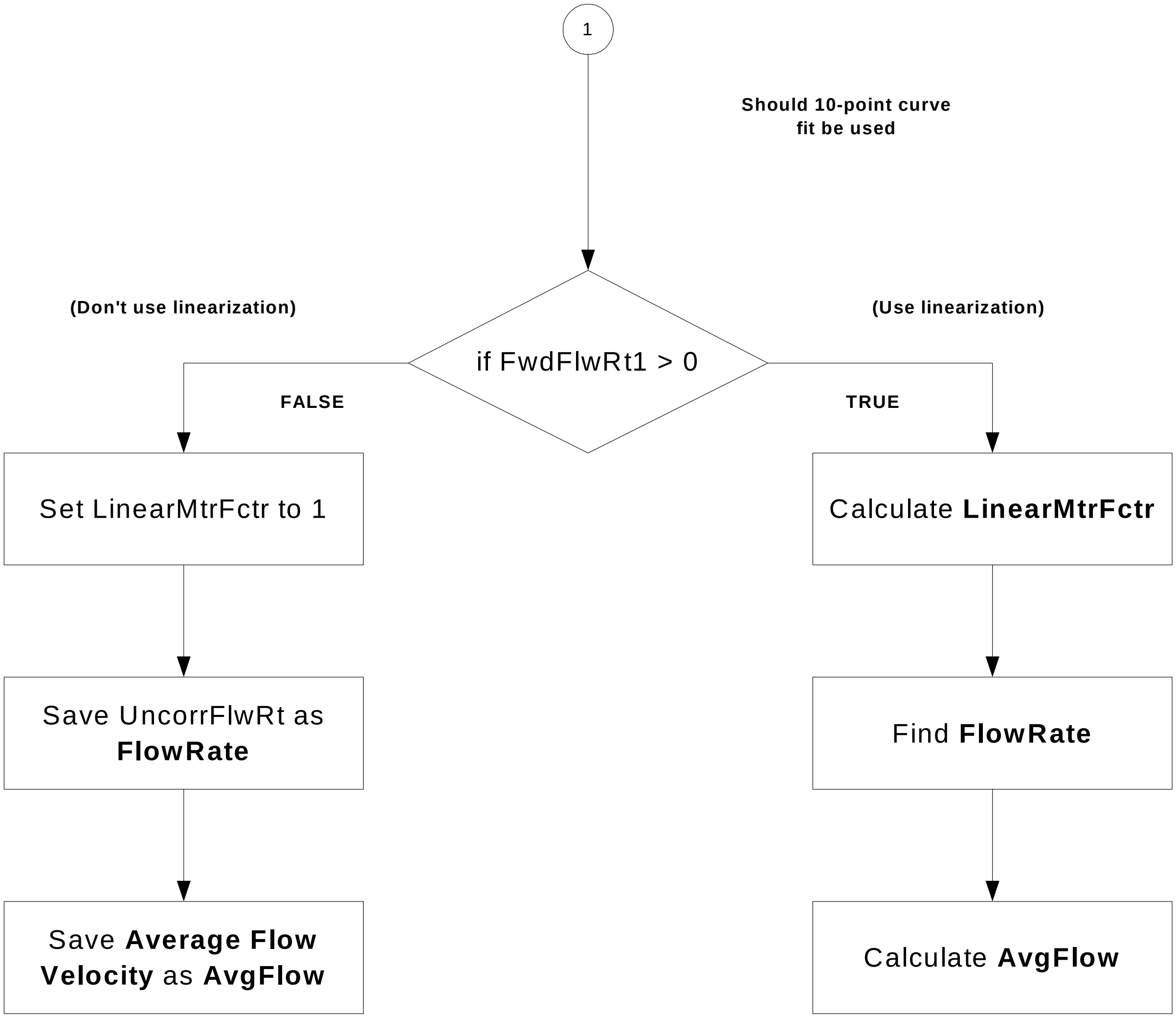

Figure E-17 Volume Calculations (Sheet 2 of 2)

APPENDIX F, MISCELLANEOUS EQUATIONS

F.1 CONVERSION FACTORS PER UNIT OF MEASUREMENT

Pulse Factor:

$$\text{Pulses/Ft}^3 = \frac{3600 \bullet [\text{Frequency Full Scale}]\ (\text{Refer to MB Reg. } 10020)}{\text{Frequency Full Scale Volume Flow Rate (Refer to MB Reg. } 10050)}$$

K Factor:

$$\text{Ft}^3\text{/Pulse} = \frac{\text{Frequency Full Scale Volume Flow Rate (Refer to MB Reg. } 10050)}{3600 \bullet [\text{Frequency Full Scale}]\ (\text{Refer to MB Reg. } 10020)}$$

Volume Flow Rate:

$$Q(\text{ACFH}) = 19.63495 \bullet D^2 \bullet \text{Velocity (fps) (Diameter "D" is in inches)}$$

$$Q(\text{ACMH}) = 2827.433 \bullet D^2 \bullet \text{Velocity (m/s) (Diameter "D" is in inches)}$$

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APPENDIX G, ENGINEERING DRAWINGS

G.1 ULTRASONIC METER DRAWINGS

This appendix contains the following engineering drawing(s) for the Ultrasonic Meter:

DE-15044	System Wiring Diagram Ultrasonic Flowmeter Model 3400, 3410, and 3420
D-08253	Outline and Dimensional Multipath Ultrasonic Flowmeter 4” - 36” 300 ANSI R.F. and RTJ FLG w/T-Slot Extractable Transducer
D-08254	Outline and Dimensional Multipath Ultrasonic Flowmeter 4” - 36” 600 ANSI R.F. and RTJ FLG w/T-Slot Extractable Transducer

