120598-P1
Rev B, 3/99
Instruction Manual

MKS Type 146C Cluster Gauge Vacuum Gauge Measurement and Control System

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WARRANTY

Type 146C Equipment

MKS Instruments, Inc. (**MKS**) warrants that the equipment described above (the "equipment") manufactured by **MKS** shall be free from defects in materials and workmanship for a period of one year from date of shipment and will for a period of two years from the date of shipment, 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 one year later in the case of defects in materials and workmanship, but two years later in the case of failure to comply with the date-related operations warranty, **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.

The purchaser, before returning any equipment covered by this warranty, which is asserted to be defective by the purchaser, shall make specific written arrangements with respect to the responsibility for shipping the equipment and handling any other incidental charges with the **MKS** sales representative or distributor from which the equipment was purchased or, in the case of a direct purchase from **MKS**, with the **MKS** home office in Andover, Massachusetts, USA.

This warranty does not apply to any equipment which has not been installed and used in accordance with the specifications recommended by **MKS** for the proper and normal use of the equipment. **MKS** shall not be liable under any circumstances for indirect, special, consequential, or incidental damages in connection with, or arising out of, the sale, performance, or use of the equipment covered by this warranty.

MKS recommends that all **MKS** pressure and flow products be calibrated periodically (typically every 6 to 12 months) to ensure accurate readings. When a product is returned to **MKS** for this periodic re-calibration it is considered normal preventative maintenance not covered by any warranty.

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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MKS Type 146C Cluster Gauge™ Vacuum Gauge Measurement and Control System

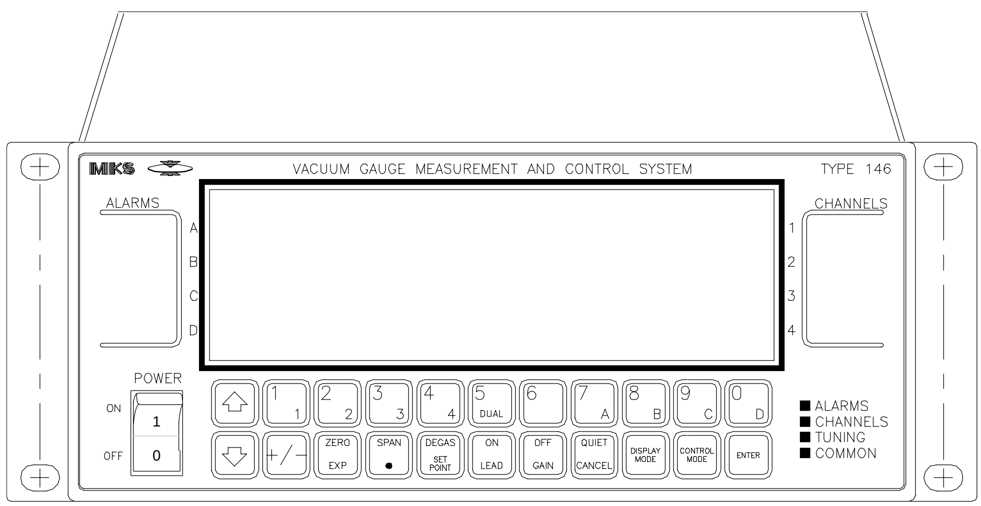

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Table of Contents

List of Figures

List of Tables

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. 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. 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.

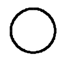
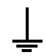
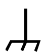
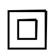
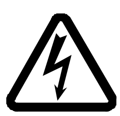
Definition of Symbols Found on the Unit			
 On (Supply) IEC 417, No.5007	 Off (Supply) IEC 417, No.5008	 Earth (ground) IEC 417, No.5017	 Protective earth (ground) IEC 417, No.5019
 Frame or chassis IEC 417, No.5020	 Equipotentiality IEC 417, No.5021	 Direct current IEC 417, No.5031	 Alternating current 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 remove instrument covers. Component replacement and internal adjustments must be made by qualified service personnel only.

GROUNDING THE PRODUCT

This product is grounded through the grounding conductor of the power cord. To avoid electrical shock, plug the power cord into a properly wired receptacle before connecting it to the product input or output terminals. A protective ground connection by way of the grounding conductor in the power cord is essential for safe operation.

DANGER ARISING FROM LOSS OF GROUND

Upon loss of the protective-ground connection, all accessible conductive parts (including knobs and controls that may appear to be insulating) can render an electrical shock.

GROUND AND USE PROPER ELECTRICAL FITTINGS

Dangerous voltages are contained within this instrument. All electrical fittings and cables must be of the type specified, and in good condition. All electrical fittings must be properly connected and grounded.

USE THE PROPER POWER CORD

Use only a power cord that is in good condition and which meets the input power requirements specified in the manual.

Use only a detachable cord set with conductors that have a cross-sectional area equal to or greater than 0.75 mm^2. The power cable should be approved by a qualified agency such as VDE, Semko, or SEV.

USE THE PROPER POWER SOURCE

This product is intended to operate from a power source that does not apply more voltage between the supply conductors, or between either of the supply conductors and ground, than that specified in the manual.

USE THE PROPER FUSE

Use only a fuse of the correct type, voltage rating, and current rating, as specified for your product.

DO NOT OPERATE IN EXPLOSIVE ATMOSPHERES

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

HIGH VOLTAGE DANGER

High voltage is present in the cable, and in the sensor when the controller is turned on.

Sicherheitshinweise

In dieser Betriebsanleitung vorkommende Symbole

Definition der mit WARNUNG!, VORSICHT! und HINWEIS überschriebenen Abschnitte in dieser Betriebsanleitung.

Warnung!

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

Vorsicht!

Das Symbol VORSICHT! weist auf eine Gefahrenquelle 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 Produkts oder von Teilen des Produkts führen kann.

Hinweis

Das Symbol HINWEIS weist auf eine wichtige Mitteilung hin, die auf einen Arbeitsablauf, eine Arbeitsweise, einen Zustand oder eine sonstige Gegebenheit von besonderer Wichtigkeit aufmerksam macht.

Am Gerät angebrachte Symbole

Der untenstehenden Tabelle sind die Bedeutungen der Symbole zu entnehmen, die an dem Gerät angebracht sind.

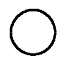
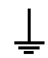
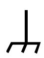
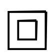
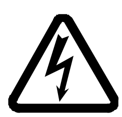
Definitionen der am Gerät angebrachten Symbole			
 Ein (Netz) IEC 417, Nr. 5007	 Aus (Netz) IEC 417, Nr. 5008	 Erde IEC 417, Nr. 5017	 Schutzleiter IEC 417, Nr. 5019
 Rahmen oder Chassis IEC 417, Nr. 5020	 Äquipotentialanschluß IEC 417, Nr. 5021	 Gleichstrom IEC 417, Nr. 5031	 Wechselstrom IEC 417, Nr. 5032
 Wechselstrom und Gleichstrom IEC 417, Nr. 5033-a	 Geräteklasse II IEC 417, Nr. 5172-a	 Drehstrom IEC 617-2 Nr. 020206	
 Vorsicht! Bitte Begleitdokumente lesen! ISO 3864, Nr. B.3.1	 Vorsicht! Stromschlaggefahr! ISO 3864, Nr. B.3.6	 Vorsicht! Heiße Fläche! IEC 417, Nr. 5041	

Tabelle 2: Definitionen der am Gerät angebrachten Symbole

Sicherheitsvorschriften und Vorsichtsmaßnahmen

Die untenstehenden allgemeinen Sicherheitsvorschriften sind bei allen Betriebs-phasen dieses Instruments zu befolgen. Jede Mißachtung dieser Sicherheits-vorschriften oder sonstiger spezifischer Warnhinweise in dieser Betriebsanleitung stellt eine Zuwiderhandlung der für dieses Instrument geltenden Sicherheits-standards dar und kann die an diesem Instrument vorgesehenen Schutzvor-richtungen unwirksam machen. MKS Instruments, Inc. haftet nicht für eine Mißachtung dieser Sicherheitsvorschriften seitens des Kunden.

Keine Teile austauschen und keine Veränderungen vornehmen!

Bauen Sie in das Instrument keine Ersatzteile ein, und nehmen Sie keine eigenmächtigen Änderungen am Gerät vor! Schicken Sie das Instrument zu Wartungs- und Reparatur-zwecken an einen MKS-Kalibrierungs- und -Kundendienst ein! Dadurch wird sicher-gestellt, daß alle Sicherheitseinrichtungen voll funktionsfähig bleiben.

Wartung nur durch qualifizierte Fachleute!

Das Gehäuse des Instruments darf vom Bedienpersonal nicht geöffnet werden. Das Auswechseln von Bauteilen und das Vornehmen von internen Einstellungen ist nur von qualifizierten Fachleuten durchzuführen.

Produkt erden!

Dieses Produkt ist mit einer Erdleitung und einem Schutzkontakt am Netzstecker versehen. Um der Gefahr eines elektrischen Schlages vorzubeugen, ist das Netzkabel an einer vorschriftsmäßig geerdeten Schutzkontaktsteckdose anzuschließen, bevor es an den Eingangs- bzw. Ausgangsklemmen des Produkts angeschlossen wird. Das Instrument kann nur sicher betrieben werden, wenn es über den Erdleiter des Netzkabels und einen Schutzkontakt geerdet wird.

Gefährdung durch Verlust der Schutzerdung!

Geht die Verbindung zum Schutzleiter verloren, besteht an sämtlichen zugänglichen Teilen aus stromleitendem Material die Gefahr eines elektrischen Schlages. Dies gilt auch für Knöpfe und andere Bedienelemente, die dem Anschein nach isoliert sind.

Erdung und Verwendung geeigneter elektrischer Armaturen!

In diesem Instrument liegen gefährliche Spannungen an. Alle verwendeten elektrischen Armaturen und Kabel müssen dem angegebenen Typ entsprechen und sich in einwand-freiem Zustand befinden. Alle elektrischen Armaturen sind vorschriftsmäßig anzubringen und zu erden.

Richtiges Netzkabel verwenden!

Das verwendete Netzkabel muß sich in einwandfreiem Zustand befinden und den in der Betriebsanleitung enthaltenen Anschlußwerten entsprechen.

Das Netzkabel muß abnehmbar sein. Der Querschnitt der einzelnen Leiter darf nicht weniger als 0,75 mm^2 betragen. Das Netzkabel sollte einen Prüfvermerk einer zuständigen Prüfstelle tragen, z.B. VDE, Semko oder SEV.

Richtige Stromquelle verwenden!

Dieses Produkt ist für eine Stromquelle vorgesehen, bei der die zwischen den Leitern bzw. zwischen jedem der Leiter und dem Masseleiter anliegende Spannung den in dieser Betriebsanleitung angegebenen Wert nicht überschreitet.

Richtige Sicherung benutzen!

Es ist eine Sicherung zu verwenden, deren Typ, Nennspannung und Nennstromstärke den Angaben für dieses Produkt entsprechen.

Gerät nicht in explosiver Atmosphäre benutzen!

Um der Gefahr einer Explosion vorzubeugen, darf dieses Gerät nicht in der Nähe explosiver Stoffe eingesetzt werden, sofern es nicht ausdrücklich für diesen Zweck zertifiziert worden ist.

Hochspannungsgefahr!

Bei eingeschaltetem Steuerteil liegt im Kabel und im Sensor Hochspannung an.

Informations relatives à la sécurité

Symboles utilisés dans ce manuel d'utilisation

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

Avertissement

L'indication AVERTISSEMENT signale un danger potentiel. Elle est destinée à attirer l'attention sur une procédure, une utilisation, une situation ou toute autre chose présentant un risque de blessure en cas d'exécution incorrecte ou de non-respect des consignes.

Attention

L'indication ATTENTION signale un danger potentiel. Elle est destinée à attirer l'attention sur une procédure, une utilisation, une situation ou toute autre chose présentant un risque d'endommagement ou de dégât 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 des informations importantes. Elle est destinée à attirer l'attention sur une procédure, une utilisation, une situation ou toute autre chose présentant un intérêt particulier.

Symboles apparaissant sur l'appareil

Le tableau suivant décrit les symboles apparaissant sur l'appareil.

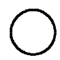
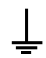
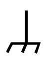
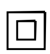
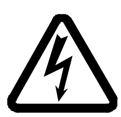
Définition des symboles apparaissant sur l'appareil			
 Marche (sous tension) IEC 417, No. 5007	 Arrêt (hors tension) IEC 417, No. 5008	 Terre (masse) IEC 417, No. 5017	 Terre de protection (masse) IEC 417, No. 5019
 Masse IEC 417, No. 5020	 Equipotentialité IEC 417, No. 5021	 Courant continu IEC 417, 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 secousse électrique ISO 3864, No. B.3.6	 Attention : surface brûlante IEC 417, No. 5041	

Tableau 3: Définition des symboles apparaissant sur l'appareil

Mesures de sécurité et mises en garde

Prendre toutes les précautions générales suivantes pendant toutes les phases d'utilisation de cet appareil. Le non-respect de ces précautions ou des avertissements contenus dans ce manuel entraîne une violation des normes de sécurité relatives à l'utilisation de l'appareil et le risque de réduire le niveau de protection fourni par l'appareil. MKS Instruments, Inc. ne prend aucune responsabilité pour les conséquences de tout non-respect des consignes de la part de ses clients.

NE PAS SUBSTITUER DES PIÈCES OU MODIFIER L'APPAREIL

Ne pas utiliser de pièces détachées autres que celles vendues par MKS Instruments, Inc. ou modifier l'appareil sans l'autorisation préalable de MKS Instruments, Inc. Renvoyer l'appareil à un centre d'étalonnage et de dépannage MKS pour tout dépannage ou réparation afin de s'assurer que tous les dispositifs de sécurité sont maintenus.

DÉPANNAGE EFFECTUÉ UNIQUEMENT PAR UN PERSONNEL QUALIFIÉ

L'opérateur de l'appareil ne doit pas enlever le capot de l'appareil. Le remplacement des composants et les réglages internes doivent être effectués uniquement par un personnel d'entretien qualifié.

MISE À LA TERRE DE L'APPAREIL

Cet appareil est mis à la terre à l'aide du fil de terre du cordon d'alimentation. Pour éviter tout risque de secousse électrique, brancher le cordon d'alimentation sur une prise de courant correctement câblée avant de le brancher sur les bornes d'entrée ou de sortie de l'appareil. Une mise à la terre de protection à l'aide du fil de terre du cordon d'alimentation est indispensable pour une utilisation sans danger de l'appareil.

DANGER LIÉ À UN DÉFAUT DE TERRE

En cas de défaut de terre, toutes les pièces conductrices accessibles (y compris les boutons de commande ou de réglage qui semblent être isolés) peuvent être source d'une secousse électrique.

MISE À LA TERRE ET UTILISATION CORRECTE D'ACCESSOIRES ÉLECTRIQUES

Des tensions dangereuses existent à l'intérieur de l'appareil. Tous les accessoires et les câbles électriques doivent être conformes au type spécifié et être en bon état. Tous les accessoires électriques doivent être correctement connectés et mis à la terre.

UTILISATION D'UN CORDON D'ALIMENTATION APPROPRIÉ

Utiliser uniquement un cordon d'alimentation en bon état et conforme aux exigences de puissance d'entrée spécifiées dans le manuel.

Utiliser uniquement un cordon d'alimentation amovible avec des conducteurs dont la section est égale ou supérieure à 0,75 mm^2. Le cordon d'alimentation doit être approuvé par un organisme compétent tel que VDE, Semko ou SEV.

UTILISATION D'UNE ALIMENTATION APPROPRIÉE

Cet appareil est conçu pour fonctionner en s'alimentant sur une source de courant électrique n'appliquant pas une tension entre les conducteurs d'alimentation, ou entre les conducteurs d'alimentation et le conducteur de terre, supérieure à celle spécifiée dans le manuel.

UTILISATION D'UN FUSIBLE APPROPRIÉ

Utiliser uniquement un fusible conforme au type, à la tension nominale et au courant nominal spécifiés pour l'appareil.

NE PAS UTILISER DANS UNE ATMOSPHÈRE EXPLOSIVE

Pour éviter tout risque d'explosion, ne pas utiliser l'appareil dans une atmosphère explosive à moins qu'il n'ait été approuvé pour une telle utilisation.

DANGER DE HAUTE TENSION

Une haute tension est présente dans le câble et dans le capteur lorsque le contrôleur est sous tension.

Información sobre seguridad

Símbolos usados en el manual de instrucciones

Definiciones de los mensajes de ADVERTENCIA, PRECAUCIÓN Y OBSERVACIÓN usados en el manual.

Advertencia

El símbolo de ADVERTENCIA indica un riesgo. Pone de relieve un procedimiento, práctica, condición, etc., que, de no realizarse u observarse correctamente, podría causar lesiones a los empleados.

Precaución

El símbolo de PRECAUCIÓN indica un riesgo. Pone de relieve un procedimiento, práctica, etc., de tipo operativo que, de no realizarse u observarse correctamente, podría causar desperfectos al instrumento, o llegar incluso a causar su destrucción total o parcial.

Observación

El símbolo de OBSERVACIÓN indica información de importancia. Pone de relieve un procedimiento, práctica, condición, etc., cuyo conocimiento resulta esencial.

Símbolos que aparecen en la unidad

En la tabla que figura a continuación se indican los símbolos que aparecen en la unidad.

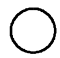
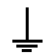
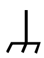
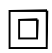
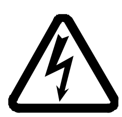
Definición de los símbolos que aparecen en la unidad			
Encendido (alimentación eléctrica) IEC 417, N.° 5007	 Apagado (alimentación eléctrica) IEC 417, N.° 5008	 Puesta a tierra IEC 417, N.° 5017	 Protección a tierra IEC 417, N.° 5019
 Caja o chasis IEC 417, N.° 5020	 Equipotencialidad IEC 417, N.° 5021	 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. Consultar 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 que aparecen en la unidad

Procedimientos y precauciones de seguridad

Las precauciones generales de seguridad que figuran a continuación deben observarse durante todas las fases de funcionamiento del presente instrumento. La no observancia de dichas precauciones, o de las advertencias específicas a las que se hace referencia en el manual, contraviene las normas de seguridad referentes al uso previsto del instrumento y podría impedir la protección que proporciona el instrumento. MKS Instruments, Inc., no asume responsabilidad alguna en caso de que el cliente haga caso omiso de estos requerimientos.

NO UTILIZAR PIEZAS NO ORIGINALES NI MODIFICAR EL INSTRUMENTO

No se debe instalar piezas que no sean originales ni modificar el instrumento sin autorización. Para garantizar que las prestaciones de seguridad se observen en todo momento, enviar el instrumento al Centro de servicio y calibración de MKS cuando sea necesaria su reparación y servicio de mantenimiento.

REPARACIONES EFECTUADAS ÚNICAMENTE POR TÉCNICOS ESPECIALIZADOS

Los operarios no deben retirar las cubiertas del instrumento. El cambio de piezas y los reajustes internos deben efectuarlos únicamente técnicos especializados.

PUESTA A TIERRA DEL INSTRUMENTO

Este instrumento está puesto a tierra por medio del conductor de tierra del cable eléctrico. Para evitar descargas eléctricas, enchufar el cable eléctrico en una toma debidamente instalada, antes de conectarlo a las terminales de entrada o salida del instrumento. Para garantizar el uso sin riesgos del instrumento resulta esencial que se encuentre puesto a tierra por medio del conductor de tierra del cable eléctrico.

PELIGRO POR PÉRDIDA DE LA PUESTA A TIERRA

Si se pierde la conexión protectora de puesta a tierra, todas las piezas conductoras a las que se tiene acceso (incluidos los botones y mandos que pudieran parecer estar aislados) podrían producir descargar eléctricas.

PUESTA A TIERRA Y USO DE ACCESORIOS ELÉCTRICOS ADECUADOS

Este instrumento funciona con voltajes peligrosos. Todos los accesorios y cables eléctricos deben ser del tipo especificado y mantenerse en buenas condiciones. Todos los accesorios eléctricos deben estar conectados y puestos a tierra del modo adecuado.

USAR EL CABLE ELÉCTRICO ADECUADO

Usar únicamente un cable eléctrico que se encuentre en buenas condiciones y que cumpla los requisitos de alimentación de entrada indicados en el manual.

Usar únicamente un cable desmontable instalado con conductores que tengan un área de sección transversal equivalente o superior a 0,75mm². El cable eléctrico debe estar aprobado por una entidad autorizada como, por ejemplo, VDE, Semko o SEV.

USAR LA FUENTE DE ALIMENTACIÓN ELÉCTRICA ADECUADA

Este instrumento debe funcionar a partir de una fuente de alimentación eléctrica que no aplique más voltaje entre los conductores de suministro, o entre uno de los conductores de suministro y la puesta a tierra, que el que se especifica en el manual.

USAR EL FUSIBLE ADECUADO

Usar únicamente un fusible del tipo, clase de voltaje y de corriente adecuados, según lo que se especifica para el instrumento.

EVITAR SU USO EN ENTORNOS EXPLOSIVOS

Para evitar el riesgo de explosión, no usar este instrumento o en un entorno explosivo, a no ser que haya sido certificado para tal uso.

PELIGRO POR ALTO VOLTAJE

Cuando el controlador está encendido, se registra alto voltaje en el cable y en el sensor.

Chapter One: General Information

Introduction

The Type 146C Cluster Gauge™ Vacuum Gauge Measurement and Control System is a versatile, ½ rack instrument which can power and provide concurrent readouts for up to four different vacuum gauges, or a combination of gauges and flow controllers. The instrument can support capacitance manometers (4, 5, or 6 decade), Pirani, and ion gauges. A Dual Channel feature automatically switches from one gauge to another, thus providing the potential for a continuous pressure reading display from 10^{-10} to 10^{3} Torr. The channel in the main display can automatically switch from a rough vacuum gauge to a high vacuum gauge during pumpdown or backfill. The 146 unit can accept a user-defined set point to operate a flow controller. If more than one flow controller is used, a *Totaling* feature allows one controller to control the total flow of all the controllers combined. With the optional Control board installed, the 146 unit can govern an upstream solenoid valve, a downstream throttle valve, or one or more ratio controllers in a closed-loop pressure control system.

The 146 unit arrives from the factory with four default recipes, each with an individual set point, phase lead, and gain setting. The recipes can easily be customized to meet the needs of different applications. By using the keyboard on the front panel, operators can: set alarm relay parameters, display pressure or leakage readings, choose display units (Torr, Pascal, mbar), and configure communication data. Control parameters such as base, lead, gain, integral, softstart, and start can also be adjusted through the front panel. Gauges can be zeroed and spanned individually, or cross-calibrated for span. There is an automatic ion gauge powerdown at high pressures, and a sensor powerdown for cryo-pump regeneration. The non-volatile memory stores all parameter entry values as well as sensor data such as capacitance manometer zero correction, and HPS Pirani spans. Diagnostic tests are included for basic troubleshooting.

The 146 instrument has a front panel window with a 4½ digit main display, and three 2½ digit displays. The LCD window is backlit with an electro-luminescent lamp, and has an automatic one-hour timeout. Although the LCD is readable without backlighting, any keystroke re-illuminates the backlight in addition to performing its usual function. All commands can be activated through the front panel, or the unit can be controlled via an interface with a computer through an RS-232 serial communication link. A front panel lockout feature disables command control through the front panel (except for the [QUIET/CANCEL] key). The 146 unit front panel lockout commands are entered through the available digital control lines or RS-232 messages.

Another option is the displayless unit. Here, 146 units have their normal front panel replaced with a panel that has only a power switch, LED, and 25-pin Type “D” connector. One or more of these displayless units can be placed in remote locations and controlled through a portable front panel which has the normal display, or through RS-232 communications. The panel can be connected to each remote unit in turn with a ribbon cable. In summary, the 146 instrument is designed to allow operators the ability to calibrate gauges; control and fine tune their pressure system, and still provide flexibility for system upgrades.

How this Manual is Organized

This manual is designed to provide detailed, step by step instructions for all the functions the Type 146 unit can perform. It also supplies overview and background information to help you acquire a general understanding of the 146 instrument, and how to use it. A color-coded operational diagram offers a pictorial representation of the modes, functions, and appropriate keys that are used to operate the 146 unit. The operational diagram and quick reference guides (on yellow paper) may be all you need to operate the 146 unit once you have familiarized yourself with its functions.

Before installing the Type 146 unit in your system and/or operating it, carefully read and familiarize yourself with all precautionary notes in *Safety Procedures and Precautions* 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 in Normal Mode,* describes how to use the instrument and explains all the functions and features.

Chapter Five, *Operation in Leakage Mode,* describes the use of the leakage mode.

Chapter Six, *Operation in Tuning Mode,* explains when to use the tuning mode.

Chapter Seven, *Operation in Setup Mode,* defines the use of the setup mode.

Chapter Eight, *Operation in Control Mode,* explains how to configure a Control board to control your process.

Chapter Nine, *RS-232 Communications,* describes how to communicate with the 146 unit through RS-232 communications.

Chapter Ten, *Maintenance,* lists maintenance tips for your 146 unit.

Chapter Eleven, *Troubleshooting,* describes the diagnostic commands supported by the front panel.

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

Appendix B, *Parts List/Accessories,* lists all the accessories supported by the 146 unit.

Appendix C, *RS-232 Error Codes*, explains RS-232 error messages.

Appendix D, *Front Panel Error/StatusMessages,* explains the front panel messages.

Appendix E, *Instrument Default Values,* lists the default value for all operating parameters.

Appendix F, *Underrange and Overrange Values,* lists the out-of-range pressures for different gauges.

Appendix G, *Board Specific Commands,* lists the commands that apply to each board type.

Format of Instructions

Each set of directions contained in this manual includes all the steps necessary to perform a particular task. Even though some steps are identical for several operations, they are repeated in each set of instructions. This means you do not have to read preceding chapters, but may go directly to a description of a function, and you will be provided with all the steps necessary to perform that task.

Although detailed instructions are provided, it is very useful to read the overview sections at the beginning of the manual. A better understanding of the 146 unit will make operation of it more intuitive. The displayless option is discussed in a separate section at the end of *Chapter Three: Overview*.

This manual follows the functional design of the 146 instrument. That is, after the introductory and overview sections, each of the five modes in which the 146 unit can operate, is discussed in a separate chapter.

Conventions Used in this Manual

Keys: All the keys mentioned in this manual are displayed on the front panel of the 146 unit. In this manual, the keys are referred to by the names (functions) printed on them. The key names (functions) are written with the key name inside straight brackets. For example, [ENTER].

Most keys on the keyboard have more than one function printed on them. In this manual, both functions are shown, separated by a slash, even though only one of the functions may be applicable to a set of instructions. For example, [ON/LEAD] is a key with two functions printed on it.

When two keys must be pressed simultaneously, this is shown by presenting the keys side by side. The instructions explicitly describe what you are to do. For example, to indicate that the up and down arrow keys must be pressed simultaneously, the keys are presented as shown:

[△] and [▽]

and the instructions might read ...

Press the Up and Down arrow keys simultaneously.

If there is a shortcut key, or shortcut key sequence, the instructions are written to use the shortcut sequence. Instructions are written with the fewest steps possible.

Legends: Legends or any messages displayed on the front panel window, are written with three blank spaces before and after the legend/message, and written in capital letters. For example, the legend *No Sensor* is written as NO SENSOR .

Italics: *Italics* are used to stress a word or concept. For example, instructions may read:

Do *not* discard any packing material, until the 146 unit has been inspected.

Modes: Modes are always written in proper format (the first letter is capitalized). For example, the three standard modes available with the 146 unit are Normal Mode, Leakage Mode, and Setup Mode.

Boards: The names for the boards are always written in proper format (the first letter is capitalized). For example, the two optional modes for the 146 unit are available only if the optional Control board is installed.

Terminology Used in this Manual

The definitions supplied below are not standardized definitions, but are definitions specific to the 146 unit and this manual.

Front Panel The front panel of the 146 unit is shown in Figure 1, page 21. It includes the front panel window, the alarm and channel label areas, the keypad, and the power switch.

Front Panel Window The front panel window is also referred to as simply the window, or the LCD screen. All pressure readings, legends, system messages, alarm and channel information, and user-defined parameters, are displayed in the window.

Window Displays Within the front panel window are four areas where pressure readings and parameter fields are displayed. The locations of the four areas remain fixed in the window, although the information displayed in them changes. The four displays are referred to as the left, center, right, and main displays.

The left display is located in the upper left area of the front panel window.

The center display is located in the upper middle area of the front panel window.

The right display is located in the upper right area of the front panel window.

The main display is the largest display, and is located in the bottom center area of the front panel window. The pressure readings for channels 1, 2, and 3, are shown in the left, center, and right displays respectively. Any channel can be selected for display in the main display area. The default is for the channel 1 pressure reading to appear in the main display. The exception to this is when all four channels are used, whereupon the pressure reading for channel 4 appears in the main display. Channel 4 can only be monitored in the main display.

Alarm Label Area The alarm label area is an etched rectangle on the left side of the front panel. Use this area to affix custom labels referring to alarms A through D.

Channel Label Area The channel label area is an etched rectangle on the right side of the front panel. Use this area to affix custom labels referring to channels 1 through 4.

Mode The 146 instrument is designed to operate in five different modes. The associated parameters and functions of each mode are viewed in the front panel window, and operable through the front panel keypad (and the RS-232 serial port). The three standard modes of the Type 146 instrument are Normal Mode (the default mode), Leakage Mode, and Setup Mode. Two other modes, Tuning Mode and Control Mode are available when the optional Control board is installed in the 146 unit.

Function A function is a task the 146 unit can perform. For example, spanning a sensor with a reference is a task the 146 unit can perform. Other tasks include switching channels in the main display, and adjusting set point values. Each function is given a separate *How To...* section within this manual. Refer to the Table of Contents for a complete list of all functions the 146 unit can perform.

Parameter A parameter is a value or option you add or alter when you give a command or execute a function. The result is that the command or function accomplishes its task in the way that you want. If you do not enter a parameter, the 146 unit operates according to default values. For example, the default baud rate for RS-232 communications is 9600. Unless you enter a different baud rate, this is the value the 146 instrument uses.

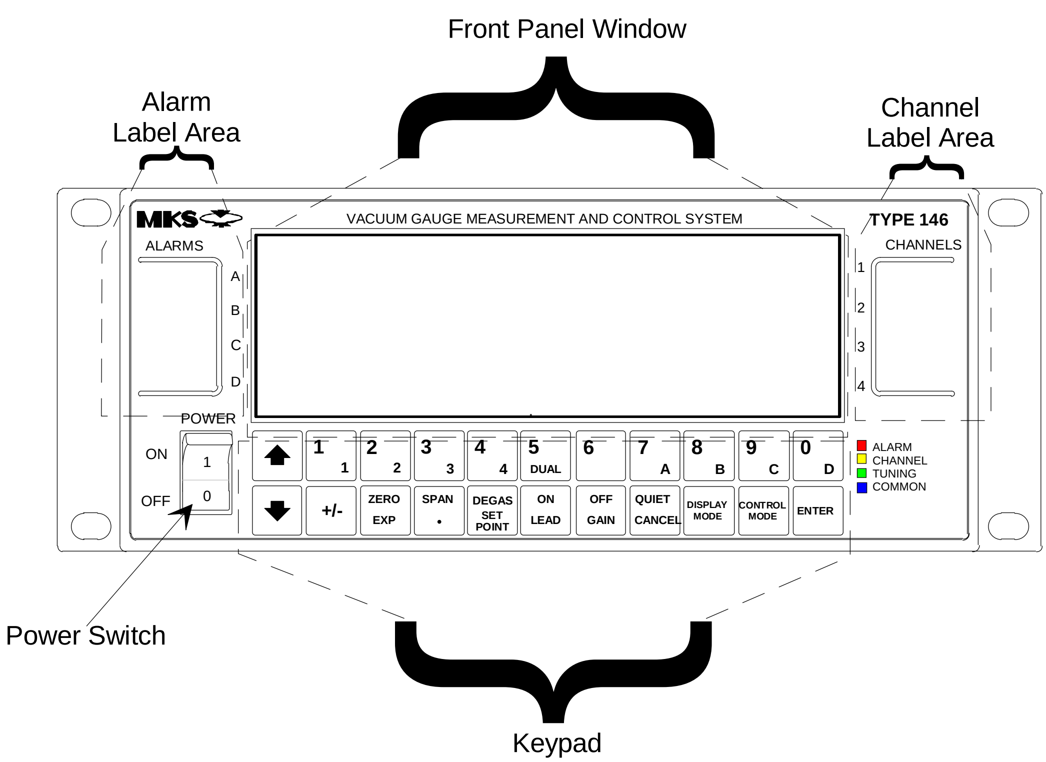


Figure 1: The Front Panel of the 146 Instrument

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 146 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 146 Instrument

MKS has carefully packed the 146 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.

Caution **Only qualified individuals should perform the installation and any user adjustments. They must comply with all the necessary ESD and handling precautions while installing and adjusting the instrument. Proper handling is essential when working with all highly sensitive precision electronic instruments.**

Unpacking Checklist

Standard Equipment

- The 146 Vacuum Gauge Measurement and Control System
- Power cord *(If you choose to supply your own power cord you must ensure that it complies with the applicable national regulatory requirements, such as UL or CSA.)*
- A set of self-adhesive labels for Alarm and Channel identification on the front panel of the 146 unit
- Instruction Manual (this manual)

Optional Equipment

- Electrical Connector Accessories Kit, 146C-K1, (includes mating connectors for all the connectors and two screwlock assemblies for each connector cover supplied)
- Rack Mounting Kit
- Interface Cables

Boards

All or some of the following boards may have been ordered with your basic 146 unit. Examine the rear panel of the 146 unit to make sure your unit conforms to your order code. Refer to Figure 4, page 27, to see how to identify these boards by their connectors on the rear panel. Also, refer to the explanation of an order form code in Figure 5, page 28. The boards should be placed within the 146 unit in the same order as they are listed on your order form.

Also on the order form configuration sheet, are specific configuration instructions. For example, the unit can be set up for a single channel Pirani board (the default is a dual channel board), or for a low power HPS hot cathode (the default is for a high power gauge).

Labels are placed at each occupied board slot on the rear panel of the 146 unit. The labels identify the channel number(s) and type of board installed in the slot.

- Capacitance Manometer Board
- Dual Pirani/Convection Board
- Cold Cathode Board
- Hot Cathode Board
- Mass Flow Controller Board
- Auxiliary Output Board
- Control Board
- Binary Coded Decimal (BCD) Board
- Dual Thermocouple Board

Optional Accessories

Refer to *Appendix B: Parts List/Accessories,* page 303

- Gauges
- Valves
- Mass Flow Controllers
- Cables for Gauges/Valves/Mass Flow Controllers
- Remote Front Panel with cable
- Displayless Type 146 Units (indicated as such in the order code)
- RM-6 Rack Mount (MKS p/n RM6)
- RS-232 Cable for Displayless Units (MKS p/n CB146-21)
- Labels for rear panel board identification (MKS p/n LB-1141011)

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.

Refer to *Appendix B: Parts List/Accessories*, page 303, for a complete list of interface cables available.

Generic Shielded Cable Description

MKS offers a full line of cables for all MKS equipment. 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. Refer to Figures 2 and 3, page 26. (A ¼ inch 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); and

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

Example 1: Preferred Method To Connect Cable

(shown on a transducer)

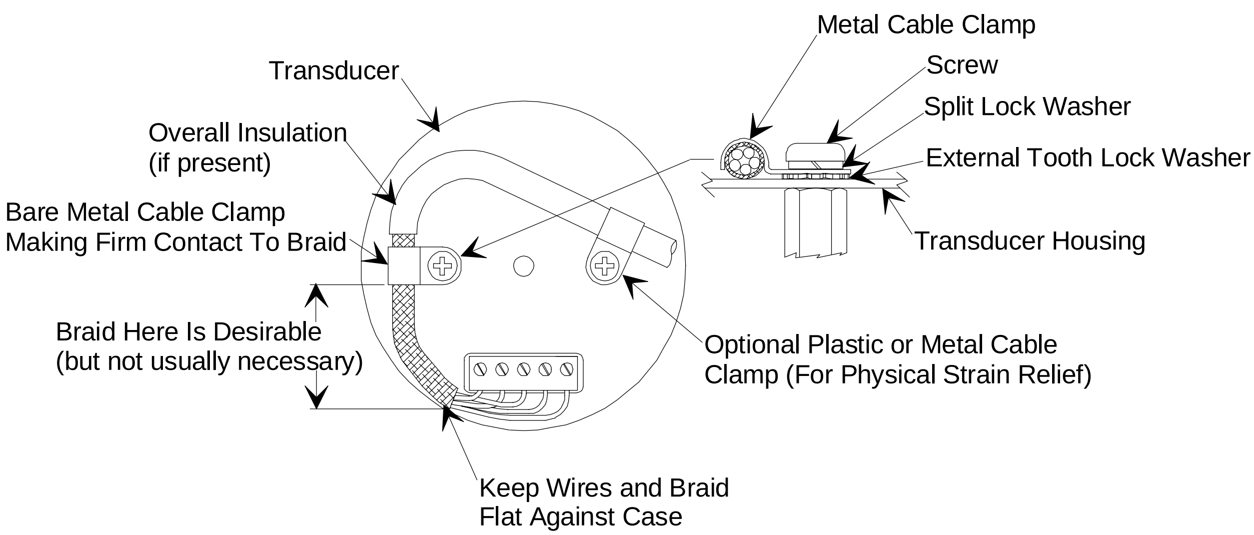


Figure 2: Preferred Method

Example 2: Alternate Method To Connect Cable

(shown on a transducer)

