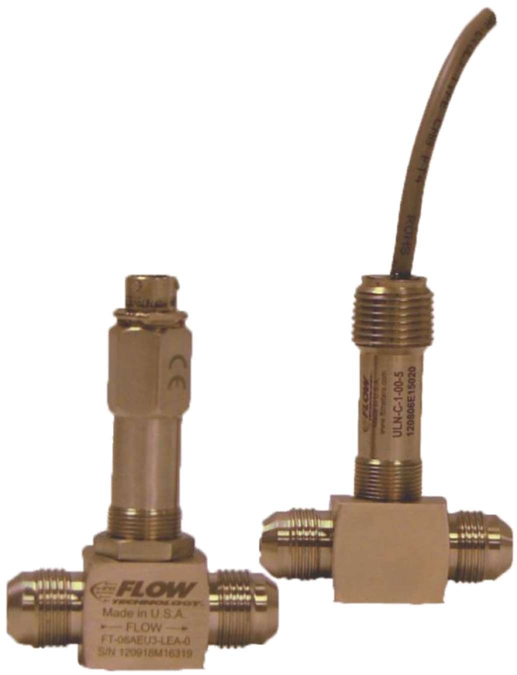
microLinK

Temperature Compensating Linearizing Pickoff



Installation and Operation Manual

FTI FLOW TECHNOLOGY™

TM-100736, Rev A

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Flow Technology Inc.
8930 South Beck Ave
Suite #107
Tempe, AZ 85284

Tel: +1 480 240 3400
Fax: +1 480 240 3401
www.ftimeters.com

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1 INTRODUCTION

1.1 Scope

This manual provides information and guidance for personnel responsible for the installation, operation, and maintenance of the microLinK flow meter pickoff manufactured by Flow Technology, Inc.

1.2 Purpose

The contents of this manual are for general information and to describe the operational characteristics of the microLinK flow meter pickoff. This manual does not include instructions for special applications or factory repair.

1.3 Description

The microLinK pickoff is a compact design that includes a built-in modulated carrier (RF) coil, temperature sensor, signal conditioning, and a microprocessor. The pulse output is a scaled linear frequency, which can be configured to represent either volumetric or mass flow rate. In addition, CANbus is available for serial communication. The microLinK pickoff offers temperature compensation combined with linearization and a wide input power voltage range. Viscosity effects on the K Factor are compensated for by proper calibration techniques and on-line temperature measurements to establish the fluid viscosity and fluid density. The viscosity and density information is processed simultaneously with an efficient frequency measurement and linearization technique that optimizes accuracy while providing fast response. Comprehensive filtering options are available to meet virtually any installation requirements.

NIST recommended equations with the Strouhal Roshko correlation are used to characterize the flow meter and improve the accuracy of the flow measurement. The equations were developed by NIST and can be used with flow meters that produce a frequency output. The dimensionless Strouhal Roshko correlation is used to correct for the expansion and contraction of the materials the flow meter is constructed of due to temperature changes.

The microLinK pickoff is complemented by a Windows® configuration program, Visual LinK™. The user-friendly Visual LinK™ configuration software is used to configure the microLink and also to recall data from the system that was configured previously. Visual LinK™ software allows the user to input, edit and screen plot calibration data and fluid property data for easy visual data verification.

The microLinK is valid for use in the European community under the CE certification program. A declaration of conformity is shown in Appendix F.

The microLinK is available in three standard package options; see Appendix A for a model number breakdown. Examples of the package options are shown in Figure 1 through Figure 3.

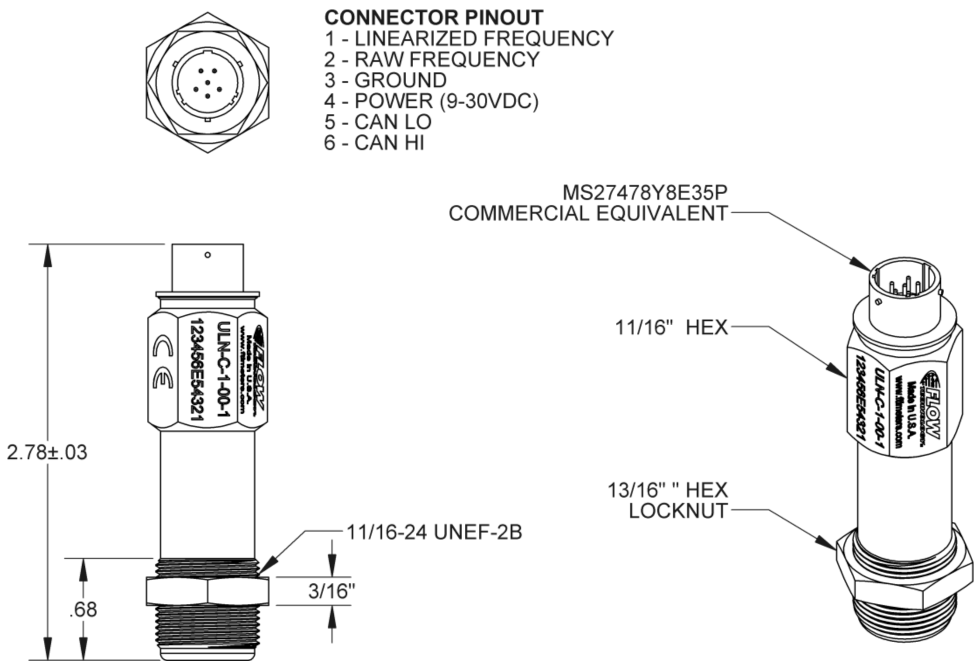


Figure 1 – microLinK MS Connector Option (-1 option)

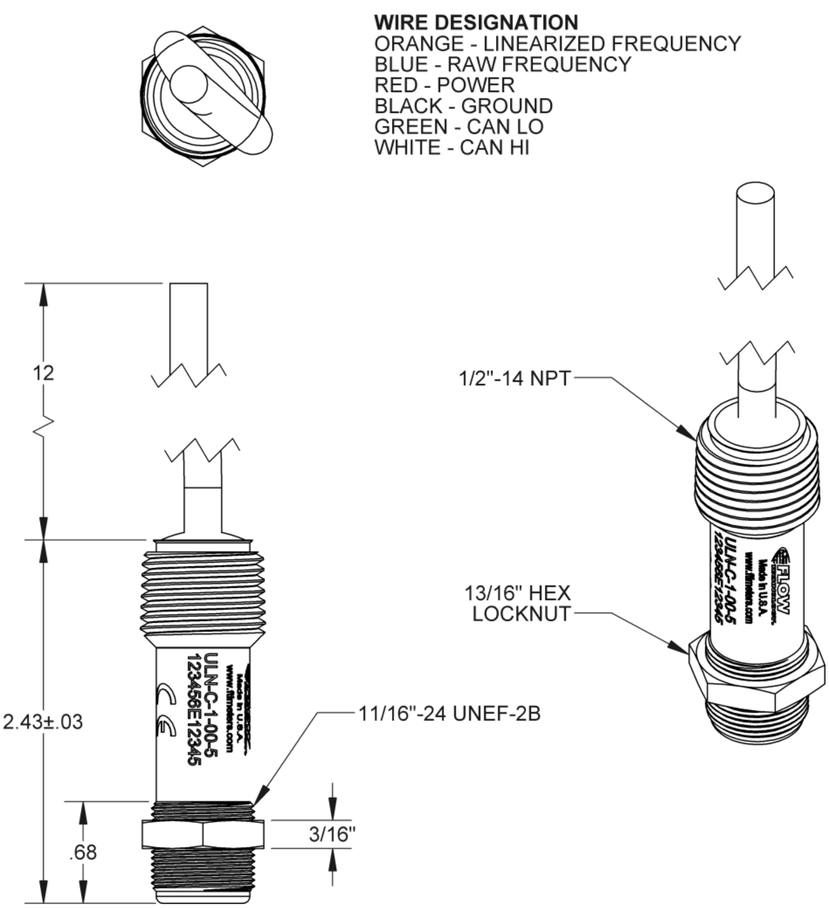


Figure 2 – microLinK Flying Leads with NPT Option (-5 option)

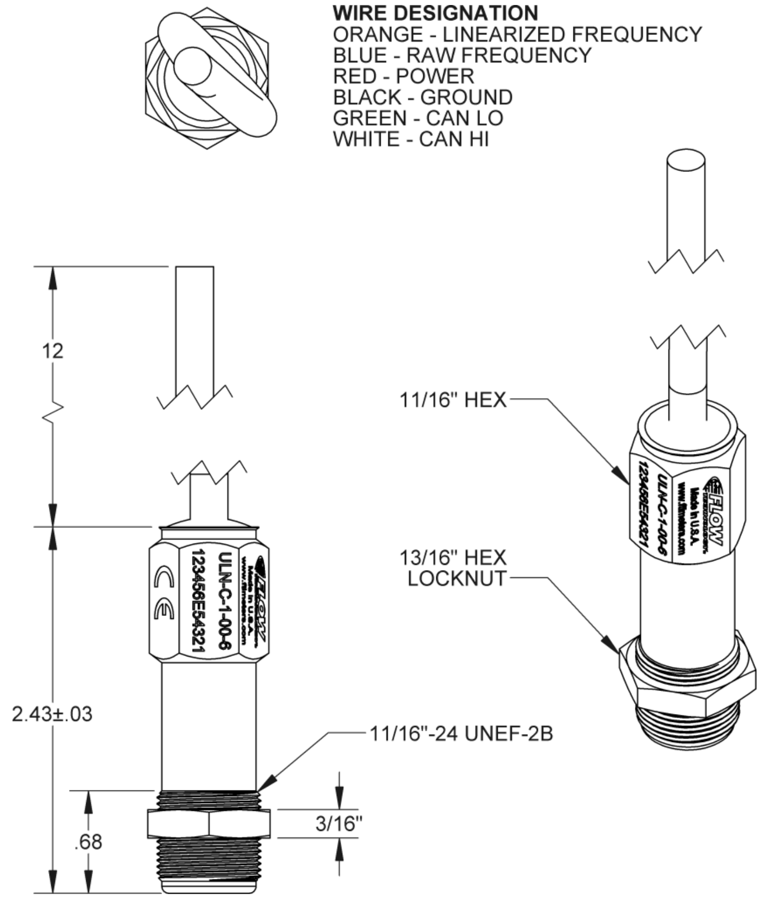


Figure 3 – microLinK Flying Leads, no NPT (-6 option)

2 INSTALLATION

2.1 Inspection

The microLinK pickoff has been tested and programmed to linearize the output of its mated flow meter prior to shipment. The equipment is ready for immediate installation upon receipt. Please check the unit to assure that no damage has occurred during shipment. Verify that the model number of the unit received matches the equipment ordered.

2.2 Mechanical Installation of the microLinK Pickoff to the Flow Meter

The pickoff should bottom in the well of the flow meter housing but only be finger tightened to approximately 4 lb-in (0.5 N-m) max to prevent distortion of the meter housing. The pickoff is secured in position by tightening the lock nut to approximately 25 lb-in (2.8 N-m). The pickoff can be removed by loosening the hex lock nut and unscrewing the pickoff from the housing.

2.3 Electrical Installation

This section provides the professional installer with information for connecting the microLinK to the user's system.

WARNING:

Verify that the power is off before connecting or servicing!

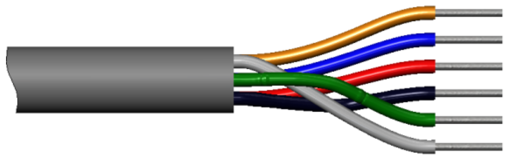
The connecting cable between the flow meter and the electronic instrumentation should be use 22-28 AWG conductors. Shielded and twisted pairs are recommended for CANbus installations. The cable should not be installed in a conduit or tray containing power lines, or close to strong electromagnetic sources such as electric lines, electric motors, transformers, welding machines, or high voltage lines. These sources may induce transient electrical noise in the coil and cause false reading.

The connector pinout is shown below in Figure 4. The connector on the pickoff is a commercial equivalent of MS27478Y8E35P. For package options “-5” and “-6” (flying leads) see Figure 5.

The raw frequency wire and the linearized frequency wire should not be run together in the same cable for more than 10 feet or crosstalk between the wires may occur. It is best if only the linearized frequency is connected to a wire in the cable.

CONNECTOR PINOUT
1 - LINEARIZED FREQUENCY
2 - RAW FREQUENCY
3 - GROUND
4 - POWER (9-30VDC)
5 - CAN LO
6 - CAN HI

Figure 4 – MS Connector Pinout



WIRE DESIGNATION
ORANGE - LINEARIZED FREQUENCY
BLUE - RAW FREQUENCY
RED - POWER
BLACK - GROUND
GREEN - CAN LO
WHITE - CAN HI

Figure 5 – Flying Leads Wire Designators

2.4 Programming using Visual LinK™

Visual LinK is designed to operate with the USB CAN interface from esd electronics (www.esd-electronics-usa.com). To program the pickoff using Visual LinK™ the PC will need to have the CAN interface installed. Consult TM-100823 for CANbus interface implementation.

3 THEORY OF OPERATION

3.1 Variable Definitions

Table 1 lists the variables reference in this section. Note that K-Factor, volume rate, mass rate, temperature, and density all have user-defined units. An example unit is listed in the table for clarity.

Table 1 – Variable Definitions

Variable	Description
CF_R	Roshko correction factor (dimensionless)
CF_S	Strouhal correction factor (dimensionless)
f	Meter frequency (Hz)
f_{Lin}	Scaled frequency output for flow rate (Hz)
f_{Min}	User-defined minimum output frequency (Hz)
f_{Max}	User-defined maximum output frequency (Hz)
f_{Raw}	Raw meter frequency (Hz)
K_0	Reference K-Factor (pulse/gallon)
K_A	Actual K-Factor based on operating temperature of fluid with Strouhal factor applied (pulse/gallon)
K_D	Desired K-Factor (pulse/gallon)
M_A	Actual mass flow rate (lb/min)
Q_A	Actual volumetric flow rate (gallon/minute)
Q_{Max}	User-defined maximum flow rate (gallon/minute)
T	Fluid temperature (°F)
T_0	Meter calibration temperature (°F)
TimeBase	Number of seconds in the user-defined time scale (sec)
α	Coefficient of expansion for the meter housing (in./in./°F)
ν	Kinematic viscosity (cSt)
ρ	Fluid density (lb/gal)

3.2 Overview

Fluid traveling through a turbine flow meter causes the rotor to spin with a velocity proportional to the volumetric flow rate. The pickoff coil is sensitive to the ferric content of the stainless steel rotor blades. Each blade of the spinning rotor generates a pulse while passing through the electromagnetic field surrounding the pickoff coil. These pulses, when viewed over time *(pulses per second, or hertz)*, produce a frequency that is directly proportional to the flow rate.

The relationship between the volumetric flow rate and the frequency output of a flow meter is known as the K-Factor (pulses per unit volume; i.e. pulses per gallon).

$$FlowRate = \frac{Frequency}{K - Factor} * TimeBase$$

Turbine flow meters are noted for their fast response times, repeatability and good linearity. Unfortunately, the relationship between K-Factor and flow rate becomes increasingly non-linear for turbine flow meters operating at the low end of their flow ranges where viscosity and the bearings have significant effects on rotor performance.

The microLinK pickoff compensates for the deviation of a turbine meter from the ideal performance and generates a pulse signal that is linear to within ±0.1% of reading. The linearized K-Factor is generated by using the actual K-Factor as a reference.

The microLinK pickoff linearizes the K-Factor curve of a turbine flow meter by providing up to 30 points of correction. The microprocessor compensates for the non-linearity of each segment of the curve between the points. With the programming provided by Visual LinK™, every flow meter equipped with a microLinK pickoff can be given an identical K-Factor. This allows for direct interchangeability without the need to re-program displays or batching controllers.

The microLinK pickoff requires calibration data for the flow meter and fluid property data before it can be used to calculate the flow rate as a function of meter frequency, compensate for measurement errors, and output the scaled units of volume or mass. The microLinK pickoff will output a compensated and scaled frequency for the flow rate.

In addition to the linear frequency output, the microLinK pickoff can also communicate via CANbus. Consult the microLinK CANbus Implementation Guide (TM-100823) for detailed CANbus information.

3.3 Operating Functions

3.3.1 Frequency measurement and averaging

The rotor frequency is calculated by measuring the amount of time from rising edge to rising edge of the pulses induced by the turning rotor. A routine in the processor executes every 10mS to count the number of pulses since the last time the routine executed and the elapsed time of these pulses. The routine also keeps track of the time since the last rising edge occurred (time since last pulse). If the frequency is below 100Hz, it may take several executions of the routine before a pulse is counted. At frequencies above 100Hz, the processor counts the number of pulses since the last time through the routine and the elapsed time of the pulses. With the number of pulses and elapsed time, a frequency is calculated. This frequency is stored as the *NewMeasuredFrequency*.

If the rotor rapidly slows down to a stop, the pickoff cannot know what the new frequency is until the next rising edge occurs. When the rotor has stopped, there is no new pulse and the pickoff will never be able to calculate a new frequency. However, the pickoff will *calculate* that the frequency has to be less than a value based on the time since the last rising edge. This calculation uses the time since last pulse.

A user-defined *FrequencyAveragingFactor* is used to calculate the *AverageFrequency* as shown below.

$$AverageFrequency = \frac{(AverageFrequency * FrequencyAveragingFactor) + NewMeasuredFrequency}{FrequencyAveragingFactor + 1}$$

The *AverageFrequency* is used by the processor for its calculation of flow. Note that if the *FrequencyAveragingFactor* is zero, the *NewMeasuredFrequency* is placed into *AverageFrequency* with no averaging.

The *AverageLimit* parameter can be used in conjunction with the *FrequencyAveragingFactor*. If the new measured frequency is greater than the *AverageFrequency* multiplied by the *AverageLimit* (or less than the *AverageFrequency* divided by the *AverageLimit*), the new measured frequency is put directly into *AverageFrequency*. This means that when the new measured frequency is different enough from the *AverageFrequency*, the *FrequencyAveragingFactor* is zero. This allows a moderate or even high *FrequencyAveragingFactor* to be used, but still provide a fast response to significant changes in flow. An *AverageLimit* of 1.1 will provide a rapid response to a 10% change in frequency. An *AverageLimit* of 2.0 will provide a rapid response to a 100% change in frequency. It should be noted that an *AverageLimit* of one or less is the same as a *FrequencyAveragingFactor* of zero. Therefore, an *AverageLimit* of less than one will disable the *FrequencyAveragingFactor*. This *AverageLimit* is only useful in a small number of applications and is set by FTI to a factory default value of 1E9. This very high value effectively disables the *AverageLimit*.

In addition to the *FrequencyAveragingFactor*, the *LowFrequencyCutoff* parameter is used to limit how small the frequency is allowed to be. The *LowFrequencyCutoff* parameter turns the frequency off when the frequency is less than the *LowFrequencyCutoff*. This is useful if it is known that the flow meter is not accurate below a specific frequency. The *LowFrequencyCutoff* parameter is used to prevent use of a frequency below its threshold. A more important use of the *LowFrequencyCutoff* parameter is to turn the frequency off when no pulses are measured. In the discussion above it is stated that a new frequency cannot be measured until another rising edge occurs. However, a new frequency can be estimated as being no more than 1/TimeSinceLastPulse. This provides for a rapid decrease in the estimated frequency when the rotor stops, but it also means the estimated frequency will never reach zero. The *LowFrequencyCutoff* parameter is used to turn off the frequency when the rotor has stopped and no new frequency is measured. The lower the *LowFrequencyCutoff* parameter is set to, the longer it will take *AverageFrequency* to reach zero.

3.3.2 Flow linearization and temperature compensation

The microLinK contains a linearization table for the flow meter's K-Factor information. Up to 30 points can be entered to linearize the flow meter frequency signal. The user enters the table values with Visual LinK™ and can then view or edit the data to produce the best characterization of the flow meter.

The microLinK pickoff includes a raw flow meter frequency output that allows the user to measure the unprocessed flow rate frequency along with the processed (linearized) flow rate output. The unprocessed signal can be used for troubleshooting and diagnostic information.

The pickoff contains an integral temperature sensor that determines the fluid temperature. Using the temperature, viscosity and density can be calculated from the fluid tables. Up to 20 points can be entered for the relationship between temperature and viscosity, and temperature and density for each fluid. A linear interpolation function is used to determine values between table entries. The kinematic viscosity data is used along with the flow meter frequency to linearize the volumetric flow rate. The density data is used to determine mass flow rate. Alternatively, the fluid temperature can be populated via CANbus.

All of the data are entered and configured using Visual LinK™ and are stored in the pickoff. This data can be recalled and viewed with Visual LinK™. This allows the user to have a record of the previous calibration along with a history of the instrument.

3.3.3 NIST Equations with Strouhal Roshko correlation

The microLinK uses equations developed by NIST to characterize the flow meter and improve the accuracy of the flow rate measurement. The equations were presented in the NIST paper "The Characterization of a Piston Displacement-Type Flow meter Calibration Facility and the Calibration and Use of Pulsed Output Type Flow meters" published in the Journal of Research of the National Institute of Standards and Technology. The equations can be used with any pulsed output type flow meter to improve accuracy.

The Strouhal Roshko correlation is included to correct the flow meter measurement when the actual temperature of the fluid varies from the calibration temperature. The microLinK pickoff can be configured to use (or not use) the Strouhal Roshko correction via Visual LinK™.

3.3.4 Mass flow rate output

The mass flow rate is calculated from the volumetric flow rate and fluid temperature. The microLinK performs all of the calculations and produces a linearized frequency output related to the mass flow rate.

3.3.5 Visual LinK™ configuration software

When purchased with a flow meter, the microLinK pickoff will be shipped fully programmed and should not require any input from the user prior to installation. Should the pickoff require re-programming or modification in the field, Visual LinK™ can be downloaded from the Flow Technology, Inc. website (www.ftimeters.com). Visual LinK™ is Windows® software that allows the user to enter calibration data, enter fluid property data, configure the input signals and configure the output signals.

The microLinK pickoff is connected to a PC computer or a notebook computer with Windows® installed and a CAN interface. The pickoff is then configured by reading in or entering calibration data or and fluid property data. Visual LinK™ will directly read a Flow Technology flow meter calibration data electronic file. Multiple files can be read and displayed simultaneously to assist with editing the UVC curve. Alternately, the data can be entered manually. The data is displayed on a graph that allows the user to easily verify the data and avoid errors. The data can be edited, as required, to provide the best characterization of the sensor.

The kinematic viscosity for the liquid being measured can be selected from a library or entered manually. A calculator is included in Visual LinK™ to make manual entry of the viscosity table easier. Given the minimum and maximum points, the calculator will calculate a table of values relating temperature to kinematic viscosity. The ASTM correlation (Appendix C) or the Andrade correlation (Appendix D) can be selected to perform the viscosity calculation. When a kinematic viscosity table is complete for a specific fluid, it can be saved in the library so that it can be recalled and used. The data for the fluid density can also be read from the library or entered manually. The manually entered data can be saved and recalled.

All configuration data can be saved in an electronic job file and can also be stored in the microLinK pickoff. When the configuration is complete, Visual LinK™ can download the data into the pickoff.

3.4 microLinK Outputs

The microLinK is configured for a pulse output where the frequency represents the flow rate. The frequency can be set to represent volumetric or mass flow rate. CANbus communication is also provided for transferring data such as temperature, volumetric flow rate, and other parameters. Please see TM-100823 for detailed CANbus information.

3.5 Operating Sequence

The microLinK pickoff uses the following sequence to read the inputs, process the data and produce outputs (reference the Process Flow Chart, Figure 7). Detailed information is provided below.

1. Read the temperature input.
2. Determine the kinematic viscosity.
3. Read flow meter frequency.
4. Use the frequency and the kinematic viscosity to determine the frequency / viscosity (f/ν).
5. Use the temperature and the thermal expansion coefficient for the flow meter material to calculate the Roshko correction.
6. Multiply f/ν actual by the Roshko correction to determine f/ν corrected.
7. Use f/ν corrected to determine the flow meter K-Factor from the flow meter calibration data.

8. Use the temperature and the thermal expansion coefficient for the flow meter material to calculate the Strouhal correction.
9. Multiply the K-Factor by the Strouhal correction to determine the corrected K-Factor.
10. Use the corrected K-Factor to calculate the linearized compensated flow rate.
11. Use the fluid temperature to determine the density of the liquid being measured. This density can then be used to produce a mass output (optional).
12. Calculate the mass flow rate.
13. Calculate and output the scaled frequency from the flow rate.

3.5.1 Temperature input

The temperature measurement can come from the on-board temperature sensor or it can be populated via CANbus. If it is populated via CANbus, the master on the CANbus network must determine the temperature and transfer it to the pickoff.

3.5.2 Determine kinematic viscosity

The kinematic viscosity is determined via a look up table using the fluid temperature to index the table. The table contains values of temperature versus kinematic viscosity for the liquid flowing through the meter. The table can contain up to 20 values from minimum to maximum viscosity corresponding to maximum and minimum temperature respectively. Visual LinK™ has a viscosity calculator that can be used to build a table of 20 values given a maximum viscosity and minimum viscosity and the corresponding temperatures. One of two algorithms can be selected with the viscosity calculator 1) ASTM D341-93 (0) and 2) Andrade's Equation (Appendix D). The calculator will use the selected equation to determine 20 points that span the viscosity extremes with a 10% margin at each end. The table can be edited as required to obtain the desired relationship between temperature and viscosity. The microLinK uses linear interpolation between table entries to determine viscosity.

If the temperature lookup value is outside the bounds of the table, the viscosity for the minimum (or maximum as appropriate) temperature will be used. See Section 3.6 for further discussion regarding over and under range.

The microLinK pickoff can contain up to three different fluid tables. Switching between fluids is handled via CANbus messages. See TM-100823 for further information regarding CANbus implementation.

3.5.3 Flow meter frequency input

For detailed information regarding frequency averaging options, see Section 3.3.1. The meter input frequency is divided by the kinematic viscosity to produce the flow parameter *FrequencyOverViscosity*. The ratio of frequency and kinematic viscosity (f/ν) is correlated with meter K-Factor during the flow meter calibration. The K-Factor versus f/ν calibration data is stored in a table in the microLinK. The f/ν parameter is used to index the table to determine the K-Factor. Up to 30 points can be stored in the table. The table can be edited by the user to best characterize the flow meter. Linear interpolation is used between table entries.

3.5.4 Strouhal Roshko Correction

The dimensionless Strouhal Roshko correlation is used to correct for the expansion and contraction of the flow meter materials of construction due to temperature changes. The Strouhal Roshko equations were taken from “The Characterization of a Piston Displacement-Type Flow meter Calibration Facility and the Calibration and Use of Pulsed Output Type Flow meters, Journal of Research of the National Institute of Standards and Technology”. The correction is based on the thermal expansion coefficient of the flow meter housing material. If the thermal expansion coefficient is set to 0, the correction factors reduce to 1.

The Strouhal Roshko correction can be viewed as a transfer function between actual measurement conditions and the calibration conditions. First the f/ν parameter is determined at the actual conditions. Then the Roshko correction is applied to transfer the f/ν parameter from the actual conditions to the calibration conditions. Next the f/ν parameter is used with the calibration table to determine the K-Factor at the calibration conditions. Finally, the Strouhal correction is applied to transfer the K-Factor from the calibration conditions to the actual conditions. The process is shown graphically below.

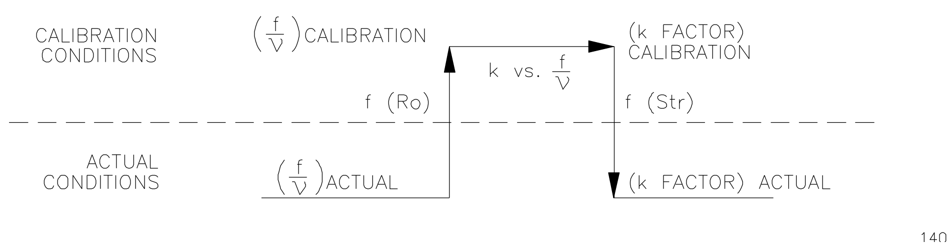


Figure 6 – Strouhal Roshko Transfer Function

3.5.5 Calculate the volumetric flow rate

Once the actual K-Factor is known, the actual volumetric flow rate can be calculated. Flow rate is calculated as;

$$Q_A = \frac{f}{K_A} * TimeBase$$

The value for *TimeBase* is equal to the number of seconds in the user-defined time unit. For example, if the flow rate units are gallons per minute, then *TimeBase* equals 60. If the units are liters per second, then *TimeBase* equals one.

3.5.6 Calculate the fluid density

Using the fluid temperature, the density can be calculated from a lookup table. The table is defined in Visual LinK™ during device programming. At least 2 points must be put into the table corresponding to the minimum and maximum density. The temperature corresponding to the minimum and maximum temperature should be the same as the temperature extremes in the viscosity table. Up to 20 points may be put into the table. The microLinK uses linear interpolation between table entries to determine density.

If the temperature lookup value is outside the bounds of the table, the density for the minimum (or maximum as appropriate) temperature will be used.

3.5.7 Mass flow rate

The actual mass flow rate can be calculated by multiplying the volumetric flow rate by the fluid density.

$$M_A = Q_A \rho$$

3.5.8 Frequency output

The output frequency is calculated as a linear interpolation between the user-defined scaling information. The following parameters are defined in Visual LinK™ and used by the processor:

MinimumFrequency	*MinimumFlowRate*
MaximumFrequency	*MaximumFlowRate*

Note that the *MinimumFrequency* is not required to be zero. The frequencies and rates cannot be negative. The flow rate values are either volumetric flow rate or mass flow rate.