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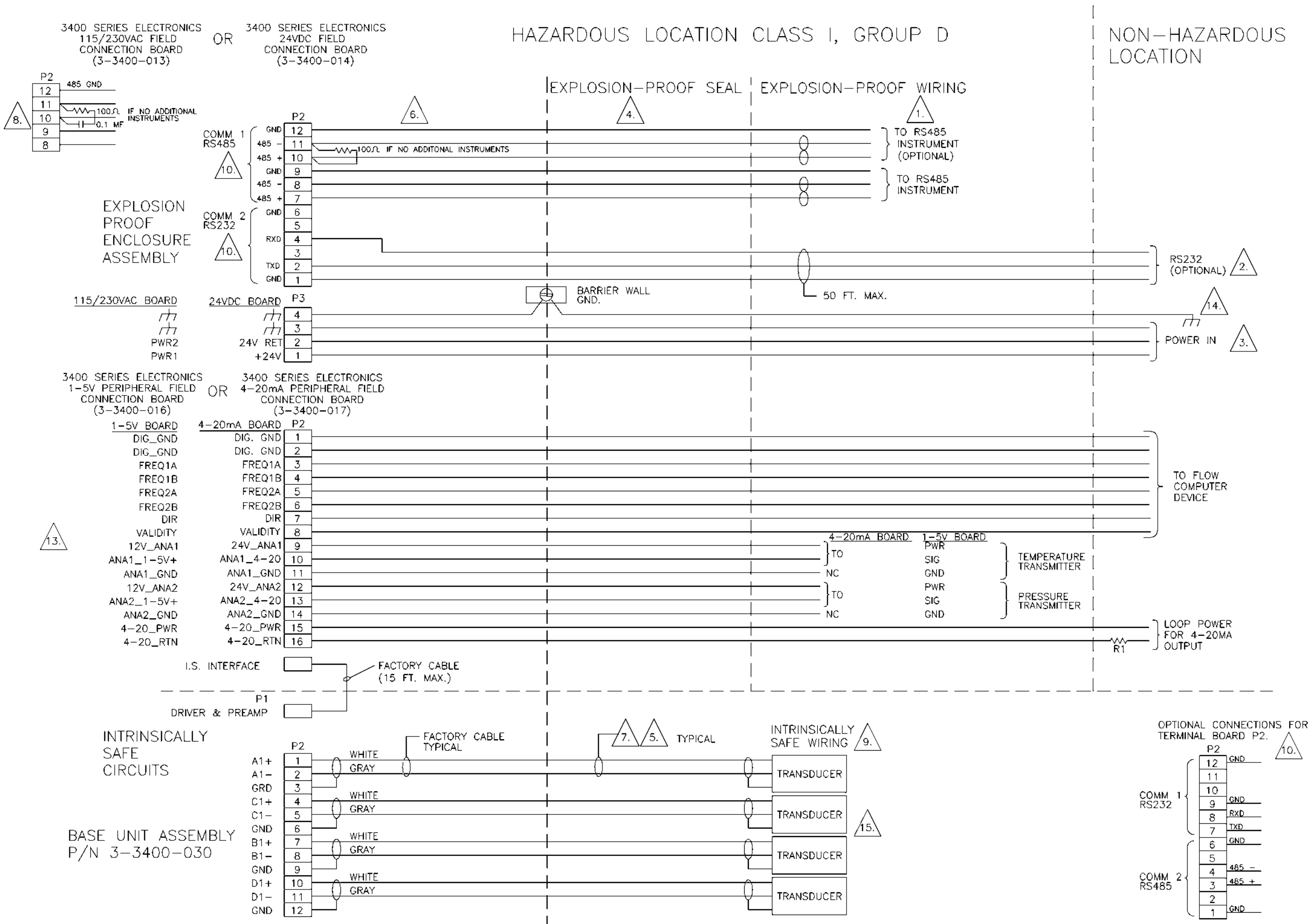
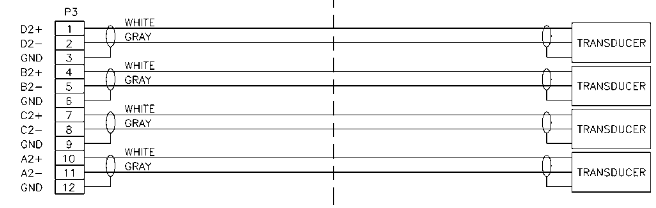




NOTES:

1. MAX LENGTH OF RS-485 WIRING IS 2,000 FT.

2. RS-485 IS THE PREFERRED COMMUNICATIONS INTERFACE. OPTIONALLY, RS-232 MAY BE USED FOR SHORT DISTANCES, (50 FT.)

3. POWER INPUT IS 115/230 VAC, 50/60 HZ. OR 24 VDC. DEPENDING ON OPTION.

4. AN EXPLOSION-PROOF SEAL IS REQUIRED WITHIN 50 MM (2 INCHES) OF THE ENCLOSURE.

5. TRANSDUCER CABLE IS 18 AWG. SHIELDED PAIR, TIGER BRAND 37-102-601 OR 20 AWG. SHIELDED PAIR, 20 AWG. DRAIN, BRAIDED SHIELD, REMKE INDUSTRIES OR EQUIVALENT, 15 FT. MAX.

6. INTERNALLY A RESISTOR (100 OHM) IS CONNECTED FROM P2 PINS 12 TO 9 TO BOARD COMMON.

7. INTRINSICALLY SAFE WIRING SHALL BE INSTALLED IN ACCORDANCE WITH THE APPROPRIATE SECTIONS OF THE NATIONAL ELECTRICAL CODE OR THE CANADIAN ELECTRICAL CODE.

