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Fluenta Flare Gas Meter

FGM 130 Functional Description
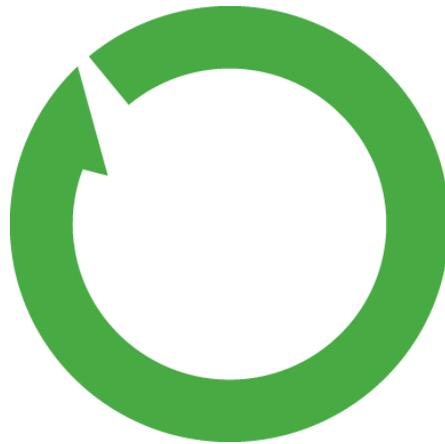
TABLE OF CONTENTS

1. INTRODUCTION

1.1 Introduction

This document describes the Fluenta FGM 130 Ultrasonic Flare Gas Metering System.

1.2 Reference Conditions

The following reference conditions are used as a basis for the Flare Gas Metering System:

Pressure   :   1.01325 barA
Temperature :   15 °C = 288.15 K

1.3 Units of Measurement

The following units of measurements are used in the Flare Gas Metering System:

Length   :   mm
Area   : m^2
Volume   : m^3 or Sm^3
Mass   :   kg
Volume flow rate   : m^3/h or Sm^3/h
Mass flow rate   :   kg/h
Density   : kg/m^3
Pressure, absolute :   bar a
Temperature   :   °C

U.S units also available.

1.4 Language

The FGM 130 Flow Computer is delivered with English text as standard. Versions displaying Spanish text are available upon request.

2. GENERAL TECHNICAL DESCRIPTION

2.1 Problems Involved in Flare gas Metering

The problems that must be overcome in order to measure flare gas are as follows :

- Large velocity variations for the gas flowing in the flare pipe.

- Large pipe diameters.

- Low pressure situation at the metering point.

- The field-mounted sensors shall operate in explosive or potentially explosive areas.

The FGM 130 is designed to operate under these difficult conditions and the capability to do so is verified by instruments presently in operation. The instrument is non-intrusive (it does not disturb the flowing gas) and has no moving parts, which makes the instrument less exposed to wear. The measurements will not be influenced by condensate or oil droplets in the flow, nor by any coating deposited on the transducers during operation.

The problem associated with high flow velocities is, among others, that the gas flowing in the pipe represent a source of noise, which reduces the recognizability of the transmitted, ultrasonic signal. Also, high gas velocities will carry the ultrasonic pulses along the pipe, which makes it even more difficult for the sensors to communicate with each other.

Low pressures, large pipe diameters and the limitations on the amount of electric power that can be applied due to explosive area regulations, are all elements that increase the difficulty in obtaining good measurements.

These problems are solved by using two different types of signals called "Continuous Wave" and "Chirp". This technique is described further in this document.

2.2 General Description of FGM 130

The FGM 130 system consists of a flow computer placed in a control room, and up to three pairs of ultrasonic sensors mounted on flare gas pipes as shown in Fig. 1, below.
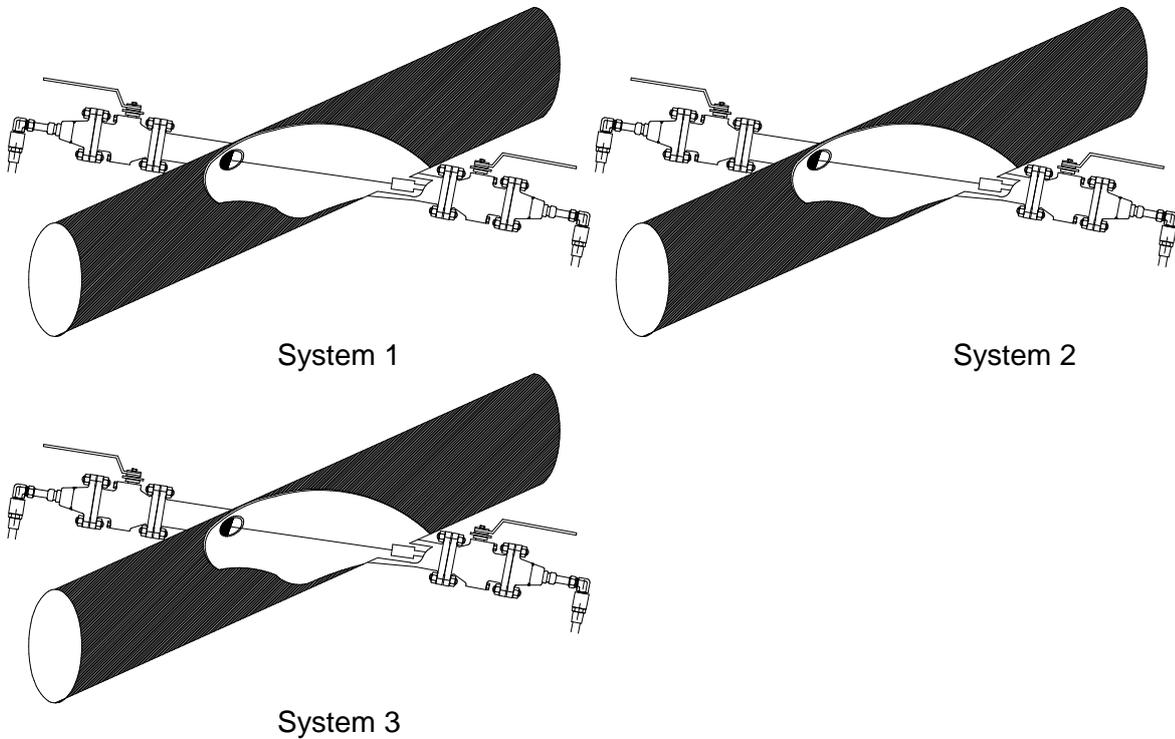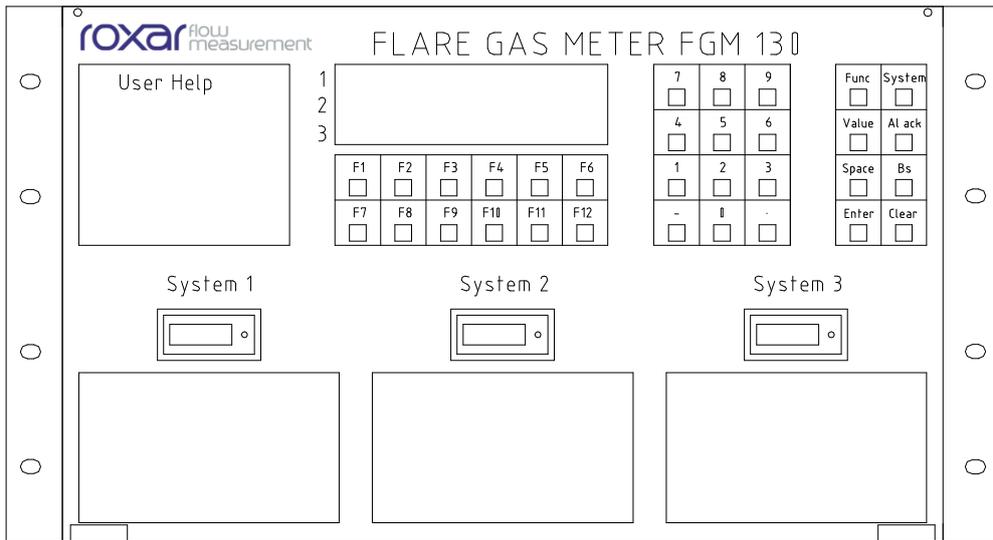

System 1

System 2

System 3

Figure. 1

The FGM 130 measures the gas velocity with the aid of the time of flight technique, which means that the ultrasonic transducers shall communicate with each other by receiving and transmitting signals.

With reference to the figure on the previous page, the measurement principle may be explained as follows:

Both transducers transmit and receive the ultrasonic pulses and the difference in transit time is measured. When gas is flowing in a pipe, a pulse travelling against the stream will use longer time to reach the opposite transducer than a pulse travelling with the flow. This time difference is used to calculate the velocity of the flowing medium by the following formula :

$$v = \frac{D}{\sin 2\phi} \cdot \frac{(t_{21} - t_{12})}{t_{12} \cdot t_{21}}$$

where :

v = velocity of flowing medium without compensation for Reynold's Number variation

D = pipe diameter

ϕ = angle of intertransducer center line to axis of pipe

t_{12} = transit time from transducer 1 to transducer 2 (down stream)

t_{21} = transit time from transducer 2 to transducer 1 (up stream)

The FGM 130 system can be split in two major components that are:

- Flow Computer unit placed in the control room

- Ultrasonic transducers mounted in the field on the flare pipe

The Flow Computer and the transducers are communicating through fibre optic cables. The electrical power is supplied to the transducers through a power supply cable from the Flow Computer. In addition to the information from the transducers, the Flow Computer requires a 4-20 mA signal from the pressure- and temperature transmitters. This is required for the FGM 130 to be able to give readings in [Sm^3/hr] and [kg/hr]. These signals may also come from an external system, since the computer is able to handle minor common mode potential differences. However, the two systems should have a common ground connection to keep the common mode potential under control.

2.3 Description of Flow Computer Unit

The Flow Computer unit has a layout as shown in Fig. 2 below.   A detailed description of the components that make up the Flow Computer unit will be given in Section 4.1.
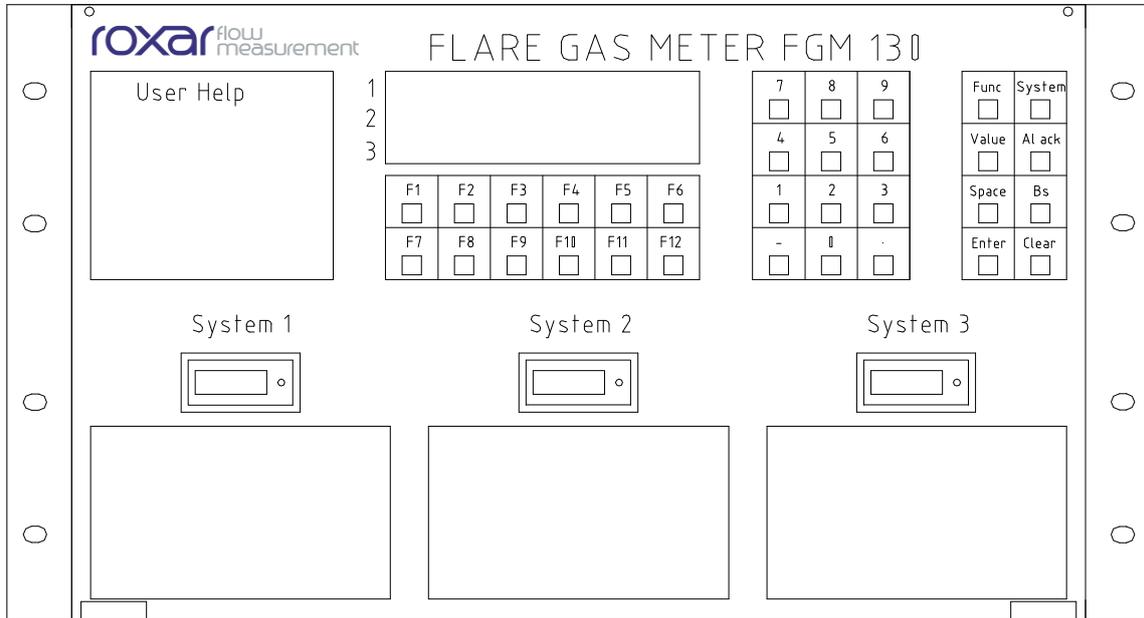
Figure 2. The FGM 130 Flow Computer Unit

2.3.1 Flow Computer and Signal Processor

The processing of the information coming from the transducers in the field and from the pressure and temperature transmitters is performed in the Flow Computer Unit. The computer controls the transmission and detection of signals to and from the transducers and performs the critical time measurements. The computer also performs calculations based on the time measurement results and presents data and alarm messages on the display unit.

2.3.2 Display/Keyboard

The display will show all data that are available in the Flow Computer. Any alarms or error messages that might arise can be read and the source of the alarm can be determined. The user can through the display and keyboard change some parameters by entering new values. The display is a 8x40 character LCD display, normally used as 3 equal 2x40 character displays, one for each system. By the use of simple operations on the keyboard the desired data can be fetched from the instrument and if necessary transferred to other units. The operation of the keyboard is described in more detail in Section 4.2.

2.3.3 Non-Resettable Counter Module

This will at all times show the accumulated volume flow through the flare pipe. The counter resolution is selected according to the expected flow rates.

2.4 Outputs

In addition to the data available on the counter and from the display, FGM 130 has eight 4 - 20 mA outputs configurable for different parameters. These signals can be connected to the operators main computer system.
Furthermore the pulse train updating the internal counters is forwarded to external counters in the platform control computer. These counters have to be of a fast incrementing electronic type.
The FGM 130 has also a serial interface link for communication with the platform control computer. The interface is selectable between RS232C, RS422 and RS485. All the user accessable outputs are located at the rear of the Flow Computer.

2.5 Pressure- and Temperature Transmitters

In order to make the necessary calculations, the Flow Computer requires pressure- and temperature inputs through 4-20mA or HART signals from the transmitters mounted at the metering point, or from the control system.

2.6 A more Detailed Explanation of the Measurement Principle

We have already explained that the measurement principle, is based on transit time difference. A more detailed description of the signal types used is given on the next page. It is the use of two different signal types, and the combination of them, that makes the FGM 130 a unique instrument for flare gas measurement purpose.

The two signal types are:

CW   = Continuous wave

Chirp = Variable frequency signal

CW - measurements:

This signal has a constant wavelength as illustrated below:
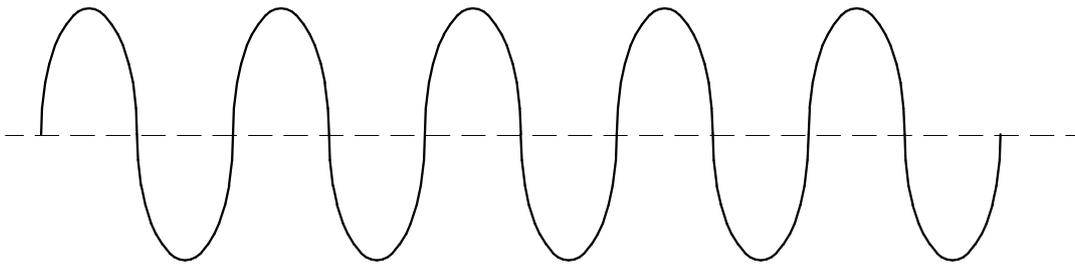
This is usually the only signal type used in ultrasonic instruments. When measuring flare gas at high velocities this signal type will be drowned by the noise generated by the flowing medium. This signal is therefore only used for low velocities together with the Chirp signals.

Chirp - measurements:

This signal is given an unique recognizable form characterised by the pulse duration and the varying signal frequency.
This signal type is used in combination with CW signals for low velocities. At higher velocities the instrument uses only these Chirp signals. Their unique form makes it possible to recognize them through the noise.
The combination of Chirp and CW at low velocities enhances the accuracy of the FGM 130 measurements for these velocities.

3. FIELD EQUIPMENT

3.1 Transducers

The transducers mounted to the flare pipe are approved by Nemko for operation in Zone 0 with safety class EEx ia IIC T6. They are mounted in transducer holders that are welded on to the flare pipe at carefully selected angles. The holders are positioned using specially designed mounting jigs.

The transducers can be retracted through ball valves if they require servicing. The pressure sealing is established using a tube fitting solution which after initial installation ensures that the transducer position remains constant even after the transducer have been taken out for servicing.

A piezo-electric X-tal is mounted inside the titanium housing at the front of the transducer. When the X-tal is subjected to an alternating electrical signal it vibrates with the same frequency as the electrical signal. The X-tal is glued to the front membrane of the titanium housing and this membrane vibrates with the X-tal. The membrane movement generates the ultrasonic signals. When a transducer receives ultrasonic signals, the membrane vibrates and the X-tal transfers this movement into an electrical signal.

3.2 Transducer Electronic Boards

Each transducer is connected to a transducer electronic board. These boards are located in the electronic enclosures mounted close to the transducers on the flare line. The electronic boards transfer the optical signals from the computer to electrical signals that are sent to the transducers. The signal received from the transducers is amplified, filtered and then transferred back to optical signals and returned to the Flow Computer. The electronic boards are powered by the certified power supplies in the Flow Computer. The power supplied is 16.2 VDC / 0.5 A maximum.

The electronic boards are moulded in epoxy and each board is mounted in a stainless steel screened box, in order to avoid interference.

3.3 Electronic Enclosures

Each pair of the transducer electronic boards are mounted in a stainless steel electronic enclosure. This enclosure should be mounted a maximum of 1.7 meters from the rear end of each transducer. The transducers are connected to this enclosure through a cable, protected by a flexible oil resistant rubber hose with a length of 2.0 meters.

3.4 Ball Valves

The ball valves are to be mounted onto the transducer holders. This enables installation and retraction of the transducers during operation, even under full line pressure.

4. FGM 130 FLOW COMPUTER UNIT

4.1 General

The Flow Computer Unit, shown in Figures 4.1 and 4.2, consists of a microcomputer module with inputs from a signal processing electronics module and with outputs to a display and a non-resettable counter. The operator interface consists of a display and keyboard unit.

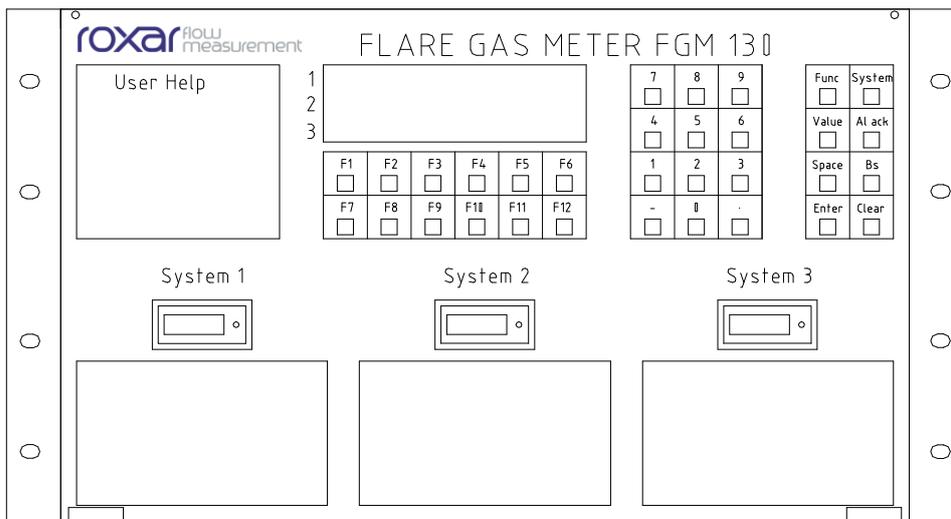The Flow Computer unit is mounted in a standard 19" rack.
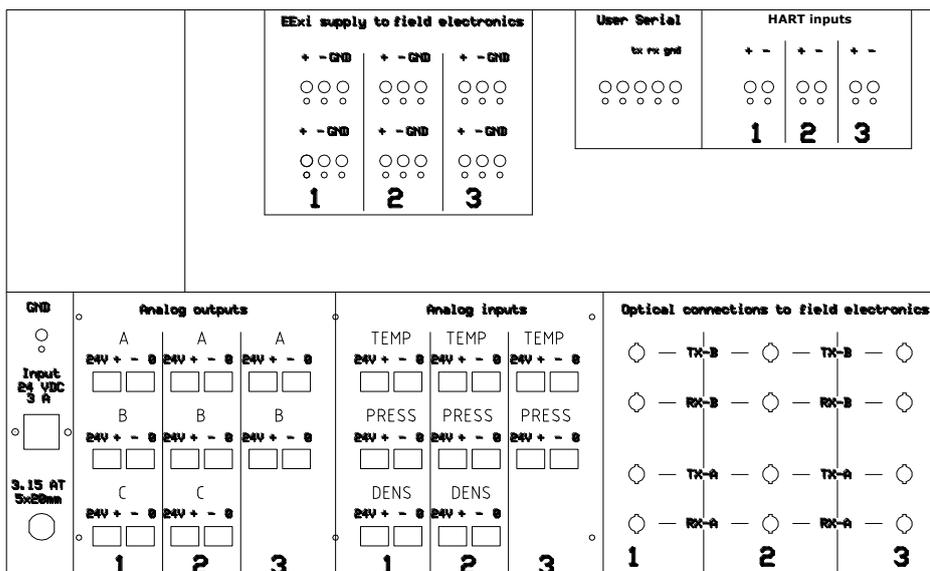

Fig. 4.1   Flow Computer

Fig. 4.2   Flow Computer rear view

4.1.1 Microcomputer

The microcomputer module consists of the SBS VCPU-33 VMEbus computer board with the following features:

Processor

MC68EC030 40 MHz microprocessor, 32 bit

Memory

1.5Mb zero wait state battery backed CMOS static RAM. Used for System execution and storing of parameters and intermediate data. The Lithium battery provides for data retention for at least 1 year in case of power failure.
2Mb ROM. Used for holding the initial system parameters at power up.

VME Communication

The SBS VCPU-33 computer module interconnects with the VMEbus through a standard DIN 41612 triple-row, 96-pin male connector (P1). The SBS VCPU-33 computer module meets all Motorola VMEbus specifications.

Serial Communication

The four asynchronous serial ports (RS232C, RS422 or RS485) interface the Flow Computer to the alphanumeric display and the keyboard, the Modbus serial communication link, the HART transmitter modem and the terminal for service purposes.

4.1.2 TX-Board

The TX-board generates the waveforms for the signals and transmits these out to the transducer electronic boards. The TX-boards controls the sequencing of signals and performs parts of the time measurements.

4.1.3 RX-Board

The RX-board receives the transmitted signals from the transducer electronic boards. The signals are processed and compared with the waveforms sent out from the TX-board. When the signal recognition is completed the time measurements on the TX-board are stopped and the results are sent to the CPU-module.

4.1.4 AD-Board

The AD-board converts the 4-20 mA input signals from the pressure- and temperature transmitters to digital signals. The 4-20 mA outputs from the FGM 130 is generated by this board based on digital values sent to it from the CPU-module.

4.1.5 Display/Keyboard

The operator interface of the Flow Computer is based on a IEE VIP 3902 consisting of a 8 x 40-character alphanumeric display and a 32-key data/function keyboard. The display/keyboard unit is shown in Fig. 4.4, below.
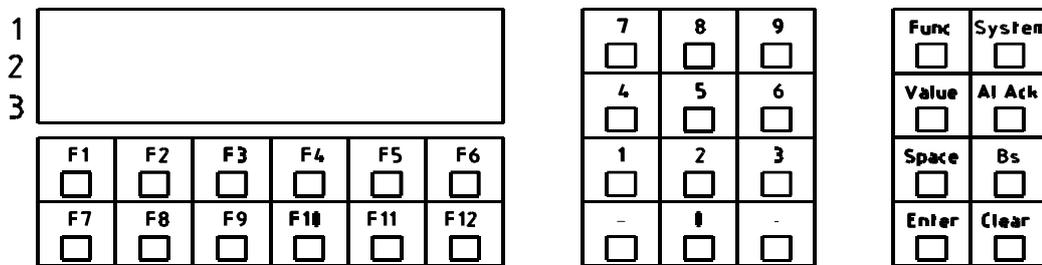
Figure 4.4   Display/Keyboard

Display Functions

The following functions are available on the display unit:

- Volume flow rate
- Mass flow rate
- Flow velocity
- Temperature
- Pressure
- Specific gravity
- Totalized volume flow
- Totalized mass
- System parameters
- Error messages
- Other messages and parameter from the Flow Computer unit

4.1.6 Non-Resettable Counter

An 8-digit electronic non-resettable counter keeps track of the totalized volume flow. The counter is powered by a self-contained Lithium battery with a lifetime of approximately ten years.

4.1.7 Fibre Optic Interface Board

Each optical fibre is connected to the correspondingly marked connector on the signal processing unit, and on the transducer electronic boards.

4.1.8 IS Barriers

The barriers used for the temperature and pressure inputs channels are normally MTL 787 for 4-20 mA input, and MTL 5042 Repeater Power Supply for HART input.
There is one barrier for each input on each flare gas metering system.

4.2 Operating the Flow Computer

The user interface through the Display/keyboard unit is based on entering commands with corresponding values. These commands are predefined and described in more detail in the "User's Manual". The corresponding value can either be a new parameter value or only a display value telling the Flow Computer to display a certain parameter or result. The sequence of operation for entering commands on the display/ keyboard is shown below. When entering a command with a corresponding value, press FUNCTION followed by the selected command number and then press VALUE followed by the desired parameter value. You send this command to the Flow Computer by pressing ENTER

FUNC

☐   Enter selected command number (from User's manual)

VALUE

☐   Enter desired parameter value (from User's manual)

ENTER

☐

4.3 Software Description

The software program implemented on the Flow Computer runs under the real-time multitasking operating system pSOS. All software is written in C.