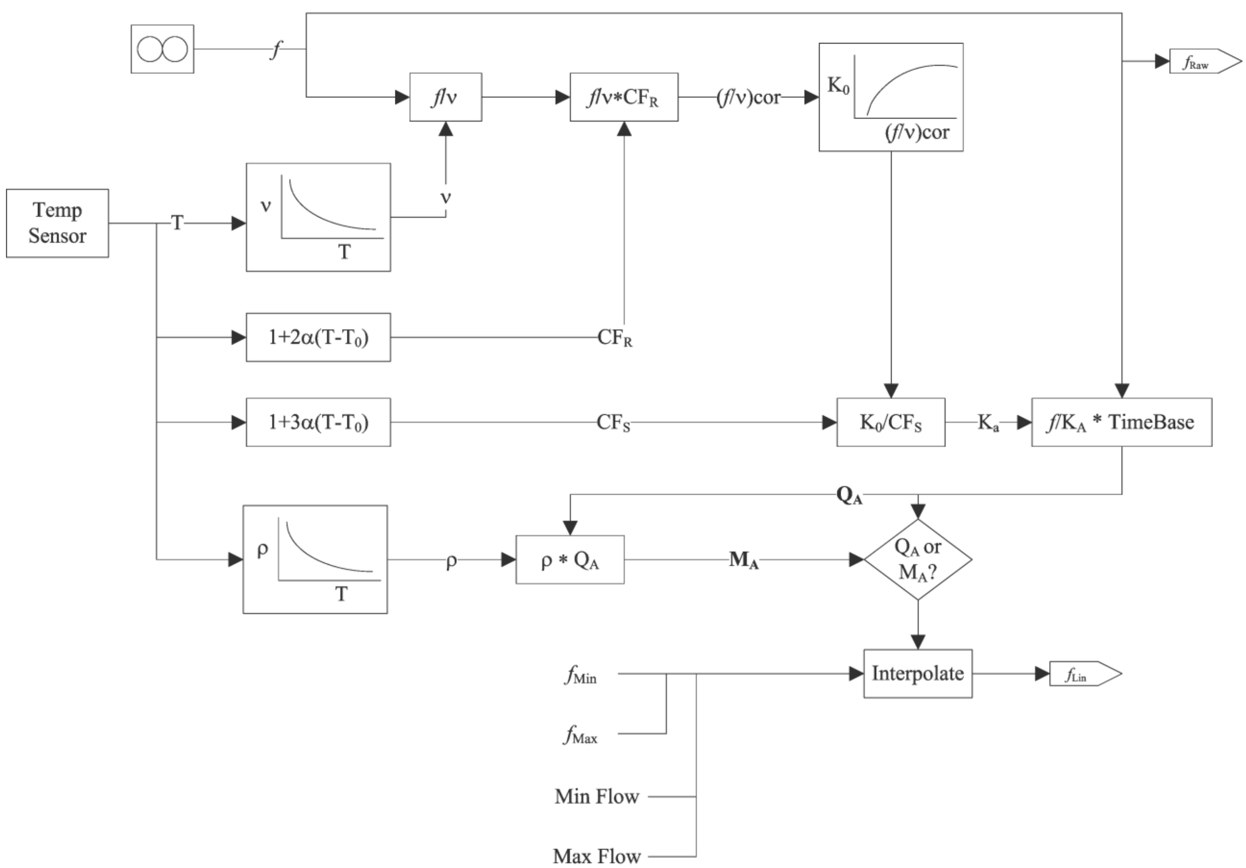


Figure 7 – microLinK Calculations Using ST vs. RO

3.6 Over and Under Range

Automatic over/under range values are assumed for each of the linearization tables: K-Factor vs. frequency/viscosity, viscosity vs. temperature, and density vs. temperature. If the lookup value for the table (frequency/viscosity or temperature) is below the minimum value in the table, then the returned value is equal to the corresponding value at the minimum lookup value. The same is true if the lookup value is greater than the maximum value in the table. This is better illustrated with an example. Consider the example table below:

Table 2 – Example Temperature-Density Table

Temperature	**Density**
-10	835
0	823
…	…
50	778
60	765

If the reported temperature is -5 degrees, then the calculated density will be 829 by way of linear interpolation. However if the temperature is -15 degrees, the calculated density will be 835 because -15 is below the minimum temperature value in the table. Likewise if the temperature is 63 degrees, the density will be 765.

It is important to understand this when entering data in the linearization tables. Ensure the tables cover the full range of expected operating conditions.

4 PROGRAMMING THE MICROLINK PICKOFF

4.1 General

When purchased as a mate to a specific turbine flow meter, the microLinK is fully programmed to the mating meter calibration with the units and scaling requested in your order. Likewise, subsequent Flow Technology, Inc. calibrations will re-program the microLinK during the mating meter re-calibration.

4.2 Equipment and Tools Required

- Visual LinK™ 5.6 or greater software
- Visual LinK™ Software Manual. FTI P/N TM-100654
- Computer
    - 2.33 GHz CPU
    - 40GB Hard Drive
    - 2 GB RAM
    - Supported Operating Systems:
        - Windows XP (SP3 or later)
        - Windows 7
- USB CAN Interface from esd electronics (www.esd-electronics-usa.com)
    - A programming kit is available from Flow Technology which includes a USB-CAN interface, programming box, power supply, and mating microLinK cable.
        - For -1 (connector) microLinK order FTI p/n 01-100754-101
        - For -5 or -6 (flying leads) microLinK order FTI p/n 01-100754-102
- Printer (optional): Windows® compatible for hardcopy reports

4.3 Electrical Connection

Refer to Figure 8 and Figure 9 for information on connecting the microLinK to the PC using the Programming Kit 01-100754-101 or 01-100754-102. The f_{RAW} and f_{LIN} connections are available for monitoring the raw and linearized frequencies if desired.

The programming kit is flexible so it can be used with a standalone pickoff or integrated into an existing CANbus network. There are four switches inside the programming box that need to be configured to match the environment. Use a small flat screwdriver to pry open the Programming Box to reveal the switches as shown in Figure 10.