8. ALTERNATE RS-485 TERMINATION CIRCUIT.

9. TRANSDUCER PAIRS REQUIRED

MODEL NO.	TRANSDUCER PAIRS REQUIRED	TYPICAL CHORDS USED
3400	4	A,B,C,D
3410	1	A
3420	2	A,B

10. COMM 1 IS PRIMARY 485 PORT, COMM 2 IS PRIMARY 232 PORT. SEE OPERATIONS MANUAL 3-9000-722 FOR SETUP DETAILS.

11. PERIPHERAL FIELD WIRING APPLICABLE ONLY TO UNITS WITH "DFI" OPTION.

12. OPTIONAL OPEN COLLECTOR OUTPUT MODULE. ONE OR TWO OF THESE MAY BE INSTALLED INSIDE DFI ELECTRONICS HOUSING. OUTPUT RATED 36VDC MAX. Vce=0.1 VOLTS @ Ic=10ma SHOWN CONNECTED ONLY TO FREQ1A FOR CLARITY. MODULE MAY BE USED ON ANY OF THE FREQUENCY OUTPUTS.

13. TWO DIFFERENT PERIPHERAL CARDS ARE USED WITH THE DFI ELECTRONICS. THE 4-20mA PERIPHERAL FIELD CONNECTION (3-3400-017) WHICH OPERATES WITH 4-20mA TRANSMITTERS AND THE 1-5V PERIPHERAL FIELD CONNECTION (3-3400-016) WHICH OPERATES WITH 1-5V TRANSMITTERS. A THIRD PERIPHERAL CARD (3-3400-011) WAS REPLACED BY THE TWO ABOVE BUT WIRING DIRECTIONS FOR IT CAN STILL BE FOUND ON SHEET 2.

TO ENSURE PROPER OPERATION OF THE UNIT, THE CORRECT WIRING DIAGRAM MUST BE USED IN INSTALLATION/SETUP. TO IDENTIFY THE PERIPHERAL CARD IN USE CHECK SILKSCREEN FOR FOLLOWING TEXT AND SEE APPROPRIATE DIAGRAM.

A. "4-20mA PERIPHERAL FIELD CONNECTION"
SEE SHEET 1 4-20mA PERIPHERAL FIELD CONNECTION BOARD (3-3400-017).

B. "1-5V PERIPHERAL FIELD CONNECTION"
SEE SHEET 1 1-5V PERIPHERAL FIELD CONNECTION BOARD (3-3400-016).

C. "PERIPHERAL FIELD CONNECTION"
SEE SHEET 2 PERIPHERAL FIELD CONNECTION BOARD (3-3400-011).

14. CONNECT ALL GROUND CONNECTIONS TO THE SAME GROUND ROD. FOR PROPER GROUND WIRING REFERENCE ISA-RPI2.6.

15. 3400 SERIES TYPE 1, 2, 11, 12, OR 17.

REV	DATE	DRN	DESCRIPTION	CHKD	APPD
K	05-20-04	MS	ECO X-205728	EM	KDG
J	9/16/02	KDG	ECO-XX-155809	EM	KDG
H	10/06/00	RD	ECO-XX-93788	EM	DLT
G	02/99	RD	ECO-XX-17523	EM	WRF
F	04/98	RD	ECO-9459	EM	WRF
E	02/12/98	RD	ECO-9359	EM	WRF
D	11/25/97	RD	ECO-9316	EM	WRF
C	03/97	KB	ECO-9160	EM	WRF
B	06/95	AH	ECO-8621	EM	WRF
A	02/95	HM	ERO-9451	EM	WRF

FILENAME: DE15044K1.DWG, DATE: 09-19-02, TIME: 12:53 P.M.

SI METRIC
THIRD ANGLE PROJECTION
MATERIAL BLOCK NOT APPLICABLE
FINISH BLOCK NOT APPLICABLE
PROJ. FILE NO. - NONE

GEOMETRIC TOLERANCES & DIMENSIONS PER ANSI Y14.5 LATEST REVISION

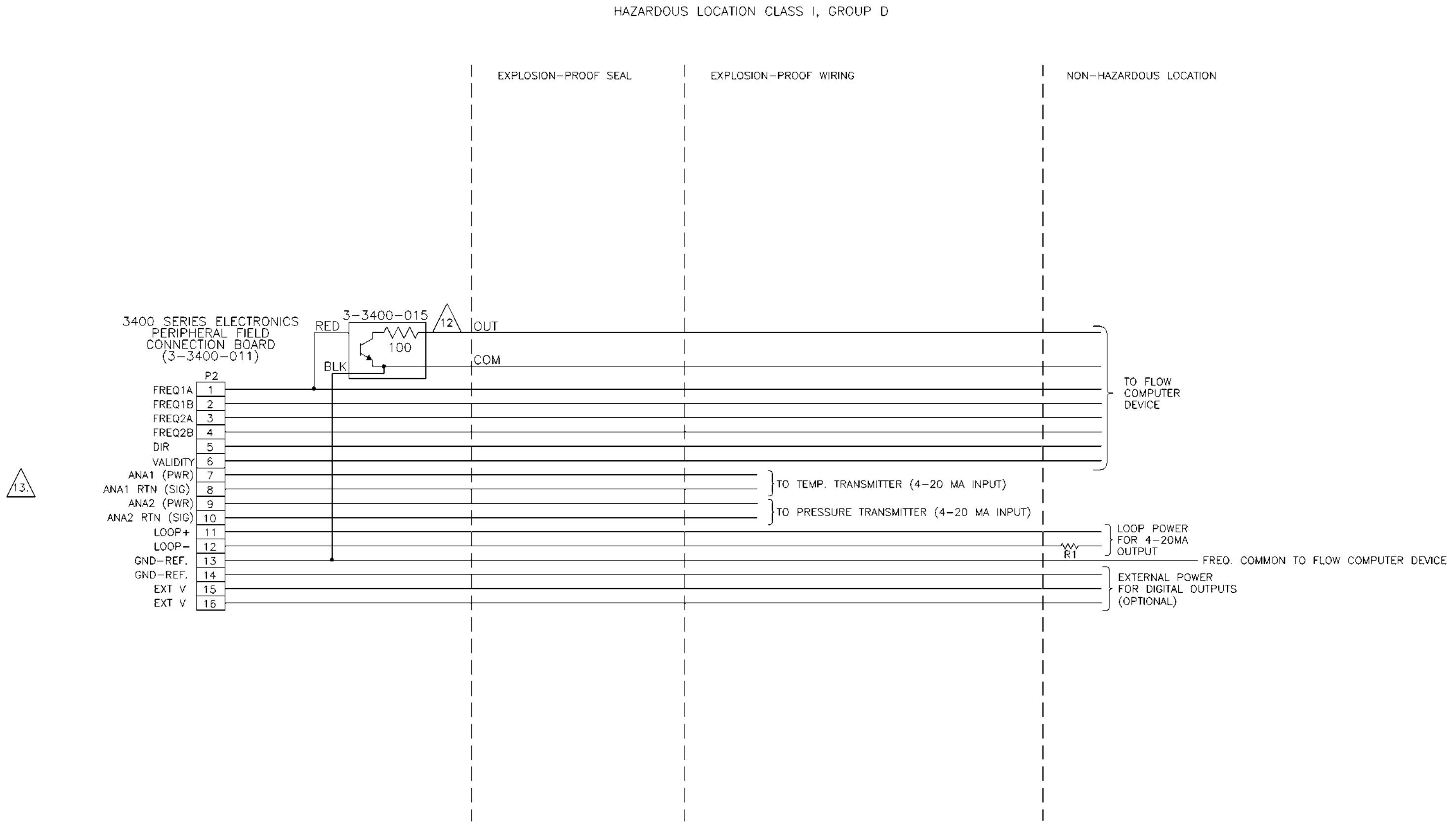
UNLESS OTHERWISE NOTED ALL DIMENSIONS IN INCHES
X.XX ±.015
X.XXX ±.005
ANGULAR ±0° 30'
FINISH 200 RA MAX

BREAK ALL SHARP CORNERS TO .003-.015 RADIUS AND REMOVE ALL BURRS

DANIEL
Daniel Measurement and Control

TITLE
SYSTEM WIRING DIAGRAM
ULTRASONIC FLOWMETER MODEL 3400, 3410 AND 3420

DRN HM | DATE 04/29/94 | DWG NO. DE-15044 | REV K
CHKD EM | DATE 02/17/95
APPD WRF | DATE 02/20/95 | SCALE NA | P/N SEE ORDER | SHT 1 OF 2



K	05-20-04	MS	ECO X-205728	EM	KDG
J	9/16/02	KDG	ECO-XX-155809	EM	KDG
H	10/06/00	RD	ECO-XX-93788	EM	DLT
G	2/99	RD	ECO-XX-17523	EM	WR
F	4/98	RD	ECO-9459	EM	DLT
E	2/12/98	RD	ECO-9359	EM	DLT
D	11/25/97	RD	ECO-9160	EM	WRF
C	3/97	KB	ECO-9160	EM	WRF
B	6/95	AH	ECO-8621	EM	WRF
A	2/95	RD	ERO-9451	EM	WRF
REV	DATE	DRN	DESCRIPTION	CHKD	APPD

FILENAME: DE15044K2.DWG, DATE: 09-19-02, TIME: 12:51 P.M.

SI METRIC

THIRD ANGLE PROJECTION

MATERIAL
BLOCK
NOT APPLICABLE

FINISH
BLOCK
NOT APPLICABLE

PROJ. FILE NO. - NONE

GEOMETRIC TOLERANCES & DIMENSIONS PER ANSI Y14.5 LATEST REVISION

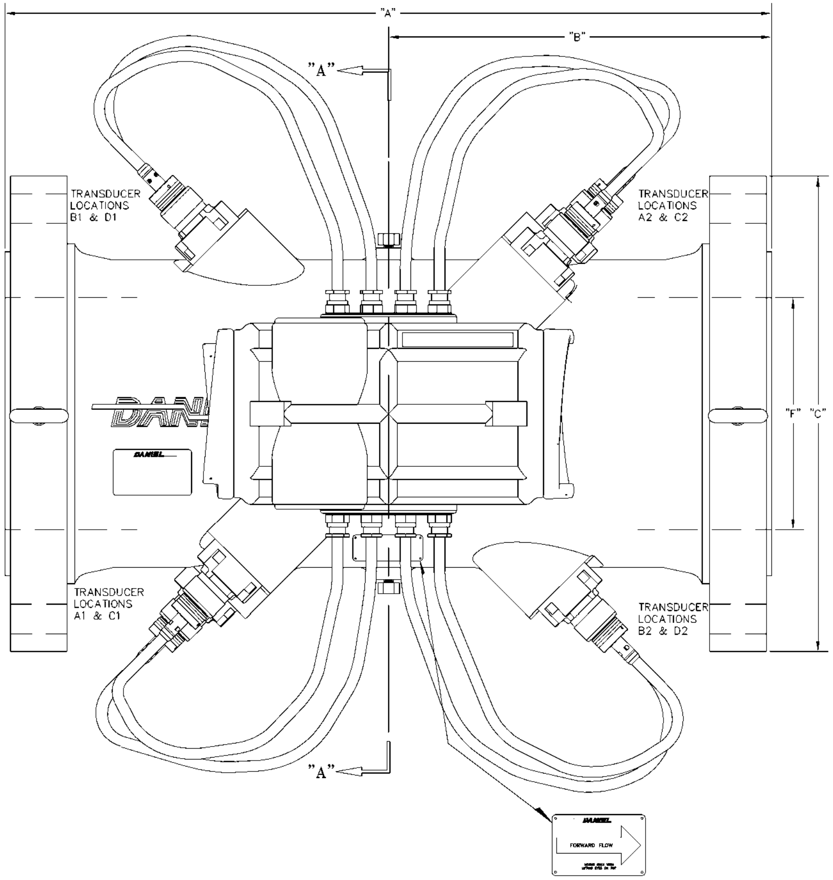
UNLESS OTHERWISE NOTED ALL DIMENSIONS IN INCHES
X.XX ±.015
X.XXX ±.005
ANGULAR ±0° 30'
FINISH 200 RA MAX

BREAK ALL SHARP CORNERS TO .003-.015 RADIUS AND REMOVE ALL BURRS

DANIEL
Daniel Measurement and Control

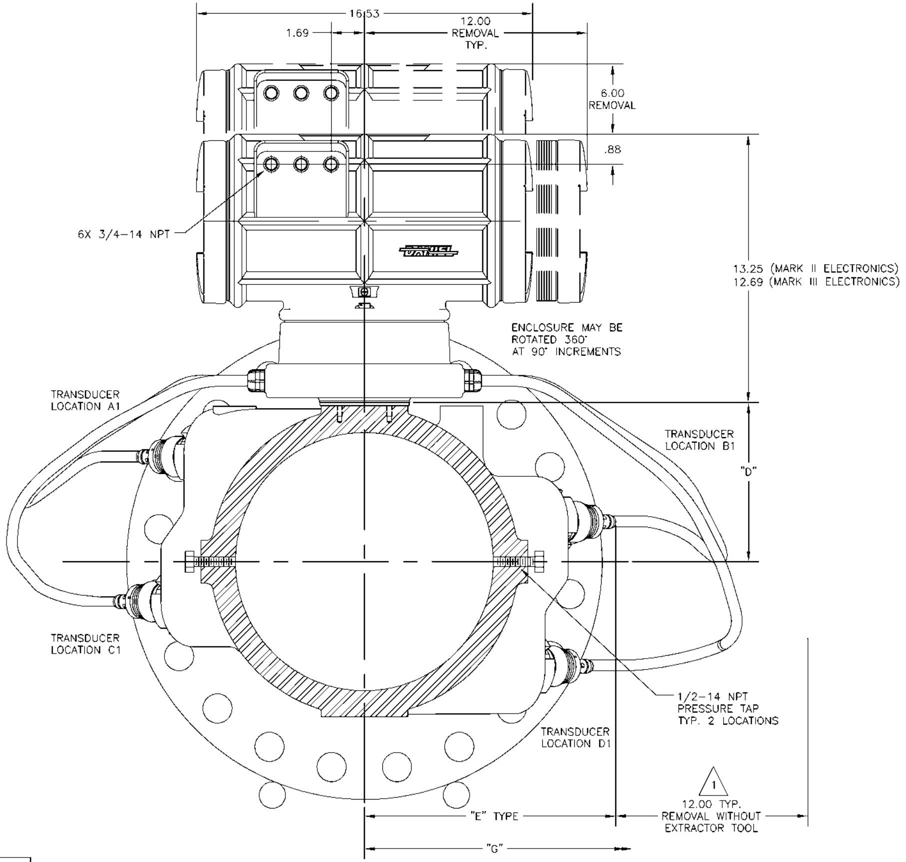
TITLE
SYSTEM WIRING DIAGRAM
ULTRASONIC FLOWMETER MODEL 3400, 3410 AND 3420

DRN HM
DATE 04/29/94
CHKD EM
DATE 02/17/95
APPD WRF
DATE 02/20/95
DWG NO. DE-15044
REV K
SCALE NA
P/N SEE ORDER
SHT 2 OF 2



NOTES:

1. LINE PRESSURE MUST BE VENTED IF TRANSDUCERS ARE REMOVED WITHOUT THE USE OF THE EXTRACTOR TOOL.



SECTION "A-A"

	OVERALL END TO END	CENTER TO END	DIAMETER OF FLANGE	CENTER OF HOUSING TO MOUNTING BOSS	CENTER OF HOUSING TO EDGE OF CENTER PATH TRANSDUCER CONNECTOR	SPACE FOR REMOVAL WITH EXTRACTOR TOOL	APPROXIMATE WEIGHT WITH T-SLOT TRANSDUCER	RING NUMBER
SIZE	A	B	C	D	E	G	W.T. (LBS)	R
4"	29.00	14.50	10.00	4.25	8.25	56.75	433	R37
6"	29.50	14.75	12.50	4.25	8.62	56.75	460	R45
8"	31.50	15.75	15.00	5.50	9.88	58.00	650	R49
10"	34.00	17.00	17.50	6.50	10.75	58.88	713	R53
12"	35.44	17.72	20.50	7.18	11.62	59.76	907	R57
16"	44.00	22.00	25.50	9.31	13.19	61.32	1545	R65
18"	51.64	25.82	28.00	10.38	14.25	62.42	2573	R69
20"	47.89	23.95	30.50	11.56	15.56	63.70	2461	R73
24"	55.36	27.68	36.00	13.94	18.06	66.22	3195	R77
30"	63.50	31.75	43.00	17.38	23.50	71.63	3975	R95
36"	69.75	34.88	50.00	20.50	25.25	73.41	5412	R98

SALES ORDER NO.: ______________________
CUSTOMER: ______________________
CUSTOMER P.O. NO.: ______________________
CERTIFIED CORRECT – DANIEL INDUSTRIES INC.:
DATE: ______________ BY ______________

TAG EQUIPMENT NUMBER	SIZE	BORE ("F")

SI METRIC

THIRD ANGLE PROJECTION

MATERIAL N/A

FINISH N/A

PROJ. FILE NO. – NONE

REV	DATE	DRN	DESCRIPTION	CHKD	APPD
B	01-22-04	MS	ECO X-184307	EM	KDG
A	10-4-02	MS	ECO X-156043	EM	KDG

FILENAME: D08253A1.DWG, DATE: 10-03-02, TIME: 9:05 A.M.

GEOMETRIC TOLERANCES & DIMENSIONS PER ANSI Y14.5 LATEST REVISION

UNLESS OTHERWISE NOTED ALL DIMENSIONS IN INCHES
X.XX ±.015
X.XXX ±.005
ANGULAR ±0° 30'
FINISH 200 RA MAX

BREAK ALL SHARP CORNERS TO .003-.015 RADIUS AND REMOVE ALL BURRS

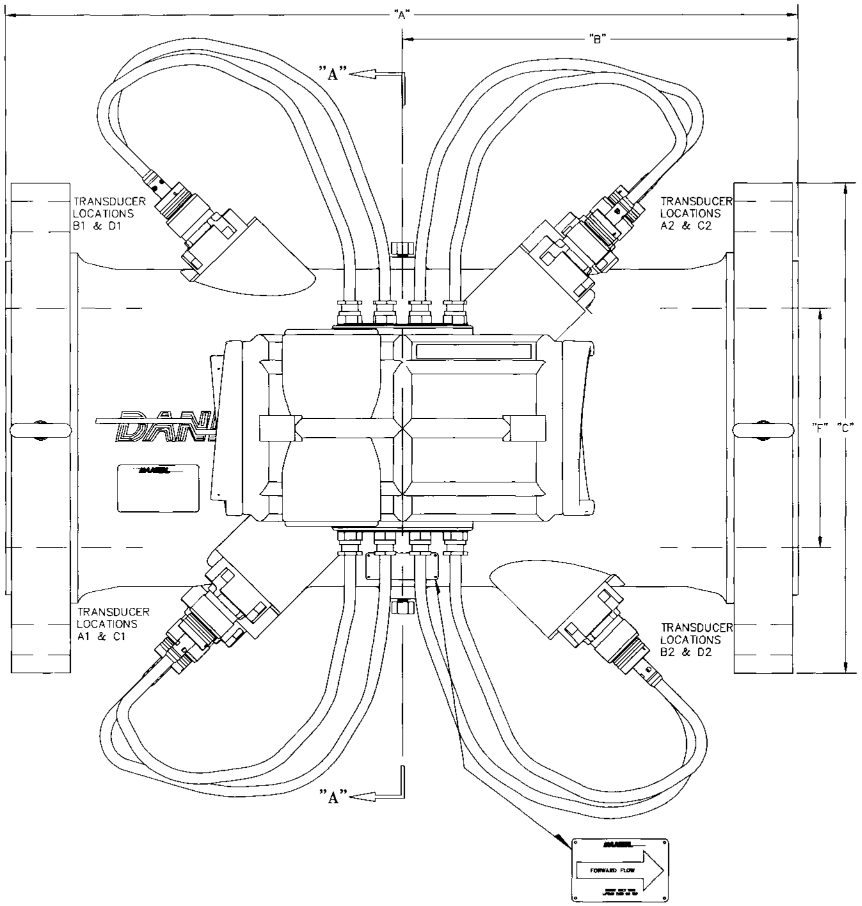
DANIEL
Daniel Measurement and Control

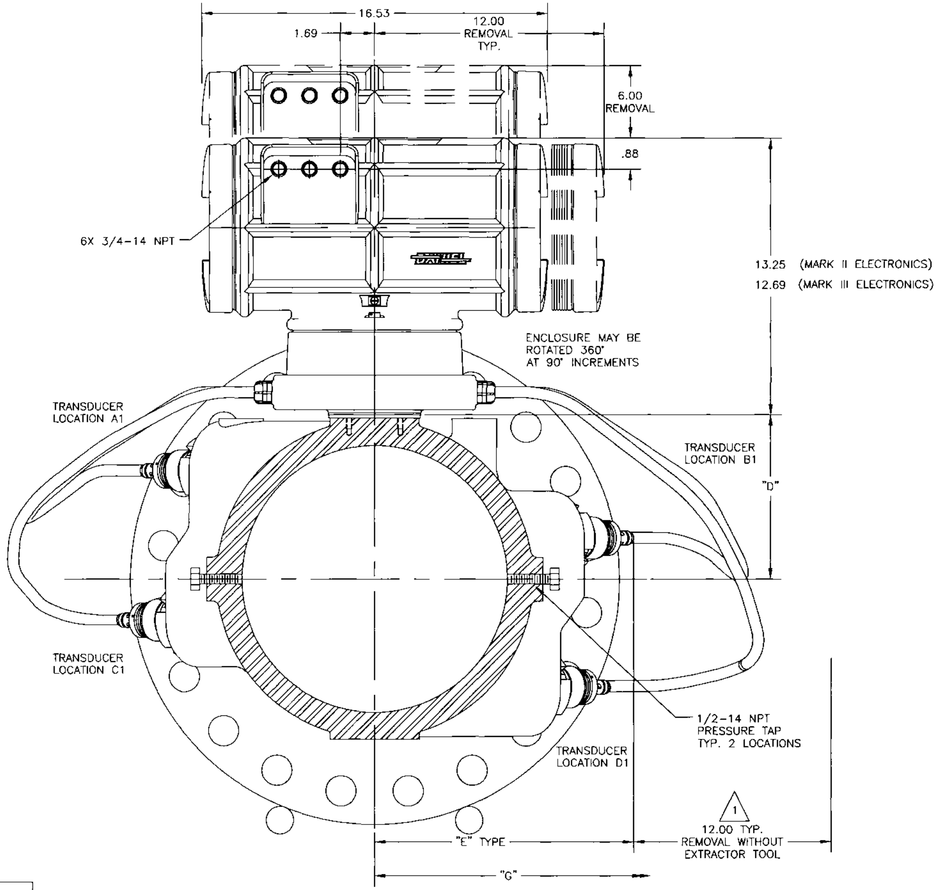
TITLE
OUTLINE & DIMENSIONAL
ULTRASONIC FLOWMETER
4"-36" 300 ANSI R.F. & RTJ FLG F/ J MOUNT
W/ T-SLOT EXTRACTABLE TRANSDUCER

DRN MS | DATE 10/03/02 | DWG NO. D-08253 | REV B
CHKD EM | DATE 10-4-02
APPD KDG | DATE 10-4-02 | SCALE NTS | P/N SEE ORDER | SHT 1 OF 1

NOTES:

1. LINE PRESSURE MUST BE VENTED IF TRANSDUCERS ARE REMOVED WITHOUT THE USE OF THE EXTRACTOR TOOL.





SECTION "A-A"

	OVERALL END TO END	CENTER TO END	DIAMETER OF FLANGE	CENTER OF HOUSING TO MOUNTING BOSS	CENTER OF HOUSING TO EDGE OF CENTER PATH TRANSDUCER CONNECTOR	SPACE FOR REMOVAL WITH EXTRACTOR TOOL	APPROXIMATE WEIGHT WITH T-SLOT TRANSDUCER	RING NUMBER
SIZE	A	B	C	D	E	G	W.T. (LBS)	R
4"	29.00	14.50	10.75	3.38	8.25	56.38	370	R37
6"	29.50	14.75	14.00	4.25	8.62	56.75	460	R45
8"	31.50	15.75	16.50	5.50	9.88	58.00	650	R49
10"	34.00	17.00	20.00	6.50	10.75	58.88	885	R53
12"	35.44	17.72	22.00	7.18	11.62	59.76	1075	R57
16"	44.00	22.00	27.00	9.31	13.19	61.32	1955	R65
18"	45.31	22.66	29.25	10.38	14.25	62.42	2800	R69
20"	50.62	25.31	32.00	11.56	15.56	63.70	3057	R73
24"	58.62	29.31	37.00	13.94	18.06	66.22	4045	R77
30"	67.00	33.50	44.50	17.38	23.50	71.63	4925	R95
36"	73.50	36.75	51.75	20.50	25.25	73.41	6425	R98

SALES ORDER NO.: ______________________
CUSTOMER: ______________________
CUSTOMER P.O. NO.: ______________________
CERTIFIED CORRECT - DANIEL INDUSTRIES INC.: ______________________
DATE: ______________ BY ______________

TAG EQUIPMENT NUMBER	SIZE	BORE ("F")

SI METRIC
THIRD ANGLE PROJECTION
MATERIAL N/A
FINISH N/A
PROJ. FILE NO. - NONE

REV	DATE	DRN	DESCRIPTION	CHKD	APPD
B	08-29-03	MOD	ECO X-184307	EM	KDG
A	10-04-02	MS	ECO X-156043	EM	KDG

FILENAME: D0825481.DWG, DATE: 08-27-03, TIME: 3:07 P.M.

GEOMETRIC TOLERANCES & DIMENSIONS PER ANSI Y14.5 LATEST REVISION

UNLESS OTHERWISE NOTED ALL DIMENSIONS IN INCHES
X.XX ±.015
X.XXX ±.005
ANGULAR ±0° 30'
FINISH 200 RA MAX

BREAK ALL SHARP CORNERS TO .003-.015 RADIUS AND REMOVE ALL BURRS

DANIEL
Daniel Measurement and Control

TITLE OUTLINE & DIMENSIONAL
MULTIPATH ULTRASONIC FLOWMETER
4"-36" 600 ANSI R.F. & RTJ FLG F/J MOUNT
W/ T-SLOT EXTRACTABLE TRANSDUCER

DRN MS DATE 10-03-02
CHKD EM DATE 10-04-02
APPD KDG DATE 10-04-02
DWG NO. D-08254
REV B
SCALE NTS
P/N SEE ORDER
SHT 1 OF 1

DANIEL MEASUREMENT AND CONTROL, INC.
RETURN POLICY FOR WARRANTY AND NON-WARRANTY MATERIAL

Use the following procedure for returning equipment to the Daniel factory in the United States.

Step 1 Obtaining a RMA Number

A Return Material Authorization (RMA) number must be obtained prior to returning any equipment for any reason.

To obtain a RMA number, call the Customer Service Department at 713-827-5033 between 8:00 a.m. and 5:00 p.m. (Central Standard Time), Monday through Friday, except holidays or email daniel.support@emersonprocess.com.

NOTICE

No product returns will be accepted without a RMA number and will be returned at the customer's expense.

For warranty consideration, the product must be returned to Daniel within twelve (12) months of the date of original shipment or within eighteen (18) months of the date of original shipment of the product to destinations outside the United States. The Purchaser must prepay any shipping charges

In addition, the Purchaser is responsible for insuring any product shipped for return, and assumes the risk of loss of the product during shipment.

- The following information is required at the time the RMA is issued:
  - Customer name
  - Contact name
  - Billing address
  - Contact Phone # and email address
  - Daniel SO #, PO #, or Invoice #
  - Item(s) to be returned
  - Reason for return
  - End user and final destination address
  - Consignee's complete name, address, contact name and phone number
- A RMA number is required for each original order. (Example: Two fittings purchased on two separate orders now being returned require two RMA numbers.)

For product returns from locations outside the United States, Daniel Customer Service personnel will provide additional shipping requirements.

Step 2 Cleaning and Decontamination

Prior to shipment, thoroughly clean and decontaminate all equipment removing all foreign substances. This includes all substances used for cleaning the equipment. The cleaning and decontamination requirement applies to any part exposed to process fluids or cleaning substances.

Shipping equipment that has not been decontaminated may be in violation of U.S. Department of Transportation (DOT) regulations. For your reference, the requirements for packaging and labeling hazardous substances are listed in DOT regulations 49 CFR 172, 178, and 179.

If you suspect that a part has been contaminated, the part must be completely drained and flushed to remove contaminants.

⚠WARNING

MAY CAUSE DEATH OR SERIOUS INJURY TO PERSONNEL

Contents may be under pressure or materials may be hazardous

Follow appropriate handling instructions for accessing pressurized equipment. Avoid contact with hazardous materials or contaminated units and parts. Failure to do so may result in death or serious injury.

Decontamination/Cleaning Statement

A blank Decontamination/Cleaning Statement is provided on the "Returned Material Authorization Repair Form for Used Equipment".

- A Decontamination/Cleaning Statement is required for each returned part.
- Fully complete each form and include a signature. If the decontamination statement is incomplete, the customer may be charged for decontamination and cleaning.

If the equipment has been exposed to a known hazardous substance with any characteristic that can be identified in the Code of Federal Regulations, 40 CFR 261.20 through 261.24, the chemical abstracts number and hazardous waste number/hazard code must be stated in the space provided on the form.

Two (2) copies of each Decontamination/Cleaning Statement must be provided:

- One (1) copy must be attached to the outside of the package.
- One (1) copy must be included inside the package.

Step 3 Material Safety Data Sheets (MSDS)

Provide a Material Safety Data Sheet (MSDS) with the returned equipment for each substance that has come in contact with the equipment being returned, including substances used for decontamination and cleaning.

A MSDS sheet is required by law to be available to people exposed to specific hazardous substances, with one exception: if the equipment has only been exposed to food-grade substances or potable water, or other substances for which an MSDS is not applicable, the Decontamination/Cleaning Statement form alone is acceptable.

Two (2) copies of each MSDS must be provided:

- One (1) copy must be attached to the outside of the package.
- One (1) copy must be provided inside the package.

Step 4 Packaging

Shipping a Device With Possible Contamination

To meet DOT requirements for identifying hazardous substances, ship only one device per package.

Shipping a Device Without Any Potential Contamination

Devices being returned may be shipped together in one package, if there is no potential of foreign substance contamination.

Step 5 Shipping

Before returning used equipment:

- Mark each package clearly with a RMA number.
- Include a Decontamination/Cleaning Statement inside the package.
- Attach a duplicate Decontamination/Cleaning statement to the outside of the package.
- Include a MSDS for each substance that has come in contact with the equipment inside the package.
- Attach a duplicate MSDS to the outside of the package.

NOTICE

No product returns will be accepted without a RMA number and will be returned at the customer's expense.

For warranty consideration, the product must be returned to Daniel within twelve (12) months of the date of original shipment or within eighteen (18) months of the date of original shipment of the product to destinations outside the United States. The Purchaser must prepay any shipping charges

Ship all * mechanical equipment to the following address:

Daniel Measurement and Control, Inc.
Attn: Service Dept.
5650 Brittmoore Rd.
Houston, TX 77041
Ref: RMA#________________

*Mechanical equipment includes: Orifice Fittings, Parts, Plates, Seal Rings, Turbine Meters, Control Valves, Provers, Strainers, Meter Tubes, Ultrasonic Meters, Flow Conditioners, etc.

Ship all * electronic equipment to the following address:

Daniel Measurement and Control, Inc.
Attn: Service Dept.
11100 Brittmoore Park Drive
Houston, TX 77041
Ref: RMA#_________________

*Electronic equipment includes: Gas Chromatographs, Petrocount Presets, Danload Preset, Ultrasonic Meter Electronics (CPU boards, transducers, etc.), 2403 Totalizer, MRT 97 Indicator, Preamps, Pick Up Coils, Prover Interface Boards, and the following Flow Computer Models: 2230, 2239, 2270, 2460, 2470, S100, 2100, and 3000.

DANIEL MEASUREMENT AND CONTROL, INC.
RETURNED MATERIAL AUTHORIZATION

REPAIR FORM FOR USED EQUIPMENT
INCLUDING DECONTAMINATION/CLEANING STATEMENT

1. Return Material Authorization (RMA) Number____________________________

2. Equipment to be returned:
Model Number ____________________ Serial Number ______________________

3. Reason for return:
____
____
____
____

Decontamination/Cleaning Fluids Process

A. List each substance in which the equipment was exposed. Attach additional documents if necessary.

Common Name	CAS# if Available	Used for Hazardous Waste (20 CFR 261)	EPA Waste Code if used for hazardous waste
		☐ Yes ☐ No	
		☐ Yes ☐ No	
		☐ Yes ☐ No	
		☐ Yes ☐ No	
		☐ Yes ☐ No	
		☐ Yes ☐ No	

B. Circle any hazards and/or process fluid types that apply:

Infectious	**Radioactive**	**Explosive**	**Pryophoric**	**Poison Gas**	
Cyanides	Sulfides	Corrosive	Oxidizer	Flammable	Poison
Carcinogen	Peroxide	Reactive-Air	Reactive-Water	Reactive-Other (list):	

Other Hazard Category (list):

C. Describe decontamination/cleaning process. Include MSDS description for substances used in decontamination and cleaning processes. Attach additional documents if necessary.

Shipping Requirements

Failure to comply with this procedure will result in the shipment being refused.

4. Write the RMA number on the shipping package.

5. Inside the package include one copy of this document and all required Material Safety Data Sheets (MSDS)

6. Outside of the package attach one copy of this document and all required Material Safety Data Sheets (MSDS).

THIS EQUIPMENT, BEING RETURNED "FOR REPAIR," HAS BEEN COMPLETELY DECONTAMINATED AND CLEANED. ALL FOREIGN SUBSTANCES HAVE BEEN DOCUMENTED ABOVE AND MSDS SHEETS ARE ATTACHED.

By:

__________________________________	______________________________
(Signature)	(Print name)
Title:______________________________	Date:_________________________
Company:_________________________	
Phone: ___________________________	Fax:_________________________

The sales and service offices of Daniel Measurement and Control are located throughout the United States and in major countries overseas.

Please contact Daniel Measurement Services at 11100 Brittmoore Park Drive, Houston, Texas 77041, or phone (713) 827-6314 for the location of the sales or service office nearest you.

Daniel Measurement Services offers both on-call and contract maintenance service designed to provide single-source responsibility for all Daniel products.

www.emersonprocess.com/daniel

DANIEL®

EMERSON™
Process Management