P_f = flow-condition absolute pressure (MPa) (readable via DFI Abs-FlowPressure 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.

A.5 DATA VALIDITY DETERMINATION

The validity indicators discussed in this section are used in determining the validity output signal value.

A.5.1 Temperature Measurement Validity

TemperatureValidity =

(11) Valid if
(EnableTemperatureInput ≠ DISABLE_INPUT) and
(UFIMode ≠ Maintenance Mode) and
(LowTemperatureAlarm ≤ FlowTemperature ≤ HighTemperatureAlarm)
Invalid otherwise

A.5.2 Pressure Measurement Validity

PressureValidity =

(12) Valid if
(EnablePressureInput ≠ DISABLE_INPUT) and
(UFIMode ≠ Maintenance Mode) and
(LowPressureAlarm ≤ FlowPressure ≤ HighPressureAlarm)
Invalid otherwise

A.5.3 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 start-up and whenever any of the user-specified AGA8 parameters in Modbus Block 54 is changed.

A.5.4 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.

A.5.5 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; 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.

A.5.6 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 single-path and dual-path meters, the flow-profile correction requires that the temperature and pressure inputs be either enabled or specified. For single-path and dual-path meters, if either the temperature or pressure input is disabled, then it is assumed that flow-profile-effect correction is not desired. In that case, the correction factor is set to 0.95 and the correction is treated as being valid. Otherwise (temperature and pressure inputs are not disabled), the flow-profile-effect correction factor is calculated as a function of Reynolds Number which is a function of the flow-condition temperature and pressure and the flow-condition natural gas mass density. The natural gas mass density is calculated as part of the AGA8 flow-condition compressibility calculation. If the AGA8 flow-condition calculation cannot be completed (such as if the flow-condition is outside of the limits for the AGA8 Gross Characterization Method), then the natural gas mass density is estimated using the Ideal Gas Law and the air mass density (from the AGA8 base-condition calculation). Thus, the flow-profile-effect correction validity (readable via FlowProfileCorrValidity in Block 60) is determined as shown below.

For single and dual-path meters, if both temperature and pressure inputs are enabled or specified:

FlowProfileCorrValidity =

(15)
Valid if
(TemperatureValidity = Valid) and
(PressureValidity = Valid) and
(AGA8BaseCalcValidity = Valid)
Invalid otherwise

For single and dual-path meters, if both temperature and pressure inputs are disabled, FlowProfile-CorrValidity=Valid.

For multi-path meters, FlowProfileCorrValidity=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 =

(16)
Valid if
(QMeterValidity = Valid) and
(ExpCorrTempValidity = Valid) and
(ExpCorrPressValidity = Valid) and
(FlowProfileCorrValidity = Valid)
Invalid otherwise

A.5.7 Base Condition Volumetric Flow Rate Validity

QBase Validity =

(17)
Valid if
(QFlowValidity = Valid) and
(AGA8FlowCalcValidity = Valid)
Invalid otherwise

A.5.8 Frequency Data Validity

FrequencyDataValidity =

(18) 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).

A.6 OUTPUT SIGNAL UPDATING

A.6.1 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:

(19) $OutputVFR = |Q| + VFRErrorCompensation$

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: