123293-P1
Rev A, 4/99
Instruction Manual

MKS Type M100B
Mass-Flo® Controller
and
M10MB Mass-Flo Meter

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WARRANTY

Type M100B/M10MB Equipment

MKS Instruments, Inc. (**MKS**) warrants that for two years from the date of shipment the equipment described above (the "equipment") manufactured by **MKS** shall be free from defects in materials and workmanship and will correctly perform all date-related operations, including without limitation accepting data entry, sequencing, sorting, comparing, and reporting, regardless of the date the operation is performed or the date involved in the operation, provided that, if the equipment exchanges data or is otherwise used with equipment, software, or other products of others, such products of others themselves correctly perform all date-related operations and store and transmit dates and date-related data in a format compatible with **MKS** equipment. THIS WARRANTY IS **MKS'** SOLE WARRANTY CONCERNING DATE-RELATED OPERATIONS.

For the period commencing with the date of shipment of this equipment and ending two years later, **MKS** will, at its option, either repair or replace any part which is defective in materials or workmanship or with respect to the date-related operations warranty without charge to the purchaser. The foregoing shall constitute the exclusive and sole remedy of the purchaser for any breach by **MKS** of this warranty.

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THIS WARRANTY IS IN LIEU OF ALL OTHER RELEVANT WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING THE IMPLIED WARRANTY OF MERCHANTABILITY AND THE IMPLIED WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE, AND ANY WARRANTY AGAINST INFRINGEMENT OF ANY PATENT.

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Mass Flow Controller Safety Information

Symbols Used in This Instruction Manual

Definitions of WARNING, CAUTION, and NOTE messages used throughout the manual.

Warning

The WARNING sign denotes a hazard to personnel. It calls attention to a procedure, practice, condition, or the like, which, if not correctly performed or adhered to, could result in injury to personnel.

Caution

The CAUTION sign denotes a hazard to equipment. It calls attention to an operating procedure, practice, or the like, which, if not correctly performed or adhered to, could result in damage to or destruction of all or part of the product.

Note

The NOTE sign denotes important information. It calls attention to a procedure, practice, condition, or the like, which is essential to highlight.

Symbols Found on the Unit

The following table describes symbols that may be found on the unit.

Definition of Symbols Found on the Unit			
On (Supply) IEC 417, No.5007	Off (Supply) IEC 417, No.5008	Earth (ground) IEC 417, No.5017	Protective earth (ground) IEC 417, No.5019
Frame or chassis IEC 417, No.5020	Equipotentiality IEC 417, No.5021	Direct current IEC 417, No.5031	Alternating current IEC 417, No.5032
Both direct and alternating current IEC 417, No.5033-a	Class ll equipment IEC 417, No.5172-a	Three phase alternating current IEC 617-2 No.020206	
Caution, refer to accompanying documents ISO 3864, No.B.3.1	Caution, risk of electric shock ISO 3864, No.B.3.6	Caution, hot surface IEC 417, No.5041	

Table 1: Definition of Symbols Found on the Unit

Safety Procedures and Precautions

The following general safety precautions must be observed during all phases of operation of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of intended use of the instrument and may impair the protection provided by the equipment. MKS Instruments, Inc. assumes no liability for the customer's failure to comply with these requirements.

DO NOT SUBSTITUTE PARTS OR MODIFY INSTRUMENT

Do not install substitute parts or perform any unauthorized modification to the instrument. Return the instrument to an MKS Calibration and Service Center for service and repair to ensure that all safety features are maintained.

SERVICE BY QUALIFIED PERSONNEL ONLY

Operating personnel must not attempt component replacement and internal adjustments. Any service must be made by qualified service personnel only.

USE CAUTION WHEN OPERATING WITH HAZARDOUS MATERIALS

If hazardous materials are used, observe the proper safety precautions, completely purge the instrument when necessary, and ensure that the material used is compatible with the wetted materials in this product, including any sealing materials.

PURGE THE INSTRUMENT

After installing the unit, or before removing it from a system, purge the unit completely with a clean, dry gas to eliminate all traces of the previously used flow material.

USE PROPER PROCEDURES WHEN PURGING

This instrument must be purged under a ventilation hood, and gloves must be worn for protection.

DO NOT OPERATE IN AN EXPLOSIVE ENVIRONMENT

To avoid explosion, do not operate this product in an explosive environment unless it has been specifically certified for such operation.

USE PROPER FITTINGS AND TIGHTENING PROCEDURES

All instrument fittings must be consistent with instrument specifications, and compatible with the intended use of the instrument. Assemble and tighten fittings according to manufacturer's directions.

CHECK FOR LEAK-TIGHT FITTINGS

Carefully check all vacuum component connections to ensure leak-tight installation.

OPERATE AT SAFE INLET PRESSURES

Never operate at pressures higher than the rated maximum pressure (refer to the product specifications for the maximum allowable pressure).

INSTALL A SUITABLE BURST DISC

When operating from a pressurized gas source, install a suitable burst disc in the vacuum system to prevent system explosion should the system pressure rise.

KEEP THE UNIT FREE OF CONTAMINANTS

Do not allow contaminants to enter the unit before or during use. Contamination such as dust, dirt, lint, glass chips, and metal chips may permanently damage the unit or contaminate the process.

ALLOW THE UNIT TO WARM UP

If the unit is used to control dangerous gases, they should not be applied before the unit has completely warmed up. Use a positive shutoff valve to ensure that no erroneous flow can occur during warm up.

Sicherheitshinweise für den Massenflußregler

In dieser Betriebsanleitung vorkommende Symbole

Bedeutung der mit WARNUNG!, VORSICHT! und HINWEIS gekennzeichneten Absätze in dieser Betriebsanleitung.

Warnung!

Das Symbol WARNUNG! weist auf eine Gefahr für das Bedienpersonal hin. Es macht auf einen Arbeitsablauf, eine Arbeitsweise, einen Zustand oder eine sonstige Gegebenheit aufmerksam, deren unsachgemäße Ausführung bzw. ungenügende Berücksichtigung zu Verletzungen führen kann.

Vorsicht!

Das Symbol VORSICHT! weist auf eine Gefahr für das Gerät hin. Es macht auf einen Bedienungsablauf, eine Arbeitsweise oder eine sonstige Gegebenheit aufmerksam, deren unsachgemäße Ausführung bzw. ungenügende Berücksichtigung zu einer Beschädigung oder Zerstörung des Gerätes oder von Teilen des Gerätes führen kann.

Hinweis

Das Symbol HINWEIS macht auf wichtige Informationen bezüglich eines Arbeitsablaufs, einer Arbeitsweise, eines Zustands oder einer sonstige Gegebenheit aufmerksam.

Erklärung der am Gerät angebrachten Symbole

Nachstehender Tabelle sind die Bedeutungen der Symbole zu entnehmen, die am Gerät angebracht sein können.

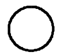
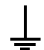
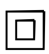
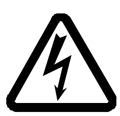
Bedeutung der am Gerät angebrachten Symbole			
 Ein (Energie) IEC 417, No.5007	 Aus (Energie) IEC 417, No.5008	 Erdanschluß IEC 417, No.5017	 Schutzleiteranschluß IEC 417, No.5019
 Masseanschluß IEC 417, No.5020	 Aquipotential- anschluß IEC 417, No.5021	 Gleichstrom IEC 417, No.5031	 Wechselstrom IEC 417, No.5032
 Gleich- oder Wechselstrom IEC 417, No.5033-a	 Durchgängige doppelte oder verstärkte Isolierung IEC 417, No.5172-a	 Dreileiter- Wechselstrom (Drehstrom) IEC 617-2, No.020206	
 Warnung vor einer Gefahrenstelle (Achtung, Dokumen- tation beachten) ISO 3864, No.B.3.1	 Warnung vor gefährlicher elektrischer Spannung ISO 3864, No.B.3.6	 Höhere Temperatur an leicht zugänglichen Teilen IEC 417, No.5041	

Tabelle 2: Bedeutung der am Gerät angebrachten Symbole

Sicherheitsvorschriften und Vorsichtsmaßnahmen

Folgende allgemeine Sicherheitsvorschriften sind während allen Betriebsphasen dieses Gerätes zu befolgen. Eine Mißachtung der Sicherheitsvorschriften und sonstiger Warnhinweise in dieser Betriebsanleitung verletzt die für dieses Gerät und seine Bedienung geltenden Sicherheitsstandards, und kann die Schutzvorrichtungen an diesem Gerät wirkungslos machen. MKS Instruments, Inc. haftet nicht für Mißachtung dieser Sicherheitsvorschriften seitens des Kunden.

Niemals Teile austauschen oder Änderungen am Gerät vornehmen!

Ersetzen Sie keine Teile mit baugleichen oder ähnlichen Teilen, und nehmen Sie keine eigenmächtigen Änderungen am Gerät vor. Schicken Sie das Gerät zwecks Wartung und Reparatur an den MKS-Kalibrierungs- und -Kundendienst ein. Nur so wird sichergestellt, daß alle Schutzvorrichtungen voll funktionsfähig bleiben.

Wartung nur durch qualifizierte Fachleute!

Das Auswechseln von Komponenten und das Vornehmen von internen Einstellungen darf nur von qualifizierten Fachleuten durchgeführt werden, niemals vom Bedienpersonal.

Vorsicht beim Arbeiten mit gefährlichen Stoffen!

Wenn gefährliche Stoffe verwendet werden, muß der Bediener die entsprechenden Sicherheitsvorschriften genauestens einhalten, das Gerät, falls erforderlich, vollständig spülen, sowie sicherstellen, daß der Gefahrstoff die von ihm benetzten, am Gerät verwendeten Materialien, insbesondere Dichtungen, nicht angreift.

Spülen des Gerätes mit Gas!

Nach dem Installieren oder vor dem Ausbau aus einem System muß das Gerät unter Einsatz eines reinen Trockengases vollständig gespült werden, um alle Rückstände des Vorgängermediums zu entfernen.

Anweisungen zum Spülen des Gerätes

Das Gerät darf nur unter einer Ablufthaube gespült werden. Schutzhandschuhe sind zu tragen.

Gerät nicht zusammen mit explosiven Stoffen, Gasen oder Dämpfen benutzen!

Um der Gefahr einer Explosion vorzubeugen, darf dieses Gerät niemals zusammen mit (oder in der Nähe von) explosiven Stoffen aller Art eingesetzt werden, sofern es nicht ausdrücklich für diesen Zweck zugelassen ist.

Anweisungen zum Installieren der Armaturen!

Alle Anschlußstücke und Armaturenteile müssen mit der Gerätespezifikation übereinstimmen, und mit dem geplanten Einsatz des Gerätes kompatibel sein. Der Einbau, insbesondere das Anziehen und Abdichten, muß gemäß den Anweisungen des Herstellers vorgenommen werden.

Verbindungen auf Undichtigkeiten prüfen!

Überprüfen Sie sorgfältig alle Verbindungen der Vakuumkomponenten auf undichte Stellen.

Gerät nur unter zulässigen Anschlußdrücken betreiben!

Betreiben Sie das Gerät niemals unter Drücken, die den maximal zulässigen Druck (siehe Produktspezifikationen) übersteigen.

Geeignete Berstscheibe installieren!

Wenn mit einer unter Druck stehenden Gasquelle gearbeitet wird, sollte eine geeignete Berstscheibe in das Vakuumsystem installiert werden, um eine Explosionsgefahr aufgrund von steigendem Systemdruck zu vermeiden.

Verunreinigungen im Gerät vermeiden!

Stellen Sie sicher, daß Verunreinigungen jeglicher Art weder vor dem Einsatz noch während des Betriebs in das Instrumenteninnere gelangen können. Staub- und Schmutzpartikel, Glassplitter oder Metallspäne können das Gerät dauerhaft beschädigen oder Prozeß und Meßwerte verfälschen.

Geräteeinheit auf Arbeitstemperatur bringen!

Wird das Gerät zur Flußregelung gefährlicher Gase verwendet, so dürfen diese nur nach Abschluß des Anwärmvorgangs zugeführt werden. Um das versehentliche Fließen von Gas während der Aufheizperiode zu verhindern, sollte ein Absperrventil (normal geschlossen) eingebaut werden.

Informations relatives à la sécurité pour le contrôleur de débit de masse

Symboles utilisés dans ce manuel d'utilisation

Définitions des indications AVERTISSEMENT, ATTENTION, et REMARQUE utilisées dans ce manuel.

Avertissement

L'indication AVERTISSEMENT signale un danger pour le personnel. Elle attire l'attention sur une procédure, une pratique, une condition, ou toute autre situation présentant un risque d'accident pour le personnel, en cas d'exécution incorrecte ou de non respect des consignes.

Attention

L'indication ATTENTION signale un danger pour l'appareil. Elle attire l'attention sur une procédure d'exploitation, une pratique, ou toute autre situation, présentant un risque d'endommagement ou de destruction d'une partie ou de la totalité de l'appareil, en cas d'exécution incorrecte ou de non respect des consignes.

Remarque

L'indication REMARQUE signale une information importante. Elle attire l'attention sur une procédure, une pratique, une condition, ou toute autre situation, présentant un intérêt particulier.

Symboles apparaissant sur l'unité

Le tableau suivant décrit les symboles pouvant apparaître sur l'unité.

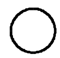
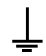
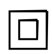
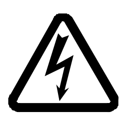
Définition des symboles apparaissant sur l'unité			
 Marche (sous tension) IEC 417, No.5007	 Arrêt (hors tension) IEC 417, No.5008	 Terre (masse) IEC 417, No.5017	 Terre de protection (masse) IEC 417, No.5019
 Masse IEC 417, No.5020	 Equipotentialité IEC 417, No.5021	 Courant continu IEC 417, No.5031	 Courant alternatif IEC 417, No.5032
 Courant continu et alternatif IEC 417, No.5033-a	 Matériel de classe II IEC 417, No.5172-a	 Courant alternatif triphasé IEC 617-2, No.020206	
 Attention : se reporter à la documentation ISO 3864, No.B.3.1	 Attention : risque de choc électrique ISO 3864, No.B.3.6	 Attention : surface brûlante IEC 417, No.5041	

Tableau 3: Définition des symboles apparaissant sur l'unité

Mesures de sécurité et précautions

Prendre les précautions générales de sécurité suivantes pendant toutes les phases d'exploitation de cet appareil. Le non respect des ces précautions ou des avertissements contenus dans ce manuel constitue une violation des normes de sécurité relatives à l'utilisation de l'appareil et peut diminuer la protection fournie par l'appareil. MKS Instruments, Inc. n'assume aucune responsabilité concernant le non respect des consignes par les clients.

PAS DE SUBSTITUTION DE PIÈCES OU DE MODIFICATION DE L'APPAREIL

Ne pas installer des pièces de substitution ou effectuer des modifications non autorisées sur l'appareil. Renvoyer l'appareil à un centre de service et de calibrage MKS pour tout dépannage ou réparation afin de garantir l'intégrité des dispositifs de sécurité.

DÉPANNAGE UNIQUEMENT PAR DU PERSONNEL QUALIFIÉ

Le personnel d'exploitation ne doit pas essayer de remplacer des composants ou de faire des réglages internes. Tout dépannage doit être uniquement effectué par du personnel qualifié.

PRÉCAUTION EN CAS D'UTILISATION AVEC DES PRODUITS DANGEREUX

Si des produits dangereux sont utilisés, prendre les mesures de précaution appropriées, purger complètement l'appareil quand cela est nécessaire, et s'assurer que les produits utilisés sont compatibles avec les composants liquides de l'appareil, y compris les matériaux d'étanchéité.

PURGE DE L'APPAREIL

Après l'installation de l'unité, ou avant son enlèvement d'un système, purger l'unité complètement avec un gaz propre et sec afin d'éliminer toute trace du produit de flux utilisé précédemment.

UTILISATION DES PROCÉDURES APPROPRIÉES POUR LA PURGE

Cet appareil doit être purgé sous une hotte de ventilation, et il faut porter des gants de protection.

PAS D'EXPLOITATION DANS UN ENVIRONNEMENT EXPLOSIF

Pour éviter toute explosion, ne pas utiliser cet appareil dans un environnement explosif, sauf en cas d'homologation spécifique pour une telle exploitation.

UTILISATION D'ÉQUIPEMENTS APPROPRIÉS ET PROCÉDURES DE SERRAGE

Tous les équipements de l'appareil doivent être cohérents avec ses spécifications, et compatibles avec l'utilisation prévue de l'appareil. Assembler et serrer les équipements conformément aux directives du fabricant.

VÉRIFICATION DE L'ÉTANCHÉITÉ DES CONNEXIONS

Vérifier attentivement toutes les connexions des composants pour le vide afin de garantir l'étanchéité de l'installation.

EXPLOITATION AVEC DES PRESSIONS D'ENTRÉE NON DANGEREUSES

Ne jamais utiliser des pressions supérieures à la pression nominale maximum (se reporter aux spécifications de l'unité pour la pression maximum admissible).

INSTALLATION D'UN DISQUE D'ÉCHAPPEMENT ADAPTÉ

En cas d'exploitation avec une source de gaz pressurisé, installer un disque d'échappement adapté dans le système à vide afin d'éviter une explosion du système en cas d'augmentation de la pression.

MAINTIEN DE L'UNITÉ À L'ABRI DES CONTAMINATIONS

Ne pas laisser des produits contaminants pénétrer dans l'unité avant ou pendant l'utilisation. Des produits contaminants tels que des poussières et des fragments de tissu, de glace et de métal peuvent endommager l'unité d'une manière permanente ou contaminer le processus.

RESPECT DU TEMPS D'ÉCHAUFFEMENT

Si l'unité est utilisée pour contrôler des gaz dangereux, ceux-ci ne doivent pas être appliqués avant l'échauffement complet de l'unité. Utiliser une valve de fermeture positive afin de garantir qu'aucun flux ne se produise par erreur pendant l'échauffement.

Medidas de seguridad del controlador de flujo de masa

Símbolos usados en este manual de instrucciones

Definiciones de los mensajes de advertencia, precaución y de las notas usados en el manual.

Advertencia

El símbolo de advertencia indica la posibilidad de que se produzcan daños personales. Pone de relieve un procedimiento, práctica, estado, etc. que en caso de no realizarse u observarse correctamente puede causar daños personales.

Precaución

El símbolo de precaución indica la posibilidad de producir daños al equipo. Pone de relieve un procedimiento operativo, práctica, estado, etc. que en caso de no realizarse u observarse correctamente puede causar daños o la destrucción total o parcial del equipo.

Nota

El símbolo de notas indica información de importancia. Este símbolo pone de relieve un procedimiento, práctica o condición cuyo conocimiento es esencial destacar.

Símbolos hallados en la unidad

La tabla siguiente contiene los símbolos que puede hallar en la unidad.

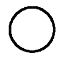
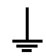
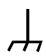
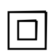
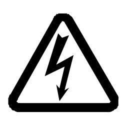
Definición de los símbolos hallados en la unidad			
 Encendido (alimentación eléctrica) IEC 417, N° 5007	 Apagado (alimentación eléctrica) IEC 417, N° 5008	 Puesta a tierra IEC 417, N° 5017	 Protección a tierra IEC 417, N° 5019
 Caja o chasis IEC 417, N° 5020	 Equipotencialidad IEC 417, N° 5021	 Corriente continua IEC 417, N° 5031	 Corriente alterna IEC 417, N° 5032
 Corriente continua y alterna IEC 417, N° 5033-a	 Equipo de clase II IEC 417, N° 5172-a	 Corriente alterna trifásica IEC 617-2, N° 020206	
 Precaución. Consulte los documentos adjuntos ISO 3864, N° B.3.1	 Precaución. Riesgo de descarga eléctrica ISO 3864, N° B.3.6	 Precaución. Superficie caliente IEC 417, N° 5041	

Tabla 4: Definición de los símbolos hallados en la unidad

Procedimientos y precauciones de seguridad

Las precauciones generales de seguridad descritas a continuación deben observarse durante todas las etapas de funcionamiento del instrumento. La falta de cumplimiento de dichas precauciones o de las advertencias específicas a las que se hace referencia en el manual, constituye una violación de las normas de seguridad establecidas para el uso previsto del instrumento y podría anular la protección proporcionada por el equipo. Si el cliente no cumple dichas precauciones y advertencias, MKS Instruments, Inc. no asume responsabilidad legal alguna.

NO UTILICE PIEZAS NO ORIGINALES O MODIFIQUE EL INSTRUMENTO

No instale piezas que no sean originales o modifique el instrumento sin autorización. Para asegurar el correcto funcionamiento de todos los dispositivos de seguridad, envíe el instrumento al Centro de servicio y calibración de MKS toda vez que sea necesario repararlo o efectuar tareas de mantenimiento.

