Supplemental Manual for Brooks® A-protocol over RS485 for GF40/GF80 Series Mass Flow Controllers and Meters

Brooks® GF40/GF80 Series
with RS485 A-protocol Communications

BROOKS®
INSTRUMENT

Dear Customer,

We recommend that you read this manual in its entirety as this will enable efficient and proper use of the A-protocol over RS485 thermal mass flow controllers and meters. Should you require any additional information concerning the A-protocol over RS485 thermal mass flow controllers and meters, please feel free to contact your local Brooks Sales and Service Office; see back cover for contact information, or visit us on the web at www.BrooksInstrument.com. We appreciate this opportunity to service your fluid measurement and control requirements, and trust that we will be able to provide you with further assistance in future.

Yours sincerely,
Brooks Instrument

Installation and Operation Manual
X-DPT-RS485-A-GF40-GF80-MFC-eng
Part Number: 541B176AAG
September, 2012

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Section 1 Introduction

Brooks® GF40/GF80 A-protocol over RS485

1.1 Introduction

The A-protocol is a digital communication protocol which provides a reliable, transaction oriented service between a master device, such as a PC, and one or more Brooks® Digital Series Mass Flow Controllers and Meters. The protocol is designed to allow a centralized controller to acquire measurement data from a Mass Flow device and, in case of Mass Flow Controllers, send setpoint values.

The Brooks RS485 on GF40/GF80 MFCs/MFMs support digital communications as defined by this manual. Communication is ASCII based and uses a command start and end byte. The physical layer supported is RS485 only.

This document is intended to give a user the means to implement the protocol structure into his own control system in order to establish communication between the control system and the RS485 based GF40/GF80 Series devices. It does not cover the non-communication functionality of these devices. For this description please refer to Installation and Operation Manual for this specific device.

The remaining sections of this document are summarized below:

- **Section 2 – Definition of Terms**
- **Section 3 – Before Starting** covers backgrounds and assumptions.
- **Section 4 – Quick Start** defines how to properly configure and wire RS485 on GF40/GF80 Series MFCs/MFMs for digital communications.
- **Section 5 – Message Protocol Structure** describes the AKT message protocol.
- **Section 6 – Communicating With Slave** describes the requirements of the Master.
- **Section 7 – ID Related Commands** describes the commands needed to retrieve the address ID of the device
- **Section 8 – Read Commands** describes the set of commands to read device attributes
- **Section 9 – Set Commands** describes the set of commands to configure device attributes.
- **Back Cover – Warranty and Contact Information**

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Section 2 Definition of Terms

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2.1 Definition of Terms

Abbreviation	Description
MFC/MFM	Mass Flow Controller/Meter Device
MSB	Most Significant Bit
LSB	Least Significant Bit

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Section 3 Before Starting

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3 Before Starting

3.1 Background & Assumptions

This manual is a supplement to the Brooks GF40/GF80 Series installation and operation manual. It is assumed that the owner of this RS485 GF40/GF80 MFC/MFM is thoroughly familiar with the theory and operation of this device. If not, it is recommended that the owner reads the installation and operation manual first before continuing with this supplement.

3.2 Numbers

Numeric values used throughout this manual will be clearly denoted as to the base numeric system it represents. All hexadecimal numbers (base 16) will be prefixed with a 0x, like 0xA4. All binary numbers (base 2) will be suffixed with a b, like 1001b. All other numbers not annotated this way will be assumed decimal (base 10).

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4 Quick Start

This section assumes the owner of the Digital Series device has a fully operational and trouble-free RS485 communications network with appropriate power supplies.

4.1 Supported Baud Rates

Data communication can be performed at a number of baud rates: 9600, 19.2K and 38.4K baud. The baud rate can be changed using the SBR command. The device is shipped with the baud rate set to 19.2K baud.