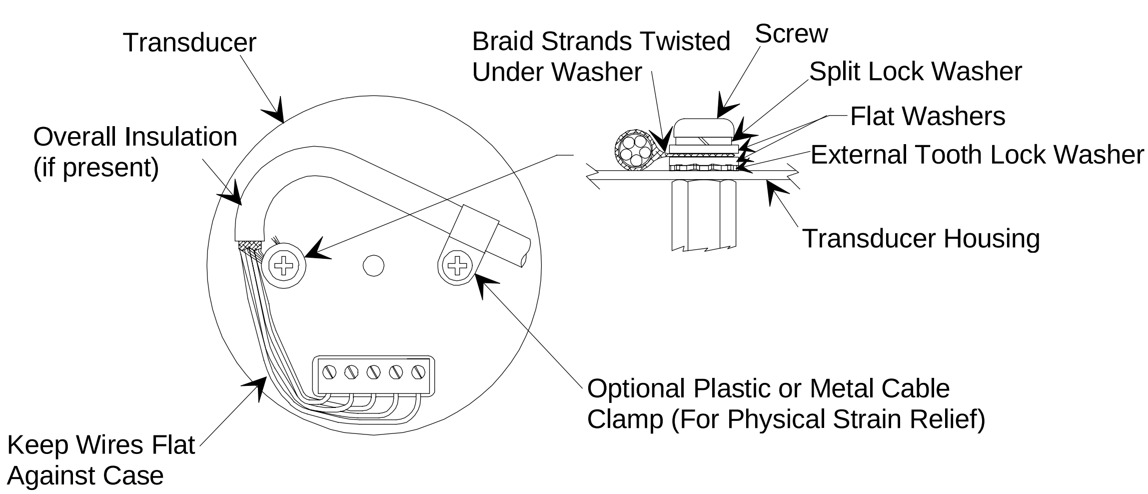


Figure 3: Alternate Method To Use When Cable Clamp is Not Available

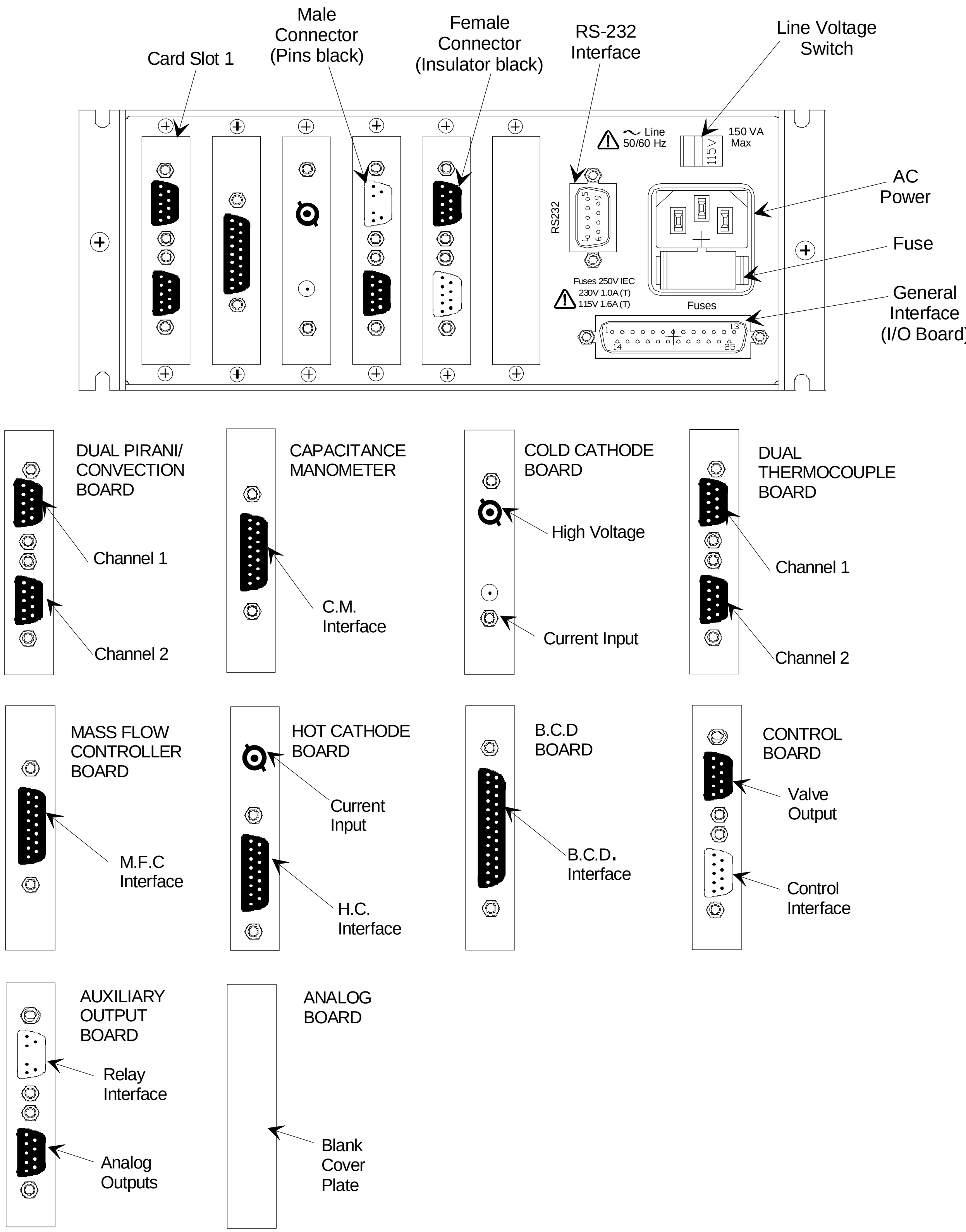


Figure 4: Rear Panel of the 146 Unit

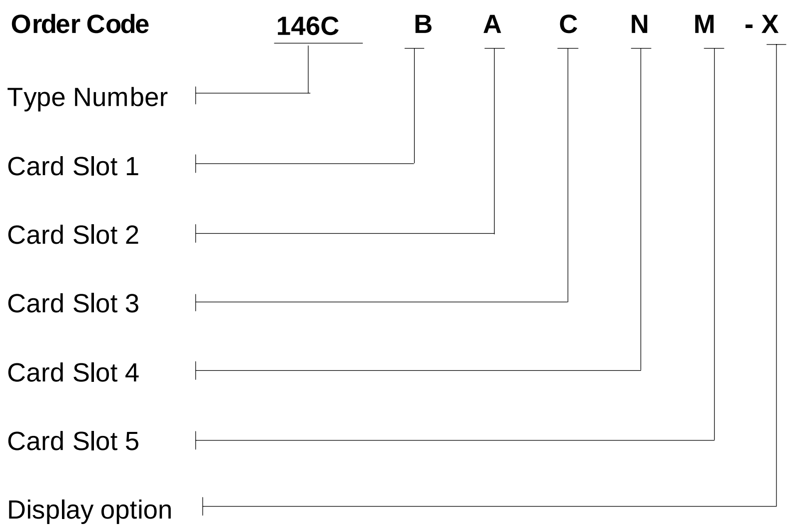


Figure 5: Model Code

Model Code Explanation

Available Boards

Channel Boards

A = Capacitance Manometer
B = Dual Pirani/Convection
C = Cold Cathode
D = Hot Cathode
E = Dual Thermocouple
F = Mass Flow Controller
O = No board installed (covered slot)

Function Boards

M = Control
N = Auxiliary Output
S = Binary Coded Decimal
O = No board installed (covered slot)

Display Option

1 = 146 unit with a front panel display

2 = 146 displayless unit (without front panel display)

Notes

1. Four is the maximum number of channels for the instrument.
2. Channel numbers are determined by the sequence of channel boards. For example, a single board installed in slot 1 becomes channel 1. If a dual channel board is installed in slot 2, it occupies channels 2 and 3.
3. Only one Control board and one Auxiliary Output board can be installed in the instrument.
4. All unused slots must be specified as O (no board) within the model code.
5. If two Hot Cathode (HC) boards are installed into one unit, both HC boards ***MUST*** be set to low power configuration. Otherwise, the 146 unit may exceed its temperature rating.

Product Location and Requirements

The Type 146 unit meets the following criteria:

- POLLUTION DEGREE 2 in accordance with IEC 664
- Transient overvoltages according to INSTALLATION CATEGORY II

Operating Environmental Requirements

- Ambient Operating Temperature: 15° to 40° C (59° to 104° F)
- Storage humidity range: 0 to 95%, non-condensing
- Main supply voltage fluctuations must not exceed ±10% of the nominal voltage
- Ventilation requirements include sufficient air circulation
- Connect the power cord into a grounded outlet

Note If you choose to supply your own power cord you must ensure that it complies with the applicable national regulatory requirements, such as UL or CSA.

Safety Conditions

The 146 unit poses no safety risk under the following environmental conditions.

- Altitude: up to 2000 m
- Maximum relative humidity: 80% for temperatures up to 31 °C, decreasing linearly to 50% at 40 °C

Mounting Instructions

- The 146 unit can be mounted in a panel cutout or in a 19 inch rack when supplied with the RM-6 Rack Mount option
- If a throttle valve is used, the maximum pressure in the gas system in which the 146 unit is installed must not exceed atmospheric pressure due to the requirements of the valve

Electrical Requirements

- Input Power requirements are 100 to 120 VAC, nominal, or 220 to 240 VAC, nominal, 50/60 Hz
- Power consumption is 150 VA, maximum
- Maintain a solid system ground for proper operation and safety to personnel

System Requirements

Pressure Transducer Selection

Refer to the description of each transducer board in *Inside the Type 146 Unit*, page 47, such as connector pinouts.

Any capacitance manometer that delivers up to ±10 Volts full scale can be used with the 146 unit. However, be aware that if a capacitance manometer which delivers *less than* ±10 Volts full scale is used, some sensor conditions such as overrange and underrange will not be detected.

The Pirani-type gauges that are compatible with the 146 unit are the HPS Pirani gauge, HPS Convection Enhanced Pirani (CEP) gauge, and the Granville Phillips Convectron® gauge.

The HPS inverted magnetron cold cathode gauge is compatible.

All Bayard-Alpert hot cathode gauges are supported. This includes both the thoriated iridium and tungsten filament gauges in nude or glass envelope configuration (where available), and the HPS low power, nude, Bayard-Alpert hot cathode.

Note Use of a hot cathode gauge with a glass tube (or envelope) voids the CE compliance. Only hot cathode gauges with nude tubes pass CE testing.

Valve Selection

The control valve may be either a proportional current driven valve, or a voltage driven throttle valve. Many valve types may be used as long as proper cabling is employed.

Mass Flow Controller Selection

All MKS mass flow controllers, and equivalent controllers, are supported.

Dimensions

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

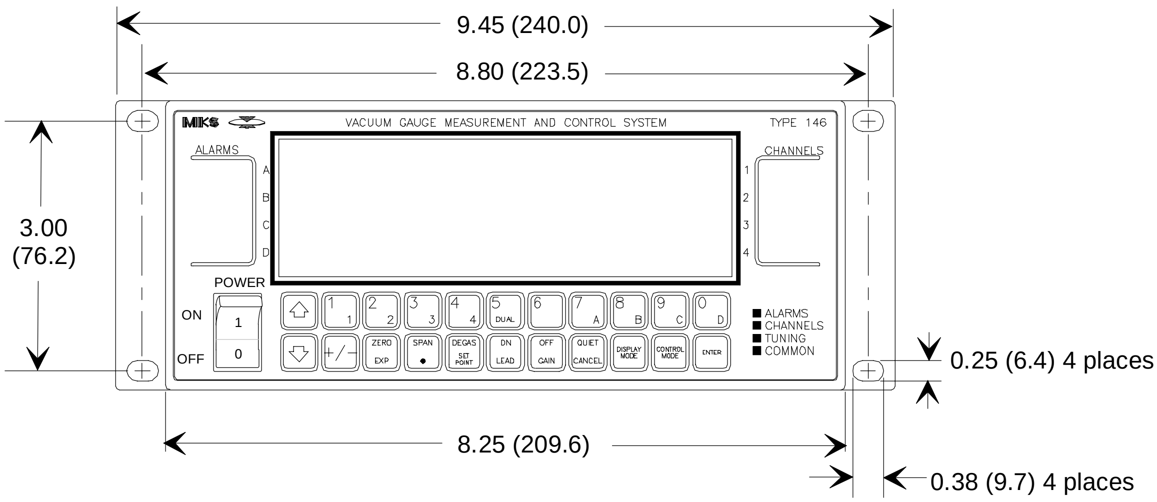


Figure 6: Front Panel Dimensions

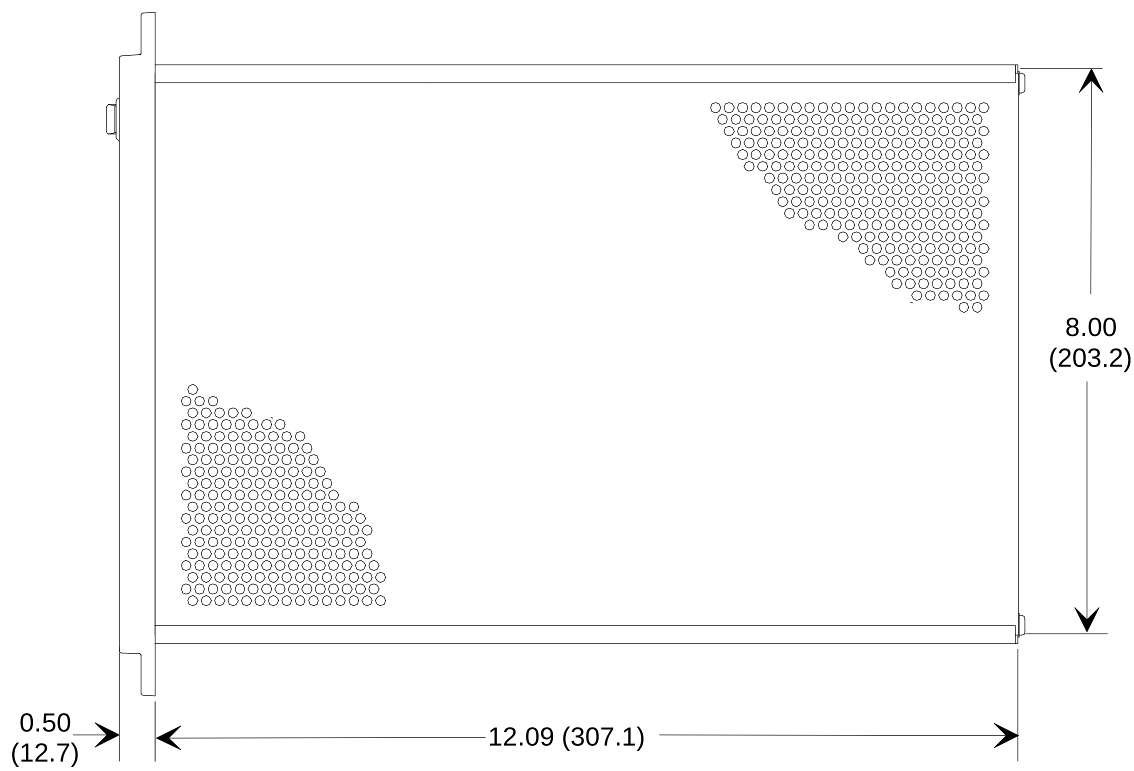


Figure 7: Top Dimensions

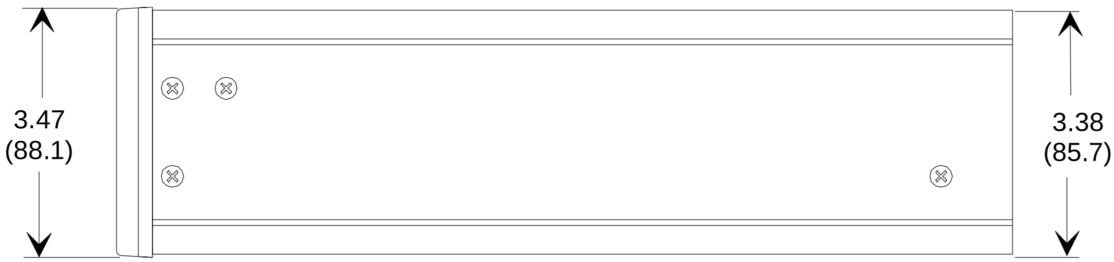


Figure 8: Side Dimensions

146 Set Up

Caution **Provide proper clearance so that the 146 unit operates within product environmental specifications (refer to *Appendix A: Product Specifications*, page 301).**

General

1. Employ proper grounding.

   Power, analog and digital commons are all tied together in the 146 power supply. The transducer signal common and power common are usually tied together internally at the sensor. Although these commons are connected together internally, it is important that each ground be used only for its stated purpose to minimize ground noise and ground-loop errors.

2. Plug the power cord into a properly grounded electrical outlet to ensure protective earthing.

Note If you choose to supply your own power cord you must ensure that it complies with the applicable national regulatory requirements, such as UL or CSA.

3. Use a voltmeter to check that the maximum potential difference between the chassis common and each of the internal grounds is no more than 3.5 Volts.

   The chassis common is connected to the 146 internal grounds through several microfarads of capacitance distributed throughout the unit. It is also clamped with 3.3 Volt, back-to-back, zener diodes shunted by several 0.1 uF capacitors in the power supply. This arrangement allows some flexibility in configuring an optimum earth-grounding scheme that is especially important when several transducers are connected to the 146 unit. The maximum potential difference between these grounds must be limited to 3.5 Volts to prevent the introduction of noise.

Checking the Fuses and AC line Voltage Select Switch

Note If the 146 unit is ordered with a full configuration form filled out, it will arrive with the correct fuse(s) and have the voltage switch set for proper AC voltage. There are no other adjustments needed for set up.

If a full configuration form was not filled out, or to confirm the set up of the 146 unit, check the type of fuses installed in the unit. Refer to *How To Replace the Fuses,* page 290.

Transducer/Mass Flow Controller Connections

Please refer to the installation instructions that came with your particular transducers or mass flow controllers.

- Connect the gauge/MFC interface cable to the appropriate 146 connector.

  Refer to Figure 4, page 27, to identify the appropriate connector.

Communication and Power Connections

Refer to Figure 4, page 27, for the location of all communication and power connections.

1. Connect the proper interface cable to the General I/O connector.
2. Connect the IBM PC® (XT®, AT®, or compatible) computer cable to the standard 9-pin female RS-232 connector.
3. If an Auxiliary Output board is installed, use a cable to connect the 146 unit to a device which can be activated through the relays on the top connector (the relay interface), and another cable to connect an analog output device to the bottom connector (the analog output interface) on the Auxiliary Output board.
4. If a Control board is installed, use a cable to connect an appropriate valve or controller to the top connector (the valve output interface) on the Control board. Table 27, page 71, lists appropriate valves and controllers. The bottom connector (the control interface) provides remote function control. Connect a PC or other remote equipment to this connector with the appropriate cable.
5. If a Control board is installed, the proper pin jumpers must be selected.

   Refer to Table 26, page 70, for details.

Installing Boards in the 146 Unit

This section describes how to install boards that have been ordered after the 146 unit has arrived.

Warning **The 146 unit has lethal voltages inside. To avoid the danger of electrical shock, the power line must be disconnected before opening the unit.**

1. Be sure the power cord is disconnected.
2. Remove the four (4) Phillips screws on the outside corners of the rear panel and the seven (7) screws from the top cover.

   Refer to Figure 9 for an illustration of how to open the 146 unit.

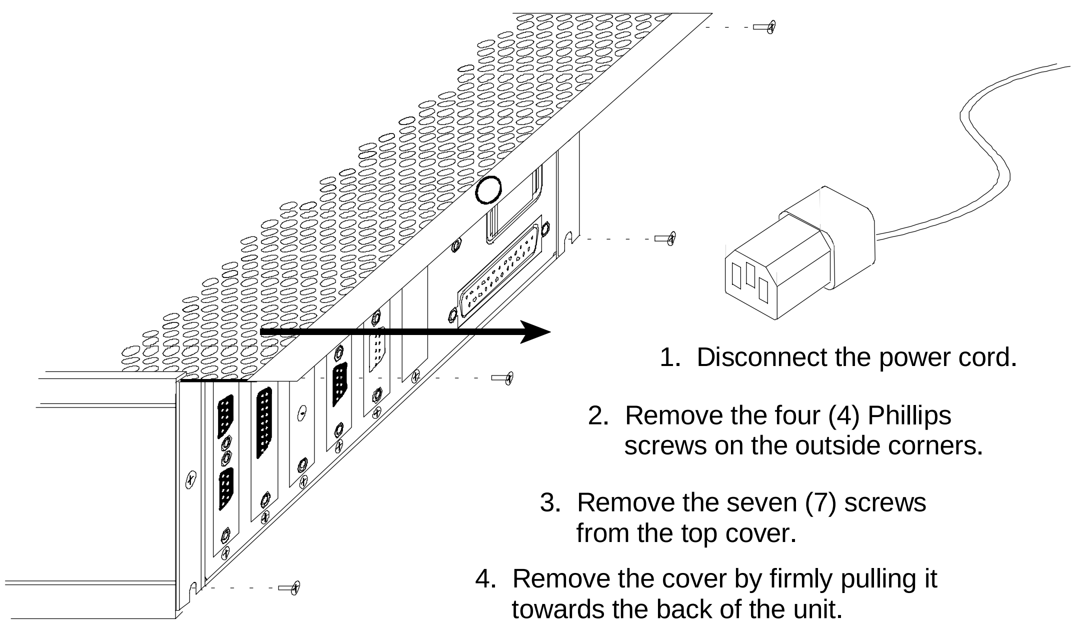


Figure 9: Opening the Type 146 Unit

3. Remove the top cover by firmly pulling it towards the back of the unit. Note the orientation of the cover since the center hole is slightly off center to accommodate a connector if a board is positioned in slot 5.
4. Carefully turn the unit over so that it is bottom-side up and remove the seven (7) screws.
5. Remove the bottom cover by firmly pulling it towards the back of the unit. Note the orientation of the cover since the center hole is slightly off center to accommodate a connector if a board is positioned in slot 5.

6. Place the unit on a flat surface in its normal orientation, with the rear panel facing you.

7. Decide where the board will go.

   We recommend that you do not move any boards already installed in the 146 unit. Instead, install a new board in an unused slot. This avoids the situation where the 146 unit changes user-defined parameters to default parameters. Refer to *New Configuration Warning Code,* on page 37, for more information concerning a configuration change in the 146 instrument.

   A. It is best to install all transducer boards in slots 1, 2, 3, or 4, whichever is the lowest numbered slot available.

   B. It is best to install the Control board in slot 5.

   C. It is best to install the Auxiliary Output board in slot 4 or 5 if no Control board is present. If a Control board is present, it is best to install the Auxiliary Output board in slot 4.

8. Unscrew the two small screws holding the slot cover that corresponds to the board slot you intend to use.

9. If your board has two Type "D" connectors (Dual Pirani, Dual Thermocouple, Control, or Auxiliary Output boards), remove the top connector's fastening screw.

   Refer to Figure 10, page 35, for placement of the top connector's fastening screw.