LAS REPARACIONES DEBEN SER EFECTUADAS ÚNICAMENTE POR TÉCNICOS AUTORIZADOS

Los operarios no deben intentar reemplazar los componentes o realizar tareas de ajuste en el interior del instrumento. Las tareas de mantenimiento o reparación deben ser realizadas únicamente por personal autorizado.

TENGA CUIDADO CUANDO TRABAJE CON MATERIALES TÓXICOS

Cuando se utilicen materiales tóxicos, es responsabilidad de los operarios cumplir las medidas de seguridad correspondientes, purgar totalmente el instrumento cuando sea necesario y comprobar que el material utilizado sea compatible con los materiales humedecidos de este producto e inclusive, con los materiales de sellado.

PURGUE EL INSTRUMENTO

Una vez instalada la unidad o antes de retirarla del sistema, purgue completamente la unidad con gas limpio y seco para eliminar todo resto de la sustancia líquida empleada anteriormente.

USE PROCEDIMIENTOS ADECUADOS PARA REALIZAR LA PURGA

El instrumento debe purgarse debajo de una campana de ventilación y deben utilizarse guantes protectores.

NO HAGA FUNCIONAR ESTE INSTRUMENTO EN UN AMBIENTE CON RIESGO DE EXPLOSIONES

Para evitar que se produzcan explosiones, no haga funcionar este producto en un ambiente con riesgo de explosiones, excepto cuando el mismo haya sido certificado específicamente para tal uso.

USE ACCESORIOS ADECUADOS Y REALICE CORRECTAMENTE LOS PROCEDIMIENTOS DE AJUSTE

Todos los accesorios del instrumento deben cumplir las especificaciones del mismo y ser compatibles con el uso que se debe dar al instrumento. Arme y ajuste los accesorios de acuerdo con las instrucciones del fabricante.

COMPRUEBE QUE LAS CONEXIONES SEAN A PRUEBA DE FUGAS

Inspeccione cuidadosamente las conexiones de los componentes de vacío para comprobar que hayan sido instalados a prueba de fugas.

HAGA FUNCIONAR EL INSTRUMENTO CON PRESIONES DE ENTRADA SEGURAS

No haga funcionar nunca el instrumento con presiones superiores a la máxima presión nominal (en las especificaciones del instrumento hallará la presión máxima permitida).

INSTALE UNA CÁPSULA DE SEGURIDAD ADECUADA

Cuando el instrumento funcione con una fuente de gas presurizado, instale una cápsula de seguridad adecuada en el sistema de vacío para evitar que se produzcan explosiones cuando suba la presión del sistema.

MANTENGA LA UNIDAD LIBRE DE CONTAMINANTES

No permita el ingreso de contaminantes en la unidad antes o durante su uso. Los productos contaminantes tales como polvo, suciedad, pelusa, lascas de vidrio o virutas de metal pueden dañar irreparablemente la unidad o contaminar el proceso.

PERMITA QUE LA UNIDAD SE CALIENTE

Si se utiliza la unidad para controlar gases peligrosos, no libere los gases hasta que la unidad termine de calentarse. Use una válvula de cierre positivo para impedir todo flujo no deseado durante el período de calentamiento.

Chapter One: General Information

Introduction

The Type M100B Mass-Flo® controller accurately measures and controls the mass flow rates of gases. The Type M10MB Mass-Flo Meter measures the flow rate of gases. These mass flow devices measure flow using a patented stacked disk bypass assembly in parallel with a sensor tube. The M100B controller and M10MB meter have three-inch footprints. The M100B controller features the ability to accept TTL level commands to remotely open and close the control valve. The controller includes a metal cover and RF bypass capacitors, and incorporates a design that virtually eliminates RFI and EMI interference.

The M100B unit can interface to complementary MKS equipment (Type 647, 246, 247, PR4000) to display the reading and to provide the power, and set point commands. (Additionally, the 167 unit can be used as a readout and set point generator, but it does not supply power; the 660 unit can be used as a power supply and readout, though it cannot send a set point to the flow controller.) Refer to the corresponding manuals for requirements and instructions.

The M100B flow units are available in a variety of types and configurations to suit specific needs. The options that must be specified when you order the flow unit include:

- *Connector:* 15-pin Type "D" connector
- *Range:* 10, 20, 50, 100, 200, 500, 1000, 2000, 5000, 10,000, 20,000, 30,000 sccm (N_2 equivalent)
- *Fittings:* Swagelok® 4-VCR® male compatible, 4-VCO® male compatible, ¼ inch Swagelok® compatible, and ⅛" Swagelok compatible
- *Seals:* Viton®, Neoprene, Buna-N

All M100B controllers have normally *closed* valves.

Design Features

The design of the M100B flow controller incorporates an advanced flow sensor, and an optimized stacked disk bypass. The latest generation two-element sensing circuit provides accurate, repeatable performance even in low flow ranges (< 10 sccm). Low temperature effect from ambient temperature change and a low attitude sensitivity effect are also ensured. The newly optimized sensor/bypass arrangement minimizes the flow splitting error for gases with different densities, which dramatically improves measurement accuracy when gases other than the calibration gas are used. In addition, the variable valve control electronics provides for fast response to any set point.

Reliability

To help provide excellent reliability, the design contains a low mechanical and electronic components count and has successfully passed the following tests:

- STRIFE, including temperature cycling and vibration (sine and random tests)

and with an overall metal braided shielded cable, properly grounded at both ends:

- CE Compliance - EMC Directive 89/336/EEC

Cleanliness Features

To ensure cleanliness, the M100B/M10MB mechanical parts undergo precision machining and a proprietary cleaning process prior to assembly. Each mass flow device is assembled and double-bagged under Class 100 conditions.

How This Manual is Organized

This manual is designed to provide instructions on how to set up, install, and operate a Type M100B/M10MB unit.

Before installing your Type M100B/M10MB unit in a system and/or operating it, carefully read and familiarize yourself with all precautionary notes in the *Safety Messages and Procedures* section at the front of this manual. In addition, observe and obey all WARNING and CAUTION notes provided throughout the manual.

Chapter One, *General Information*, (this chapter) introduces the product and describes the organization of the manual.

Chapter Two, *Installation*, explains the environmental requirements and describes how to mount the instrument in your system.

Chapter Three, *Overview*, gives a brief description of the instrument and its functionality.

Chapter Four, *Operation*, describes how to use the instrument and explains all the functions and features.

Chapter Five, *Maintenance*, lists any maintenance required to keep the instrument in good working condition.

Chapter Six, *Troubleshooting*, provides a checklist for reference should the instrument malfunction.

Appendix A, *Product Specifications*, lists the specifications of the instrument.

Appendix B, *Model Code Explanation*, describes the model code used to order the instrument.

Manual Conventions

The following conventions apply throughout this manual:

$\overline{\text{XXXXXX}}$	*For inputs:*	Indicates that the line must be pulled low to activate the function.
$\overline{\text{XXXXXX}}$	*For outputs:*	Indicates that the output is active low.

Customer Support

Standard maintenance and repair services are available at all of our regional MKS Calibration and Service Centers, listed on the back cover. In addition, MKS accepts the instruments of other manufacturers for recalibration using the Primary and Transfer Standard calibration equipment located at all of our regional service centers. Should any difficulties arise in the use of your Type M100B/M10MB instrument, or to obtain information about companion products MKS offers, contact any authorized MKS Calibration and Service Center. If it is necessary to return the instrument to MKS, please obtain an ERA Number (Equipment Return Authorization Number) from the MKS Calibration and Service Center before shipping. The ERA Number expedites handling and ensures proper servicing of your instrument.

Please refer to the inside of the back cover of this manual for a list of MKS Calibration and Service Centers.

Warning **All returns to MKS Instruments must be free of harmful, corrosive, radioactive, or toxic materials.**

Chapter Two: Installation

How To Unpack the Type M100B/M10MB Unit

MKS has carefully packed the Type M100B/M10MB unit so that it will reach you in perfect operating order. Upon receiving the unit, however, you should check for defects, cracks, broken connectors, etc., to be certain that damage has not occurred during shipment.

Note Do *not* discard any packing materials until you have completed your inspection and are sure the unit arrived safely.

If you find any damage, notify your carrier and MKS immediately. If it is necessary to return the unit to MKS, obtain an ERA Number (Equipment Return Authorization Number) from the MKS Service Center before shipping. Please refer to the inside of the back cover of this manual for a list of MKS Calibration and Service Centers.

Unpacking Checklist

Standard Equipment:

- Type M100B/M10MB Unit
- Type M100B and M10MB Instruction Manual (this book)

Optional Equipment:

- Electrical Connector Accessories Kit, M100B-K1 (includes a mate to the electrical connector if you choose to make your own interface cable)
- Interface cables (refer to Table 5, page 22)
- Power supply readout, such as the Type 647, 246, 247, PR4000 167 (no power supply, readout, and set point generator only), or 660 (no set point, readout and power supply only)
- Length Adapter Kit, allows the M100B/M10MB unit to be a drop-in replacement for a Type 1259 unit

Interface Cables

As of January 1, 1996, most products shipped to the European Community must comply with the EMC Directive 89/336/EEC, which covers radio frequency emissions and immunity tests. In addition, as of January 1, 1997, some products shipped to the European Community must also comply with the Product Safety Directive 92/59/EEC and Low Voltage Directive 73/23/EEC, which cover general safety practices for design and workmanship. MKS products that meet these requirements are identified by application of the CE Mark.

To ensure compliance with EMC Directive 89/336/EEC, an overall metal braided shielded cable, properly grounded at both ends, is required during use. No additional installation requirements are necessary to ensure compliance with Directives 92/59/EEC and 73/23/EEC.

Note

1. An overall metal braided, shielded cable, properly grounded at both ends, is required during use to meet CE specifications.
2. To order an overall metal braided shielded cable, add an "S" after the cable type designation. For example, to order a cable to connect an M100B unit to a 146 unit, use part number CB47-1-XX, where XX designates the cable length; for a braided, shielded cable use part number CB147S-1-XX.