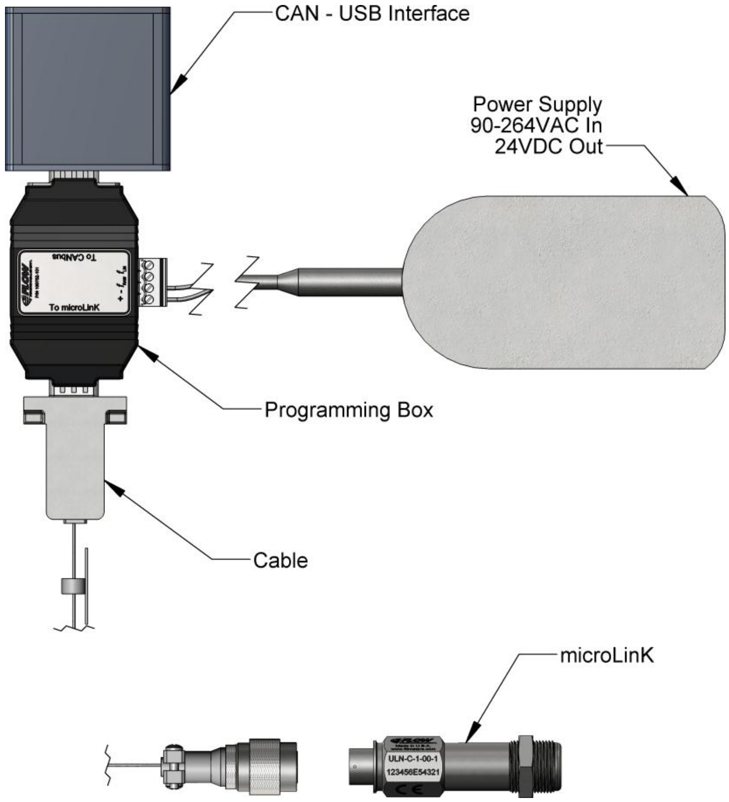


Figure 8 – 01-100754-101 Connections

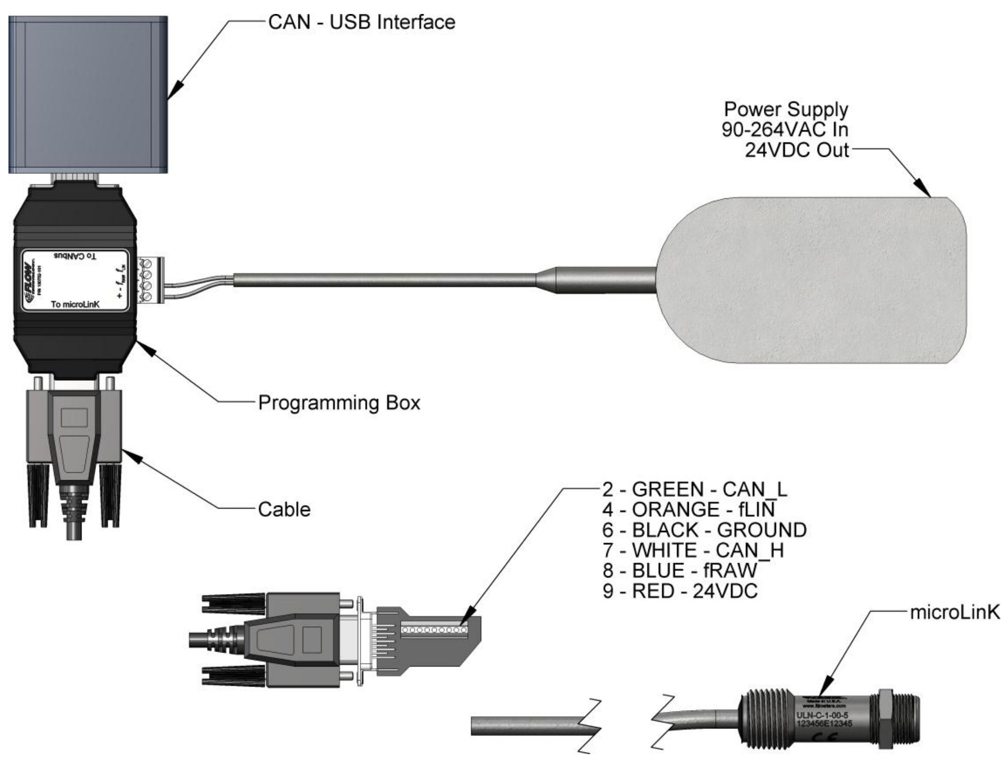


Figure 9 – 01-100754-102 Connections

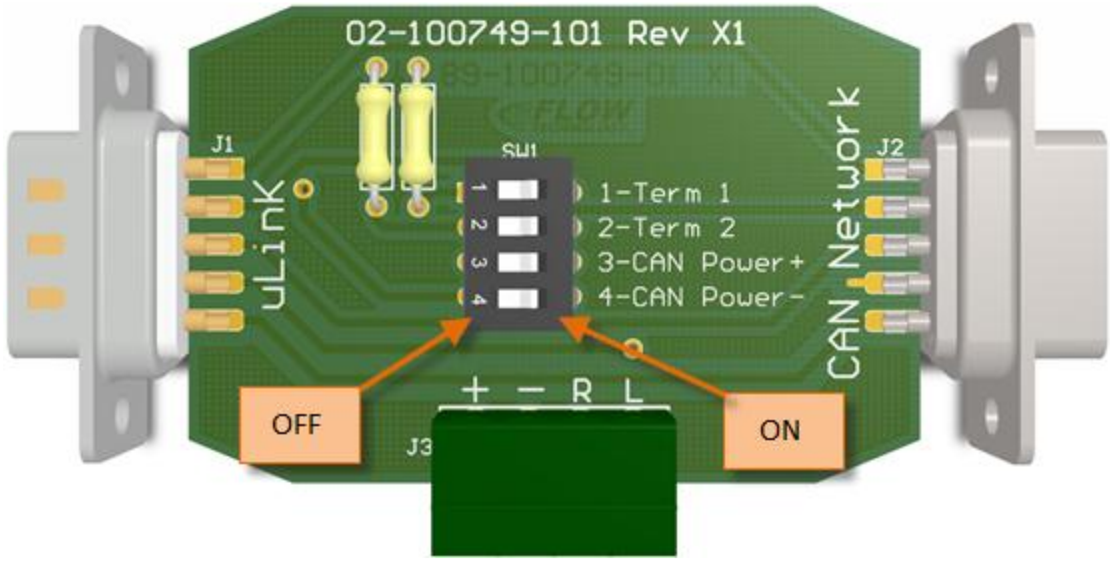


Figure 10 - Programming Box Switches

The switches are described as follows:

- 1 – Term 1: This switch activates one of the termination resistors for the CANbus data lines.
- 2 – Term 2: This switch activates a second termination resistor for the CANbus data lines.
- 3 – CAN Power+: Connects 24VDC from the external power supply to pin 9 of the CAN Network D-Sub connector. Note that 24VDC is always connected to pin 9 of the uLinK D-Sub connector.
- 4 – CAN Power-: Connects the ground from the external power supply to pin 6 of the CAN Network D-Sub connector. Note that the ground is always connected to pin 6 of the uLinK D-Sub connector.

If the programming kit is to be used with only a single pickoff and not connected to any other CAN devices, all switches should be put in the ON position.

If other devices are connected to the CAN network, a decision is needed regarding the termination resistors. Document CiA 102 requires a termination resistor at each end of the bus. If terminating resistors **are not** already in place, switch 1 and 2 should be turned to the ON position. If terminating resistors **are** already in place, switch 1 and 2 should be turned to the OFF position. If one terminating resistor is in place, then switch 1 should be placed in the ON position and switch 2 should be placed in the OFF position.

Switches 3 and 4 may be placed in the ON position IF AND ONLY IF other devices on the CAN network will not be affected by 24VDC on pin 9 of the D-Sub connector. This may be useful if other devices (other microLinKs) on the network are able to use 24VDC on pins 9 and 6. Note this is not an approved use of pin 9 according to CiA 102 (CAN Physical Layer for Industrial Applications).

5 TROUBLESHOOTING

When troubleshooting the microLinK pickoff, always ensure the wiring is correct. Connection information can be found in Figure 4 and Figure 5. For additional assistance contact Flow Technology at 800-528-4225.

Table 3 – Troubleshooting

Symptom	Possible Cause	Action to Resolve
No linearized frequency output	Power not applied	Apply power to microLinK
	No fluid flow through meter	Check if raw frequency exists
	Rotor frequency below low frequency cutoff	Increase flow rate
		Decrease low frequency cutoff
	Frequency scaling set incorrectly	Verify frequency scaling
	Invalid density or viscosity	Verify fluid data is correct
	Volumetric or mass flow turned off	Verify pulse output type object (0x2022sub9) is set to a 1 or 2
	Other error	Verify the error register (0x1001) is 0
No temperature measurement	Power not applied	Apply power to microLinK
	Temperature sensor error	Verify the error register (0x1001) is 0
	Incorrect SDO index	Read SDO index 0x2013
	Incorrect PDO Mapping	PDO 0x1A01sub2
Flow indication at zero flow conditions	EMI interference	Remove source of possible noise such as motors, generators, and high voltage signals
	Vibration is causing rotor to “wiggle”	Isolate flow meter from vibration source
		Increase low frequency cutoff to filter erroneous readings
	Insufficient grounding	Ensure flow meter housing is attached to ground
No SDO data	Power not applied	Apply power to microLinK
	Incorrect node ID	Verify the microLinK node ID
	microLinK not in Operational or Pre-Operational state	Send a NMT object “Start Remote Node” or “Enter Pre-Operational” to the microLinK
	CAN network is down	Start the CAN network
No PDO data	Power not applied	Apply power to microLinK
	microLinK not in Operational state	Send a NMT object “Start Remote Node” to the microLinK
	Event timer set to zero	Set event timer to a non-zero value (in ms)
	Event timer set too high	Set even timer to a lower value