4.2 Character Coding

A-protocol messages are coded as a series of 8-bit characters or bytes. These are transmitted serially, using a conventional UART (Universal Asynchronous Receiver/ Transmitter). As in normal RS232 and other asynchronous communication links, a start bit, a parity bit and a stop bit are added to each byte. These allow the receiving UART to identify the start of each character and to detect bit errors due to electrical noise or other interference. An A-protocol character is built up from:

8 Databits
No parity bit
1 Stop bit

4.3 Bus and Device LEDs

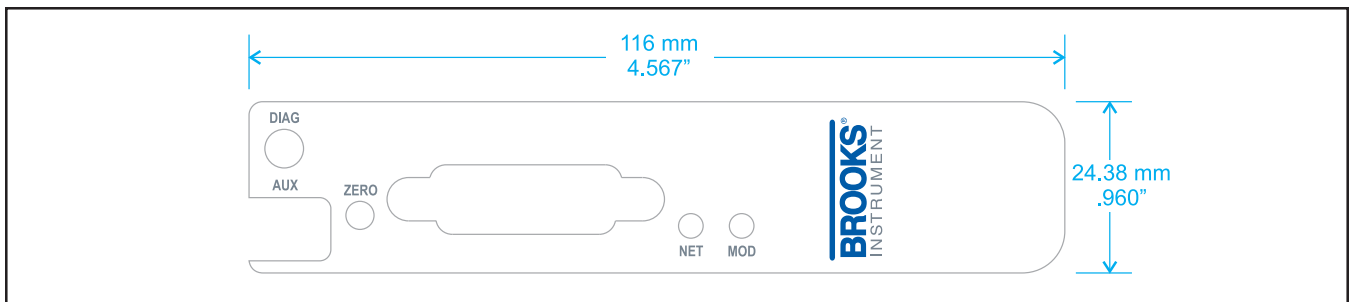The device supports a Bus and Device LED to indicate the status of network communication and the device.

Figure 4-1 RS485 Label on Cover

The Bus LED will indicate the following:

Table 4-1 Bus LED Specification

Flash Code	Description
Off	No Network Connected
Solid Green	Communication Established at least once, resets after power cycle (no periodic check)

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The Device LED will indicate the following:

Table 4-2 Device Led Specification

Flash Code	Description
Flashing Red/Green	The device is in the Self-Test/initializing mode
Solid Green	All self-tests/initialization have passed. No faults have been detected
Flashing Red	A recoverable fault has been detected. ex.: low/high flow alarm
Solid Red	An unrecoverable fault has occurred. ex.: internal power supply failure

4.4 Device Wiring

4.4.1 Electrical Connections

The RS485 on GF40/GF80 Series device has a 15-pin D-sub connector, for analog I/O, power supply and digital communication signals. See Table 4-3 for the pin-outs. For more detailed information refer to the instruction and operations manual.

Table 4 3 Pin-outs for D-Sub Connector

Pin No.	Function at Remote Connector
1	Setpoint Signal Ground
2	Flow Voltage Output
3	Alarm Output
4	Flow Current Output
5	Positive Supply Voltage
6	Not Used
7	Setpoint Current Input
8	Setpoint Voltage Input
9	Power Supply Common
10	Flow Signal Ground
11	Not Used
12	Valve Override Input
13	Auxiliary input
14	RXD/A-
15	TXD/A+

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4.4.2 Multi Drop

The RS485 communications interface is a multi drop connection making it possible to connect up to 32 devices to a computer on a single multi drop line as shown Figure 4-2. Most Computers are NOT equipped with RS485 ports. In order to connect an RS485 to a computer, one will need an RS485 to RS232 converter. Figure 4-2 shows the interconnection diagram of an RS485 on GF40/GF80 MFC/MFM via an RS485 bus and an RS485 to RS232 converter to the RS232 serial port of a typical computer. The RS485 bus requires two matching resistors of 120W, one at the end of the bus and one at the beginning, near the converter. Note the control line from the PC to the converter necessary to control the data direction of the RS485 buffers. The RTS ("Request To Send") line shown in Figure 4-2 because this line is used to control data direction in many of the commercially available converters. The actual line used depends on the converter selected.

Table 4-4 D-Connector Communication Pins

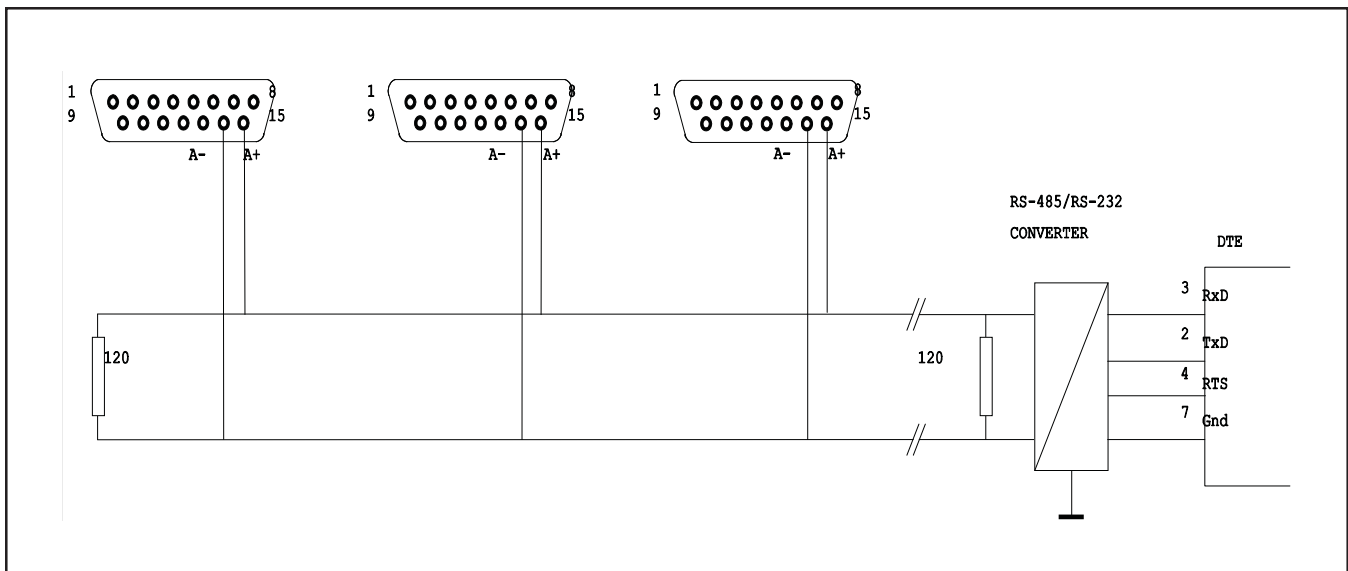| D-Connector Pin Number	RS485
Pin #14	B (inverted driver side)
Pin #15	A (non-inverted driver side)

Figure 4-2 RS485 Multi Drop Interconnection DMFM/C and PC

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Section 5 Message Protocol Structure

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5 Message Protocol Structure

5.1 Introduction

The A-protocol is a "master-slave" protocol: each message transaction is originated by the master (central) station, whereas the slave (field) device only replies when it receives a command message addressed to it. The reply from the slave device will acknowledge that the command has been received and it may contain the data requested by the master.

5.2 Request Message

The request message, sent from master to slave, consists of the fields indicated in Figure 5-1, these fields will be described in the sections below.

[STX]	ID	Command	Data	[CR]

Figure 5-1 A-protocol Command Request Structure

5.2.1 Start Character

The start transmission character, [STX] 0x02, signals that a communication transaction is beginning.

5.2.2 Addressing Concept

The ID field is the unit network address set by software. The unit ID is a 2 byte ASCII field and indicates a hexadecimal number in the range 0x00-0x63 (0-100). ID 0x00 is used as a broadcast address. In case the broadcast address is used, all MFCs in the network will execute the command, but no MFCs will send a response. This doesn't yield for commands SID and RID.

5.2.3 Command

The Command field consists of three ASCII bytes. Read commands start with R and the Set commands start with S. For more information on commands see Section 7 ID related commands, Section 8 Read commands and Section 9 Set commands.

5.2.4 Data

The Data field varies in length depending upon the command and will be empty if there is no data.

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5.2.5 End Character

Carriage return is a single byte, [CR] 0x0D, which signals that the communication transaction is complete. If there is no data, [CR] immediately follows the command field.

5.3 Response Message

There are two possible responses to a transmission packet:
- a response that contains no data (an acknowledgement or negative acknowledgement)
- a response that contains data.

5.4 Response Without Data

5.4.1 OK (Acknowledgement)

O	K	[CR]

Figure 5-2 Positive Acknowledgement

If the response packet contains the 2 bytes ASCII text OK, then the transmission packet has been received and the command acknowledged.

5.4.2 NG (Negative Acknowledgement)

N	G	[CR]

Figure 5-3 Negative Acknowledgement

If the response packet contains the 2 bytes ASCII text NG, then the transmission has not been received, or the transmission ordered or requested an action or reading that is out of parameters.

5.5 Response With Data

Status	Data	[CR]

Figure 5-4 Response With Data

A data response contains both a Status field and a Data field

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5.5.1 Status

The status field is a single ASCII byte, possible notations are:
  N = No alarm or error
  Z = Executing zero point calibration
  A = Alarm exists
  E = Error exists
  X = Alarm(s) *and* error(s) exist
Note: The Status field is indicated as [Status] in the communication command tables starting at Section 7 ID Related Commands.

5.5.2 Data

The Data field contains the data requested by the read command.

5.6 Broadcast

It is possible to transmit the same command to all MFCs by using ID 0x00. All MFCs in the system, regardless of their network address, will execute the command, but none of the networked MFCs will send a response. The SID and RID commands are special in that they will address the device using the serial nr, passed along as data. Only the device with the specified serial number will respond, irrespective of the ID passed along with the command.

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Section 6
Communicating With Slave

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6 Start Communicating With Slave

In order to start communicating with a slave device the first thing to do is to retrieve the IDs of the connected devices. The RID command shall be used to perform this task. It accepts a serial number (max 12 digits) as data and the broadcast ID. This serial number is derived from the serial number of the device, it will contain the last 12 (or less) numerical [0..9] digits of the device's serial number.

6.1 Examples
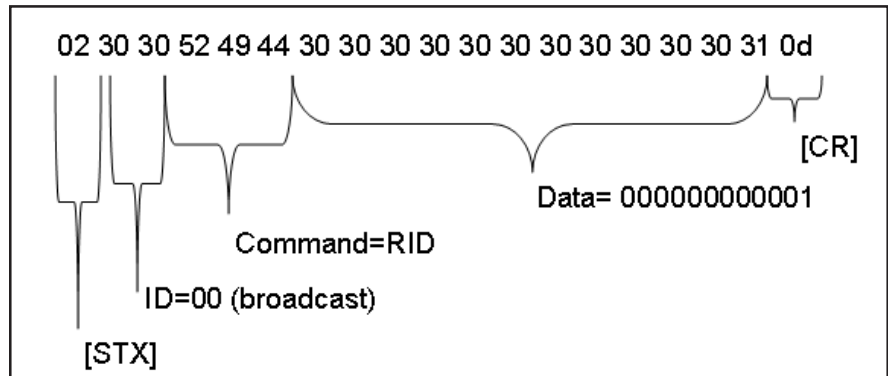
Figure 6-1 RID Command Request

Figure 6-1 RID Command Request shows the hexadecimal byte sequence of the RID command issued by a master application.
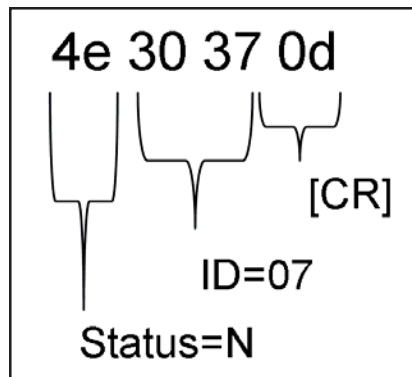
Figure 6-2 RID Command Response

Figure 6-2 RID Command Response shows the hexadecimal byte response transmitted by the slave device on the RID command request.

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Start Communicating With Slave

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Section 7 ID Related Commands

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7.1 ID Related Commands

Table 7-1 ID and Serial Number Commands

Command	Command Descriptions

SID
set unit ID
	Sets the unit ID number. The ID consists of 2 ASCII bytes indicating a hexadecimal number in the range [0x00..0x63] (0-100). To set the unit ID, you must address the command to all MFCs on the network (ID field = 00) and enter the serial number followed by the new unit ID number.
	    Format = [STX] 00**SID** [serial number [1]] [new two-digit unit ID] [CR]
	    Response data = OK [CR]

RID
read unit ID
	Reads the unit ID number. The ID consists of 2 ASCII bytes indicating a hexadecimal number in the range [0x00..0x63] (0-100). To read the unit ID, you must address the command to all MFCs on the network (ID field = 00) and enter the serial number.
	    Format = [STX] 00**RID** [serial number[1] [CR]
	    Response data = [Status] xx [CR]

RSR
read serial number
	Read the serial number.
	    Format = [STX] id**RSR** [CR]
	    Response data = [serial number] [CR]

[1] This serial number is derived from the serial number of the device, it will contain the last 12 (or less) numerical [0..9] digits of the device's serial number.

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Section 8 Read Commands

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8.1 Read Commands

Table 8-1 Read Commands

Command	READ Command Descriptions
RBR read baud rate	Reads the baud rate of the communication interface Format = [STX] id**RBR** [CR] Response data = [Status] x [CR] x=0 for baud rate is 9600 x=1 for baud rate is 19200 x=2 for baud rate is 38400
RVM read valve control mode	Reads the valve control mode (open, closed, or controlled). Format = [STX] id**RVM** [CR] Response data = [Status] x [CR] O = Valve open C = Valve closed N = Valve controlled by set point
RMD Read set point mode	Reads the set point input mode (digital or analog). Format = [STX] id**RMD** [CR] Response data = [Status] x [CR] D = Digital mode A = Analog mode
RFX read flow output	Reads flow output as a percentage of full-scale flow. Range is from 0% to 100% (in 0.01% increments). Format = [STX] id**RFX** [CR] Response = [Status] [±xxxx]x.xx [CR]
RDC read set point	Reads the flow set point as a percentage of full scale flow. Range is from 0 to 100 (in 0.01 increments). Format = [STX] id**RDC** [CR] Response data = [Status] [xxxx]x.xx [CR]
RVD read valve voltage	Reads the valve voltage as a percentage of full rated valve voltage. Range is 0% to 100% (in 1% increments). Format = [STX] id**RVD** [CR] Response = [Status] xxx [CR]
RFK read user full scale flow	Reads the user full scale flow (in sccm). Format = [STX] id**RFK** [CR] Response data = [Status] [±xxxx]x.xx [CR]
RGN read gas name	Reads the gas name. Range is from 1 to 20 characters. Format = [STX] id**RGN** [CR] Response data = [Status] [1 to 20 characters] [CR]
RGT read gas table	Sets the gas table number. Range is from 1 to 8. Format = [STX] id**RGT** [CR] Response data = [Status] [1 to 8 characters] [CR]
RFW read flow alarm range	Reads the flow alarm range as a percentage of full-scale flow. Range is 0% to 98% (in 0.01% increments). Format = [STX] id**RFW** [CR] Response data = [Status] [±xxxx]x.xx [CR]
RFT read flow alarm latch time	Reads the flow alarm latch time. Range is 0 s to 99 s (in 1s increments). Format = [STX] id**RFT** [CR] Response data = [Status] xx [CR]

Section 8 Read Commands

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Table 8-1 Read Commands (Continued)

RFT
read flow alarm latch time
	Reads the flow alarm latch time. Range is 0 s to 99 s (in 1s increments).
	    Format = [STX] id**RFT** [CR]
	    Response data = [Status] xx [CR]

RFI
read flow alarm state
	Reads the flow alarm enable state.
	    Format = [STX] id**RFI** [CR]
	    Response data = [Status] x [CR]
	        0 = Disabled
	        1 = Enabled

RVA
read valve alarm set point
	Reads the valve alarm set point as a percentage of full-scale flow. Range is 0% to 100% (in 1% increments).
	    Format = [STX] id**RVA** [CR]
	    Response data = [Status] [xx]x [CR]

RVW
read valve alarm set point
	Reads the valve alarm bandwidth as a percentage of full-scale flow. Range is 0% to 98% (in 1% increments).
	    Format = [STX] id**RVW** [CR]
	    Response data = [Status] [xx]x [CR]

RVT
read valve alarm latch time
	Reads the valve alarm latch time. Range is 0 s to 99 s (in 1s increments).
	    Format = [STX] id**RVT** [CR]
	    Response data = [Status] xx [CR]

RVI
read valve alarm state
	Reads the valve alarm enable state.
	    Format = [STX] id**RVI** [CR]
	    Response data = [Status] x [CR]
	        0 = Disabled
	        1 = Enabled

RAS
read alarm status
	Reads the alarm status. The response data is in a hexadecimal ASCII format representing bit flags. If a bit is set (i.e., = 1), then the corresponding condition is true.
	    Format = [STX] id**RAS** [CR]
	    Response data = [status] xx [CR]
	        Bit 0 = Flow alarm high
	        Bit 1 = Flow alarm low
	        Bit 2 = Valve alarm high
	        Bit 3 = Valve alarm low
	        Bits 4 through 7 = Not used

RER
Read error status
	Reads the error status. The response data is in a hexa-decimal ASCII format representing bit flags. If a bit is set (that is, = 1), then the corresponding condition is true.
	    Format = [STX] id**RER** [CR]
	    Response data = [status] xx [CR]
	        Bit 0 = Communication error
	        Bit 1 = None
	        Bit 2 = EEPROM error
	        Bit 3 = Zero Point Correction Error 1. Zero point deviation is > ±10% of the last calibrated value.
	        Bit 4 = Zero Point Correction Error 2. Zero point deviation is > ±10% of the default value set at shipment.
	        Bits 5 through 7 = Not used

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Section 9 Set Commands

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9.1 Set Commands

Table 9-1 Set Commands

Command	Set Command Descriptions

SBR
set the baud rate
	Sets the baud rate of the communication interface
	    Format = [STX] id**SBR** x[CR]
	    Response data = OK[CR]
	        x=0 for baud rate is 9600
	        x=1 for baud rate is 19200
	        x=2 for baud rate is 38400

SVO
open valve
	Sets the control valve fully open.
	    Format = [STX] id**SVO** [CR]
	    Response data = OK [CR]

SVC
close valve
	Sets the control valve fully closed.
	    Format = [STX] id**SVO** [CR]
	    Response data = OK [CR]

SVN
enable valve control
	Enables valve control. When valve control is enabled, flow is controlled by the set point (set by command **SDC**).
	    Format = [STX] id**SVN** [CR]
	    Response data = OK [CR]

SDM
set digital set point control
	Sets digital (RS-485 input) set point control mode.
	    Format = [STX] id**SDM** [CR]
	    Response data = OK [CR]

SAM
set analog set point control
	Sets analog (analog input) set point control mode. This mode is the default mode at reset.
	    Format = [STX] id**SAM** [CR]
	    Response data = OK [CR]

SDC
set flow set point
	Sets the flow set point as a percentage of full scale flow. Range is from 0 to 100 (in 0.01 increments).
	    Format = [STX] id**SDC** [xxxx]x.xx [CR]
	    Response data = OK [CR]

SZP
start zero point adjustment
	Starts the zero point adjustment function.
	    Format = [STX] id**SZP** [CR]
	    Response data = OK [CR]
	After the initial OK response, the MFC will reply to all status commands with a specially formatted message:
	Zxx [CR]. When the zero calibration is complete the reply format will return to normal (Nxx [CR]).

SGN
set gas name
	Sets the gas name. Range is from 1 to 20 characters.
	    Format = [STX] id**SGN** [1 to 20 characters] [CR]
	    Response data = OK [CR]

SGT
set gas table
	Sets the gas table number. Range is 1 to 8.
	    Format = [STX] id**SGT** x [CR]
	    Response data = OK [CR]

SAF
enable flow alarm
	Enables the flow alarm.
	    Format = [STX] id**SAF** [CR]
	    Response data = OK [CR]

SFI
disable flow alarm
	Disables the flow alarm.
	    Format = [STX] id**SFI** [CR]
	    Response data = OK [CR]

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Table 9-1 Set Commands (Continued)