Interface Cables		
To Connect the M100B/M10MB Unit to . . .	**Use the MKS Cable . . .**	
	Standard	**Shielded**
PR4000, 146,186, 167, 647	CB147-1-XX	CB147S-1-XX
246, 247	CB259-5-XX	CB259S-5-XX
XX indicates the cable length, in feet; standard length is 10 ft		

Table 5: Interface Cables

Generic Shielded Cable Guidelines

Should you choose to manufacture your own cables, follow the guidelines listed below:

1. The cable must have an overall metal *braided* shield, covering all wires. Neither aluminum foil nor spiral shielding will be as effective; using either may nullify regulatory compliance.
2. The connectors must have a metal case which has direct contact to the cable's shield on the whole circumference of the cable. The inductance of a flying lead or wire from the shield to the connector will seriously degrade the shield's effectiveness. The shield should be grounded to the connector before its internal wires exit.
3. With very few exceptions, the connector(s) must make good contact to the device's case (ground). "Good contact" is about 0.01 ohms; and the ground should surround all wires. Contact to ground at just one point may not suffice.
4. For shielded cables with flying leads at one or both ends; it is important at each such end, to ground the shield *before* the wires exit. Make this ground with absolute minimum length. (A ¼ inch (6.35 mm) piece of #22 wire may be undesirably long since it has approximately 5 nH of inductance, equivalent to 31 ohms at 1000 MHz). After picking up the braid's ground, keep wires and braid flat against the case. With very few exceptions, grounded metal covers are not required over terminal strips. If one is required, it will be stated in the Declaration of Conformity or in the instruction manual.
5. In selecting the appropriate type and wire size for cables, consider:

   A. The voltage ratings.

   B. The cumulative I^2R heating of all the conductors (keep them safely cool).

   C. The IR drop of the conductors, so that adequate power or signal voltage gets to the device.

   D. The capacitance and inductance of cables which are handling fast signals, (such as data lines or stepper motor drive cables).

   E. That some cables may need internal shielding from specific wires to others; please see the instruction manual for details regarding this matter.

Product Location and Requirements

1. Maintain the normal operating temperature between 0° and 50° C (32° and 122° F).
2. Observe the pressure limits:
   A. Maximum gas inlet pressure is 150 psig.
   B. Operational differential pressure is:
      10 to 40 psid for ≤ 5000 sccm units
      15 to 40 psid for 10,000 to 30,000 sccm units
      The standard orifice is sized for control over this range with the outlet at atmospheric pressure.
3. Provide power input at ±15 VDC (±10%) @ 200 mA.
   A. Maximum voltage/current at startup is ±15 VDC (±10%) @ 200 mA.
   B. Typical steady state voltage/current should be ±15 VDC (±10%) @ 100 mA.
4. Allow 15 minutes warm-up time.
5. Use high purity gas and filters in line upstream of the MFC.
6. Leave the power to the instrument on at all times, for optimal performance.

For additional information refer to *Appendix A: Product Specifications,* page 49.

Setup

Follow the guidelines below when setting up the M100B/M10MB unit.

1. Set the controller into position where it will be connected to a gas supply.

   Placement of flow components in an orientation other than that in which they were calibrated (typically horizontal) may cause a small zero shift. The zero offset can be removed according to the instructions in *How To Zero the Flow Device*, page 36.

2. Install the flow controller in the gas stream such that the flow will be in the direction of the arrow on the side of the controller.

3. Allow adequate clearance for the cable connector and tubing.

   Straight Shielded connectors require approximately 3” height. Right Angle connectors require approximately 2” height.

4. Position the flow controller to provide access to the zero potentiometer.

   The zero potentiometer is located on the inlet side of the flow controller body.

Refer to Figure 1, page 26, for outline dimensions, and Figure 4, page 28, for the mounting dimensions of the MFC/MFM.

Dimensions

Note All dimensions are listed in inches with millimeters referenced in parentheses.

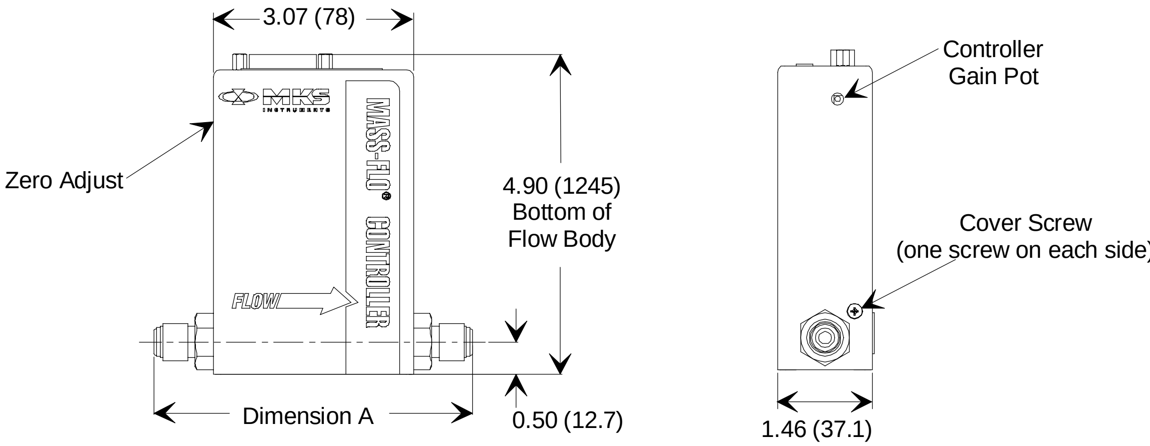


Figure 1: Front and Side Views of the M100B/M10MB Mass Flow Device

Measurement for Dimension A	
Fitting Choice	**Measurement, inches (mm)**
Swagelok 4-VCR compatible	4.88 (123.9)
4-VCO compatible	4.56 (115.8)
¼ inch Swagelok compatible	4.44 (112.8)
⅛ inch Swagelok compatible	4.31 (109.5)

Table 6: Measurement for Dimension A

Note The method used to measure the overall length of the unit varies with the type of fitting. For VCR and VCO compatible fittings, the unit is measured from mating face to mating face. For Swagelok compatible fittings, the unit is measured from fitting end to fitting end (less nut).

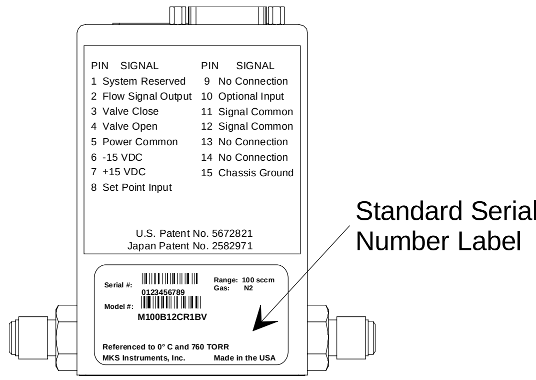


Figure 2: Back View of the Type M100B/M10MB Mass Flow Device

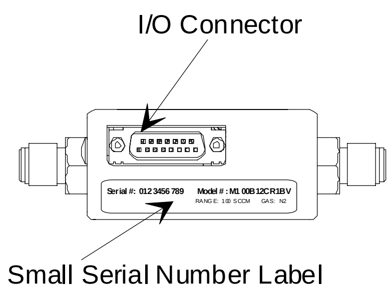


Figure 3: Top View of the Type M100B/M10MB Mass Flow Device

Note

Each M100B/M10MB unit carries two serial number labels, a small label on the top (as shown in Figure 3) and the standard label on the back (as shown in Figure 2). This allows you to read the serial number label more easily when the unit is installed in your system.

Gas Line Connections

Connect the gas line (via tubing) from the gas supply to the flow controller's inlet, and from the flow controller's outlet, to the downstream tubing.

Fittings

The M100B/M10MB flow device is available with the following fittings:

- Swagelok 4-VCR male compatible
- Swagelok 4-VCO male compatible
- ¼ inch Swagelok compatible
- ⅛ inch Swagelok compatible

Refer to Table 6, page 26, for details.

Mounting the M100B/M10MB Unit

Tapped holes are provided in the base of the unit for mounting. Refer to Figure 4 for the size and location of the mounting holes.

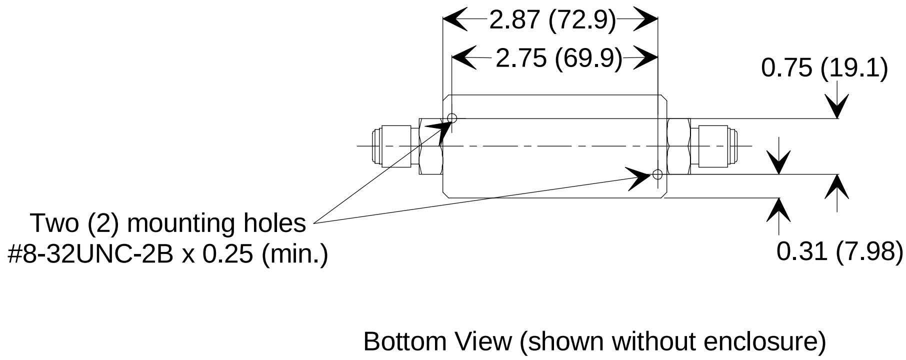


Figure 4: Mounting Dimensions

Electrical Information

If you are using the M100B/M10MB unit with any equipment other than corresponding MKS power supply/readout units, consult the manufacturer's specifications for connection, and for proper electrical and power characteristics. Refer to *Appendix A: Product Specifications*, page 49, for electrical requirements of the M100B/M10MB unit.

The M100B/M10MB unit has an I/O connector pinout that matches other MKS flow devices.

Standard I/O Connector

Table 7 lists the pinout of the 15-pin Type "D" I/O connector.

I/O Connector Pinout			
Pin	**Assignment**	**Pin**	**Assignment**
1	System Reserved	9	No Connection
2	Flow Signal Output (0 to +5 VDC)	10	Optional Input
3	$\overline{\text{Valve Close}}$ *	11	Signal Common
4	$\overline{\text{Valve Open}}$ *	12	Signal Common
5	Power Supply Common	13	No Connection
6	-15 VDC	14	No Connection
7	+15 VDC	15	Chassis Ground
8	Set Point Input* (0 to +5 VDC)		
** Pin assignment is for an MFC only, an, MFM has a "Reserved" pin assignment*			

Table 7: I/O Connector Pinout

Note

1. The "No Connection" pin assignment refers to a pin with no internal connection. The "Reserved" pin assignment refers to a pin with an internal connection, that may be assigned a function in the future.
2. The 0 to 5 VDC flow signal output comes from pin 2 and is referenced to pin 12 (signal common).
3. Any appropriate 0 to 5 VDC input signal of less than 20K ohm source impedance referenced to pin 12 can be used to supply a set point signal to pin 8.

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Chapter Three: Overview

Gas Correction Factor

A Gas Correction Factor (GCF) is used to indicate the ratio of flow rates of different gases that will produce the same output voltage from a mass flow controller. The GCF is a function of specific heat, density, and the molecular structure of the gases. Nitrogen is used as the baseline gas (GCF = 1) since flow controllers are usually calibrated with nitrogen.