Appendix A Model Number Break Down

ULN-C-1-00*aaxxx*

aa	Package Configuration -1 = MS Connector -5 = Flying Leads with NPT -6 = Flying Leads without NPT
xxx	Specials – Determined by FTI at time of order

Appendix B microLinK Specifications

Input Power	Specifications	
24 VDC nominal	9 to 30 VDC, 60 mA max, 600 mW @ 24VDC	

Rotor Sensing	Specifications	
Frequency Range	5-2500 Hz typical, dependent on meter configuration	

Temperature Input	Specifications	
On-board Temperature Sensor	Temperature Range:	-40° to +125°C

Linearization	Specifications	
Flow meter K-Factor	Number of Points:	2 to 30
	Interpolation Method:	Linear
	Correlation:	Strouhal vs. Roshko (per NIST publication)
Viscosity	Number of Points:	2 to 20 per fluid
	Interpolation Method:	Linear
	Correlation:	ASTM D341-93 or Andrade's Equation or user defined
Density	Number of Points:	2 to 20 per fluid
	Interpolation Method:	Linear

Communications	Specifications	
Interface	CAN 2.0A, 11-bit identifiers CANopen i.a.w. CiA 301, v4.0.2	
Bit Rate	20, 50, 125, 250, 500, 800, or 1000 kbits/sec	

Outputs	Specifications	
Frequency (Flowrate)	Raw Frequency:	0 to 5 VDC pulse
	Linearized Frequency:	0 to 5 VDC pulse (.5 to 5000 Hz)
	Transmission Distance:	250 ft maximum
	Output Configuration:	NPN collector output with internal 1.8 kΩ pull up resistor (to 5V) and 560Ω series limiting resistor

Performance	Specifications	
Accuracy	Linearized Frequency: Temperaure:	0.1% of reading or better ±2°C, increased accuracy possible with user calibration
Linearization Latency	< 20ms + period of input pulse	

Environment	Specifications
Temperature Range	-40° to +125°C
Humidity	0 to 85% RH non-condensing

Approvals	Specifications
CE	EN 61000-6-2:2005, EN 61000-6-4:2006

Connector	Specifications
6 pin Mate	FTI p/n 15-94965-01 (MS27473E8F35S)
Backshell	FTI p/n 15-93357-01 (MS27506-A-8-2)

Cabling	Specifications
Cable type	Alpha Wire 1216C
#conductors, size	6, 24AWG (7x32), 3 twisted pairs
Cable diameter	.213” (5.4mm) max
Conductor insulation	.010” (0.25mm) wall PVC
Jacket	.032” (0.81mm) wall PVC

Appendix C Viscosity Calculation Using ASTM D341-93

Viscosity-Temperature charts were derived with computer assistance to provide linearity over a greater range on the basis of the most reliable of modern data. The general relationship is:

$$\log \log Z = A - B \log T \qquad (1)$$

where:

Z	$= (v + 0.7 + C - D + E - F + G - H)$,
log	= logarithm to base 10,
v	= kinematic viscosity, cSt (or mm^2/s),
T	= temperature, K or °R,
A and B	= constants,
C	$= \exp(-1.14883 - 2.65868v)$,
D	$= \exp(-0.0038138 - 12.5645v)$,
E	$= \exp(5.46491 - 37.6289v)$,
F	$= \exp(13.0458 - 74.6851v)$,
G	$= \exp(37.4619 - 192.643v)$, and
H	$= \exp(80.4945 - 400.468v)$.

Terms *C* through *H* are exponentials on the natural base e since this simplifies computer programming. Equation 1 uses logarithms to the base 10 for general convenience when used in short form.

The limits of applicability are listed below:

$Z = (v = 0.7)$	2×10^7 to 2.00 cSt
$Z = (v = 0.7 + C)$	2×10^7 to 1.65 cSt
$Z = (v = 0.7 + C - D)$	2×10^7 to 0.90 cSt
$Z = (v = 0.7 + C - D + E)$	2×10^7 to 0.30 cSt
$Z = (v = 0.7 + C - D + E - F + G)$	2×10^7 to 0.24 cSt
$Z = (v = 0.7 + C - D + E - F + G - H)$	2×10^7 to 0.21 cSt

It is obvious that Eq 1 in the simplified form: $\log \log (v + 0.7) = A - B \log T$ will permit kinematic viscosity calculations for a given fluid in the majority of instances required. The constants *A* and *B* can be evaluated for a fluid from two data points. Kinematic viscosities or temperatures for other points can then be readily calculated.

More convenient equations are given below. These are necessary when calculations involve kinematic viscosities smaller than 2.0 cSt.

$$\log \log Z = A - B \log T \qquad (2)$$

$$Z = v + 0.7 + \exp(-1.47 - 1.84v - 0.51v^2) \qquad (3)$$

$$v = [Z - 0.7] - \exp(-0.7487 - 3.295\,[Z - 0.7]) + 0.6119\,[Z - 0.7]^2 - 0.3193\,[Z - 0.7]^3) \qquad (4)$$

where:

log = logarithm to base 10,

v = kinematic viscosity, cSt (or mm^2/s),

T = temperature, K or °R, and

A and *B* = constants.

Inserting Eq 3 into Eq 2 will permit solving for the constants *A* and *B* for a fluid in which some of the experimental kinematic viscosity data fall below 2.0 cSt. This form can also be used to calculate the temperature associated with a desired kinematic viscosity.

Conversely, the kinematic viscosity associated with a stated temperature can be found from the equation determined as in Eq 4 by solving for *Z* in the substituted Eq 2, and then subsequently deriving the kinematic viscosity from the value of *Z* by the use of Eq 4.

Appendix D Viscosity Calculation Using Andrade's Equation

The viscosity correction algorithm will require two reference points or data pairs, one at the minimum viscosity and temperature maximum and the other at the maximum viscosity and temperature minimum. The two data pairs will then be used to compute the temperature versus viscosity table. As an example:

Given ($\mathbf{v}_{R1}$ @ T_{R1}) and ($\mathbf{v}_{R2}$ @ T_{R2}) compute $\mathbf{A}_L$ and $\mathbf{B}_L$ according to the following equations:

$\mathbf{B}_L = T_{R1} * T_{R2} \ln (\mathbf{v}_{R1}/\mathbf{v}_{R2})/(T_{R2}-T_{R1})$ $\mathbf{A}_L = \mathbf{v}_{R1}/(\exp(\mathbf{B}_L/T_{R1}))$

Note: The temperatures used in the calculation are absolute. If the English system is in use the temperatures must be in degrees Rakine where $^oR = ^oF + 459.67$. If the metric system is in use the temperature must be in degrees Kelvin where $^oK = ^oC + 273.15$.