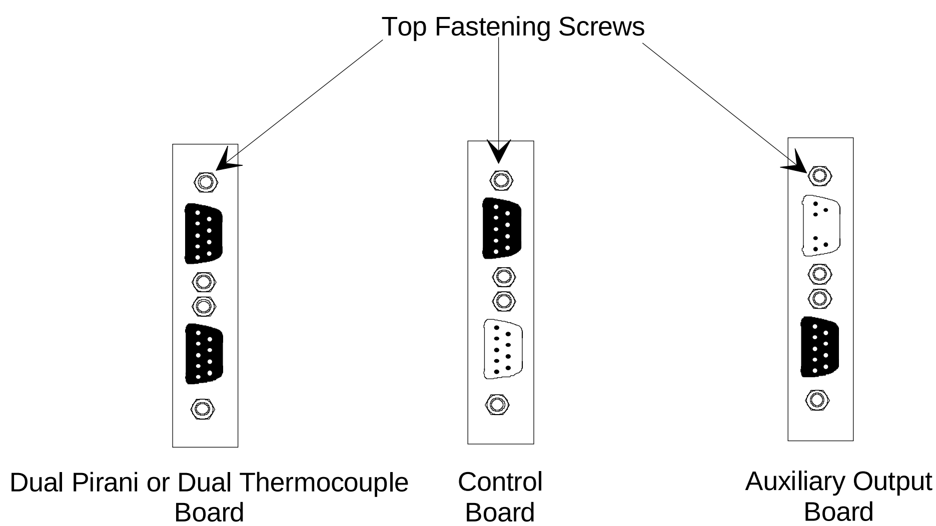


Figure 10: Fastening Screw Positions

10. Slide the board inside the unit so that the connector(s) protrude through the opening in the rear panel.

11. Line the board up so that the female connector on the board is directly over the male connector on the mother board.

12. Gently push the board onto the male connector.

13. If your board has two Type “D” connectors (Dual Pirani, Dual Thermocouple, Control, or Auxiliary Output boards), replace the top connector’s fastening screw.

14. Turn the unit over so that it is bottom-side up.

15. Take the screw that came with the board, and use it to fasten the board to the bottom of the unit.

16. Replace the bottom cover by inserting it into the grooves provided, and firmly sliding it towards the front of the unit. Replace the seven (7) screws that fasten the bottom cover.

    The center screw on the bottom cover is slightly off center to avoid interfering with a connector if a board is positioned in slot 5. Therefore, the cover must be in the correct orientation for the screw holes to line up properly.

17. Carefully turn the unit right-side up.

18. Replace the top cover by inserting it into the grooves provided, and firmly sliding it towards the front of the unit. Replace the seven (7) screws that fasten the top cover.

    The center screw on the top cover is slightly off center to avoid interfering with a connector if a board is positioned in slot 5. Therefore, the cover must be in the correct orientation for the screw holes to line up properly.

19. Replace the four (4) Phillips screws on the outside corners of the rear panel.

20. Plug in the power cord.

New Configuration Warning Code (C11)

Under most circumstances, when there is a configuration change in the 146 unit, a warning code (C11) is displayed and an alarm audio tone goes off when the unit is powered up again. The alarm sound is silenced by pressing the [QUIET / CANCEL] key. This also deletes the C11 code from the front panel window. The purpose of the warning code and alarm sound is to remind you that there *may* be parameter changes within the unit caused by the configuration change. *If* there is a change, it will involve resetting of parameters to their default values for one or more channels.

Note The beginning of this section describes what happens in *most* instances when there is a configuration change in the 146 instrument. The exceptions to this general description are discussed at the end of this section under the title *Exceptions.*

The recommended procedure for installing boards, explained in the previous section, avoids altering any user-defined parameters. The C11 warning code and alarm are still activated, however, when a new board is added because this still entails a configuration change. All parameters associated with the new board are set at default values.

If a board is removed from the unit, and not replaced with the same type board, the code and alarm are activated upon power up. Also, the user-defined parameters in any transducer boards installed in higher numbered slots, go to default values. The channel numbers associated with those boards are also changed if a transducer board (of any type), is not installed to replace the removed board.

For example, assume the 146 unit has three transducer boards installed. There are Capacitance Manometer boards in slots one and two (corresponding to channels 1 and 2), and a Cold Cathode board in slot three (channel 3). If a Capacitance Manometer board is removed from slot two, the Cold Cathode board (previously channel 3) becomes channel 2, and all user-defined parameters for the cold cathode change to default values. The parameters associated with channel 1 remain unchanged because the channel number for that board has remained unchanged.

If a board is not changed, but the gauge attached to the board is replaced, the C11 code and alarm are *not activated*, however, *there still may be parameter changes within the unit*. Whether or not there are parameter changes depends upon if the gauge is being replaced with another gauge of the same type (no parameter changes), or if the user-defined parameters are valid and appropriate for the new type of gauge. For example, replacing a 120 capacitance manometer with a 107 capacitance manometer might entail parameter changes. If the user-defined sensor range entered for the Type 120 gauge is valid for the Type 107 gauge, then it is preserved. If the user-defined sensor range is not valid, however, the sensor range changes to the Type 107 default value.

Exceptions

If the configuration change in the 146 unit is extensive or involves global parameters, *all* user-defined parameters are reset to factory defaults. As in the previous discussion, the C11 warning code is displayed at the next power up. In addition, the E4 error code is displayed after the unit its turned off and then on again. Therefore, if the C11 warning code is displayed on power up, it is a good idea to cycle the power again to determine the full extent of the configuration change on user-defined parameters.

An optional displayless 146 unit cannot display any error codes unless a remote front panel is connected to it. The presence of error conditions (such as C11 or E4) is indicated when the LED on the displayless unit remains red instead of turning to green a few seconds after power up. For more information about the displayless unit and remote front panel option, refer to *Displayless 146 Unit*, page 98.

146 Start Up

1. Be sure the AC power cord is disconnected.

2. Push the power switch to the OFF position.

3. Plug in the power cord.

4. Push the power switch to the ON position.

   The 146 unit responds by activating the front panel window, and testing all LCD segments. Within 5 seconds the screen changes and the 146 unit defaults to Normal Mode. The pressure readings for all attached, active gauges are displayed.

5. Allow the system to warm up.

   For rated accuracy, the 146 unit should be allowed to warm up for 5 minutes. Refer to the start up instructions that came with your particular transducers for additional start up procedures and warm up times. A cold or hot cathode gauge must be turned on since it is off when the 146 unit powers up.

6. Initiate gas flow in a manner appropriate to your system.

   The system is now operational. If a Control board is installed, the 146 unit can control the system according to default settings, or according to the settings specified in your configuration sheet.

Chapter Three: Overview

The Front Panel

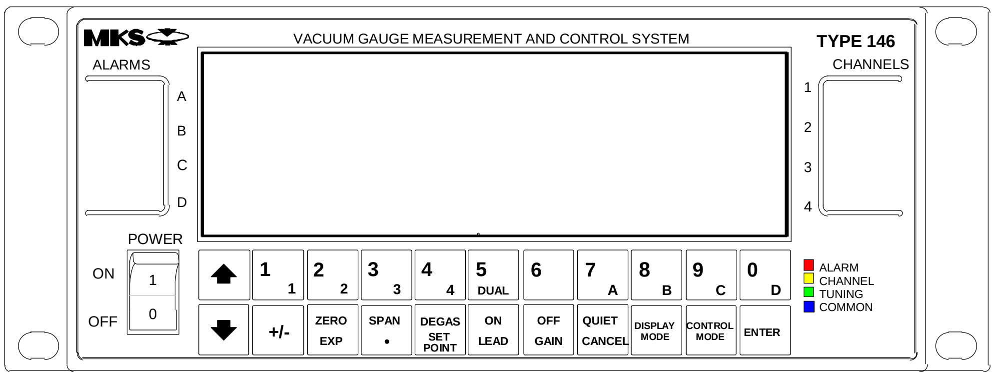


Figure 11: Front Panel of the Type 146 Instrument

The front panel includes the power switch, the alarm and channel label areas, the keys, and the front panel window. All modes can be accessed through the front panel and from the RS-232 serial port. All commands can be activated through the front panel (and most can be activated through the RS-232 serial port).

The keys on the front panel are color coded to group them according to their functions.

The Power Switch

The Power switch controls the electrical power to the 146 unit. The 146 unit uses the universal symbols for power on (1) and power off (0).

Overview of Keys and Their Functions

This overview explains the way keys function in general. Any exceptions to the general rules are noted within each appropriate chapter.

What Happens when a Key is Pressed

With each valid key press, a soft beep is sounded. An invalid key press does not evoke any sound, but causes the INVALID legend to temporarily appear on the far right side of the front panel window. An inappropriate key sequence, such as trying to zero a channel that has been turned off, evokes a single loud beep. An incomplete key sequence times out after 3 seconds, and evokes two loud beeps.

Key Color Codes		
Red Keys		**Relates to Alarms**
	[7/**A**], [8/**B**], [9/**C**], and [0/**D**]	Used to select one of the four alarms (A through D).
	[**QUIET**/CANCEL]	Silences any alarm as its first function.
Yellow Keys		**Relates to Channels**
	[1**1**], [2**2**], [3**3**], [4**4**], and [5**DUAL**]	Used to select one of the four channels (1 through 4) or the dual channel display function.
	[**ZERO**/EXP] & [**SPAN**/.]	Used to zero, or span channels.
	[**DEGAS**/SET POINT]	Used to degas hot cathode gauges.
	[**ON**/LEAD] & [**OFF**/GAIN]	Used to turn channels and sensors on or off.
Green Keys		**Used in Tuning Mode**
	[DEGAS/**SET POINT**]	Used to select control parameter Set Point.
	[ON/**LEAD**]	Used to select control parameter Lead
	[OFF/**GAIN**]	Used to select control parameter Gain
Blue Keys		**Common to all modes**
	[1$_{1}$], [2$_{2}$], [3$_{3}$], [4$_{4}$], [5$_{\text{DUAL}}$], [6], [7**A**], [8**B**], [9**C**], [0**D**], ⬆, ⬇, [ENTER], [+/-,], [QUIET/**CANCEL**], [ZERO/**EXP**], [DISPLAY MODE], [CONTROL MODE]	For mode/ function selection, and parameter entry.

Table 5: Key Color Codes

Specific Keys and Their Functions

Some keys have more than one function printed on them, but only one of the functions is enabled at any given time. Table 6 describes the function of each key on the front panel. If a function is restricted to a certain mode or modes, the table lists the applicable mode(s) within parentheses.

Description of the Front Panel Keys	
Key	**Description**
⬆ and ⬇	1. Scrolls through lists of functions. 2. Increments or decrements an active parameter by the smallest unit available (Tuning Mode). 3. Activates the Open/Close Override functions for MFCs (Normal and Leakage Modes).
[+/-]	1. Adds a positive or negative sign to an active parameter, or to the exponent of the active parameter. 2. Toggles between the first and second part of an active, two-part parameter setting up Dual Channels. The first part is the channel number, and the second part is a High or Low setting. The [+/-] key toggles between the first and second part of this parameter.
[ZERO/EXP]	1. Zeros a sensor, or zeroes a sensor to a reference. 2. Creates an exponent when entering a value in scientific notation. 3. Toggles between mTorr and scientific notation for some numeric parameters.
[SPAN/.]	1. Spans a sensor, or spans a sensor to a reference. 2. Enters a decimal in numeric parameters.
[DEGAS/SET POINT]	1. Makes the **SET POINT** parameter the active parameter. (Tuning Mode only). 2. Turns the degas function on for hot cathode gauges (Normal and Leakage Modes).

Table 6: Description of the Front Panel Keys
(Continued on next page)

Description of the Front Panel Keys *(Continued)*	
Key	**Description**
[ON/LEAD]	1. Turns a channel/alarm/degas on. (Normal and Leakage Modes). 2. Makes the lead parameter the active parameter. (Tuning Mode only).
[OFF/GAIN]	1. Turns a channel/alarm/degas off. (Normal and Leakage Modes). 2. Makes the gain parameter the active parameter. (Tuning Mode only).
[QUIET/CANCEL]	In all modes *except* Control Mode, this key performs the following functions (if they apply), in the order presented here: 1. Quiets any alarms. 2. Returns to initial value of parameter. (Tuning and Setup Modes). 3. Returns to initial status of the mode. (Tuning and Setup Modes). 4. Returns to Normal Mode. In Control Mode: 1. Quiets any alarms. 2. Toggles out of Control Mode into the previous mode. 3. Returns to Normal Mode.
[DISPLAY MODE]	1. Scrolls through Normal, Leakage, Tuning (when available), and Setup Modes. 2. Exits from Control Mode, and changes the display to the next mode in the above sequence of modes.
[CONTROL MODE]	Toggles in and out of Control Mode.
[ENTER]	Causes the 146 unit to accept the active parameter which is currently displayed (provided the parameter is valid), and move to the next parameter in sequence, if there is one.
[DISPLAY MODE]	Scrolls through Normal, Leakage, Tuning (if the optional Control board is installed), and Setup Modes.
[CONTROL MODE]	Toggles in and out of Control Mode (if the optional Control board is installed).

Table 6: Description of the Front Panel Keys

The Front Panel Window

Initial View Upon Power Up

On power up, the 146 unit goes through its normal initialization and provides a full LCD test display in the front panel window, shown in Figure 12.

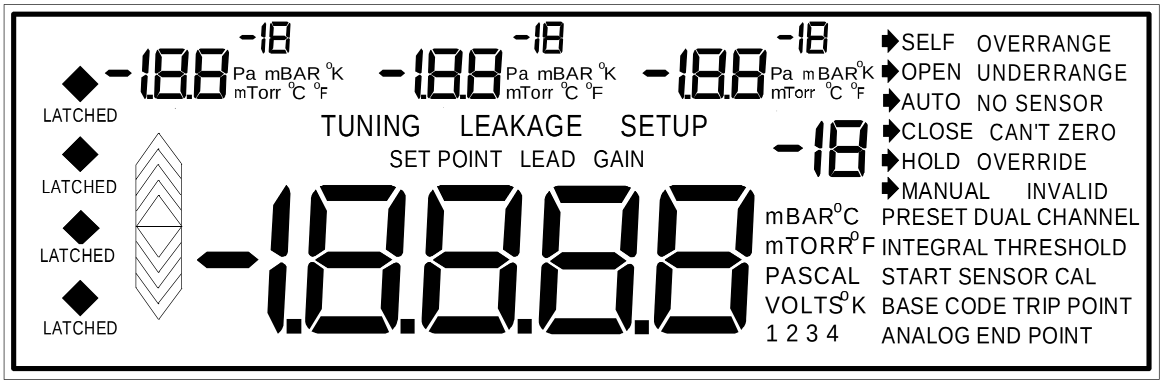


Figure 12: Full LCD Display

When initialization is complete, the 146 unit defaults to Normal Mode operation. The front panel back-light has an automatic timed turn off. If no keys are pressed, the back-light shuts off after one hour. The window is reactivated by pressing any key (the key also executes any command associated with it).

What to Look For

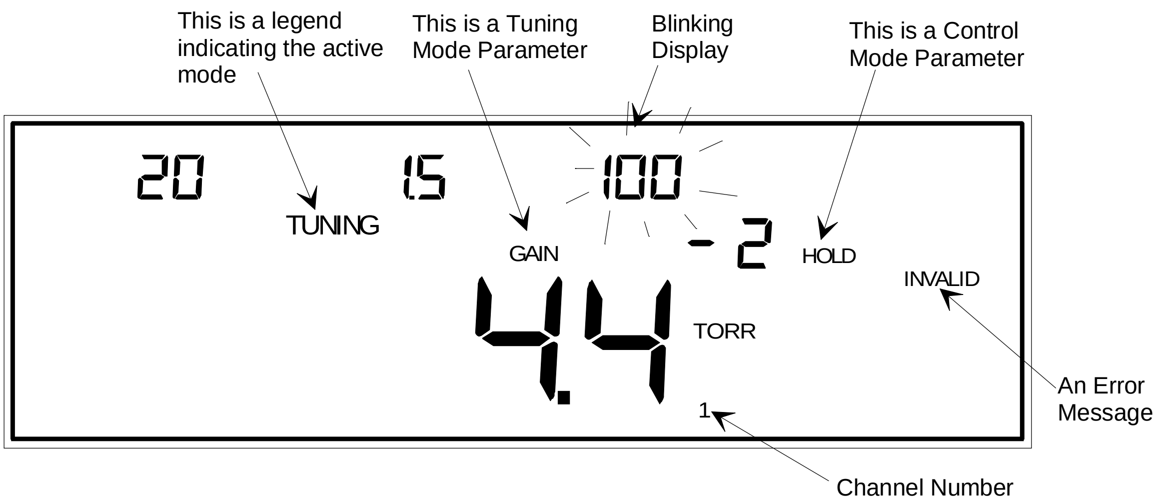


Figure 13: Explanation of the Front Panel Display

A Blinking Display: A blinking parameter in the window indicates that this parameter is the active entry—its value can be confirmed or edited. You may edit the blinking parameter, or press the [ENTER] key to move to the next editable parameter (if there is one).

Legends: The 146 unit displays many different legends. Some legends indicate which mode the 146 unit is operating in, some provide a choice of parameters (for example OPEN, AUTO, CLOSE , HOLD, or MANUAL), and some show which parameter is currently available for editing (for example SET POINT, LEAD, or GAIN).

Channel Number: The small number to the bottom right of the main display, indicates the channel whose pressure reading is currently being shown in the main display. The left, center, and right displays do not need to have a channel number because they always display channels 1, 2, and 3 respectively, when in Normal or Leakage Modes.

Error Codes: The 146 unit is able to determine several different error conditions (such as a disconnected sensor). Refer to Appendices C and D for a list of error codes and what they mean.

IMPORTANT

It is important to be familiar with the various legends, error messages, and parameters which can be displayed in the front panel window. These messages convey valuable information about which mode the 146 unit is operating in, the status of the 146 unit and the sensors connected to it, the currently editable parameter, and more.

Take the time to look at Figure 12, page 43, to see all the standard legends, error messages, and parameters of the 146 unit, and where they are displayed in the window. Refer to Table 7, page 45, for a summary of the standard messages. In addition to these standard messages, error codes (see *Appendix D: Front Panel Error/Status Messages*, page 307), can also be displayed. Error codes appear in the main, left, center, or right displays, whichever display is most appropriate.

Note The front panel also displays status information and error codes. Refer to *Appendix D: Front Panel Error/Status Messages*, page 307, for more information.

Standard Front Panel Messages	
Category	**Messages and their Meaning**
Mode Identification	**TUNING**: The 146 unit is in Tuning Mode. **LEAKAGE**: The 146 unit is in Leakage Mode. **SETUP**: The 146 unit is in Setup Mode.
Alarm/Relay Status	***A diamond***: A diamond indicates an alarm *condition*. **LATCHED**: This message indicates the status of an alarm *relay*.
Tuning Mode Parameters	**BASE**: The BASE parameter is currently editable. **START**: The START parameter is currently editable. **INTEGRAL**: The INTEGRAL parameter is currently editable. **PRESET**: The PRESET parameter is currently editable. **SET POINT**: The SET POINT parameter is currently editable. **LEAD**: The LEAD parameter is currently editable. **GAIN**: The GAIN parameter is currently editable. ***No parameter is displayed***: When in Tuning Mode, if: 1. None of the above parameters is displayed ***and*** 2. The HOLD or MANUAL Control Mode legend is displayed ***and*** 3. The [ENTER] key is pressed, ***then*** the VALVE POSITION parameter is currently editable.
Control Mode Valve Positions	**OPEN**: The valve output signal is set to 100%. **AUTO**: The valve is controlled according to a selected recipe. **CLOSE**: The valve output signal is set to zero. **HOLD**: The valve is held at its current position. **MANUAL**: The valve output signal is changed to a preset value.

Table 7: Standard Front Panel Messages
(Continued on next page)

Standard Front Panel Messages (*Continued*)	
Category	**Messages and their Meaning**
Setup Mode Functions	**DUAL CHANNEL THRESHOLD**: This parameter is currently editable. **SENSOR CAL**: Perform sensor calibration/MFC setup **TRIP POINT**: The alarm trip point parameter is currently editable. **CODE**: This indicates that a miscellaneous code can be selected. **ANALOG ENDPOINT**: Parameters for the Analog Output can be edited.
Sensor Status	**OVERRANGE**: The system pressure has gone above a sensor's range. **UNDERRANGE**: The system pressure has gone below a sensor's range. **NO SENSOR**: No sensor is connected to an active channel. **CAN'T ZERO**: The 146 unit cannot zero a sensor because the sensor is outside of its acceptable zeroing range.
Other	**INVALID**: An invalid keystroke has been used.

Table 7: Standard Front Panel Messages

Labels on the 146 Unit

The 146 unit has a serial number label and an informational label on the side of the unit. The informational label states that the CE compliance applies to the model code configuration set at the factory only. If you modify the unit in any way, such as adding a board, check with the factory to determine whether the new configuration is CE compliant.

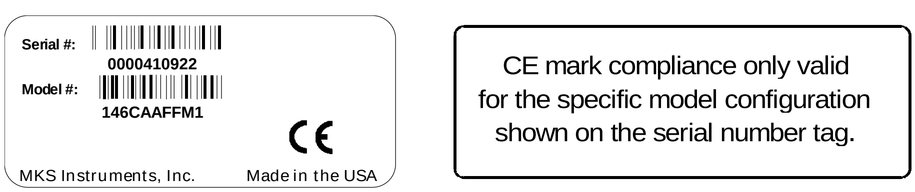


Figure 14: Labels on the 146 Unit

Note

Not all configurations of the 146 unit are CE compliant. Units that are *not* CE compliant cannot display the "CE" symbol on the serial number label. Consult the factory to determine whether a specific configuration is CE compliant.

