

## Installation and Operation Manual Supplement

SM-VA-MT3809G-Alarms-eng

Part Number: 541B193AAG

April, 2014

# Brooks® Model MT3809G Metal Tube Variable Area Flowmeters IEC 61508:2010 Safety Manual



# Essential Instructions

**Read this page before proceeding!**

Brooks Instrument designs, manufactures and tests its products to meet many national and international standards. These products must be properly installed, operated and maintained to ensure they continue to operate within their normal specifications. The following instructions must be adhered to and integrated into your safety program when installing, operating and maintaining Brooks Instrument products.

- To ensure proper performance, use qualified personnel to install, operate, update, program and maintain the product.
- Read all instructions prior to installing, operating and servicing the product. If this instruction manual is not the correct manual, please see back cover for local sales office contact information. Save this instruction manual for future reference.

## WARNING

Do not operate this instrument in excess of the specifications listed in the Instruction and Operation Manual. Failure to heed this warning can result in serious personal injury and / or damage to the equipment.

- If you do not understand any of the instructions, contact your Brooks Instrument representative for clarification.
- Follow all warnings, cautions and instructions marked on and supplied with the product.
- Install your equipment as specified in the installation instructions of the appropriate instruction manual and per applicable local and national codes. Connect all products to the proper electrical and pressure sources.
- Operation: (1) Slowly initiate flow into the system. Open process valves slowly to avoid flow surges. (2) Check for leaks around the flow meter inlet and outlet connections. If no leaks are present, bring the system up to the operating pressure.
- Please make sure that the process line pressure is removed prior to service. When replacement parts are required, ensure that qualified people use replacement parts specified by Brooks Instrument. Unauthorized parts and procedures can affect the product's performance and place the safe operation of your process at risk. Look-alike substitutions may result in fire, electrical hazards or improper operation.
- Ensure that all equipment doors are closed and protective covers are in place to prevent electrical shock and personal injury, except when maintenance is being performed by qualified persons.

## European Pressure Equipment Directive (PED)

All pressure equipment with an internal pressure greater than 0.5 bar (g) and a size larger than 25mm or 1" (inch) falls under the Pressure Equipment Directive (PED).

- The Specifications Section of this manual contains instructions related to the PED directive.
- Meters described in this manual are in compliance with EN directive 97/23/EC.
- All Brooks Instrument Flowmeters fall under fluid group 1.
- Meters larger than 25mm or 1" (inch) are in compliance with PED category I, II or III.
- Meters of 25mm or 1" (inch) or smaller are Sound Engineering Practice (SEP).

## European Electromagnetic Compatibility (EMC)

The Brooks Instrument (electric/electronic) equipment bearing the CE mark has been successfully tested to the regulations of the Electro Magnetic Compatibility (2004/108/EC (EMC directive 89/336/EEC)).

Special attention however is required when selecting the signal cable to be used with CE marked equipment.

Quality of the signal cable, cable glands and connectors:

- Brooks Instrument supplies high quality cable(s) which meets the specifications for CE certification.
- If you provide your own signal cable you should use a cable which is overall completely screened with a 100% shield.
- “D” or “Circular” type connectors used should be shielded with a metal shield. If applicable, metal cable glands must be used providing cable screen clamping.
- The cable screen should be connected to the metal shell or gland and shielded at both ends over 360 Degrees.
- The shield should be terminated to an earth ground.
- Card Edge Connectors are standard non-metallic. The cables used must be screened with 100% shield to comply with CE certification.
- The shield should be terminated to an earth ground.
- For pin configuration : Please refer to the enclosed Instruction Manual.

## ESD (Electrostatic Discharge)

### CAUTION

This instrument contains electronic components that are susceptible to damage by static electricity. Proper handling procedures must be observed during the removal, installation or other handling of internal circuit boards or devices.

#### Handling Procedure:

1. Power to unit must be removed.
2. Personnel must be grounded, via a wrist strap or other safe, suitable means before any printed circuit card or other internal device is installed, removed or adjusted.
3. Printed circuit cards must be transported in a conductive container. Boards must not be removed from protective enclosure until immediately before installation. Removed boards must immediately be placed in protective container for transport, storage or return to factory.

#### Comments:

This instrument is not unique in its content of ESD (electrostatic discharge) sensitive components. Most modern electronic designs contain components that utilize metal oxide technology (NMOS, SMOS, etc.). Experience has proven that even small amounts of static electricity can damage or destroy these devices. Damaged components, even though they appear to function properly, exhibit early failure.

**Model MT3809G**

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Dear Customer,

We appreciate this opportunity to service your flow measurement and control requirements with an integrated system from Brooks Instrument. Every day, flow customers all over the world turn to Brooks Instrument for solutions to their gas and liquid low-flow applications. Brooks provides an array of flow measurement and control products for various industries from biopharmaceuticals, oil and gas, fuel cell research and chemicals, to medical devices, analytical instrumentation, semiconductor manufacturing, and more.

The Brooks product you have just received is of the highest quality available, offering superior performance, reliability and value to the user. It is designed with the ever changing process conditions, accuracy requirements and hostile process environments in mind to provide you with a lifetime of dependable service.

We recommend that you read this manual in its entirety. Should you require any additional information concerning Brooks products and services, please contact your local Brooks Sales and Service Office listed on the back cover of this manual or visit [www.BrooksInstrument.com](http://www.BrooksInstrument.com)

Yours sincerely,

Brooks Instrument

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Model MT3809G

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## **1. Introduction**

IEC 61508 is a basic safety publication of the International Electrotechnical Commission (IEC) and has been widely accepted as the basis for the specification, design and operation of safety instrumented systems.

The safety function of the MT3809G Variable Area Flowmeter provides a flowrate alarm indication when the flowrate is above or below a specified trip point within specified accuracy.

This manual provides the necessary requirements for integration of the MT3809G with Inductive Alarms into an IEC 61508 safety instrumented system.

### **1.1. Documentation and Standards**

IEC 61508-2: ed2, 2010 – Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems

Electrical & Mechanical Component Reliability Handbook, 2<sup>nd</sup> edition, 2008 – exida LLC, ISBN 978-0-9727243-6-6

X-VA-MT3809G-MT3810G – Brooks Instrument Models MT3809G and MT3810G Metal Tube Variable Area Flowmeters Instruction and Operation Manual

DS-VA-MT3809G - Brooks Instrument MT3809G Series Metal Tube Variable Area Flowmeters Data Sheet

### **1.2. Terms and Definitions**

Basic Safety	Freedom from unacceptable risk of harm.
BPCS	Basic Process Control System – a system which responds to input signals from the process, its associated equipment, other programmable systems and/or an operator and generates output signals causing the process and its associated equipment to operate in the desired manner but which does not perform any safety instrumented functions with a claimed SIL greater than or equal to 1.
Fail-safe State	State where switch output is in the state corresponding to an alarm condition. In this condition the switch contacts will normally be

	open.
Fail Dangerous	Failure that does not respond to an input from the process (i.e. not switching to the fail-safe state).
Fail Dangerous Detected	Failure that is dangerous but is detected.
Fail Dangerous Undetected	Failure that is dangerous and that is not detected.
Fail No Effect	Failure of a component that is part of the safety function but that has no effect on the safety function.
Fail Safe	Failure that causes the switch to go to the defined fail-safe state without an input from the process.
FMEDA	Failure Modes, Effects, and Diagnostics Analysis.
Functional Safety	Part of the overall safety relating to the process and the BPCS which depends on the correct functioning of the SIS and other protection layers.
HFT	Hardware Fault Tolerance.
PFDAVG	Average Probability of Failure on Demand.
SFF	Safe Failure Fraction – a fraction of the overall random failure rate of a device that results in either a safe failure or a detected dangerous failure.
SIF	Safety Instrumented Function – a safety function with a specified SIL which is necessary to achieve functional safety. Typically a set of equipment intended to reduce the risk due to a specified hazard (a safety loop).
SIL	Safety Integrity Level – a discrete level (one out of four) for specifying the safety integrity requirements of the safety instrumented functions to be allocated to the safety instrumented systems. SIL 4 has the highest level of safety integrity, and SIL 1 has the lowest level.
SIS	Safety Instrumented System – an instrumented system used to implement one or more safety instrumented functions. An SIS is composed of any combination of sensors, logic solvers, and final elements.



### 1.3. Theory of Operation

The MT3809G Metal Tube Variable Area Flowmeter is an instrument used to measure the flow rate of liquids and gases. Its operation is based on the variable area principle, where flow raises a float in a tapered tube increasing the area for passage of the flow. The float will reach a stable position when the force exerted by the flowing fluid + the buoyancy equals the gravitational force. A change in flow rate upsets this force balance and will move up or down the float until it again reaches a position where the forces are in balance.

When the flow is outside a flow band set by means of the low flow- and high flow inductive alarm switches, a trip-low or trip-high signal will be provided.

For details, please refer to the Brooks Instrument Models MT3809G and MT3810G Metal Tube Variable Area Flowmeters Instruction and Operation Manual (X-VA-MT3809G-MT3810G)

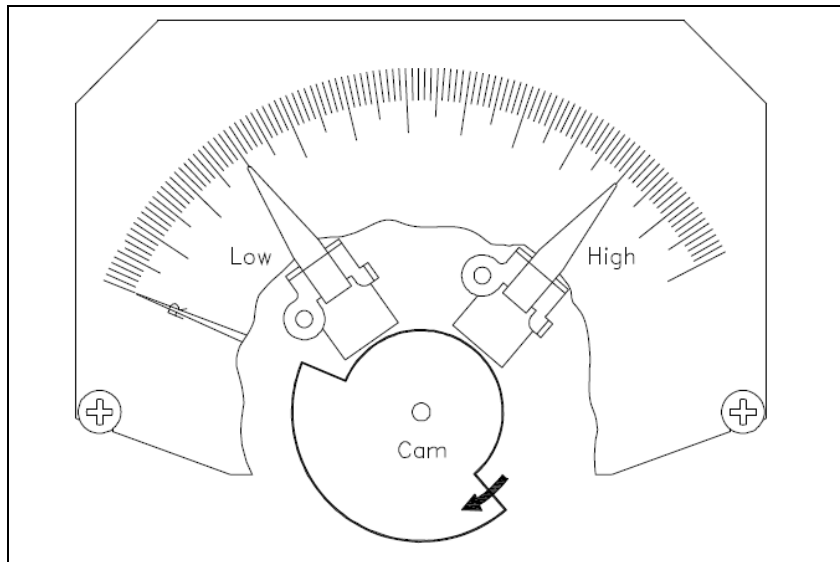


Figure 1 Low- and High Flow Inductive Alarm setting

**1.4. Model Code information for Safety Instrumented System (SIS) Inductive Alarm Switches**

Brooks Instrument Models MT3809G equipped with Safety Instrumented System (SIS) Inductive Alarm Switches are marked with a code B, C, F, G, K or L on position XV of the instrument model code. For detailed information refer to the Brooks Instrument MT3809G Series Metal Tube Variable Area Flowmeters Data Sheet (DS-VA-MT3809G).

Code Pos.	Applicable for	
	3809	3810
XV	x	x
	x	
	x	
	x	
	x	
	x	
	x	
	x	
	x	
	x	
	x	
	x	
	x	
	x	

**ELECTRONICS CONFIGURATION**

- A Indicator only
- B Inductive Alarm, 1 Switch
- C Inductive Alarm, 2 Switches
- D Transmitter, 4 - 20 mA / HART compatible
- E Transmitter, 4 - 20 mA / HART compatible w/Pulse Output & Alarm Contacts
- F Transmitter, 4 - 20 mA / HART compatible w/ Inductive Alarm 1 Sw\*
- G Transmitter, 4 - 20 mA / HART compatible w/ Inductive Alarm 2 Sw\*
- H Transmitter, 4 - 20 mA / HART compatible + LOI (DIGITAL DISPLAY)
- J Transmitter, 4 - 20 mA / HART compatible w/Pulse Output & Alarm Contacts + LOI (Digital Display)
- K Transmitter, 4 - 20 mA / HART compatible w/ Inductive Alarm 1 Sw + LOI (Digital Display)\*
- L Transmitter, 4 - 20 mA / HART compatible w/ Inductive Alarm 2 Sw +LOI (Digital Display)\*

\*Relay Power Supply Recommended

**Sample Standard Model Code**

I-IV	V	VI	VII	VIII & IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX
3809	G	A	B	02	B	F	C	C	3	E	4	C	0	A	B

## **2. Safety Function Specification**

The Safety Function of the Brooks Instrument MT3809G Flowmeter is to provide a flow alarm indication when the flowrate is above or below a specified trip point within specified accuracy.

### **2.1. Installation and Operation Limits**

It is very important that the Brooks Instrument MT3809G Flowmeter is installed and operated in accordance with the Brooks Instrument Models MT3809G and MT3810G Metal Tube Variable Area Flowmeters Instruction and Operation Manual (X-VA-MT3809G-MT3810G). If the use of the Brooks Instrument MT3809G Flowmeter is not in compliance with these instructions and/or operated beyond limits, the SIL capability and reliability data becomes invalid.

Under normal conditions the maximum operating life time will be 10 years.

### **2.2. Failure Modes, Effects and Diagnostics Analysis (FMEDA)**

The design of the Brooks Instrument MT3809G Flowmeter with Inductive Alarms has been assessed by means of a Failure Modes, Effects and Diagnostics Analysis (FMEDA). A detailed report is available upon request (reference: "*exida FMEDA report – BRO 11-06-060 R001 V1, R2, May 24, 2013*")

The Safety Integrity Level (SIL) of an entire Safety Instrumented Function (SIF) must be verified via a calculation of the  $PFD_{AVG}$  considering redundant architectures, proof test interval, proof test effectiveness, any automatic diagnostics, average repair time and the specifies failure rates of all products included in the SIF

### **2.3. Description of failure categories**

Fail-Safe State	State where the output exceeds the user defined threshold.
Fail Safe	Failure that causes the output to go to the define fail-safe state without a demand from the process

Fail Dangerous	Failure that does not respond to a demand from the process (i.e. being unable to go to the defined fail-safe state).
Fail Dangerous Undetected	Failure that is dangerous and that is not being diagnosed by automatic diagnostics
Fail Dangerous Detected	Failure that is dangerous but is being detected by automatic diagnostics
No Effect	Failure of a component that is part of the safety function but that has no effect on the safety function

The failure categories listed above expand on the categories listed in IEC 61508 which are only safe and dangerous, both detected and undetected. In IEC 61508, edition 2010, the No Effect failure cannot contribute to the failure rate of the safety function. Therefore they are not used for the Safe Failure Fraction calculation needed when Route 2H failure data is not available.





**3. Safety Related Characteristics**

**3.1. Assumptions and planning**

The following assumptions have been made during the Failure Modes, Effects and Diagnostics Analysis of the Brooks Instrument MT3809G:

- Only a single component failure will fail the entire MT3809G flowmeter.
- Failure rates are constant; wear-out mechanisms are not included.
- Propagation of failures is not relevant.
- All components that are not part of the safety function and cannot influence the safety function (feedback immune) are excluded.
- The stress levels are average for an industrial environment and can be compared to profile 4 for wetted parts and profile 3 for all others within operating and environmental temperature limits.