Appendix C: Gas Correction Factors, page 55, lists the gas correction factors for some commonly used pure gases. If the gas you are using is not listed, you must calculate its GCF. The equations for calculating gas correction factors are listed in *How To Calculate the GCF for Pure Gases*, page 31, and *How To Calculate the GCF for Gas Mixtures,* page 32.

Note

1. When using the GCF, the accuracy of the flow reading may vary by ±5%, however, the repeatability will remain ±0.2% of FS.
2. All MKS readouts have Gas Correction Adjustment controls to provide direct readout.

How To Calculate the GCF for Pure Gases

To calculate the Gas Correction Factor for *pure* gases, use the following equation:

$$GCF_x = \frac{(0.3106)\ (s)}{(d_x)\ (cp_x)}$$

where:

GCF_X = Gas Correction Factor for gas X

0.3106 = (Standard Density of nitrogen) (Specific Heat of nitrogen)

s = Molecular Structure correction factor where S equals:

1.030 for Monatomic gases

1.000 for Diatomic gases

0.941 for Triatomic gases

0.880 for Polyatomic gases

d_X = Standard Density of gas X, in g/l (at 0° C and 760 mm Hg)

cp_X = Specific Heat of gas X, in cal/g° C

How To Calculate the GCF for Gas Mixtures

For gas mixtures, the calculated Gas Correction Factor is not simply the weighted average of each component's GCF. Instead, the GCF (relative to nitrogen) is calculated by the following equation:

$$GCF_M = \frac{(0.3106)\ (a_1 s_1 + a_2 s_2 + \ldots a_n s_n)}{(a_1 d_1 cp_1 + a_2 d_2 cp_2 + \ldots a_n d_n cp_n)}$$

where:

GCF_M = Gas Correction Factor for a gas mixture

0.3106 = (Standard Density of nitrogen) (Specific Heat of nitrogen)

a_1 through a_n = Fractional Flow of gases 1 through n
Note: a_1 through a_n must add up to 1.0

s_1 through s_n = Molecular Structure correction factor for gases 1 through n where S equals:

1.030 for Monatomic gases

1.000 for Diatomic gases

0.941 for Triatomic gases

0.880 for Polyatomic gases

d_1 through d_n = Standard Density for gases 1 through n, in g/l (at 0° C and 760 mmHg)

cp_1 through cp_n = Specific Heat of gases 1 through n, cal/g° C

Note

The values for s, d, and cp_x are available for most gases, refer to *Appendix C: Gas Correction Factors*, page 55.

The values for a_1 through a_n (which must add up to 1.0) are application dependent.

Example

Calculate the GCF for a gas mixture of argon (gas 1) flowing at 150 sccm and nitrogen (gas 2) flowing at 50 sccm, where:

Argon (Ar)	**Nitrogen (N_2)**
$a_1 = \frac{150}{200} = 0.75$	$a_2 = \frac{50}{200} = 0.25$
$s_1 = 1.030$	$s_2 = 1.000$
$d_1 = 1.782$ g/l	$d_2 = 1.250$ g/l
$cp_1 = 0.1244$ cal/g ° C	$cp_2 = 0.2485$ cal/g ° C

then:

$$GCF_M = \frac{(0.3106)\ [(0.75)(1.030) + (0.25)(1.000)]}{(0.75)(1.782)(0.1244)\ + (0.25)(1.250)(0.2485)}$$

$$= \frac{(0.3106)\ [(0.7725) + (0.25)]}{(0.1663)\ + (0.0777)}$$

$$= \frac{(0.3106)\ (1.0225)}{0.244}$$

$$= \frac{0.3176}{0.244}$$

$$GCF_M = 1.302$$

How To Read Mass Flow at a Different Reference Temperature

The equations for calculating the GCF assume that the MFC was calibrated at a reference temperature of 0° C (~273° K). If you want to read the mass flow as if the MFC was calibrated at a different reference temperature, adjust the calculated GCF value using the following equation:

$$\text{Temperature Corrected GCF} = \text{GCF} \times \frac{T_x}{T_s}$$

where:

T_X = Reference temperature (K)

T_S = 273.15° K (~ equal to 0° C)

Labels

Each M100B/M10MB unit has two serial number labels, a small one on the top side and the standard, larger label on the back side. Each label shows the serial number, the model code, the full scale flow range, and the calibration gas.

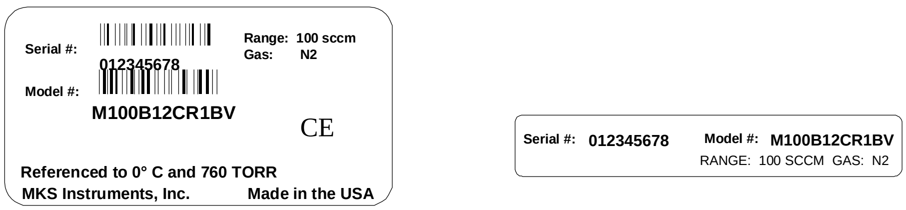


Figure 5: Serial Number Label

Chapter Four: Operation

How To Start Up the Flow Device

1. Leak test the fittings on the MFC/MFM using standard leak test procedures.

   Do *not* proceed to the next step until you are certain that there is no gas leakage.

2. Plug the power supply/readout cable (MKS or customer-supplied) into the 15-pin Type "D" connector located at the top of the flow controller.

   Plug the other end of the cable into an MKS or MKS-compatible power supply/readout unit.

3. Apply power to the MFC instrument.

   When power is first applied, the output signal jumps to over +5 VDC.

   You can monitor the flow output signal as the heaters stabilize and the output approaches zero. Approximately 15 minutes after power up, the output signal should be within 10 mV (0.2% F.S.) of the final voltage at all specified flow rates.

Warning

If the MFC is being used to control dangerous gases, be sure that the system is *fully warmed up* before applying gases to the system. You may choose to install a positive shutoff valve to prevent inadvertent gas flow during the warm-up period.

Once the flow device is completely warmed up, you can proceed to zero the unit as required.

How To Zero the Flow Device

Ensure that no gas flow is entering the flow device.

1. Apply gas, at a regulated pressure, to the MFC/MFM.

2. If your system includes a positive shutoff valve, located either upstream or downstream of the instrument, close it.

3. *For an MFC:* Command the control valve open by sending a full scale set point (5 VDC) signal, or connect pin 4 (valve open) to pin 11 or 12 (signal ground).

   A positive flow may occur momentarily while the gas pressure equalizes across the flow controller.

Note A set point command signal greater than 50 mV (1% of full scale) is required for the flow controller to generate an output.

For an MFM: Skip to step 2 in *Adjust the Zero Pot.*

Adjust the Zero Pot

1. *For an MFC only:* Once flow through the controller has stopped (reached zero flow), remove the set point or valve open command.

2. Turn the Zero pot (located on the inlet side of the flow device) until the readout displays zero.

   Note For best results, turn the zero pot a small amount, and then wait for the signal to stabilize before turning it again.

   Refer to Figure 1, page 26, for the location of the Zero pot. If you are using an MKS power supply/readout unit, the flow device can also be zeroed at the front panel of the readout unit.

3. Open the positive shutoff valve.

   An MFC may indicate a small, positive flow (<1.0% F.S.) due to a leak through its control valve. However, do ***not*** “zero out” this flow since it represents an actual flow measurement inherent in the system.

How To Adjust the Controller Gain

The controller gain adjustment is used to eliminate flow oscillation. Different flow conditions (inlet and outlet pressures) require different controller gain settings for steady, oscillation-free flow in combination with a fast flow response.

The controller gain adjustment pot is located on the upstream side of the controller.

To decrease flow oscillation: Turn the controller gain adjustment counterclockwise while monitoring the output.

Note If the flow output jumps beyond the set point, you have turned the gain too far counterclockwise. Turn the gain control clockwise slightly.

To increase controller response: Turn the controller gain adjustment clockwise.

Note All M100B flow controllers are initially tuned with the inlet pressure set at 25 psig and the outlet pressure at atmospheric pressure. If these conditions are close to the conditions in which you will use the flow controller, the unit should require a minimal adjustment to the gain.

How To Override the Valve

The valve override feature enables the control valve to be fully opened (purged) or closed independent of the set point command signal. Refer to Table 7, page 29, for the appropriate pin locations.

To *open* the valve, apply a TTL low to pin 4 *or* connect pin 4 to signal ground (pin 12).

To *close* the valve, apply a TTL low to pin 3 *or* connect pin 3 to signal ground (pin 12).

Priority of the Commands

The M100B flow controller executes commands based on a hierarchical command structure. The highest priority command is Valve Open, followed by Valve Close, and Set Point Control. Therefore, if the flow controller is operating under Set Point Control, you can send a Valve Open command to force the valve to the full open position.

Note When both the Valve Close and Valve Open pins are pulled down, the Valve Open command takes precedence and the valve is moved to the open position.

How To Use the Optional Input

The M100B/M10MB units provide an optional input feature that allows them to control flow based on 0 to 5 V signals from external sensing devices. A common application of this feature is pressure control using inputs from a pressure transducer.

Implement the optional feature by simply routing the output from the desired external device to the appropriate "optional input" position for the particular connector. Refer to Table 7, page 29, for the pinout assignments. Voltage to the optional input overrides the signal generated by the unit's own internal flow sensor. The control electronics drives the valve so that the optional input signal matches the set point. Provide the 0 to 5 V set point to the same input pin as in standard flow control.

Metered flow output is still available on the standard output pin identified in the applicable pin assignments. Refer to Table 7, page 29, for the pinout assignments.

Chapter Five: Theory of Operation

General Information

The M100B/M10MB flow devices measure the mass flow rate of a gas and, the M100B MFC, controls the flow rate according to a given set point. The control range is from 2 to 100% of Full Scale (F.S.) with an accuracy of ±1% of F.S. for ranges less than or equal to 5K sccm, ±1.5% of F.S. for ranges greater than 5K sccm.

Flow Path

Upon entering the flow device the gas stream passes first through the metering section of the instrument for its mass flow to be measured. For the M10MB MFM the gas then exits the unit. For the M100B MFC, the gas moves on through the control valve for its rate of flow to be regulated according to the given set point, and then exits the instrument at the established rate of flow.

The metering section consists of a sensor tube and parallel bypass.

The geometry of the sensor tube, in conjunction with the specified full scale flow rate, ensures fully developed laminar flow in the sensing region. The bypass elements, in those instruments containing them, are specifically matched to the characteristics of the sensor tube to achieve a laminar flow splitting ratio that remains constant throughout each range.