Inside the Type 146 Unit

General Information

There are six board slots inside the 146 unit. The sixth slot is for the Analog board, which comes standard with the 146 unit, and must be installed in slot 6. Transducer and MFC boards should be installed in slots 1, 2, 3, or 4; whichever is the lowest numbered slot available. The 146 unit can only support one Control board, and one Auxiliary Output board.

Labels are placed on the rear panel to mark the channel number and board type of each board installed in the unit when it leaves the factory. A complete set of labels is supplied if an unconfigured base unit is ordered. Additional labels are available (MKS p/n LB-1141011).

Note

Use overall metal braided shielded cables, properly grounded at both ends, for all connections to ensure CE compliance. Refer to *Interface Cables*, page 25, for additional information.

Capacitance Manometer Board

The Capacitance Manometer board has one 15-pin female Type “D” connector. Table 8 shows the connector pinout. Refer to Table 9, page 49, for a list of MKS capacitance manometers supported, along with their cables.

Capacitance Manometer Pinout	
Pin Number	**Assignment**
1	+15 Volts
2	Signal +
3	$\overline{\text{Remote Zero}}$ *
4	$\overline{\text{x0.1 Range Select}}$ * *or* PROM Clock**
5	Power Ground
6	-15 Volts
7	+15 Volts
8	Remote Zero Out-of-Range *
9	-15 Volts
10	PROM Write**
11	Digital Ground
12	Signal -
13	$\overline{\text{Range Identification}}$ * *or* PROM Read**
14	$\overline{\text{Bypass Remote Zero}}$ *
15	Chassis Ground
** Feature on the 120 transducer only* *** Feature on the 107 transducer only*	

Table 8: Capacitance Manometer Pinout

Note

If a pin has a function that is not supported by your transducer, do not connect a signal to it. Circuitry on the Capacitance Manometer board may be damaged if an inappropriate signal is connected.

MKS Capacitance Manometers and Cables		
Type	**Description**	**Cable Number**
107B	6 Decade Sensor	CB107-1-10, CB107S-1-10
120	Highest Accuracy Standalone	CB120-1-10, CB120S-1-10
122A	General Purpose	CB112-2-10, CB112S-2-10
127A	Heated General Purpose	CB259-5-10, CB259S-5-10
128	High Temperature General Purpose	CB259-5-10, CB259S-5-10
220	NEMA Case	CB112-10-10, CB112S-10-10
221	Remote Sensor	CB112-14-10, CB112S-14-10
223	Differential Sensor	CB112-2-10, CB112S-2-10
124, 224, 225	General Purpose with Alarms	CB112-2-10, CB112S-2-10
390 or 690 with a 270	Highest Accuracy	CB112-6, CB112S-6
622	Absolute Transducer	CB112-2-10, CB112S-2-10
623	Absolute Transducer	CB112-2-10, CB112S-2-10
624	Absolute Transducer (heated)	CB112-2-10, CB112S-2-10
625	Absolute Transducer (heated)	CB112-2-10, CB112S-2-10
626	Absolute Transducer	CB259-5-10, CB259S-5-10
627	Absolute Transducer (heated)	CB259-5-10, CB259S-5-10
628	Absolute Transducer (heated)	CB259-5-10, CB259S-5-10
700 Series	Mini-Baratron® Absolute and Gage Pressure Transducers	consult factory
800 Series	Ultraclean Mini-Baratron Absolute and Gage Pressure Transducers	consult factory

Table 9: MKS Capacitance Manometers and Cables

Pirani/Convection

On the end of the Pirani/Convection board are two 9-pin female Type "D" connectors, since the board can support up to two gauges. Table 10 shows the connector pinout. The top connector is the lower numbered channel, and the bottom connector is the higher numbered channel. For example, if this board is installed in slot 1, the top connector is channel 1, and the bottom connector is channel 2.

Pirani/Convection Connector Pinout	
Pin Number	**Assignment**
1	Drive +
2	Chassis Ground
3	Signal +
4	Signal -
5	Power Ground
6	Drive +
7	Bridge Delta +
8	Bridge Delta -
9	Power Ground

Table 10: Pirani/Convection Connector Pinout

Pirani Sensors and Cables	
Sensor Type	**Part Number**
Pirani Tube with KF-16	103150010
Pirani Tube with ⅛" NPT	103150011
Pirani Tube with ½" VCR	103150012
Pirani Tube with 1⅓" CF	103150013
Pirani Tube with 2¾" CF	103150014
Cable Type	**Part Number**
10 foot cable for all HPS Pirani sensors	CB146-15, CB146S-15
146 to HPS CEP gauge	CB146-37, CB146S-37
146 to G.P. Convectron®	CB146-14, CB146S-14
146 cable adapter for G.P. Convectron cable	CB146-1, CB146S-1

Table 11: Pirani Sensors and Cables

Configuring the Dual Channel Pirani/Convection Board as Single Channel Board

The Pirani/Convection board can function as a single channel board. MKS will have configured the board as a single channel board, if you requested it when you placed the order. The board will be configured for dual channel operation if you did not specify single channel operation. If you did not request the single channel configuration, but wish to configure the board for single channel operation, follow these instructions.

Warning

The 146 unit has lethal voltages inside. To avoid the danger of electrical shock, disconnect the power line *before* opening the unit.

1. Be sure the power cord is disconnected.

2. Disconnect all cables from the 146 unit.

3. Remove the four (4) Phillips screws on the outside corners of the rear panel and the seven (7) screws from the top cover.

4. Remove the top cover by firmly pulling it towards the back of the unit. Note the orientation of the cover since the center hole is slightly off center to accommodate a connector if a board is positioned in slot 5.

5. Carefully turn the unit over so that it is bottom-side up and remove the seven (7) screws.

6. Remove the bottom cover by firmly pulling it towards the back of the unit. Note the orientation of the cover since the center hole is slightly off center to accommodate a connector if a board is positioned in slot 5.

7. Remove the Phillips screw that is securing the Pirani/Convection board to the bottom of the 146 unit.

8. Carefully turn the unit right-side up.

9. Unscrew the two small screws holding the slot cover on the Pirani/Convection board.

10. Remove the top fastening screw that is above the upper connector.

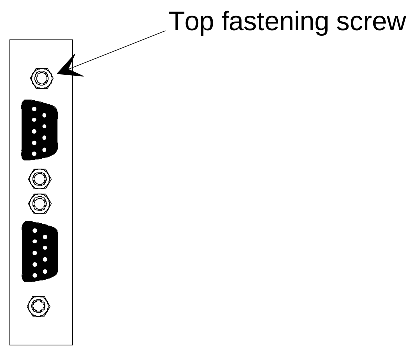


Figure 15: Dual Pirani Board Connectors

11. Carefully but firmly pull the Pirani/Convection board out of the 146 unit.

12. Remove the jumper that is currently on any jumper pack numbered JP2 through JP8 (typically the jumper is stored on JP2).

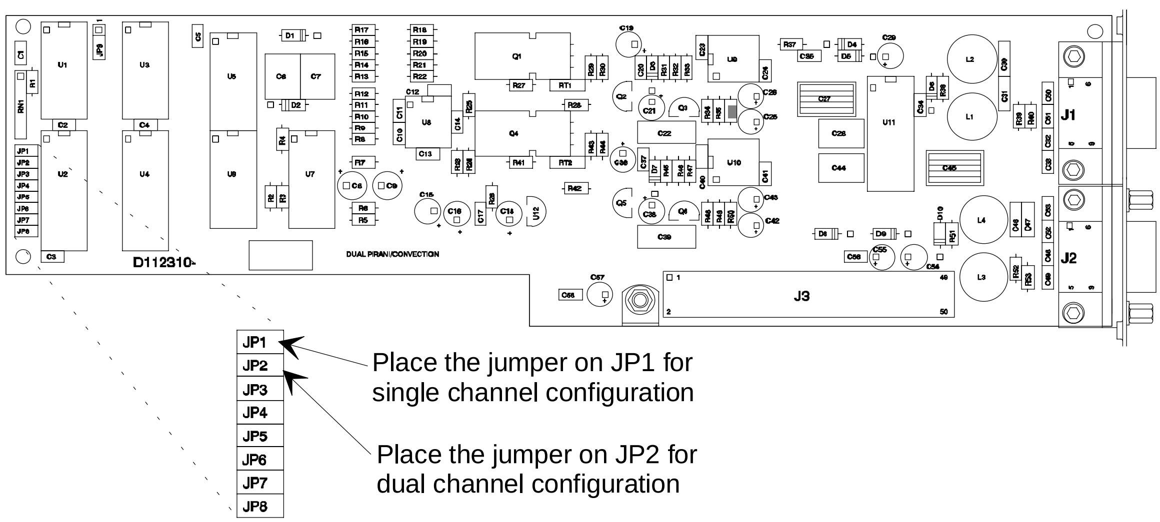


Figure 16: Jumper Placement on the Pirani/Convection Board

13. Place the jumper on JP1.

    The board is now configured as a single channel Pirani/Convection board. The top connector becomes the only active channel.

Note Only the top connector is active when the Pirani/Convection board is configured for single channel operation.

14. Slide the board back inside the unit so that the connectors protrude through the opening in the rear panel.

15. Line the board up so that the female connector on the board is directly over the male connector on the mother board.

16. Gently push the board onto the male connector.

17. Replace the top connector’s fastening screw.

18. Turn the unit over so that it is bottom-side up.

19. Replace the Phillips screw that fastens the board to the 146 unit.

20. Replace the bottom cover by inserting it into the grooves provided, and firmly sliding it towards the front of the unit. Replace the seven (7) screws that fasten the bottom cover.

    The center screw on the bottom cover is slightly off center to avoid interfering with a connector if a board is positioned in slot 5. Therefore, the cover must be in the correct orientation for the screw holes to line up properly.

21. Carefully turn the unit right-side up.

22. Replace the top cover by inserting it into the grooves provided, and firmly sliding it towards the front of the unit. Replace the seven (7) screws that fasten the top cover.

    The center screw on the top cover is slightly off center to avoid interfering with a connector if a board is positioned in slot 5. Therefore, the cover must be in the correct orientation for the screw holes to line up properly.

23. Replace the four (4) Phillips screws on the outside corners of the rear panel.

24. Plug in the power cord.

Cold Cathode

Located on the end of the Cold Cathode board are two coaxial connectors. Table 12 shows the connector pinout. A list of MKS sensors, along with their cables, is shown in Table 13.

Cold Cathode Connector Pinout	
High Voltage	**High Voltage BNC**
High Voltage	Center
Chassis Ground	Shield
Ion Current SMA	
Ion Current	Center
Chassis Ground	Shield

Table 12: Cold Cathode Connector Pinout

Cold Cathode Sensors And Cables	
Sensor and Cable Type	**Part Number**
Cold Cathode with NW-40-KF	104210001
Cold Cathode with 2¾” CF	104210002
Cold Cathode with 1” tube	104210003
Cold Cathode with NW-25-KF	104210004
Cold Cathode Cable (10 ft.)	100006171

Table 13: Cold Cathode Sensors and Cables

Note

One characteristic common to all ion gauges is an inability to establish an ion current at high pressures. The gauge may, therefore, respond as if the pressure is extremely low. Keep this characteristic in mind when setting a disconnect threshold, alarm trip points, or if you designate an ion gauge as a reference channel.

Hot Cathode

Located on the end of the Hot Cathode board is one coaxial connector and one 15-pin female Type "D" connector. Table 14 shows the connector pinout of the coaxial connector and Table 16 shows the Type "D" connector pinout. A list of MKS hot cathode gauges, along with their cables, is shown in Table 15.

Note

Only hot cathode gauges with nude tubes are CE compliant. Hot cathode gauges with glass tubes are not CE compliant. If your 146 unit is CE compliant, you must use a hot cathode gauge with a nude tube for the unit to remain CE compliant.

The 146 unit offers several power control features designed for use with hot cathode gauges. If the 146 unit detects a disconnected hot cathode, a tube short, or an open filament in the HC gauge, it automatically turns off power to the gauge. To restore power to the gauge, toggle the HC channel off and on again. This feature is always enabled.

Hot Cathode Coaxial Connector Pinout	
Ion Current SMA	
Ion Current	Center
Chassis Ground	Shield

Table 14: Hot Cathode Coaxial Connector Pinout

Hot Cathode Sensors and Cables	
Sensor Type	**Part Number**
All MKS Hot Cathode Gauges Types IG-xx, RG75, and NRC563	consult factory
HPS low power, nude, Bayard-Alpert (B/A) hot cathode KF-40	100005987
HPS low power, nude, Bayard-Alpert (B/A) hot cathode 2¾ CF	100005980
Other nude or B/A tubes - thoriated iridium or tungsten filament	Consult factory
Cable Description	**Part Number**
Cable for glass envelope tubes	CB146-13, CB146S-13
Cable for glass envelope tubes and external power	CB146-16, CB146S-16
Cable for nude hot cathode tube	CB146-19, CB146S-19

Table 15: Hot Cathode Sensors and Cables

Hot Cathode Type "D" Connector Pinout	
Pin Number	**Assignment**
1	Filament +
2	Chassis Ground
3	Filament -
4	+15 Volt Output
5	115 Volt Output
6	Grid/Degas -
7	External -15 Volts (high power)
8	Grid/Degas +
9	Filament +
10	External +15 Volts
11	Filament -
12	Power Ground
13	Grid/Degas -
14	External -15 Volts (Current limited)
15	Grid/Degas +

Table 16: Hot Cathode Type "D" Connector Pinout

Note All ion gauges show an inability to establish an ion current at high pressures. The gauge may respond as if the pressure is extremely low. Keep this characteristic in mind when setting a disconnect threshold, alarm trip points, or if you designate an ion gauge as a reference channel.

Provision for External Power to a Hot Cathode

The 146 unit can supply a maximum of 45 watts to a hot cathode. If the hot cathode is undergoing a high power degas, all of the 45 watts is used for the degassing process. If the hot cathode is undergoing a low power degas, the filament is powered for measurement, and the remaining power is used for the degassing function.

Power from the internal power supply is supplied to the hot cathode board via looping the supply in the rear panel connector. If preferred, a cable can be supplied which does not loop the power into the hot cathode board. The optional cable provides a line that can be connected to an external power source. The external power source would then power the hot cathode board. A 90 watt, ± 15 Volt, external power supply can provide 60 watts for degassing in the high or low power degas mode.

Configuring the Hot Cathode Board for a Low Power Hot Cathode

The Hot Cathode board can be configured for a low power hot cathode (the default is for a high power gauge). MKS will configure the board at the factory, if specified on the order. If you did not request the low power configuration, but wish to use the board with a low power hot cathode, follow these instructions.

Caution

1. Be sure to have the correct setting for your hot cathode. Damage may occur to a low power hot cathode gauge if you operate it with the high power gauge configuration because excessive power would be applied to the grid during degas.

2. If two Hot Cathode (HC) boards are installed in one unit, the HC boards *MUST* be set to low power configuration. Otherwise, the 146 unit may exceed its temperature rating.

Warning

The 146 unit has lethal voltages inside. To avoid the danger of electrical shock, disconnect the power line *before* opening the unit.

1. Be sure the power cord is disconnected.

2. Disconnect all cables from the 146 unit.

3. Remove the four (4) Phillips screws on the outside corners of the rear panel and the seven (7) screws from the top cover.

4. Remove the top cover by firmly pulling it towards the back of the unit. Note the orientation of the cover since the center hole is slightly off center to accommodate a connector if a board is positioned in slot 5.

5. Carefully turn the unit over so that it is bottom-side up and remove the seven (7) screws.

6. Remove the bottom cover by firmly pulling it towards the back of the unit. Note the orientation of the cover since the center hole is slightly off center to accommodate a connector if a board is positioned in slot 5.

7. Remove the Phillips screw that is securing the Hot Cathode board to the bottom of the 146 unit.

8. Carefully turn the unit right-side up.

9. Unscrew the two small screws holding the slot cover on the Hot Cathode board.

10 Carefully but firmly pull the Hot Cathode board out of the unit.

11. Remove one of the shorting jumpers which is currently stored on JP4.

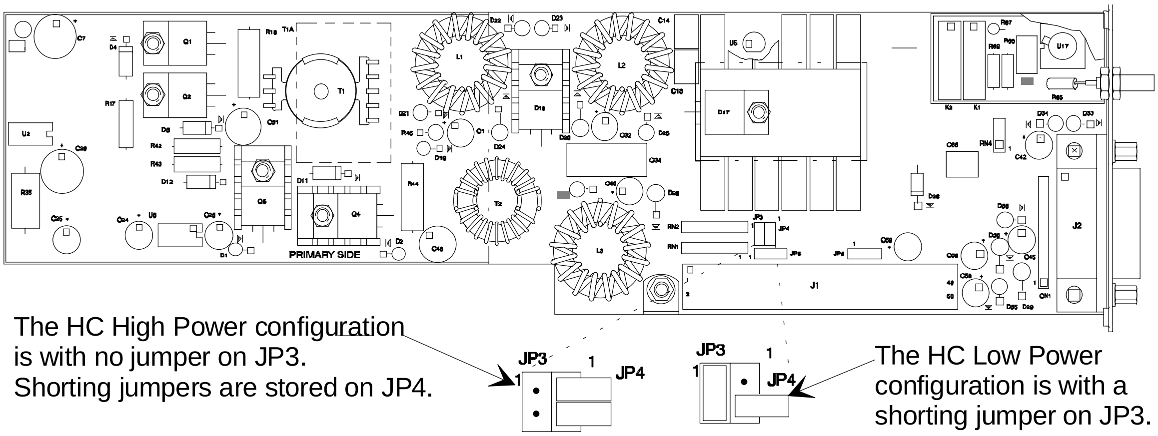


Figure 17: Jumper Placement on the Hot Cathode Board

12. Place the shorting jumper on JP3 to configure the board for a low power hot cathode.

13. Slide the board back inside the unit so that the connectors protrude through the opening in the rear panel.

14. Line the board up so that the female connector on the board is directly over the male connector on the mother board.

15. Gently push the board onto the male connector.

16. Turn the unit over so that it is bottom-side up.

17. Replace the Phillips screw that fastens the board to the 146 unit.

16. Replace the bottom cover by inserting it into the grooves provided, and firmly sliding it towards the front of the unit. Replace the seven (7) screws that fasten the bottom cover.

    The center screw on the bottom cover is slightly off center to avoid interfering with a connector if a board is positioned in slot 5. Be sure to align the cover correctly.

17. Carefully turn the unit right-side up.

18. Replace the top cover by inserting it into the grooves provided, and firmly sliding it towards the front of the unit. Replace the seven (7) screws that fasten the top cover.

    The center screw on the top cover is slightly off center to avoid interfering with a connector if a board is positioned in slot 5. Be sure to align the cover correctly.

19. Replace the four (4) Phillips screws on the outside corners of the rear panel.

20. Plug in the power cord.

Thermocouple Board

The Thermocouple board has two 9-pin female Type "D" connectors since the board can support up to two thermocouple gauges. Table 17 shows the connector pinout. The top connector is the lower numbered channel, and the bottom connector is the higher numbered channel. For example, if this board is installed in slot 1, the top connector is channel 1, and the bottom connector is channel 2.

The 146 instrument supports the following thermocouples:

- MKS TC-1A
- Hastings DV-6M

Note Units equipped with a Thermocouple board cannot carry a CE mark since there are no CE compliant thermocouple gauges available.

Thermocouple Connector Pinout	
Pin Number	**Assignment**
1	Drive +
2	Drive -
3	Signal +
4	Drive -
5	Drive +
6	Gauge ID
7	Digital Ground
8	Keyed Position
9	Chassis Ground

Table 17: Thermocouple Connector Pinout

Cabling Information for the Thermocouple Board		
Cable	**Part Number**	**Available Lengths**
146 to TC-1A	CB146-6-XX, CB146S-6-XX	10 ft to 25 ft
146 to DV-6M	CB146-8-XX, CB146S-8-XX	10 ft to 100 ft
Extension cable, 146 to TC-1A	CB146-7-XX, CB146S-7-XX	26 ft to 100 ft
where XX indicates the length		

Table 18: Cabling Information for the Thermocouple Board

Configuring the Dual Thermocouple Board as Single Channel Board

The Thermocouple board can function as a single channel board. MKS will have configured the board as a single channel board, if you requested it when you placed the order. The board will be configured for dual channel operation if you did not specify single channel operation. If you did not request the single channel configuration, but wish to configure the board for single channel operation, follow these instructions.