4.3.1 Initialization Module

At power up control is first passed to the Initialization Module. This module does a bit pattern check in the parameter ROM and the battery backed CMOS RAM to determine whether "cold" or "warm" start should be performed.
A "cold" start indicates that data has been lost from battery backed CMOS RAM due to battery failure or that battery backup has not been installed. At "cold" start all critical system parameters are loaded from ROM and the system is set up with system default values.

During a "warm" start critical system parameters are loaded from battery backed CMOS RAM, so that parameters modified by the operator are retained and do not need to be re-entered. When system parameters have been loaded into RAM the other tasks are set to their initial states and the program start running.

The Initialization Module also performs saving of modified system parameters to battery backed CMOS RAM.

4.3.2   Flow Rate Calculation Module

The Flow Rate Calculation Module loops continuously, calculating new flow rates and totalized volumes based on results from the other program tasks.

4.3.3   Data Acquisition Module

The Data Acquisition Module loops continuously, reading data from the temperature, pressure and specific gravity inputs, the chirp values and, depending on the flow, data from the cw detector. During the same cycle it enables the next chirp, and conditionally, the next cw, keeping track of whether the next measurement is upstream or downstream. Throughout the loop it updates the flow counter. The updating of the flow counter is done at a regular basis, with counts passed from the Filtering Module.

4.3.4   Sorting Module

The Sorting Module reads, checks and sorts data from the data area where the Data Acquisition Module stored them. The upstream and downstream chirp values are read and sorted in increasing order in two arrays. These arrays are then passed to the Filtering Module, Ref. Section 4.3.5. The inputs for temperature, pressure and specific gravity are read and checked against their specified upper and lower limit values. In case an out-of-limit value is read an error indication is given at the display. Instead of the out-of-limit value the Flow Computer automatically uses a predefined fixed value or the last value read that were found to be within the limits. These values are passed to the Filtering Module and the Input/output Module, Ref. Section 4.3.6.

4.3.5   Filtering Module

The Filtering Module receives data from the Sorting Module, check the data and performs all the mathematical operations before data is sent to the Input/Output Module and the Data Acquisition Module. Based on a filtering criterion, the upstream and downstream chirp arrays are filtered until all remaining values are within an acceptable range as defined by a filtering algorithm. If the dispersion of the data is too large, the arrays might be reduced to a size below a defined minimum size. As this could indicate a transducer defect, an error warning will be given. Now the velocity, volume flow rate and mass flow are calculated, total volume and mass integrated and the incremental values passed to the Data Acquisition Module. All calculated values are also available to the Input/Output Module.

4.3.6 Input/Output Module

This module basically does all the I/O requested by the system and the operator. It is called by the Data Acquisition Module when the Filtering Module finishes its calculations, and presents the data on the display. When a command is entered from the keyboard, the command is decoded by the Flow Computer and the appropriate action taken. If the command indicates a parameter modification and an enable code has not yet been given, an error message is displayed and the command is rejected. If the given command indicates a parameter modification and it is accepted, the parameter and the new value is passed to the Initialization Module which saves the new value in battery backed CMOS RAM. Finally the module does an error indication check and displays action to be taken, if an error is detected.

4.3.7 Device Integrity

To prevent unauthorized or accidental modifications of system parameters, new parameter values cannot be entered, unless an enable code has been given. However, data can still be displayed through use of the pre-programmed function keys. When the keyboard is enabled in the "Command" or "Service" mode, it is reset to the disabled state through a keyboard disable timeout routine if more than 5 minutes has passed since the last operator entry on the keyboard or through input of an invalid enable code.

4.4 Inputs

4.4.1 Pressure

The pressure input signal is in the form of a 2-wire, 4-20 mA signal or through HART transmitter modem. The locally mounted transmitter is either powered by the 24 VDC power supply in the FGM 130 Flow Computer, or it receives power from an external source.

4.4.2 Temperature

The temperature input signal is also in the form of a 2-wire, 4-20 mA signal or through HART transmitter modem. The locally mounted temperature transmitter is powered as the pressure transmitter.