Measurement Technique

The flow measurement is based on differential heat transfer between temperature sensing heater elements, which are attached symmetrically to the sensor tube. This senses the thermal mass movement that is converted to mass flow via the specific heat, C_p, of the gas. The resulting signal is amplified to provide a 0 to 5 VDC output that is proportional to mass flow.

Control Circuitry

The controller employs the above measurement technique and utilizes a control circuit that provides drive current for the proportioning control valve. The flow controller accepts a 0 to 5 VDC set point signal, compares it to its own flow signal, and generates an error voltage. This error signal is then conditioned by a PID (Proportional-Integral-Derivative) algorithm and amplified so that it can reposition the controlling valve, thus reducing the controller error to within the resolution specification of the instrument.

Since the control valve is *normally closed,* the M100B unit pulls the plug *away* from the seat to regulate the gas flow rate.

Chapter Six: Maintenance

General Information

In general, no maintenance is required other than proper installation and operation, and zero adjustment. If a controller fails to operate properly upon receipt, check for shipping damage, and check the power/signal cable for correct continuity. Any damage should be reported to the carrier and MKS Instruments immediately. If there is no obvious damage and the continuity is correct, it may be necessary to return the unit to MKS Instruments for service. Refer to *Customer Support*, page 20, for instructions.

Note MKS recommends that all flow products be calibrated periodically (typically every 6 to 12 months) to ensure accurate readings. Re-calibration is considered normal preventative maintenance and is not covered by any warranty.

Periodically check for wear on the cables and inspect the enclosure for visible signs of damage.

How To Clean the Unit

Periodically wipe down the unit with a damp cloth.

Zero Adjustment

For best accuracy and repeatability, you should check the zero setting periodically and reset it, if necessary. Refer to *How To Zero the Flow Device*, page 36, for instructions on setting the zero. The frequency of checking the zero is dependent on the specific accuracy and repeatability required by your process. It is also recommended that the instrument be recalibrated annually if no other time interval has been specifically established. Refer to the inside of the back cover of this instruction manual for a complete list of MKS Calibration and Service centers.

Repair

Contact any authorized MKS Sales Office or Calibration and Service Center should you encounter any difficulties or problems using your flow controller/meter.

Note If it is necessary to return the instrument to MKS for repair, please contact any of the MKS international service/calibration centers listed on the inside of the back cover of this manual for an ERA (Equipment Return Authorization) number to expedite handling and ensure proper servicing of your instrument.

Chapter Seven: Troubleshooting

Troubleshooting Chart

Symptoms	Possible Cause	Remedy
No output or overrange at zero (after warm-up)	Improper cable	Verify that the correct cable is being used.
	Valve override function applied	Disconnect valve override.
	Electronics malfunctioning	Return for service.
Unit indicates a negative flow	Unit installed in gas stream backwards	Reinstall unit in proper flow direction.
Controller does not track set point	Improper zero adjustment	Zero meter output, according to *How To Zero the Flow Device*, page 36.
Controller does not function	Electronics malfunctioning	Return for service.
	Valve sticking	Readjust the valve, following the instructions in *How To Adjust the Valve Preload*, page 44.
Oscillation	Too high a controller gain setting	Reduce (turn counter-clockwise) controller gain.
	Incorrect upstream pressure regulator	Check manufacturers' specifications.
	Upstream pressure too high	Reduce upstream pressure.
Excessive closed conductance	Inadequate valve preload	Readjust the valve, according to *How To Adjust the Valve Preload*, page 44.
Unit does not achieve full flow	Upstream pressure too low	Increase upstream pressure.
	Excessive valve preload	Readjust the valve, according to *How To Adjust the Valve Preload*, page 44.
Controller outputs flow in excess of set point	Controller gain adjustment is set too far counterclockwise.	Turn the controller gain pot slightly clockwise until flow recovers.

Table 8: Troubleshooting Chart

How To Adjust the Valve Preload

Warning

Before performing MFC valve adjustments, you MUST purge your process equipment and the MFC with an inert gas, such as argon or nitrogen, and isolate the MFC from toxic and hazardous gases. Use an inert surrogate gas while adjusting the valve preload as a safeguard against inadvertent exposure to any toxic or hazardous gas. A release of hazardous or toxic gas could cause serious injury. If necessary, remove the MFC from the process equipment to adjust the valve.

Questions concerning the safe handling of toxic or hazardous gases may be answered by consulting your corporate policy, a government agency such as OSHA or NIOSH, or experts familiar with your process gas.

MKS assumes no liability for safe handling of toxic or hazardous gases.

Caution

All valves are adjusted at the factory for proper leak integrity and flow control response. Adjust the valve *only* if the *Troubleshooting Chart,* (Table 8, page 43), recommends that you do so.

This procedure requires the following equipment:

- Any special safety equipment necessary to handle the gas in use
- 3/32” allen wrench for retaining screws (4-40 socket head cap screws)
- 3/16” allen wrench for the centershaft
- 9/16” wrench for the lock nut
- Digital Multi Meter (DMM)
- 6” long clip lead with fine clips
- Two 1 mm x 1 mm (0.025” x 0.025”) by ½” (approximately) long electrical pins

1. Disconnect the cable to power down the unit.

2. Use a $^{3}/_{32}$" allen wrench to remove the enclosure retaining screws. There is one screw located on each side of the unit. (Refer to Figure 1, page 26.) Remove the enclosure cover.

3. Reconnect the cable to power up the unit.

4. Set your processing system to supply the MFC with a non-hazardous gas (Ar, N_2, or He) and purge thoroughly.

Warning

You MUST use a "safe" gas while making any valve adjustments to safeguard against inadvertent exposure to any toxic or hazardous gas. DO NOT adjust the valve while a hazardous or toxic gas is flowing through the MFC.

If you cannot use a "safe" gas within your processing system, remove the MFC and purge the unit as required by your corporate policies and any appropriate safety procedures. Once the unit is purged properly perform the valve adjustment outside of the system, maintaining the same orientation (flow direction) as used in the processing system.

Choose a "safe" gas with a similar molecular weight as the actual process gas. More specifically, helium is best used as a substitute for other very light gases such as hydrogen.

5. Set the gas supply regulator to the maximum expected operating pressure of your processing system.

Warning

Follow your corporate policy on handling toxic or hazardous gases. Your corporate policy on handling these gases *supersedes* the instructions in this manual. MKS assumes no liability for the safe handling of such materials.

If appropriate, remove the MFC from the process tool and make the adjustments using a surrogate gas.

6. Close all isolation valves in the system, both upstream and downstream of the MFC.

7. Zero the unit, following the instructions in *How To Zero the Flow Device*, page 36.

8. Disconnect the electrical connector from the PC Control board.

9. Insert the suitable pins into the connector and run a clip lead from one pin to one pin on the PCB.

10. Use a clip lead to place the DMM in series between the valve connector pin and the remaining pin on the PCB, as shown in Figure 6.

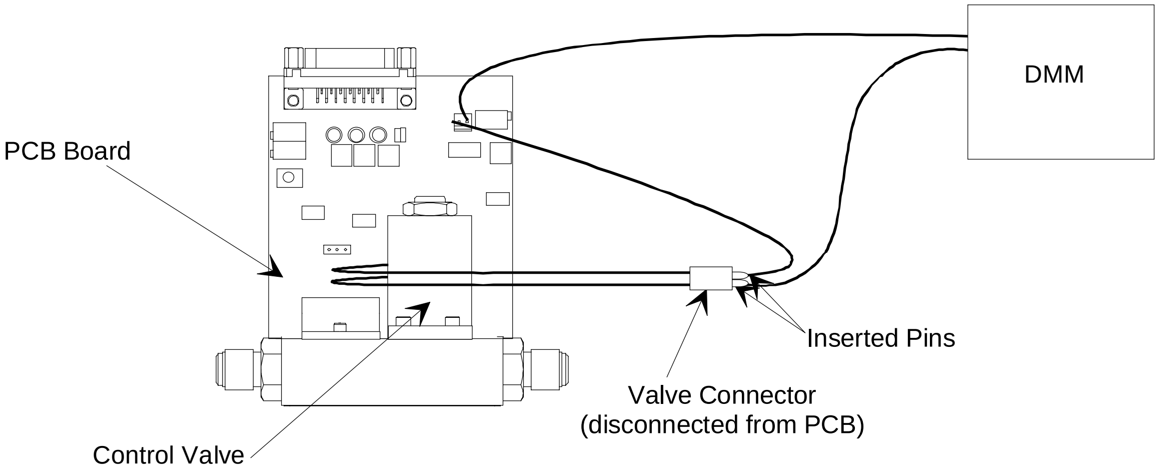


Figure 6: Control Valve Connected to a Digital Multi Meter (DMM)

11. Set the DMM to measure current in the 10 to 100 mA range.

12. Open all upstream and downstream isolation valves in the system.

13. Hold the centershaft in place with a 3/16" allen wrench and loosen the jam nut using a 9/16" crescent wrench.

    Refer to Figure 7 for the location of the lock nut and centershaft.

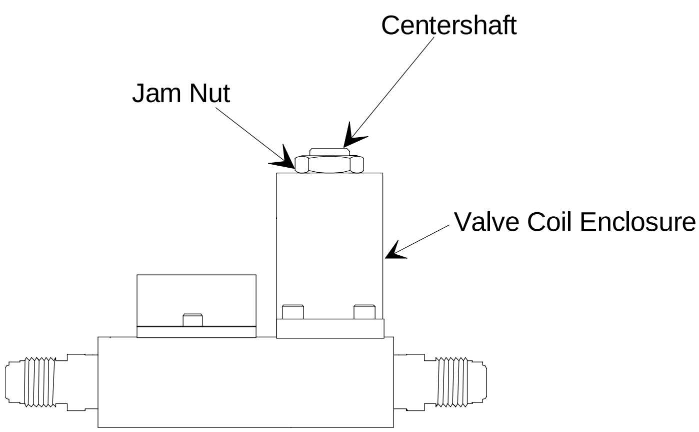


Figure 7: Location of the Lock Nut and Centershaft

14. Provide a set point input signal to the MFC of 0.25 Volts to represent 5% flow.

15. *Slowly* turn the centershaft while monitoring the DMM: clockwise rotation increases the current required to open the valve; counterclockwise rotation decreases it.

Target Values for Preload Setting	
F.S. Range (sccm)	**Target Current (mA)**
10, 20, 50	20
100 throug 20,000	25
30,000	30

Table 9: Target Values for Preload Setting

Note Always make adjustments by turning counterclockwise first and then turning clockwise to the proper setting. This procedure ensures that the adjustment will remain fixed when you retighten the lock nut.