Warning **The 146 unit has lethal voltages inside. To avoid the danger of electrical shock, disconnect the power line *before* opening the unit.**

1. Be sure the power cord is disconnected.
2. Disconnect all cables from the 146 unit.
3. Remove the four (4) Phillips screws on the outside corners of the rear panel and the seven (7) screws from the top cover.
4. Remove the top cover by firmly pulling it towards the back of the unit. Note the orientation of the cover since the center hole is slightly off center to accommodate a connector if a board is positioned in slot 5.
5. Carefully turn the unit over so that it is bottom-side up and remove the seven (7) screws.
6. Remove the bottom cover by firmly pulling it towards the back of the unit. Note the orientation of the cover since the center hole is slightly off center to accommodate a connector if a board is positioned in slot 5.
7. Remove the Phillips screw that is securing the Thermocouple board to the bottom of the 146 unit.
8. Carefully turn the unit right-side up.
9. Unscrew the two small screws holding the slot cover on the Thermocouple board.

10. Remove the top fastening screw that is above the upper connector.

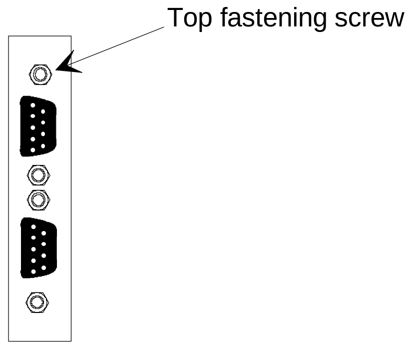


Figure 18: Top Fastening Screw on the Dual Thermocouple Board

11. Carefully but firmly pull the Thermocouple board out of the 146 unit.

12. Locate jumper JP1, as shown in Figure 19.

    There should be a jumper on pin 1.

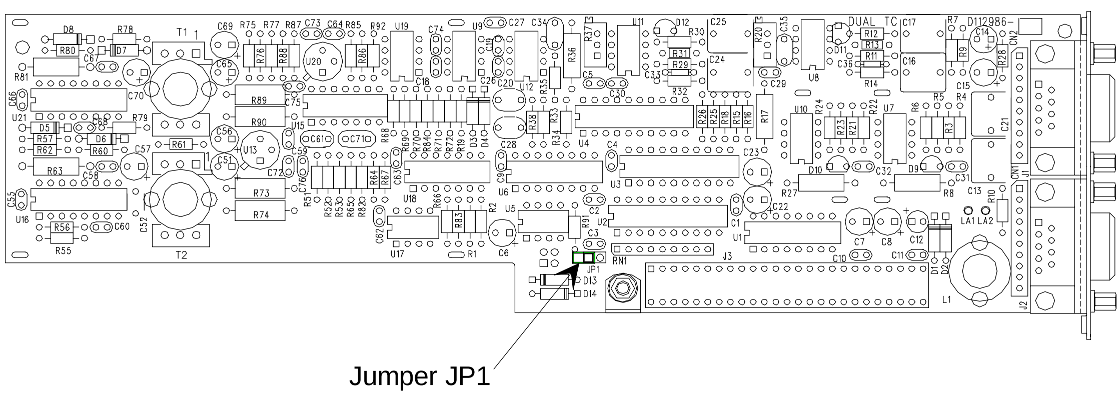


Figure 19: Jumper Placement on the Thermocouple Board

13. Move the jumper to short pins 1 and 2.

    The board is now configured as a single channel Thermocouple board. The top connector becomes the only active channel.

Note Only the top connector is active when the Thermocouple board is configured for single channel operation.

14. Slide the board back inside the unit so that the connectors protrude through the opening in the rear panel.

15. Line the board up so that the female connector on the board is directly over the male connector on the mother board.

16. Gently push the board onto the male connector.

17. Replace the top connector's fastening screw.

18. Turn the unit over so that it is bottom-side up.

19. Replace the Phillips screw that fastens the board to the 146 unit.

20. Replace the bottom cover by inserting it into the grooves provided, and firmly sliding it towards the front of the unit. Replace the seven (7) screws that fasten the bottom cover.

    The center screw on the bottom cover is slightly off center to avoid interfering with a connector if a board is positioned in slot 5. Therefore, the cover must be in the correct orientation for the screw holes to line up properly.

21. Carefully turn the unit right-side up.

22. Replace the top cover by inserting it into the grooves provided, and firmly sliding it towards the front of the unit. Replace the seven (7) screws that fasten the top cover.

    The center screw on the top cover is slightly off center to avoid interfering with a connector if a board is positioned in slot 5. Therefore, the cover must be in the correct orientation for the screw holes to line up properly.

23. Replace the four (4) Phillips screws on the outside corners of the rear panel.

24. Plug in the power cord.

Mass Flow Controller Board

On the end of the Mass Flow Controller (MFC) board is a 15-pin female Type "D" connector. The table below shows the connector pinout. A list of MKS mass flow controllers, along with their cables, is shown in Table 20, page 64.

Mass Flow Controller Connector Pinout	
Pin Number	**Assignment**
1	No Connection
2	Signal In +
3	Valve Close output (active low open collector)
4	Valve Open output (active low open collector)
5	Power Ground
6	-15 Volts
7	+15 Volts
8	Set Point Signal Output
9	Fault Input (active low TTL): Reserved
10	Open
11	Set Point Remote Sense
12	Signal Common
13	No Connection
14	No Connection
15	Chassis Ground

Table 19: Mass Flow Controller Connector Pinout

Note

A "No Connection" assignment indicates that the pin has no internal connection.

Mass Flow Controllers And Cables	
MFC And Cable Type	**Part Number**
All MKS Mass Flow Controllers except Types 1749/1759	Consult the factory for a complete list of MFC types, ranges, and part numbers
Cable for MFCs w/ Edge Card connector	CB147-7
Cable for MFCs w/ 15-pin Type "D" connector	CB147-1, CB147S-1
Cable for MFCs w/ 9-pin Type "D" connector	CB147-12, CB147S-12

Table 20: Mass Flow Controllers and Cables

Note

You must use the appropriate CB147-X cable to enable the MFC override commands. The CB259-5 and CB259-10 cables do not support the open and close override commands. However, using these cables will not damage either unit.

General I/O Connector

The General I/O connector is a 25-pin male Type "D" connector. This connector brings out the analog output 1 signal, Relay A and B contacts, and remote zero, alarm latch, and front-panel-lockout digital control lines. The front panel lockout feature provides a security measure to prevent inadvertent command entry through the front panel. The front panel can also be locked or unlocked via RS-232 communications. The Relay A and B contacts can handle up to 1A at 30 VDC. Table 21 lists the pinout functions of the General I/O connector.

General I/O Connector Pinout	
Pin Number	**Assignment**
1	Chassis
2	$\overline{\text{Remote Zero Channel 3}}$
3	$\overline{\text{Remote Zero Channel 4}}$
4	$\overline{\text{Latch Relay B}}$
5	$\overline{\text{Latch Relay D}}$
6	Digital Ground
7	Reserved
8	Reserved
9	Analog Output 1
10	$\overline{\text{Front Panel Lockout}}$
11	Relay B Normally Open
12	Relay B Common
13	Relay B Normally Closed
14	$\overline{\text{Remote Zero Channel 1}}$
15	$\overline{\text{Remote Zero Channel 2}}$
16	$\overline{\text{Latch Relay A}}$
17	$\overline{\text{Latch Relay C}}$
18	Digital Ground
19	Reserved

Table 21: General I/O Connector Pinout
(Continued on next page)

General I/O Connector Pinout *(Continued)*	
Pin Number	**Assignment**
20	Reserved
21	Reserved
22	Analog 1 Common (Single Ground)
23	Relay A Normally Open
24	Relay A Common
25	Relay A Normally Closed

Table 21: General I/O Connector Pinout

Remote Zero Line Function with Ion Gauges

The Remote Zero lines on the General I/O connector act as an On/Off toggle switch for ion gauges. A high to low transition on the Remote Zero line turns the ion gauge off. A low to high transition turns the ion gauge on. This feature is supported for both hot cathode and cold cathode gauges.

Auxiliary Output Board

The Auxiliary Output board contains relays C and D (which supplement relays A and B), and analog outputs 2 and 3. The modified, male 9-pin Type “D” connector at the top of the board allows operation of 120 VAC devices. The 9-pin female Type “D” connector at the bottom of the board carries relay status, analog output signals 2 and 3, and their return lines. Table 22 lists the pin functions of the relay connections and Table 23 lists the functions for the analog outputs.

Relay Output (Top) Connector Pinout	
Pin Number	**Assignment**
1, 6, 2	Relay C (NO, C, NC)*
4, 9, 5	Relay D (NO, C, NC)*
* *NO = Normally Open, NC = Normally Closed, C = Common to both*	

Table 22: Relay Output (Top) Connector Pinout

Status/Analog Output (Bottom) Connector Pinout	
Pin Number	**Assignment**
1	Relay C Status (high = energized)
2	Relay D Status (high = energized)
3	Reserved
4	Reserved
5	Analog 2 Common (Signal Ground)
6	Analog 3 Out
7	Analog 3 Common (Signal Ground)
8	Analog 2 Out
9	Digital Ground

Table 23: Status/Analog Output (Bottom) Connector Pinout

Auxiliary Output Board - Fail-Safe Feature

Relays C and D on the Auxiliary Output board are associated with the 146 instrument's Fail-Safe feature. When the 146 unit is powered on, this feature is activated. The processor waits until pressure readings are stable before activating any of the relays in the 146 unit.

The Fail-Safe feature includes a timed hardware reset that causes relays C and D to go to default positions. The processor in the 146 unit prevents the timed hardware reset from executing by sending out an interrupt pulse every 10 milliseconds. If the 146 unit's software crashes, the interrupt pulse stops and the timed hardware reset executes, causing relays C and D to go to default positions.

Code 7x in the 146 diagnostics feature, is used to determine if the Fail-Safe system is operating, and its response time. When Code 7x is used, the processor sends a relay setup command to relays C and D, and then checks to see if the relays have responded. If the relays do not respond, the abbreviation **Err** (for Error), appears in the main display. If the relays do respond, the Fail-Safe test continues; the Code 7x function determines the Fail-Safe system response time, and displays it in the main display (in milliseconds). The response time is the elapsed time between when an interrupt pulse is received by the hardware reset, and when relays C and D go to the default position (de-energized state).

To confirm that the Fail-Safe feature is operating properly, refer to *Code 7x: Response Time for Fail-Safe Feature,* page 299.

Control Board

The Control board has two 9-pin Type "D" connectors (one female, one male). The female connector is located at the top of the board. It carries the valve drive lines, and the PCS (pressure control signal) output used for throttle valves or ratio controllers. Table 24 shows the pinout for this connector. Table 27, page 71, shows some of the valves that interface to the 146 unit.

Control Valve (Top) Connector Pinout	
Pin Number	**Assignment**
1	Power Ground
2	+ 15 Volts
3	Analog Set Point +
4	Analog Set Point -
5	PCS Signal
6	Valve Drive +
7	Valve Drive -
8	PCS Common (Signal Ground)
9	Chassis Ground

Table 24: Control Valve (Top) Connector Pinout

When using the Valve Drive + and - outputs (pins 6 and 7 in Table 24), the full scale valve drive current (140 or 200 mA), and the compliance voltage (14 or 26 Volts), must be selected via the proper pin jumpers. For the Type 146 unit, compliance voltage is the voltage needed to sustain a given constant current throughout a range of valve types. Unless otherwise specified in your system configuration sheet, the default jumper packs are JP3 and JP5. This default enables the 146 unit to drive a Type 148 or 248 Valve. Refer to Table 26, page 70, for a complete jumper pack description. Refer to the following instructions to configure the 146 instrument to drive different valves.

The male connector carries open, close, manual, and set point recipe select digital control lines. It also carries the analog set point input. Table 25, page 70, lists the pinout of this connector. Table 28, page 71, lists MKS flow controllers that interface to the 146 unit.

Control Interface (Bottom) Connector Pinout	
Pin Number	**Assignment**
1	Analog Set Point + (signal)
2	$\overline{\text{Set Point B}}$
3	$\overline{\text{Set Point C}}$
4	$\overline{\text{Set Point D}}$
5	Digital Ground
6	Analog Set Point - (return)
7	$\overline{\text{Open}}$
8	$\overline{\text{Manual}}$
9	$\overline{\text{Close}}$

Table 25: Control Interface (Bottom) Connector Pinout

Control Board Pin Jumpers		
Jumper Pack	**Voltage/Current**	**Jumpered For. . .**
JP1	200 mA	154 valve
JP2	reserved	
JP3	140 mA	148, 153, and 248 valves
JP4	26 Volts	154 valve
JP5	14 Volts	148, 153, and 248 valves

Table 26: Control Board Pin Jumpers

Control Valves and Cables		
Valve Type	**MKS Valve**	**Part Number for Cable**
Solenoid	148, 248	CB251-2-10, CB251S-2-10
Smart Throttle (not powered by the 146)	153	CB153-4-10, CB153S-4-10
Smart Throttle (powered by the 146)	153	CB153-13-10, CB153S-13-10
High Flow Solenoid	154	CB251-2-10 w/ CB-248-1 adapter CB251S-2-10 w/ CB-248-1 adapter

Table 27: Control Valves and Cables

Flow Controllers and Cables		
Equipment Description	**MKS Product**	**Cable Number**
4 Channel flow, with CRT	147	CB146-3, CB146S-3
1 Channel Flow	246	CB246-3, CB246S-3
4 Channel Flow	247	CB247-9, CB247S-9

Table 28: Flow Controllers and Cables

How To Configure the Control Board to Drive Different Valves

1. Be sure the power cord is disconnected.

Warning **The 146 unit has lethal voltages inside. To avoid the danger of electrical shock, disconnect the power line *before* opening the unit.**

2. Disconnect all cables from the 146 unit.
3. Remove the four (4) Phillips screws on the outside corners of the rear panel and the seven (7) screws from the top cover.
4. Remove the top cover by firmly pulling it towards the back of the unit. Note the orientation of the cover since the center hole is slightly off center to accommodate a connector on a board positioned in slot 5.
5. Carefully turn the unit over so that it is bottom-side up and remove the seven (7) screws.
6. Remove the bottom cover by firmly pulling it towards the back of the unit. Note the orientation of the cover since the center hole is slightly off center to accommodate a connector on a board positioned in slot 5.
7. Remove the shorting jumpers that are currently placed on and jumper packs numbered JP1 through JP5.

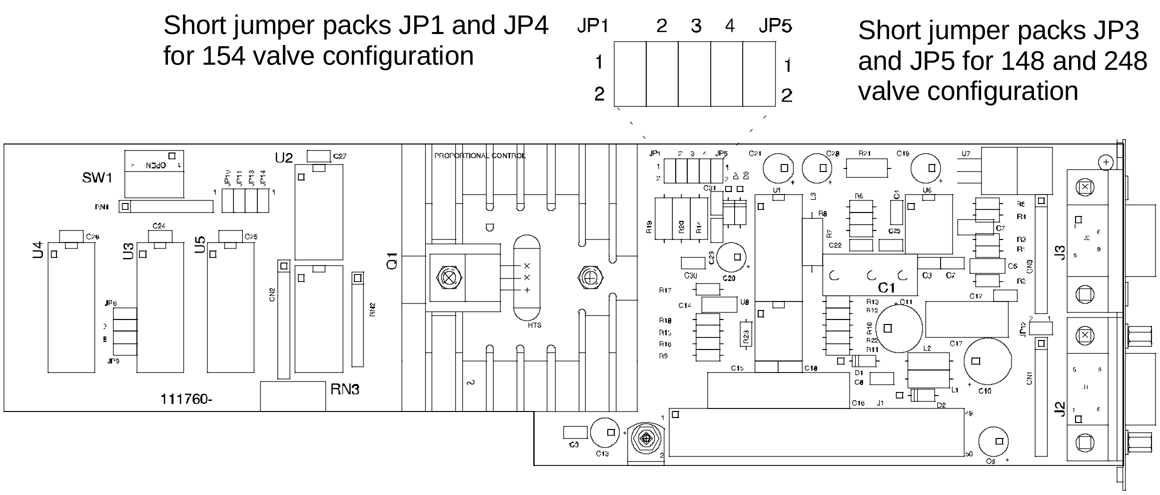


Figure 20: Jumper Placement on the Control Board

8. Place the shorting jumpers on JP1 and JP4 (for a Type 154 valve) or place the jumpers on JP3 and JP5 (for Type 148 or 248 valves).

9. Replace the bottom cover by inserting it into the grooves provided, and firmly sliding it towards the front of the unit. Replace the seven (7) screws that fasten the bottom cover.

   The center screw on the bottom cover is slightly off center to avoid interfering with a connector on a board in slot 5. Therefore, the cover must be in the correct orientation for the screw holes to line up properly.

10. Carefully turn the unit right-side up.

11. Replace the top cover by inserting it into the grooves provided, and firmly sliding it towards the front of the unit. Replace the seven (7) screws that fasten the top cover.

    The center screw on the bottom cover is slightly off center to avoid interfering with a connector on a board in slot 5. Therefore, the cover must be in the correct orientation for the screw holes to line up properly.

12. Replace the four (4) Phillips screws on the outside corners of the rear panel and the seven (7) screws on the top cover.

13. Replace the four (4) screws on the rear panel.

14. Plug in the power cord.

The Displayless Front Panel Connector Pinout

When ordered as an optional displayless unit, the 146 instrument arrives with a front panel that only contains a power switch, LED, and a 25-pin female Type "D" Interface connector. This connector allows an RS-232 communications source to be connected to the front of the displayless unit. The pinout of the connector is listed in Table 30, page 75. The RS-232 cable used on the front panel connector (MKS p/n CB146-21) is not the same as the RS-232 cable used for rear panel communications (refer to Table 32, page 77, for the proper MKS part number).

Both the Interface connector, located on the front panel, and an RS-232 connector, located on the rear panel, support RS-232 communication between the 146 unit and a computer. However, the 146 unit only accepts command messages through one port at a time, though it can report status information on both ports simultaneously. The 146 unit determines which port takes precedence based on the state of pin 4 of the Interface connector.

Pin 4 left open: The rear panel connector (RS-232) is active; the front panel connector (Interface) is passive. The RS-232 connector takes precedence. It will accept command messages and respond to query messages. The device connected to the Interface connector can only receive RS-232 communications that are currently being issued *from* the 146 unit, through the rear panel.

Pin 4 grounded: The front panel connector (Interface) is active; the rear panel connector (RS-232) is passive. The Interface connector takes precedence so that the device connected to the front panel can communicate fully with the 146 unit. Any device connected to the rear panel RS-232 connector can only receive messages that are currently being issued *from* the 146 unit, through the front panel.

For regular operation, use the RS-232 connector on the rear panel to connect the 146 unit to your system. The Interface connector provides a convenient port to connect a portable computer to the 146 unit should you need to troubleshoot the unit.

Pin 8 can supply a +5V signal, which can be used to power one of several types of remote terminals.

The functions on pins 5 and 20 are special options that must be specifically requested from the factory.

Remote Front Panel Cable	
RS-232 Cable to Remote Front Panel	CB146-21, CB146S-21

Table 29: Remote Front Panel Cables

Front Panel Connector Pinout on the Displayless 146 Unit	
Pin Number	**Assignment**
1	Chassis Ground
2	RS-232 Transmit
3	RS-232 Receive
4	$\overline{\text{RS-232 Receive Enable}}$ (connect to digital ground to override rear connector RS-232)
5	RS-232 CTS (special option)
6	Spare
7	Digital Ground
8	Filtered +5 Volts
9	Keyboard P4
10	Keyboard P5
11	Keyboard P6
12	Keyboard P7
13	Keyboard P8
14	Display Backlight Enable
15	Display Data U2
16	Display Data U3
17	Display Data U4
18	Display Data Clock
19	Keyboard P3
20	RS-232 RTS (special option)
21	Keyboard P2
22	Keyboard P1
23	Keyboard P11
24	Keyboard P10
25	Keyboard P9

Table 30: Front Panel Connector Pinout on the Displayless 146 Unit

The Binary Coded Decimal (BCD) Board

The BCD board has an unwired, 25-pin female Type "D" connector. This board provides input/output signals for hot cathode gauges.

The first four signals listed are inputs. The active low for the inputs requires about a 1 mA sink, 0.8 Volts maximum. The data inputs are read every 100 ms and require the recognition of a transition. A minimum pulse width of 100 ms must be observed for the inputs to be activated.