The 20-point viscosity table will be produced by dividing the range of viscosities into 20 equally spaced viscosity values. As an example, given v_{R1} = 21 cSt @ 50 ^{o}F and v_{R2} = 2 cSt @ 198 ^{o}F the $\mathbf{B}_L$ and $\mathbf{A}_L$ values would be computed as:

$\mathbf{B}_L = T_{R1} * T_{R2} \ln (\mathbf{v}_{R1}/\mathbf{v}_{R2})/(T_{R2}-T_{R1}) = (50+459.67)*(198+459.67) * \ln(21/2)/(198-50)$

$\mathbf{B}_L = 509.67 * 657.67 * (2.3026)/(148) = 5.325 X 10^3$

$\mathbf{A}_L = \mathbf{v}_{R1}/(\exp(\mathbf{B}_L/T_{R1})) = 21/(\exp(\mathbf{B}_L/T_{R1})) = 21/(\exp(5325/509.67) = 6.092 X 10^{-4}$

Using Andrade's equation ($v_{TR} = \mathbf{A}_L * \exp(\mathbf{B}_L/T_R)$) to compute the viscosity at 140 ^{o}F gives.
$v_{(T=140F)} = 6.092 X 10^{-4} * \exp(5.325 X 10^3 / (140 + 459.67)) = 4.38$

To use the same equation to compute temperatures one would have $T_{FA} = \mathbf{B}_L/\ln(V_{TA}/\mathbf{A}_L) - 459.67$

To divide the 2 cSt to 21 cSt range into 20 table entries one would start at 2 and increase at a incremental rate of ($v_{max} - v_{min}$) / (# of Table entries - 1) or 19 cSt / 19 = 1 cSt.

v_T = 2 cSt	$T_F = \mathbf{B}_L/\ln(2/\mathbf{A}_L) - 459.67$	T_F = 198
v_T = 3 cSt	$T_F = \mathbf{B}_L/\ln(3/\mathbf{A}_L) - 459.67$	T_F = 166.65
v_T = 4 cSt	$T_F = \mathbf{B}_L/\ln(4/\mathbf{A}_L) - 459.67$	T_F = 146.16
v_T = 5 cSt	$T_F = \mathbf{B}_L/\ln(5/\mathbf{A}_L) - 459.67$	T_F = 131.16
v_T = 6 cSt	$T_F = \mathbf{B}_L/\ln(6/\mathbf{A}_L) - 459.67$	T_F = 119.44
v_T = 7 cSt	$T_F = \mathbf{B}_L/\ln(7/\mathbf{A}_L) - 459.67$	T_F = 109.89
v_T = 8 cSt	$T_F = \mathbf{B}_L/\ln(8/\mathbf{A}_L) - 459.67$	T_F = 101.87
v_T = 9 cSt	$T_F = \mathbf{B}_L/\ln(9/\mathbf{A}_L) - 459.67$	T_F = 94.98
v_T = 10 cSt	$T_F = \mathbf{B}_L/\ln(10/\mathbf{A}_L) - 459.67$	T_F = 88.96
v_T = 11 cSt	$T_F = \mathbf{B}_L/\ln(11/\mathbf{A}_L) - 459.67$	T_F = 83.63
v_T = 12 cSt	$T_F = \mathbf{B}_L/\ln(12/\mathbf{A}_L) - 459.67$	T_F = 78.85

v_T = 13 cSt	$T_F = \mathbf{B}_L/\ln(13/\mathbf{A}_L) - 459.67$	T_F = 74.52
v_T = 14 cSt	$T_F = \mathbf{B}_L/\ln(14/\mathbf{A}_L) - 459.67$	T_F = 70.58
v_T = 15 cSt	$T_F = \mathbf{B}_L/\ln(15/\mathbf{A}_L) - 459.67$	T_F = 66.96
v_T = 16 cSt	$T_F = \mathbf{B}_L/\ln(16/\mathbf{A}_L) - 459.67$	T_F = 63.62
v_T = 17 cSt	$T_F = \mathbf{B}_L/\ln(17/\mathbf{A}_L) - 459.67$	T_F = 60.52
v_T = 18 cSt	$T_F = \mathbf{B}_L/\ln(18/\mathbf{A}_L) - 459.67$	T_F = 57.63
v_T = 19 cSt	$T_F = \mathbf{B}_L/\ln(19/\mathbf{A}_L) - 459.67$	T_F = 54.93
v_T = 20 cSt	$T_F = \mathbf{B}_L/\ln(20/\mathbf{A}_L) - 459.67$	T_F = 52.39
v_T = 21 cSt	$T_F = \mathbf{B}_L/\ln(21/\mathbf{A}_L) - 459.67$	T_F = 50.00

The table values would be down loaded into the Linear LinK™ TCI via the Host program. The host program would also have the ability to edit each entry in the table. This feature would allow customers to customize the table for variations in the fluid when Andrade's equation does not produce the desired accuracy.

Appendix E Strouhal and Roshko Correction

The Strouhal correction value "S_t" is the product of the k-factor of the meter times the cubic value of the dimensional change as a function of temperature. The equation is as follows:

$$S_t = k_0\text{-factor} * D_0^3 * [1 + 3\alpha(T - T_0)]$$ where k_0, D_0, and T_0 are at reference conditions.

The Roshko correction is the product of the ratio of meter frequency to viscosity times the square of the dimensional change as a function of the temperature. The equation is as follows:

$$R_0 = (f_m/\nu_A) * D_0^2 * [1 + 2\alpha(T-T_0)]$$

Where f_m is the uncorrected frequency and ν_A is the actual viscosity.

The Roshko correction requires that the ratio of meter frequency to viscosity at non reference conditions be multiplied by the dimensional change as a function of temperature before the k-factor is computed. The equation is as follows:

$$(f_{mc}/\nu_A) = (f_m/\nu_A) * [1 + 2\alpha(T-T_0)]$$

Where f_{mc}/ν_A is the corrected ratio of frequency to viscosity. The corrected value, (f_{mc}/ν_A), would then be used to find the k_{0c}-factor at reference conditions.

The Strouhal correction for flow at non reference conditions requires that the reference k_{0c}_factor found after Roshko correction be divided by the dimensional change as a function of temperature. The equation is as follows:

$$k_A\text{-factor} = (k_{0c}\text{-factor})/[1 + 3\alpha(T-T_0)]$$

Where k_A-factor is the actual k-factor for the meter at non reference conditions. This value can then be used to compute the volume flow rate by dividing the meter frequency by the corrected k-factor. The equation is as follows:

$$Q_A = f_m/k_A\text{-factor}$$

Time Base Correction

Once the corrected volumetric flow rate is computed a time base correction will be applied to convert to the appropriate output units. As an example:

Given that the value of Q_A is computed in gallons per second and the required user units are gallons per minute. A correction factor of 60 would be required. Multiply the volumetric flow rate in seconds by 60 to convert to volumetric flow rate in minutes.

$$Q_A \text{ in gal/sec} * 60 \text{ sec / min} = Q_A \text{ in gal/min}$$

Appendix F Declaration of Conformity

FLOW TECHNOLOGY™ 8930 S. Beck Avenue, Suite 107, Tempe, Arizona 85284

Phone: (480) 240-3400 **Fax:** (480) 240-3401 **e-mail:** ftimarket@ftimeters.com **website:** www.ftimeters.com

CE - DECLARATION OF CONFORMITY

Manufacturer Name: FTI Flow Technology Inc.

Manufacturer Address: 8930 South Beck Avenue, Suite 107, Tempe, AZ 85284 USA

Type of Equipment: Turbine Flow Meter Pickoff

Application of Council Directive: 2004/108/EC (EMI), 2011/65/EU (RoHS)

Standards to which Conformity is Declared:

EN 61000-6-2:2005 – Generic standards – Immunity standard for Industrial Environments

EN 61000-6-4:2006 – Generic standards – Emission standard for Industrial Environments

Test Report: EN-100991

Pickoff Model Number: ULN-C-1-00aaxxx

aa = Package Configuration
- -1 = MS Connector
- -5 = Flying Leads with NPT
- -6 = Flying Leads without NPT

xxx = Special – Determined by FTI at time of order

Serial Number(s): ALL Year of First Manufacture: 2012

Place Tempe, AZ, USA

I, the undersigned, hereby declare that the equipment specified above conforms to the above Directive and Standards, and this Declaration is supported by a Technical File located at the Factory

Ralph Duffill, General Manager
FTI Flow Technology, Inc.

AC - 101002 Rev A per ECO 22352