Caution **Do not overturn the centershaft! Excessive turning may damage the plug and cause poor closed conductance and flow control.**

16. Holding the centershaft in place, re-tighten the jam nut. As you tighten the jam nut, monitor the DMM to ensure that the current remains within 1 mA of the target value. You may need to repeat this procedure more than once.

17. Change the set point input signal to 0.0 Volts.

18. Monitor the MFC output to verify that the valve closed conductance is within specification.

    Refer to *Appendix A: Product Specifications*, page 49, for the valve closed conductance specification. If the valve fails to meet the closed conductance specification, return the unit to MKS for service.

19. Change the inlet pressure to the minimum expected in use.

20. Change the set point input signal to 5.0 Volts (100% of full scale).

18. Observe the MFC output and control valve current. *Record the valve current.*

    The MFC output should be 5.0 Volts (100%) and the valve current no greater than the limits in Table 10. If the valve current exceeds these limits, return the unit to MKS for service.

Maximum Valve Currents	
UUT Flow Capacity (sccm) (N_2 Equivalent)	**Maximum Valve Current 9mA) at 100% Set Point and Minimum Pressure**
500 and under	45
1000 through 10K	55
20K and 30K	62

Table 10: Maximum Valve Currents

19. Remove the DMM and leads. reconnect the valve connector.

20. Reposition the enclosure over the unit and tighten the retaining screws (one on each side).

21. Reconnect the interface cable.

Appendix A: Product Specifications

Performance Specifications

Accuracy[1] ≤ 5K sccm > 5K sccm	 ±1% F.S. ±1.5% F.S.
Control Range	2.0 to 100% F.S.
Controller Settling Time[2]	< 2 seconds (to within 2% of set point)
Full Scale Ranges (nitrogen equivalent)	10, 20, 50, 100, 200, 500, 1000, 2000, 5000, 10,000, 20,000, 30,000 sccm
Maximum Inlet Pressure	150 psig
Operational Differential Pressure[3] ≤ 5000 sccm 10,000 to 30,000 sccm	 10 to 40 psid 15 to 40 psid
Pressure Coefficient	0.02% Rdg./psi
Repeatability	±0.2% F.S.
Resolution (measurement)	0.1% F.S.
Temperature Coefficients Zero Span	 < 0.10% F.S./° C (1000 ppm) < 0.08% of Rdg/° C (800 ppm)
Warm-up Time (to within 0.2% of steady-state)	15 minutes
CE Mark Compliance	EMC Directive 89/336/EEC

Environmental Specifications

Storage Humidity Range	0 to 95% relative humidity, non-condensing
Operating Temperature	0° to 50° C (32° to 122° F)
Storage Temperature	-20° to 80° C (-4° to 176° F)

[1]Includes non-linearity, hysteresis, and non-repeatability referenced to 760 mmHg and 0° C.

[2]Controller settling time per SEMI E17-91, specified for flows starting from 0 to 10% (or greater) F.S.

[3]Operational differential pressure is referenced to an MFC outlet pressure at atmosphere.

Electrical Specifications

CE Compliance[4]	EMC Directive 89/336/EEC
Connector Type	15-pin Type "D"
Input Voltage/Current Required Maximum at Start Up (first 5 seconds)[5] Typical at Steady State	 ±15 VDC (±10%) @ 200 mA ±15 VDC (±10%) @ 100 mA
Output Impedance	< 1 ohm
Output Signal/Minimum Load	0 to 5 VDC into > 10K ohm
Set Point Command Signal (controllers only)	0 to 5 VDC from < 20K ohm

Physical Specifications

Body (height x width x length) *without fittings*	< 4.9 in x ≤ 1.5 in x 3 in < 12.4 cm x ≤ 3.8 cm x 7.6 cm
Fitting Choice	Swagelok® 4-VCR® male compatible Swagelok 4-VCO® (male) compatible ¼" Swagelok compatible ⅛" Swagelok compatible
Internal Surface Area (500 sccm unit)	7.7 in^2 (49.7 cm^2)
Internal Volume (500 sccm unit)	0.27 in^3 (4.43 cm^3)
Leak Integrity External (scc/sec He) Through closed valve	 $< 1 \times 10^{-9}$ < 1.0% F.S. @40 psi
Materials Wetted Body and Valve Seat Seals	 316L SST, nickel, Elgelloy Viton®, Buna-N (with Kalrez Sahara 85 plugs), Neoprene (with Kalrez Sahara 85 plugs),
Weight	≤ 1.9 lbs (0.86 kg)

Due to continuing research and development activities, these product specifications are subject to change without notice.

[4]An overall metal braided, shielded cable, properly grounded at both ends, is required during use.

[5]Add 100 mA to start up current if the valve is energized.

Appendix B: Model Code Explanation

Model Code

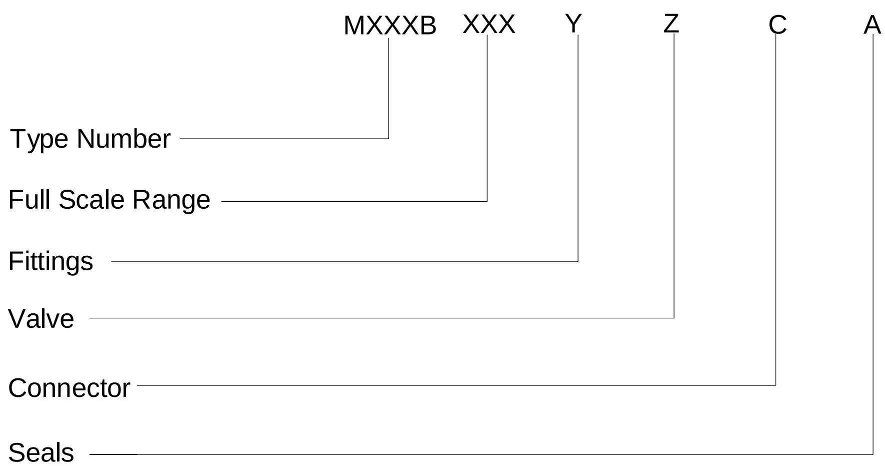
Use the MKS Type M100B Mass-Flo Controller (MFC) when both gas flow control and measurement are required. The instrument is available with the flow control valve in a normally closed configuration. Use the MKS Type M10MB Mass-Flo Meter (MFM) when only gas measurement is required.

The desired instrument and options are identified in the model code when you order the unit. All parts of the product code apply to both the mass flow controller and the mass flow meter.

The model code is identified as follows:

MXXXBXXXYZCA

where:



Type Number (MXXXB)

This designates the model number of the instrument.

The mass flow controller (with the valve) is identified as the Type M100B.

The mass flow meter (no valve) is identified as the Type M10MB.

Full Scale Range - sccm of Nitrogen (XXX)

The full scale range is indicated by a two digit / one letter code.

	Ordering Code
10	11C
20	21C
50	51C
100	12C
200	22C
500	52C
1,000	13C
2,000	23C
5,000	53C
10,000	14C
20,000	24C

Fittings (Y)

The type of fittings used is designated by a single letter code.

	Ordering Code
Swagelok 4-VCR Male (compatible)	R
Swagelok 4-VCO Male (compatible)	G
Swagelok ¼" tube (compatible)	S
Swagelok ⅛" tube (compatible)	P
Length adapter with VCR fittings	L
Length adapter with Swagelok fittings	W

Valve (Z)

Two valve configurations are available, designated by a single number code.

	Ordering Code
Normally Closed (Type M100B MFC *only*)	1
No Valve (Type M10MB MFM *only*)	3

Connector (C)

The connector field designates a 15-pin Type "D" connector, indicated by a single letter code.

	Ordering Code
15-pin Type "D" standard pinout	B

Seals (A)

The seals are indicated by a single letter code.

	Ordering Code
Viton	V
Neoprene (with Kalrez Sahara 85 plugs)	N
Buna-N (with Kalrez Sahara 85 plugs)	B

How To Order a Mass Flow Controller

To order the Type M100B MFC with a 500 sccm full scale range, 4-VCR fittings, a normally closed valve, a standard 15-pin Type "D" connector, and Neoprene sealing materials, the product code is:

M100B 52C R 1 B N

How To Order a Mass Flow Meter

To order the Type M10MB MFM with a 500 sccm full scale range, 4-VCR fittings, standard 15-pin Type "D" connector, no valve, and Viton materials, the product code is:

M10MB 52C R 3 B V

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Appendix C: Gas Correction Factors

Common Gases

GAS	SYMBOL	SPECIFIC HEAT, Cp cal/g^{0}C	DENSITY g/l @ 0^{0}C	CONVERSION FACTOR
Air	- - -	0.240	1.293	1.00
Ammonia	NH_3	0.492	0.760	0.73
Argon	Ar	0.1244	1.782	1.39[1]
Arsine	AsH_3	0.1167	3.478	0.67
Boron Trichloride	BCl_3	0.1279	5.227	0.41
Bromine	Br_2	0.0539	7.130	0.81
Carbon Dioxide	CO_2	0.2016	1.964	0.70[1]
Carbon Monoxide	CO	0.2488	1.250	1.00
Carbon Tetrachloride	CCl_4	0.1655	6.86	0.31
Carbon Tetraflouride (Freon - 14)	CF_4	0.1654	3.926	0.42
Chlorine	Cl_2	0.1144	3.163	0.86
Chlorodifluoromethane (Freon - 22)	$CHClF_2$	0.1544	3.858	0.46
Chloropentafluoroethane (Freon - 115)	C_2ClF_5	0.164	6.892	0.24
Chlorotrifluoromethane (Freon - 13)	$CClF_3$	0.153	4.660	0.38
Cyanogen	C_2N_2	0.2613	2.322	0.61
Deuterium	D_2	1.722	0.1799	1.00
Diborane	B_2H_6	0.508	1.235	0.44
Dibromodifluoromethane	CBr_2F_2	0.15	9.362	0.19
Dichlorodifluoromethane (Freon - 12)	CCl_2F_2	0.1432	5.395	0.35
Dichlorofluoromethane (Freon - 21)	$CHCl_2F$	0.140	4.592	0.42
Dichloromethysilane	$(CH_3)_2SiCl_2$	0.1882	5.758	0.25

(Table continued on next page)