Note that the transmitters are connected to the Flow Computer through the barrier in cabinet. The analogue inputs are realized as floating 20 ohm resistors, through which the loop current flows. The common mode voltage range is within -10 to +24 volts with respect to the Flow Computer's ground level.

If HART transmitters are utilised, these are connected through a repeater power supply and a HART modem, which converts the digital values superimposed on the analogue current loop to process values in the Flow Computer.

4.5 Outputs

4.5.1 4-20mA Outputs

The FGM 130 has eight analogue 4-20 mA output channels; 3 channels for system 1 and 2, and 2 channels for system 3. All of them can individually be set to one of the following:

- Standard Volume Flow
- Actual Volume Flow
- Mass Flow
- Density (Standard conditions)
- Density (Actual)
- Molecular Weight
- Pressure
- Temperature
- Alarm = 4 mA
- Alarm = 20 mA

The outputs are optically isolated and can either be powered by an external loop or the internal 24 VDC common mode.

4.5.2 Pulse Outputs for Totalised Volume

The pulse signal updating the non-resettable counter for accumulated total volume flow can also be used to update a pulse input channel on the control system computer. The pulse has to be connected to an optocoupler. A pulse on the input of the optocoupler will cause a drop in the voltage across the output terminals that are connected to the control system. The length of the pulse is approximately 1 ms.

4.5.3 Modbus Serial Interface

This function is described in full detail in the "Modbus interface specification for FGM 130" suppliers doc. no.: RFM-TD-00289-111.

5. FLOW CALCULATIONS

5.1 Flow Calculations for Software

Formulae and data used in calculations are as follows

1. $$v = \frac{D}{\sin 2\phi} \cdot \frac{(t_{21} - t_{12})}{t_{12} \cdot t_{21}}$$

   where:

v	=	velocity [m/s] of flowing medium without compensation for Reynold's number variations.
D	=	inner pipe diameter (m).
ϕ	=	angle of intertransducer centre line to axis of the pipe.
t_{12}	=	transit time (sec) from Transducer 1 to Transducer 2 (downstream).
t_{21}	=	transit time (sec) from Transducer 2 to Transducer 1 (upstream).

2. $$\text{Re} = \frac{v \cdot D \cdot P \cdot T_0 \cdot Z_0}{\mu \cdot P_0 \cdot T \cdot Z}$$

   where:

Re	=	Reynold's number
P	=	Measured pressure in Bar A
P_o	=	1.01325 Bar A (std. cond.)
μ	=	Kinematic viscosity (See value below)
T_0	=	288.15 K = 15 ^{0}C (std. cond.)
T	=	Measured temperature in Kelvin
Z_0	=	Compressibility factor at standard conditions
Z	=	Compressibility factor at operating conditions

   Z, Z_0 and Kin.Visc. are operator entries (default);

Z_0	=	1.0
Z	=	1.0
K.Visc.=		15 x 10^{-6} m^2/s

3. $k = 0.889 + 0.0091 \cdot \log_{10}\text{Re} + 0.0001 \cdot (\log_{10}(\text{Re}))^2$

   where:

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k = correction factor used as compensation for Reynold's number variations.

4. $\overline{V} = k \cdot v$ where:

$\overline{V}$ = velocity [m/s] of flowing medium compensated for Reynold's number variations.

5. $Q_v = A \cdot \overline{V} \cdot \dfrac{P}{P_0} \cdot \dfrac{T_0}{T} \cdot \dfrac{Z_0}{Z} \cdot 3600$

where:

Q_v = Volume flow (Sm^3/h)
A = Crossectional area of pipe (m^2)

6. If fixed gravity are used (Densitymode = 0) then:

$Q_m = Q_V \cdot spec.grav. \cdot 1.225$

where:

Q_m = Mass flow (Kg/h)
spec. grav. = Specific gravity for the actual gas
1.225   = Density for air at standard conditions

If calculated gravity are used (Densitymode = 1) then :

$Q_m = Q_V \cdot (1/M) \cdot \rho_b$ where:

ρ = Calculated density [kg/m^3]
$M = \dfrac{P}{P_0} \cdot \dfrac{T_0}{T} \cdot \dfrac{Z_0}{Z}$

Q_m expressed related to velocity:

$Q_m = A \cdot \overline{v} \cdot \rho_b \cdot 3600$