The remaining signals are outputs. The open collector is tied to +5 Volts with 5.6K ohms. Data changes after the falling edge of a strobe, and is valid on the strobe's rising edge. The strobe pulse is approximately 5 microseconds, and the BCD data is updated at a rate of 100 ms.

BCD Connector Pinout	
Pin Number	**Assignment**
3	$\overline{\text{Remote Off}}$
4	$\overline{\text{Remote Degas}}$
16	Reserved
17	Reserved
18	Least significant digit 1
19	Least significant digit 2
6	Least significant digit 4
5	Least significant digit 8
20	Most significant digit 1
21	Most significant digit 2
8	Most significant digit 4
7	Most significant digit 8
22	Exponent digit 1
23	Exponent digit 2
10	Exponent digit 4
9	Exponent digit 8
11	Exponent digit 10
24	Strobe
25	Status

Table 31: BCD Board Pinout

(Continued on next page)

BCD Connector Pinout *(Continued)*	
Pin Number	**Assignment**
12	Inverse of Status
2, 14	External Digital Ground
13	Digital Ground (Reserve)
1 and shell	Chassis Ground
15	Digital +5 Volts (Reserved)

Table 31: BCD Board Pinout

The RS-232 Connector

Located on the rear panel is the standard, 9-pin male Type "D" connector that is used for serial communications. Table 32 lists the pin functions employed by this interface. The *RS-232 Communications* chapter describes the RS-232 protocol used in the 146 unit.

RS-232 Connector Pinout and Cables	
Pin Number	**Assignment**
2	TXD*
3	RXD*
5	Digital Ground
7	CTS*
Cable for AT® or compatible	CB-146-2, CB-146S-2
Cable for XT® or compatible	CB-146-4, CB-146S-4
* *TXD =Transmit Data, RXD =Receive Data, CTS =Clear To Send*	

Table 32: RS-232 Connector Pinout and Cables

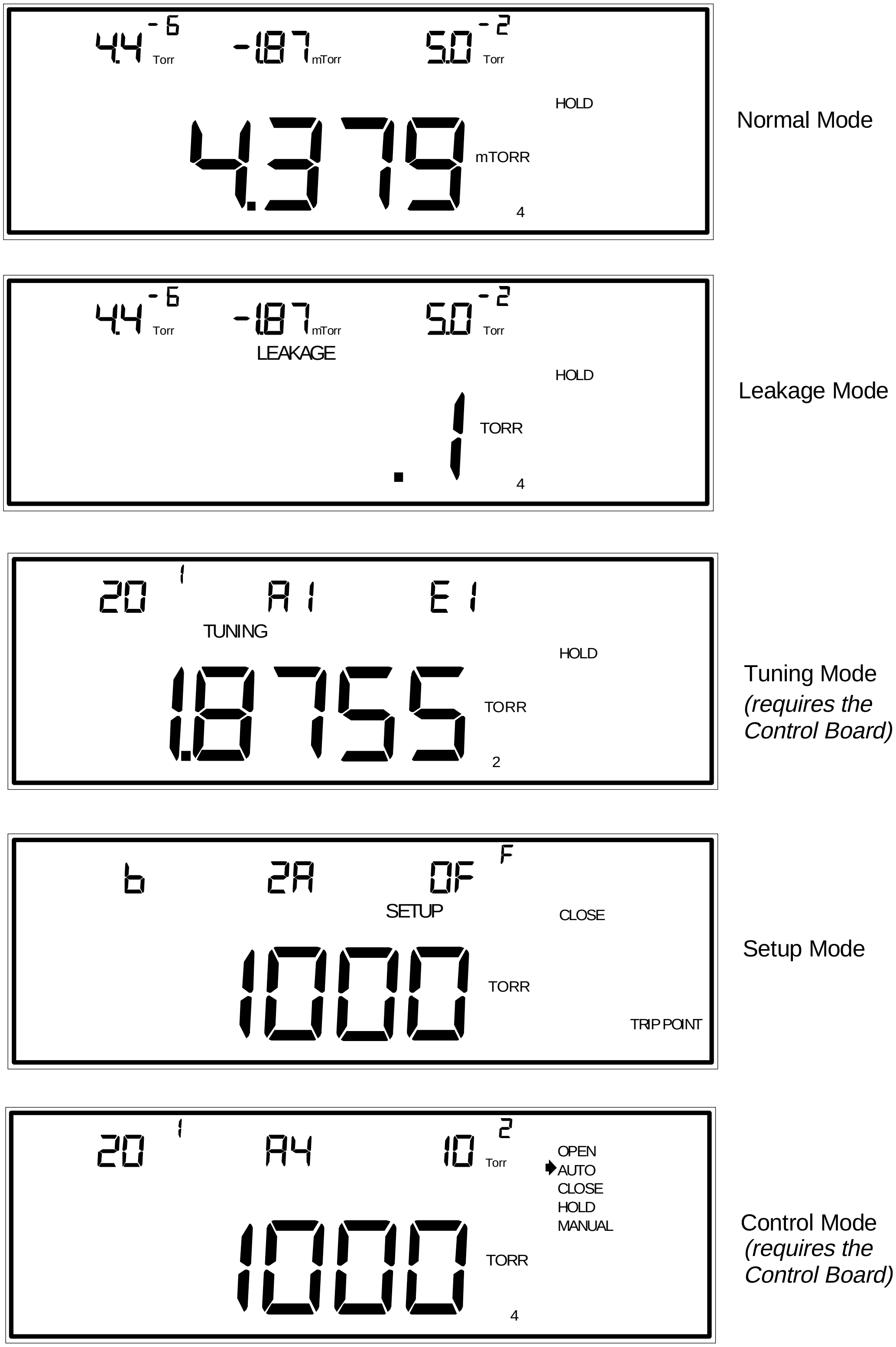


Figure 21: Sample Display for Each Mode

Overview of Modes

There are three standard modes for the 146 unit: Normal, Leakage, and Setup. Two additional modes are available if the optional Control board is installed: Control and Tuning. All commands for all modes are accessible with the front panel keypad. Most commands are accessible through the RS-232 communications port. Some operating conditions (such as valve control functions), are also operable through hardwired connections on the rear panel.

When the 146 unit is powered up, it goes through a full screen LCD test, and all displays in the front panel window light up. After roughly five seconds, the screen changes and the unit defaults to Normal Mode.

How To Tell which Mode You Are In

Refer to Figure 21, page 78, for a sample figure of each mode. Each mode provides a main display and three upper displays.

Normal Mode	The screen is *not* labeled.
Leakage Mode	Displays the LEAKAGE legend.
Setup Mode	Displays the SETUP legend.
Tuning Mode	Displays the TUNING legend.
Control Mode	Displays the five valve positions (OPEN, AUTO, CLOSE, HOLD, and MANUAL). When entering Control Mode from Leakage, Tuning, or Setup Modes, the legends for those modes continue to be displayed. It is the presence or absence of the complete valve position list that indicates whether or not the 146 unit is in Control Mode.

How To Change from One Mode to Another

Use the [DISPLAY MODE] key to scroll through Normal, Leakage, Tuning, and Setup Modes.

Use the [CONTROL MODE] key to toggle in and out of Control Mode.

Overview of the Five Modes

Normal

Normal Mode is the default mode, and is a general system status mode. When in this mode, the default is for the channel 1 pressure reading to appear in the main display. The exception to this is if all four channels are used, whereupon the pressure reading for channel 4 appears in the main display. Channel 4 can only be monitored in the main display.

Leakage

Leakage Mode is indicated by the legend LEAKAGE . Leakage Mode is similar to Normal Mode because the same functions can be performed in both modes. The major difference is what is shown in the Main display. *Instantaneous leakage*, or *leakage rate* is shown in the main display when the unit is in Leakage Mode.

Leakage Rate is the rate of pressure change over a user-defined time period. Instantaneous leakage is the difference between base pressure and the current sensor reading. Base pressure simply means the initial pressure recorded when Leakage Mode is first entered. Base pressures are stored for each channel.

Leakage Mode can be used as a general system status mode, or for maintenance. If a system does not maintain its pressure, this mode can be used to show how fast the system is leaking.

Normal and Leakage Mode Sensor Status Messages

In addition to a normal display of pressure, the 146 unit provides important sensor status information in the channel displays. When appropriate, this information replaces the display of pressure. The status information is presented as follows:

Normal and Leakage Mode Status Codes	
A blank display	No channel installed.
E0	Disconnected sensor. If any sensor becomes disconnected from a powered channel, the NO SENSOR legend appears on the right side of the window, and the channel's pressure reading is replaced with **E0**.
E1	Bad sensor. A sensor is considered bad if it is unable to provide pressure information. This determination is sensor dependent. The bad sensor's pressure reading is replaced with **E1**.
" - - - - "	Underrange sensor (lower segments of the display are turned on) When a sensor's input goes under range, the UNDERRANGE legend appears on the right side of the window.

Table 33: Normal and Leakage Mode Status Codes
(Continued on next page)

Normal and Leakage Mode Status Codes *(Continued)*	
" - - - - "	Overrange sensor (upper segments of the display are turned on) When a sensor's input goes over range, the OVERRANGE legend appears on the right side of the window.
" .. " or " .... "	Channel turned off (decimal points in the display are turned on)
" . "	Channel auto-powered off. A single decimal point is displayed for any ion gauge channel that is turned off with the Auto Power feature. This distinguishes it from a user commanded turn off condition.

Table 33: Normal and Leakage Mode Status Codes

Setup

Setup Mode is indicated by the SETUP legend. Setup Mode is used to set up the 146 unit to operate according to the needs of a particular control system. For example, alarm trip points are entered in Setup Mode, and the 146 instrument can be set up to read pressure over a range that is spanned by two sensors. All miscellaneous codes for the 146 unit are contained within Setup Mode.

Tuning

Available only if the Control board is installed

This mode is indicated by the TUNING legend. In Tuning Mode, specific control parameters can be adjusted to help fine tune the 146 unit for optimum control performance. These parameters can be changed individually as the need arises, or changed as part of an associated collection of control parameters, called a recipe. In either case, the best lead and gain parameters can be matched with different set points, and associated with a different control channel.

In Tuning Mode there is a deviation indicator which indicates where the controlling sensor's pressure reading is relative to set point.

Control

Available only if the Control board is installed

The Control Mode is used to control a valve in one of five ways. The five valve control positions are OPEN, AUTO, CLOSE, HOLD, and MANUAL. In addition, one of the four recipes (edited in Tuning Mode), can be selected as the active recipe. When the 146 unit is set to operate in AUTO mode, it uses the parameters associated with the active recipe to operate the control valve.

In Control Mode there is a deviation indicator which indicates where the controlling sensor's pressure reading is relative to set point.

Operational Diagram

Included with this manual is an operational diagram depicting the procedures used to perform tasks with the 146 unit. The purpose of the diagram is to provide a pictorial quick reference guide to the different modes of the 146 unit, the functions (tasks) contained within each mode, and instructions needed to perform those functions. The instructions included in the diagram are complete, but terse. Once you are familiar with the 146 instrument, however, this diagram may be all you need to refresh your memory on how to perform the functions shown.

The black text in the diagram represents keys on the front panel of the 146 unit. For example, the word [ENTER] is written in black text and it represents the [ENTER] key on the 146 front panel. Blue text is used for instructions and general information. For example, the instruction *1. Enter sensor range* is written in blue text. Red text designates the five modes of the 146 unit (*Normal, Leakage*, *Setup*, *Tuning*, and *Control*), and the functions the instrument can perform (smaller red text). For example, the function *Set Alarm Trip Points* is written in red text. Heavy black lines separate the modes.

The different colors of the wedges in the chart indicate the flow of instructions. Starting at the center of the diagram, you may enter any of the black wedges containing a mode name (large, red text), by pressing the key indicated. For example, use [CONTROL MODE] to enter Control Mode, and use [DISPLAY MODE] to scroll through the other modes. Once in the correct black wedge, the flow of instructions always proceeds to a new colored wedge that is touching whatever wedge you are in. The sequence is always black to blue, blue to red, and red to green.

Example 1:

SELECT A MODE

Starting at the center of the diagram, the 146 unit defaults to Normal Mode (this is indicated by the dotted line arrow). Use the [DISPLAY MODE] key to scroll to Leakage Mode.

PROCEED TO A BLUE COLORED WEDGE

There is only one new colored wedge touching the Leakage Mode wedge. This is the blue colored wedge that Leakage Mode shares with Normal Mode. The wedge contains general information.

PROCEED TO A RED COLORED WEDGE

There are 10 red colored wedges touching the blue wedge you are in. You may perform any of the functions described in those wedges. For example, one function listed is *Turn a Channel On or Off*. To accomplish this, follow the directions inside the function’s red colored wedge.

Example 2:

SELECT A MODE

Starting at the center of the diagram, the 146 unit defaults to Normal Mode. Use the [DISPLAY MODE] key to scroll to Tuning Mode.

PROCEED TO A BLUE COLORED WEDGE

There are two blue colored wedges touching the Tuning Mode wedge. Choose the one that reads *To edit recipes:*. Contained in this blue wedge are instructions. When you complete the instructions you may move on to the next new colored wedge.

PROCEED TO A RED COLORED WEDGE

There is only one red colored wedge into which you may move. The wedge contains general information.

PROCEED TO A GREEN COLORED WEDGE

There are three green colored wedges touching the red wedge you are in. You may perform any of the functions described in those wedges. For example, one function listed is *Adjust Set Point*. To accomplish this, follow the directions inside the function's green colored wedge.

Example 3:

SELECT A MODE

Starting at the center of the diagram, the 146 unit defaults to Normal Mode. Use the [DISPLAY MODE] key to scroll to Tuning Mode (the same mode as in example 2).

PROCEED TO A BLUE COLORED WEDGE

There are two blue colored wedges touching the Tuning Mode wedge. This time, choose the one that reads *To adjust parameters:*. Contained in this blue wedge are instructions. When you complete the instructions you may move on to the next new colored wedge.

PROCEED TO A RED COLORED WEDGE

There are 6 red colored wedges touching the blue wedge you are in. One of these wedges is the same red wedge we moved into in example 2. This means that there are two avenues that you may follow to reach the same three functions (Adjust Set Point, Gain, and Lead). In this example, however, choose the red wedge which contains the function *Adjust Start*. Follow the instructions written in this red wedge to adjust the value for Start.

Effects of Channel Changes

When a Channel's Condition Changes from Measuring To . . .

Source Channel goes from Measuring to:	PCS Output currently in Auto Mode	Analog Output (see note #1)	Relay Operation	Auto Power Reference Channel	Dual Channel Operation
Manual off	Normal operation, use default overrange pressure.	Output goes to 10.5 VDC.	Deactuated and Alarm turns off (see note #2)	Disabled. If source channel is Auto Off, it becomes Manually Off.	Normal operation but Manually Off in continuous range.
Auto off	Normal operation, use default overrange pressure.	Output goes to 10.5 VDC.	Deactuated and Alarm turns off (see note #2)	Disabled. If source channel is Auto Off, it becomes Manually Off.	Normal operation but Auto Off in continuous range.
Disconnected	Normal operation, use default overrange pressure.	Output goes to 10.5 VDC.	Deactuated and Alarm turns off (see note #2)	Disabled. If source channel is Auto Off, it becomes Manually Off.	Normal operation but Disconnected in continuous range.
Underranged	Normal operation, use default underrange pressure.	Normal operation, use default underrange pressure.	Normal operation, use default underrange pressure.	Normal operation, use default underrange pressure.	Normal operation but underrange in continuous range.
Overranged	Normal operation, use default overrange pressure.	Normal operation, use default overrange pressure.	Normal operation, use default overrange pressure.	Normal operation, use default overrange pressure.	Normal operation but overranged in continuous range.
Failed	Normal operation, use default overrange pressure.	Output goes to 10.5 VDC.	Deactuated. (see note #2)	Disabled. If source channel is Auto Off, it becomes Manually Off.	Normal operation but Failed in continuous range.
Zeroing	Normal operation	Normal operation	Normal operation	Normal operation	Normal operation

Table 34: When a Channel's Condition Changes from Measuring To ...

When a Channel's Condition Changes to Measuring/Initializing From . .

Source channel goes to Measuring or Initializing from:	PCS Output currently in Auto Mode	Analog Output (see note #1)	Relay Operation	Auto Power Reference Channel	Dual Channel Operation
Manual off	Normal operation	Normal operation	Normal operation	Re-enabled if it was enabled before being turned off, and the source channel remains Manually Off.	Normal operation
Auto off	Normal operation	Normal operation	Normal operation	Re-enabled if it was enabled before being turned off, and the source channel remains Manually Off.	Normal operation
Disconnected	Normal operation	Normal operation	Normal operation	Re-enabled if it was enabled before being disconnected, and the source channel remains Manually Off.	Normal operation
Underranged	Normal operation	Normal operation	Normal operation	Normal operation, use default underrange pressure.	Normal operation
Overranged	Normal operation	Normal operation	Normal operation	Normal operation, use default overrange pressure.	Normal operation
Zeroing	Normal operation	Normal operation	Normal operation	Normal operation	Normal operation

Table 35: When a Channel's Condition Changes To Measuring/Initializing From ...

Notes

Note 1: The information in this column applies to all analog outputs *except for set points*. Set point type analog outputs continue to output the specified set point voltage regardless of the source channel's condition.

Note 2: The stated result will not occur if the relay is currently tripped or latched. If the latched condition is removed, the relay will respond as stated. Additionally, if the alarm is on, it will turn off.

Overview of Alarms

From a design viewpoint, the alarm system in the 146 unit consists of several, single pole, double throw relays. Two alarms (A and B) come standard with the 146 unit and are available on the General I/O connector. The optional Auxiliary Output board provides two additional alarms (C and D).

From an operational viewpoint, the alarm system consists of user-defined *alarm trip points*, user-defined relay *untripped states*, a user-defined relay *latching state*, and front panel window displays. Also, users can turn individual alarms, or the entire alarm audio system, on or off.

Individual alarms can be turned on/off in Normal or Leakage Modes (refer to *How To Turn an Alarm On or Off,* in either the *Operation in Normal Mode* or *Operation in Leakage Mode* chapter). When an individual alarm is turned off, the alarm's relay will be in its deactuated state, and nothing associated with that alarm (alarm audio tone, alarm diamond display, or alarm relay activity) will change regardless of the pressure.

Alarm trip points are entered, and individual alarms can be turned on/off (enabled/disabled) in Setup Mode (refer to *How To Set Alarm Trip Points,* in the *Operation in Setup Mode* chapter). The alarm audio tone (a continuous high tone) can be permanently turned on/off in Setup Mode (refer to *How to Adjust Alarms,* in the *Operation in Setup Mode* chapter).

To understand how to configure the alarm relay system in the 146 unit, it is necessary to understand what an *alarm condition* means. In the 146 instrument, **an alarm condition exists when pressure rises above the alarm trip point pressure**. The alarm condition is indicated by a diamond on the left side of the front panel, and an alarm audio tone. In addition, if the alarm is set to remain latched after an alarm condition ceases (the pressure drops below the alarm trip point), then a LATCHED legend also appears on the front panel.

The first alarm relay parameter to set up is the relay *untripped state*. Actuation and deactuation simply refer to how an alarm relay is configured during a non-alarm condition. The relay untripped state is adjusted in Setup Mode. Individual alarms can be assigned an actuated or deactuated state.

When a relay is set up as actuated, the letter **A** appears in the center display when adjusting the alarm trip point in Setup Mode. When a relay is set up as deactuated, the letter **d** appears in the center display. Refer to *How To Set Alarm Trip Points* in the *Operation in Setup Mode* chapter, for instructions on how to change the actuation state of an alarm. If a relay is set up as a deactuated relay and an alarm condition arises, the relay will respond as shown in Figure 22. (The signals are available on the General I/O connector.)

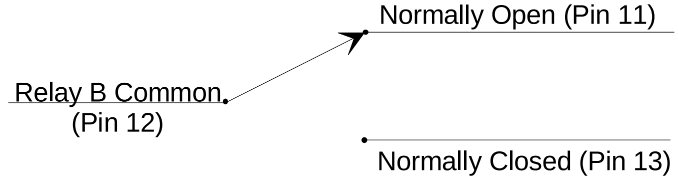


Figure 22: Relay B during an Alarm Condition, when configured as a Deactuated Relay

If a relay is set up as an actuated relay and an alarm condition arises, the relay will be configured as shown in Figure 23.