GAS	SYMBOL	SPECIFIC HEAT, Cp cal/g^{o}C	DENSITY g/l @ 0^{o}C	CONVERSION FACTOR
Dichlorosilane	SiH_2Cl_2	0.150	4.506	0.40
1,2-Dichlorotetrafluoroethane (Freon - 114)	$C_2Cl_2F_4$	0.160	7.626	0.22
1,1-Difluoroethylene (Freon - 1132A)	$C_2H_2F_2$	0.224	2.857	0.43
2,2-Dimethylpropane	C_5H_{12}	0.3914	3.219	0.22
Ethane	C_2H_6	0.4097	1.342	0.50
Fluorine	F_2	0.1873	1.695	0.98
Fluoroform (Freon - 23)	CHF_3	0.176	3.127	0.50
Freon - 11	CCl_3F	0.1357	6.129	0.33
Freon - 12	CCl_2F_2	0.1432	5.395	0.35
Freon - 13	$CClF_3$	0.153	4.660	0.38
Freon - 13 B1	$CBrF_3$	0.1113	6.644	0.37
Freon - 14	CF_4	0.1654	3.926	0.42
Freon - 21	$CHCl_2F$	0.140	4.592	0.42
Freon - 22	$CHClF_2$	0.1544	3.858	0.46
Freon - 23	CHF_3	0.176	3.127	0.50
Freon - 113	$C_2Cl_3F_3$	0.161	8.360	0.20
Freon - 114	$C_2Cl_2F_4$	0.160	7.626	0.22
Freon - 115	C_2ClF_5	0.164	6.892	0.24
Freon - 116	C_2F_6	0.1843	6.157	0.24
Freon - C318	C_4F_8	0.1866	8.93	0.164
Freon - 1132A	$C_2H_2F_2$	0.224	2.857	0.43
Helium	He	1.241	0.1786	.- - -2
Hexafluoroethane (Freon - 116)	C_2F_6	0.1843	6.157	0.24
Hydrogen	H_2	3.419	0.0899	.- - -2
Hydrogen Bromide	HBr	0.0861	3.610	1.00

(Table continued on next page)

GAS	SYMBOL	SPECIFIC HEAT, Cp cal/g^{o}C	DENSITY g/l @ 0^{o}C	CONVERSION FACTOR
Hydrogen Chloride	HCl	0.1912	1.627	1.00
Hydrogen Fluoride	HF	0.3479	0.893	1.00
Isobutylene	C_4H_8	0.3701	2.503	0.29
Krypton	Kr	0.0593	3.739	1.543
Methane	CH_4	0.5328	0.715	0.72
Methyl Fluoride	CH_3F	0.3221	1.518	0.56
Molybdenum Hexafluoride	MoF_6	0.1373	9.366	0.21
Neon	Ne	0.246	0.900	1.46
Nitric Oxide	NO	0.2328	1.339	0.99
Nitrogen	N_2	0.2485	1.250	1.00
Nitrogen Dioxide	NO_2	0.1933	2.052	.- - -2
Nitrogen Trifluoride	NF_3	0.1797	3.168	0.48
Nitrous Oxide	N_2O	0.2088	1.964	0.71
Octafluorocyclobutane (Freon - C318)	C_4F_8	0.1866	8.93	0.164
Oxygen	O_2	0.2193	1.427	0.993
Pentane	C_5H_{12}	0.398	3.219	0.21
Perfluoropropane	C_3F_8	0.194	8.388	0.17
Phosgene	$COCl_2$	0.1394	4.418	0.44
Phosphine	PH_3	0.2374	1.517	0.76
Propane	C_3H_8	0.3885	1.967	0.36
Propylene	C_3H_6	0.3541	1.877	0.41
Silane	SiH_4	0.3189	1.433	0.60
Silicon Tetrachloride	$SiCl_4$	0.1270	7.580	0.28
Silicon Tetrafluoride	SiF_4	0.1691	4.643	0.35
Sulfur Dioxide	SO_2	0.1488	2.858	0.69

(Table continued on next page)

GAS	SYMBOL	SPECIFIC HEAT, Cp cal/g^{o}C	DENSITY g/l @ 0^{o}C	CONVERSION FACTOR
Sulfur Hexafluoride	SF_6	0.1592	6.516	0.26
Trichlorofluoromethane (Freon - 11)	CCl_3F	0.1357	6.129	0.33
Trichlorosilane	$SiHCl_3$	0.1380	6.043	0.33
1,1,2-Trichloro - 1,2,2-Trifluoroethane (Freon - 113)	CCl_2FCClF_2 or ($C_2Cl_3F_3$)	0.161	8.360	0.20
Tungsten Hexafluoride	WF_6	0.0810	13.28	0.25
Xenon	Xe	0.0378	5.858	1.32

[1]Empirically defined

[2]Consult MKS Instruments, Inc. for special applications.

NOTE: Standard Pressure is defined as 760 mmHg (14.7 psia). Standard Temperature is defined as 0^{o} C.

Appendix D: MFC Sizing Guidelines

General Information

To select the correct MFC for an application, you must determine the:

- flow controller range
- appropriate valve configuration

The flow controller range depends on the desired flow rate and the gas correction factor for the gas to be used. MKS states the flow controller ranges based on flow rate of nitrogen; the flow rate for other gases may vary.

The proper valve configuration depends upon the flow range, inlet pressure, differential pressure across the unit, and density of the gas. Proper valve configurations have been established for all standard flow ranges flowing nitrogen under standard operating pressures. These configurations are suitable for virtually all gases and pressure conditions.

How To Determine the Flow Controller Range

The Type M100B controller is available in ranges of 5, 10, 20, 50, 100, 200, 500, 1000, 2000, 5000, 10,000, 20,000, and 30,000 sccm (N_2 equivalent). To select the appropriate range, you must determine the flow rate of nitrogen that is equivalent to the flow rate of the desired gas. Calculate the ratio of the GCF of nitrogen (1.00) to the GCF of the desired gas (refer to *Appendix C: Gas Correction Factors*, page 55) as shown in the following example.

Example:

You need a flow rate of 250 sccm of argon (Ar). What range flow controller should you use?

1. Find the Gas Correction Factor of Ar (refer to *Appendix C: Gas Correction Factors*, page 55).

   The GCF for Ar is 1.41.

2. Insert the GCF of Ar in the following formula:

$$\frac{(\text{GCF of } N_2)}{(\text{GCF of Ar})} = \frac{(x)}{(\text{Desired flow rate of Ar})}$$

where x is the equivalent flow rate of nitrogen (sccm).

$$\frac{(1.00)}{(1.41)} = \frac{(x)}{(250 \text{ sccm Ar})}$$

$$x = 177 \text{ sccm } N_2$$

A flow rate of 250 sccm of Ar will produce a flow rate equivalent to 177 sccm of N_2. This falls within the range of a 200 sccm flow controller.

When calculating equivalent N_2 flows using gas correction factors, be sure to use a flow controller with a sufficient flow rate range. For example, if the calculated equivalent N_2 flow in the example shown above is 205 sccm, use a 500 sccm flow controller. The 500 sccm instrument can then be calibrated such that 205 sccm N_2 = full scale.

Note When using a gas with a density *higher* than nitrogen, be sure that the control valve full scale range can accommodate the desired flow rate. Please call the MKS Applications group if you have any questions.

How To Determine the Valve Configuration

1. Determine the maximum flow coefficient (C_V), for the gas of interest, using the equation:

$$C_V\ (\max) = \left(\text{Max. Flow Rate, sccm}\right)\left(\sqrt{\frac{\text{Gas Density}}{1.293}}\right)\left(C_V\ \text{Pressure Factor}\right)$$

where:

Gas Density is listed in *Appendix C: Gas Correction Factors*, page 55.

C_V Pressure Factor is listed in Table 11, page 61.

C_V Pressure Factors (multiplied by 100,000)										
P1 (psia)	**Differential Pressure (psid)**									
	50	**40**	**30**	**20**	**15**	**10**	**5**	**2**	**1**	**0.5**
165	0.042	0.046	0.052	0.063	0.072	0.087	0.122	0.192	0.272	0.384
150	0.044	0.048	0.055	0.066	0.075	0.092	0.128	0.202	0.285	0.403
125	0.049	0.054	0.061	0.073	0.083	0.101	0.141	0.221	0.312	0.441
100	0.058	0.062	0.069	0.082	0.094	0.113	0.158	0.248	0.349	0.493
75	0.077	0.077	0.082	0.097	0.110	0.132	0.183	0.286	0.404	0.570
50	0.116	0.116	0.116	0.123	0.138	0.164	0.226	0.352	0.495	0.699
30	—	—	0.194	0.194	0.194	0.220	0.297	0.458	0.642	0.904
25	—	—	—	0.232	0.232	0.246	0.329	0.503	0.704	0.991
20	—	—	—	0.291	0.291	0.291	0.373	0.565	0.789	1.109
15	—	—	—	—	0.387	0.387	0.441	0.659	0.915	1.283
10	—	—	—	—	—	0.578	0.581	0.821	1.131	1.578
5	—	—	—	—	—	—	1.156	1.232	1.643	2.261
2	—	—	—	—	—	—	—	2.890	2.905	3.725
1	—	—	—	—	—	—	—	—	5.779	5.811

Table 11: C_V Pressure Factors

2. Select the valve configuration with the C_V value that is closest to, though larger than, the C_V value calculated in step 1.

   The C_V value represents the *maximum* flow rate for the unit. Choose the valve configuration *above* your calculated C_V value to ensure that the unit can deliver the required flow.

Valve Configuration Selection Guide		
Valve Configuration	**Nominal Range (N_2) sccm**	**Cv x 10^5**
1	10	2.44
2	20	4.88
3	50	12.21
4	100	24.42
5	200	48.84
6	500	122.11
7	1000	244.22
8	2000	488.44
9	5000	1221.11
10	10000	1924.47
11	20000	3848.94
12	30000	5773.41

Table 12: Valve Configuration Selection Guide

Example

Suppose you need to flow boron trichloride at a rate of 250 sccm and the inlet pressure is 20 psia. Your process runs at atmospheric pressure, so the differential pressure is 5 psid.

1. Determine the maximum flow factor (C_V) for the gas of interest, using the equation listed in step 1, on page 61.

   The *Gas Density* for boron trichloride, listed in *Appendix C: Gas Correction Factors*, page 55, is 5.227. The *C_V Pressure Factor*, read from Table 11, page 61, for a 20 psia inlet and 5 psid differential pressure, is 0.373. Therefore, our equation becomes:

$$C_V\,(\text{max}) = \left(250\ \text{sccm}\right)\left(\sqrt{\frac{5.227}{1.293}}\right)\left(0.373\right)$$

$$C_V = 187.5$$

2. Select the valve configuration with a C_V value that is closest to, though larger than, the C_V value calculated in step 1.

   A C_V value of 187.5 falls between 122.11 (configuration 6) and 244.22 (configuration 7). To ensure that the unit can deliver the 250 sccm flow, choose configuration 7.

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