Profile	General Description	Profile acc. IEC 60654-1	Ambient Temp (°C)		Temp cycle (°C/365 days)
			Average (External)	Mean (Inside box)	
3	General field products - may have moderate self heating and are subjected to daily temperature swings	C3	25	45	25
4	Unprotected mechanical field products – may have minimal self heating, are subject to daily temperature swings and rain or condensation	D1	25	30	35
4	Process wetted parts – typically valve and sensor parts that are process wetted	Per Installation and Operation instruction			

- Materials are compatible with process conditions

- The device is installed per Brooks Instrument instructions
- Flowmeters are installed such that the controlled substance will flow through the flowmeter in the direction indicated by the flow arrow, located on the body
- The flowmeters are generally applied in relative clean gas or liquid, therefor no severe service has been considered in the analysis
- Recommended calibration intervals are observed and used to implement proof testing of the device
- Repair and inspection intervals have to be based on the safety calculations
- Modifications made without specific authorization of Brooks Instrument are strictly prohibited
- The parameters given by the FMEDA are considered as planning support. The end-user is responsible for the overall functional safety of the application
- The hardware that implements the safety function has been reviewed in accordance with IEC 61508-2. Since there is no software involved IEC 61508-3 is not applicable

### 3.2. FMEDA results

The Brooks Instrument MT3809G flowmetes analysis resulted in suitability for use in SIL 2 safety functions in accordance with IEC 61508-2: 2010.

*3809G Variable Area Flow Meter with Inductive Alarm*

*Device Type                    A*

*HFT                                0*

*SIL                                 2*

*PFD<sub>AVG</sub>                        1.52E-03 for 1 Year*

*Failure Rate as per        IEC 61508, ed2, 2010*

<i>Device</i>	$\lambda_{SD}$	$\lambda_{SU}$	$\lambda_{DD}$	$\lambda_{DU}$	<i>SFF</i>
<i>3809G – VA Meter, (Trip High)</i>	<i>0 FIT</i>	<i>34 FIT</i>	<i>0 FIT</i>	<i>184 FIT</i>	<i>15.5%</i>
<i>3809G – VA Meter, (Trip Low)</i>	<i>0 FIT</i>	<i>140 FIT</i>	<i>0 FIT</i>	<i>77 FIT</i>	<i>64.6%</i>



The failure rate data used for this analysis is as per route 2H approach according to 7.4.4.3 of IEC 61508. Therefore the 3809G Variable area Flowmeter meets the hardware architectural constraints for up to SIL 2 with a single device when the listed failure rates are used. For the listed PFDAVG valve a mission time of 10 years has been assumed with a Mean Time To Restoration of 24 hours and proof test interval equals 1 year.

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## **4. Operation and Maintenance**

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### **4.1. Lifetime**

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According to section 7.4.9.5 of IEC 61508-2, a useful lifetime, based on experience, should be assumed.

Although a constant failure rate is assumed by the probabilistic estimation method this only applies provided that the useful lifetime of components is not exceeded. Beyond their useful lifetime the result of the probabilistic calculation method is therefore meaningless, as the probability of failure significantly increases with time. The useful lifetime is highly dependent on the subsystem itself and the operating conditions.

This assumption of a constant failure rate is based on the bathtub curve. Therefore it is obvious that the  $PFD_{AVG}$  calculation is only valid for components that have this constant and that the validity of the calculation is limited to the lifetime of each component.

It is the responsibility of the end user to maintain and operate the MT3809G flowmeter per Brooks Instrument instructions. Furthermore regular inspection should show that all components are clean and free from damage.

Based on general field failure data a useful period of approximately 10 years is expected for the MT3809G flowmeter. When plant experience indicates a shorter useful lifetime than indicated here, the number based on plant experience should be used.

## 4.2. Proof-test

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According to section 7.4.5.2 f) of IEC 61508-2 proof tests shall be undertaken to reveal dangerous faults which are undetected by diagnostic tests. This means that it is necessary to specify how dangerous undetected faults which have been noted during the Failure Modes, Effects, and Diagnostic Analysis can be detected during proof testing.

### **Suggested Proof Test:**

The suggested proof test consists of a two point calibration check per table below. The suggested proof test will detect 92.1% of possible DU failures in the MT3809G flow meter configured with Trip High application and 95.0% of possible DU failures in the MT3809G flow meter configured with Trip Low application.

Step	Action
1.	Bypass the safety function and take appropriate action to avoid a false trip
2.	Perform a two-point calibration of the flowmeter over the full working range
3.	Remove the bypass and otherwise restore normal operation

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Model MT3809G

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Model MT3809G

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:

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

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