Command	Set Command Descriptions
SFW set flow alarm range	Sets the flow alarm range as a percentage of full-scale flow. Range is 0% to 98% (in 0.01% increments). An alarm will occur when the flow is not within ±(range/2) of the alarm set point. Format = [STX] id**SRW** xx.xx [CR] Response data = OK [CR]
SFT set flow alarm latch time	Sets the flow alarm latch time. Range is 0 s to 99 s (in 1 s increments). The alarm will not occur until the flow exceeds the specified limits for the flow alarm latch time period. Format = [STX] id**SFT** xx [CR] Response data = OK [CR]
SVA set valve alarm set point	Sets the valve alarm set point as a percentage of full scale flow. Range is 0% to 100% (in 1% increments). Format = [STX] id**SVA** xxx [CR] Response data = OK [CR]
SVW set valve alarm bandwidth	Sets the valve alarm bandwidth as a percentage of full-scale flow. Range is 0% to 98% (in 1% increments). The alarm will occur when the valve voltage is not within ±(bandwidth/2) of the valve alarm value. Format = [STX] id**SVW** xxx [CR] Response data = OK [CR]
SVT set valve alarm latch time	Sets the valve alarm latch time. Range is 0 s to 99s (in 1s increments). The alarm will not occur until the flow exceeds the specified limits for the flow alarm latch time period. Format = [STX] id**SVT** xx [CR] Response data = OK [CR]
SAC Clear alarm(s)	Clears the flow alarm. Format = [STX] id**SAC** [CR] Response data = OK [CR]
SEC Clear error(s)	Clears the error status. Format = [STX] id**SEC** [CR] Response data = OK [CR]
SAV Enable valve alarm	Enables the valve alarm. Format = [STX] id**SAV** [CR] Response data = OK [CR]
SVI Disable valve alarm	Disables the valve alarm. Format = [STX] id**SVI** [CR] Response data = OK [CR]

LIMITED WARRANTY

Seller warrants that the Goods manufactured by Seller will be free from defects in materials or workmanship under normal use and service and that the Software will execute the programming instructions provided by Seller until the expiration of the earlier of twelve (12) months from the date of initial installation or eighteen (18) months from the date of shipment by Seller.

Products purchased by Seller from a third party for resale to Buyer ("Resale Products") shall carry only the warranty extended by the original manufacturer.

All replacements or repairs necessitated by inadequate preventive maintenance, or by normal wear and usage, or by fault of Buyer, or by unsuitable power sources or by attack or deterioration under unsuitable environmental conditions, or by abuse, accident, alteration, misuse, improper installation, modification, repair, storage or handling, or any other cause not the fault of Seller are not covered by this limited warranty, and shall be at Buyer's expense.

Goods repaired and parts replaced during the warranty period shall be in warranty for the remainder of the original warranty period or ninety (90) days, whichever is longer. This limited warranty is the only warranty made by Seller and can be amended only in a writing signed by an authorized representative of Seller.

BROOKS SERVICE AND SUPPORT

Brooks is committed to assuring all of our customers receive the ideal flow solution for their application, along with outstanding service and support to back it up. We operate first class repair facilities located around the world to provide rapid response and support. Each location utilizes primary standard calibration equipment to ensure accuracy and reliability for repairs and recalibration and is certified by our local Weights and Measures Authorities and traceable to the relevant International Standards.

Visit www.BrooksInstrument.com to locate the service location nearest to you.

START-UP SERVICE AND IN-SITU CALIBRATION

Brooks Instrument can provide start-up service prior to operation when required.
For some process applications, where ISO-9001 Quality Certification is important, it is mandatory to verify and/or (re)calibrate the products periodically. In many cases this service can be provided under in-situ conditions, and the results will be traceable to the relevant international quality standards.

CUSTOMER SEMINARS AND TRAINING
Brooks Instrument can provide customer seminars and dedicated training to engineers, end users and maintenance persons.

Please contact your nearest sales representative for more details.

HELP DESK
In case you need technical assistance:

USA	☎ 888 275 8946	Korea	☎ +82 31 708 2521
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Germany	☎ +49 351 215 2040	China	☎ +86 21 5079 8828
Japan	☎ +81 3 5633 7100	Singapore	☎ +6297 9741

Due to Brooks Instrument's commitment to continuous improvement of our products, all specifications are subject to change without notice.

TRADEMARKS
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HART .... HART Communications Foundation

ISO 9001 QUALITY SYSTEM

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