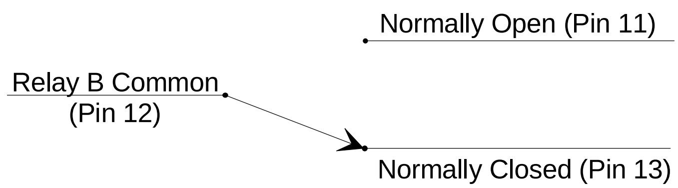


Figure 23: Relay B during an Alarm Condition, when configured as an Actuated Relay

Refer to Table 21, page 65, for the pinouts of relays A and B, and Table 22, page 67, for the pinouts of relays C and D.

The last user-defined function is the relay *latching state*. This parameter determines the alarm relay behavior after an alarm condition ceases. If the relay latching state is activated (a low at the rear panel input), a relay remains in its alarm position even after pressure drops below the alarm trip point. If the relay latching state is deactivated (high), a relay returns to its previous position after the pressure drops below the alarm trip point.

The alarm latching state can only be altered via a signal sent through the General I/O connector on the rear panel (contact closure to ground), or with an RS-232 *unlatch-all-alarmed-relays* command. If no latching signal is connected to the rear panel, the relay latching status is deactivated (high), and the relay will switch contacts back and forth as the pressure crosses above and below trip point.

For example, assume relay B is set to be actuated during an alarm condition, but the pressure is still below the alarm trip point. The relay latching state for alarm B is not activated. When the pressure rises above the trip point set for alarm B, relay B switches contacts (Figure 23). When the pressure drops below the trip point again, the relay switches back to its previous position because the relay latching state is deactivated.

Use relay B as our second example, and it is still set to be actuated during an alarm condition. In this example, however, the latching state is *activated*. When the pressure rises above the trip point set for alarm B, relay B switches contacts as it did before. The relay is said to be latched. When the pressure drops below the trip point again, the relay does **not** change contacts. The relay remains latched until it is unlatched via the General I/O connector, or through the RS-232 command (only possible if the pressure is below the trip point).

Default Settings of the Trip Point Alarms	
Parameter	**Default Setting**
Actuation State	Actuated
Channel	1
Latching State	Disabled
Trip Point Value	1000 Torr

Table 36: Default Settings of the Trip Point Alarms

Alarm Conditions

An alarm condition occurs when a channel's pressure reading goes over the alarm trip point. When an alarm condition arises, the 146 responds in four ways. In this example, the latching state is enabled, but the relay is initially unlatched.

1. The alarm audio tone starts. This can be quieted with the [QUIET/CANCEL] key.

2. A diamond is displayed on the left side of the front panel window, and corresponds to one of the four red alarm letters beside it on the front panel. A diamond indicates an alarm condition, and not the status of the alarm relays.

3. The alarm relay condition switches. That is, if a relay contact was open, it becomes closed.

4. If the latching state for the alarm is enabled, a LATCHED legend appears on the left side of the front panel window. The latched legend indicates the state of the alarm relay after an alarm condition, not the state of the alarm condition itself. If the latching state for the alarm is disabled, no LATCHED legend appears.

Note An alarm audio tone goes off if a gauge becomes disconnected. This is not a trip point alarm condition, and no relays are altered. To remedy the situation, reconnect the sensor and press the [QUIET/CANCEL] key.

Here are two scenarios to further illustrate what happens in an alarm condition, and what happens when a sensor (on an active channel) is disconnected.

Scenario 1: A Trip Point Alarm Condition

In this situation, all the relays are unlatched, and no alarm conditions are present. The alarm latching state is enabled.

1. The pressure reading on a channel goes above the alarm trip point for that channel.
   - A. The alarm audio tone goes off.
   - B. A diamond appears in the front panel window, corresponding to a red alarm letter on the front panel.
   - C. An alarm relay switches contacts (and becomes latched because of the latching state).
   - D. A LATCHED legend appears in the front panel window.

2. Quiet the alarm audio tone by pressing the [QUIET/CANCEL] key.
   - A. The alarm audio tone is quieted, but the relay remains latched.
   - B. An alarm audio tone will go off again during the next alarm condition, regardless of the relay latching state.

3. The channel's pressure reading drops below the alarm trip point.
    A. The diamond in the window disappears, but the relay remains latched.
4. Unlatch the alarm relay via the connector on the General I/O connector.
    A. The alarm relay becomes unlatched.
    B. The LATCHED legend in the window disappears.

Scenario 2: A Disconnected Sensor

In this situation, the alarm relay status is irrelevant, as is the latching state.

1. A sensor becomes disconnected.
    A. The alarm audio tone goes off.
    B. An UNDERRANGE legend temporarily appears in the upper right section of the front panel window.
    C. A NO SENSOR legend is displayed in the window, corresponding to one of the four yellow channel numbers on the right side of the front panel.
    D. The code E0 replaces the pressure reading in the sensor's channel display.
2. Quiet the alarm audio tone with the [QUIET/CANCEL] key.
    A. The alarm audio tone is quieted.
    B. An alarm audio tone will go off again during an alarm condition, or if another sensor becomes disconnected.
3. Reconnect the sensor.
    A. The NO SENSOR legend in the window disappears.
    B. The sensor's pressure reading replaces the E0 code in the appropriate display.

System Design Elements

This section discusses, in a general way, how the 146 instrument can be used to control a pressure/vacuum system. A Control board must be installed in the 146 instrument for the control capabilities to function. The 146 instrument utilizes three parameters of control (gain, lead, and integral), and these are discussed in some detail. This section also provides basic information about pressure control, and explains how to recognize and correct pump choking.

General Control Theory

The 146 instrument can control a gas system via mass flow control with an MFC. The more typical source of control is with pressure sensors. Only one sensor can control the gas system at any one time. That is, the pressure reading from only one sensor is compared to a set point and used to create a valve drive signal. To change which sensor is being used to control the system, you change the channel designated as the control channel. The control parameters for each Control board can be stored in a “control recipe.” The 146 instrument supports up to four control recipes. These recipes can be edited in Tuning Mode. Each control recipe can be associated with a different channel by selecting a different control channel in Setup Mode.

The control system for a 146 instrument typically consists of six parts:

- the sensor(s)
- a gas supply
- a control valve (gas inlet or exhaust throttle valve)
- a process chamber
- a pumping system
- the 146 instrument

The system may also include one or more ratio flow controllers, or mass flow controllers if controlling via mass flow.

Normally, gas pressure is controlled by altering the pumping speed of a pump that removes gas from the system (less frequently, it is regulated by controlling gas flow into the system via a control valve). The 146 instrument can regulate the control valve, be it a downstream throttle valve or an upstream solenoid valve, or control one or more ratio flow controllers. If a Control board is not installed in the 146 instrument, a separate controller must be used to control gas pressure.

When controlling gas pressure, the 146 unit obtains a pressure reading from a sensor operating on the control channel, and compares the reading with a set point. It then sends an external control signal to position a downstream throttle valve, an upstream solenoid valve, or to regulate one or more ratio flow controllers. The gas system is continuously regulated to ensure that the actual pressure reaches, and is maintained at, the set point pressure.

The 146 instrument utilizes Proportional-Integral-Derivative (PID) control found in most industrial controllers today. The P-I-D parameters operate according to an equation. These parameters are:

1. Proportional control action (Gain) is used as a constant to create a valve drive signal that is proportional to the error signal, (the error signal is the result of comparing actual pressure with the set point). The error signal is then multiplied by a gain setting, thus creating a proportional valve drive signal. The higher the gain, the greater the change in the valve drive signal. Thus, the response is proportional to the gain.

   Provided that the gain is not set too high, adjusting it allows the system to approach set point more quickly than if a lower gain setting is used. The best tuned gain is maximized without promoting overshoot.

   $$\textbf{Valve Drive Signal} = \mathbf{K_1} \ \mathbf{x} \ \textbf{Error Signal}$$

   (K_1 is adjusted by changing the gain setting)

2. Integral control action creates a valve drive signal that is proportional to the magnitude and sign of the area under the error signal curve (error signal with respect to time).

   $$\textbf{Valve Drive Signal} = \mathbf{K_2} \ \mathbf{x} \int \textbf{(Error Signal)dt}$$

   As time passes the valve position is changed. Due to integration (and good control), the error signal approaches and is reduced to zero. An increase in the integral value increases the period of time over which the error signal is generated, and system response gets slower. This helps offset potential oscillation caused by a high gain setting.

3. Derivative control action (Phase Lead) creates a valve drive signal that is proportional to the rate of change of the sensor pressure reading. Derivative is the lead, or anticipation factor.

   $$\textbf{Valve Drive Signal} = \mathbf{K_3} \ \mathbf{x} \ \frac{\textbf{d(pressure)}}{\textbf{dt}}$$

   (K_3 is adjusted by changing the lead setting)

   Part of the lag in a control system is caused by the fact that the current pressure reading is no longer accurate by the time it is used in the PID calculations. To overcome this, the current reading is compared with a previous reading, and then the rate of change is extrapolated to arrive at a new pressure reading. The new reading more accurately represents the true pressure. The new pressure reading is substituted for the current reading in PID calculations. Thus, the derivative control mode provides an anticipation element. The valve drive signal then causes the control valve to approach its steady state position sooner than it would if there was no derivative in the above equation.

Pressure Control

The speed of pressure response is relative, and depends on chamber size and the pressure range in which the system is operating. Lower pressures (less than 10 mTorr) are usually slower because of the slower molecular flow (and reduced pumping speed). The maximum rate of rise (or fall) of pressure is determined by the following formula:

$$\frac{dP}{dt} = \frac{Fin - Fout}{V}$$

where:

$\frac{dP}{dt}$ = rate of pressure rise (or fall) in Torr/second

Fin = gas flow into the chamber in Torr-liters/second

Fout = gas flow out of the chamber (to the pump) in Torr-liters/second

V = chamber volume in liters

In systems with small flows and relatively large chamber volumes, the pressure rises (or falls) slowly. This occurs even when the control valve is fully opened or closed. With a fast upstream control valve, the maximum rate of pressure drop is a function of pump speed, and the chamber volume, but the maximum rate of pressure rise is a function of the pump speed, chamber volume, and valve size.

Pump Choking

Choking is a situation that sometimes occurs, and is the result of a peculiarity of all diffusion pumps. If too much gas is introduced at too high a pressure (that is, too great a flow rate), the pumping speed can change radically and erratically. This occurs for several reasons. For example, the pump can fill up (since the evacuation rate is less than the incoming flow rate), and as a result it momentarily cannot take up any more gas. Also, it may be that the pumping mechanism is slowed down by high friction.

In any case, the situation is easily recognized by lack of stability at the set point, and by pneumatic noise. Closing down the inlet to the pump is the only solution. Diffusion pumps should never be operated at pump inlet pressures higher than the maximum pressure set by the pump manufacturer. Refer to the specifications for your pump to determine the maximum allowable inlet pressure. A restriction between the pump and chamber may be necessary to prevent pump choking.

Mass Flow Control

The MFC board allows the 146 instrument to communicate with mass flow controllers (MFCs) to regulate the flow of gas into a system. The 146 instrument can operate in either set point, totaling, or ratio flow control mode. To select which parameter to use for control, refer to *Code 17x: Adjust MFC Set Point, Mode, and Co-channel* in the Operation in Setup Mode chapter. To select the MFC as the controlling channel, refer to *Code 14x: How To Select Polarity and the Control Channel* also in the *Operation in Setup Mode* chapter.

Set Point Mode of Operation

When using the Set Point mode of operation, the 146 instrument sends out a voltage corresponding to a user-defined set point (in sccm). The set point voltage takes into account any zero offset which may have resulted from zeroing the MFC, to ensure that the MFC controls to the desired flow rate. The 146 instrument can operate up to four MFCs. Each MFC operating in Set Point mode has a set point value assigned to it.

Totaling Mode of Operation

When using the Totaling mode of operation, two MFCs operate in conjunction with each other. One MFC (defined as the co-channel), operates according to a fixed set point. The other MFC, defined as the totaling MFC, adjusts its output voltage to maintain a user-defined total flow rate (set point) for the system. For example, you want to maintain a flow rate of 100 sccm. Enter a set point of 100 sccm and set the co-channel to a fixed flow rate of 20 sccm. The totaling MFC will subtract 20 (flow rate of the co-channel) from 100 (the set point) and adjust its voltage to produce a flow rate of 80 sccm. Therefore, the total flow rate will be 100 (20 + 80). As with the Set Point mode of operation, the 146 instrument accounts for any zero offset.

Ratio Flow Control Mode of Operation

In a Ratio control mode, the 146 instrument is capable of controlling up to four MFCs. The 146 uses a pressure control signal (PCS), or a total flow signal, as feedback. The Ratio mode uses a logical control channel to execute the PID control algorithm and achieve the desired gas ratio. The logical control channel (control channel 0) is present even if no Control board is installed. The 146 instrument calculates the control signal to correct the gas ratio and sends the signal to all MFCs configured for Ratio control.

Two possible control methods exist within Ratio mode: control with a pressure measuring control channel, and control with a flow measuring (MFC) control channel.

The ratio controllers maintain the *gas ratio*, and the 146 instrument maintains the absolute *pressure* by controlling the *total flow*.

Essentially, the Ratio mode of operation scales and proportions the 0 to 10 Volt control signal among the MFCs configured for Ratio mode, based on their chosen ratio set points. The set points can range from 0 to 200%. Since most MFCs accept a 0 to 5 Volt signal, the control signal for a given MFC is always scaled by ½, then multiplied by the ratio set point percent:

$$\text{MFC control signal} = \tfrac{1}{2}\,(\text{control signal})(\text{ratio set point }\%/100)$$

Example 1: Assume you have two MFCs configured for ratio control and you change the control set point to 100%. Each MFC has a set point of 50%. The PID control algorithm determines that full scale flow is required to meet the new set point, so the equation becomes:

MFC control signal = ½ (10 Volts)(50%/100) = 2.5 Volts

Each MFC would receive a 2.5 Volt control signal.

Example 2: If the control algorithm determined that the change necessitates a 60% flow rate, the equation becomes:

MFC control signal = ½ (6 Volts)(50%) = 1.5 Volts

Each MFC would receive a 1.5 Volt control signal.

Example 3: Assume that you have three MFCs with ratio set points of 10%, 30%, and 60%. The PID algorithm determines that a 75% control signal is required to meet the control set point. The 146 instrument calculates the control signal for each MFC:

MFC 1 = ½ (7.5 Volts)(10%) = 0.375 Volts

MFC 2 = ½ (7.5 Volts)(30%) = 1.125 Volts

MFC 1= ½ (7.5 Volts)(60%) = 2.25 Volts

The total control signal is 3.75 Volts (75% of 5 Volts).

Pressure Measuring Control

When using a pressure measuring control channel, up to three MFCs can be configured to function in a pressure control loop. In this case, the total flow of the three MFCs determines the pressure, however, the percent of gas through each MFC remains constant. For example, if the ratio set points for the three MFCs are 30%, 30%, and 40% and pressure rises in the system, the gas flow through each MFC decreases but the 30%, 30%, 40% relationship remains intact.

Flow Measuring Control

When using a flow measuring control channel, an MFC channel is selected as the control input channel. The Ratio mode MFCs follow the controlling MFC with their respective proportions of flow as set by their Ratio mode set points.

Memory Storage in the 146 Instrument

The operational parameters of the 146 unit are stored in non-volatile memory as parameters are changed. The 146 unit is designed to store most user-defined, and 146-determined data in EEPROM. A front-panel lockout command, however, is not stored. The following is a list of what is preserved in EEPROM.

<table>
<tr><th colspan="2">Data Stored in EEPROM During Power Loss</th></tr>
<tr><th>Power Down Status Data</th><th>Alarm Data (for all alarms)</th></tr>
<tr><td>Alarm information
State (enabled or disabled)
Recipe
Control mode
Channel state (on/off)</td><td>Trip point value
Associated channel number
Untripped state (actuated or deactuated)</td></tr>
<tr><th>Control Data</th><th>Recipe Data (for each recipe)</th></tr>
<tr><td>Softstart value
Alpha value
Polarity setting
Integral value
Base value
Start value
Preset value</td><td>Set point value
Gain
Lead
Analog set point range
Analog set point state (enabled or disabled)
Softstart state (enabled or disabled
Input Channel number</td></tr>
<tr><th colspan="2">Channel-Sensor Data (for all channels)</th></tr>
<tr><td>Linear Capacitance Manometer:
Zero
Pirani-type:
Gas type
Zero (if enabled)
MFC:
Co-channel
Mode</td><td>Hot Cathode:
Ion gauge factor
Disconnect threshold
High pressure shutoff
Fast Rate-of-Rise state (enabled or disabled)
Sensitivity
Cold Cathode:
Disconnect threshold
Combined gauge and GCF</td></tr>
</table>

Table 37: Data Stored in EEPROM During a Power Loss

(Continued on next page)

Data Stored in EEPROM During Power Loss *(Continued)*	
Ion Gauge Auto-Power -Off Feature	**Analog Output Data (for all 3 outputs)**
Auto-off trip point value Auto-off status (enabled or disabled) Reference channel number	Analog output type Channel number Endpoint
Configuration Data	**Analog Set Point Data**
Sensor board type (each channel) Leakage rate time base	Analog set point zero voltage Analog set point full scale voltage Channel number Analog set point full scale pressure
Communications Data	**Dual Channel Data for Displays**
Data logger interval Baud rate Communications mode (parity, data bits, stop bits) Protocol (MKS 146 or data logger)	Upper threshold Lower threshold Continuity type Associated channels in dual 1 and dual 2
General Settings	
Audio alarm state (enabled or disabled) Measurement units Auto zero state (enabled or disabled) Auto zero reference Auto power state (enabled or disabled) Auto power trip point	Channel range Channel sensitivity Span settings Span enable Display settings

Table 37: Data Stored in EEPROM During a Power Loss

Ion Gauge High Pressure Protection/Disconnect Detection

A characteristic of either hot or cold cathode gauges is that they may provide invalid pressure readings when the pressure is above 1 x 10^{-2} Torr. In addition, hot cathode tubes may be damaged at high pressures. To address these gauge limitations, the 146 unit has some high pressure, and pressure rate-of-rise protection built into its hardware, and provides user-editable protection parameters as well.

Ion Gauge Auto Power Control (Setup Mode Code 12x) CC and HC

When the pressure reading of an ion gauge exceeds a user-defined pressure limit, the gauge is powered off. When the pressure drops below the preset limit, the 146 unit restores power to the ion gauge. If a hot cathode gauge had been degassing when it was powered off, the degas function will *not* turn back on when the 146 unit restores power to the hot cathode gauge.

HC High Pressure Shutoff (Setup Mode Code 16x) HC only

When the pressure reading of a hot cathode gauge exceeds a user-defined pressure limit, the gauge is powered off. The gauge will *not* auto power on again even if the pressure drops below the shutoff pressure. To power the gauge again, the pressure must be below the shutoff limit, *and* the HC channel must be turned off and then on again. The high pressure shutoff is always active and it is intended to function as a fail-safe feature. The pressure limit should be set higher than the auto power pressure threshold.

Ion Gauge Disconnect Threshold (Setup Mode Sensor Calibration screen) CC and HC

The ion gauge disconnect threshold feature sounds an alarm and changes the gauge's reading to E0 when the channel's pressure drops below the threshold pressure. Set the disconnect threshold to a value one decade below the system base pressure for a reliable disconnect alarm. You can also set the threshold pressure to the highest pressure reading the ion gauge can reliably measure. The factory configuration has this feature disabled (disconnect threshold is -1.0).

Features Built Into the 146 Hardware

Internal Fast Rate-of-Rise Shutoff (Setup Mode Code 16x) HC only

If pressure rises rapidly to a level that potentially could harm a hot cathode's filament, the gauge is turned off and the E1 error code appears in the display. The exact pressure rate of rise is dependent upon the type of gauge, but for most Bayard-Alpert tubes it is around 3 Torr/sec. To power the gauge again, the hot cathode channel must be turned off and then on again. The factory configuration has this feature disabled. This shutoff feature is accessed through the right hand entry of the Code 16x display. Press the ON button to enable this fast pressure rate of rise shutoff feature; press the OFF button to disable it.

Internal Sensing of HC disconnect/tube shorts/open filament HC only

If the 146 unit detects a disconnected hot cathode gauge, or a tube short or open filament in the hot cathode, the gauge is immediately turned off. To restore power to the gauge, the HC channel must be turned off and then on again.

Displayless 146 Unit

A displayless 146 unit is controlled by remote RS-232 communications through the RS-232 connector on the rear panel. An additional Interface connector on the front panel provides a convenient serial communications port so you can use a portable computer to communicate with the unit while it is installed in your system.

The displayless 146 unit has only a power switch, LED, and the Interface connector. The Interface connector is a 25-pin female Type “D” connector. Refer to Table 30, page 75, for a pinout of the connector on the displayless 146 unit.

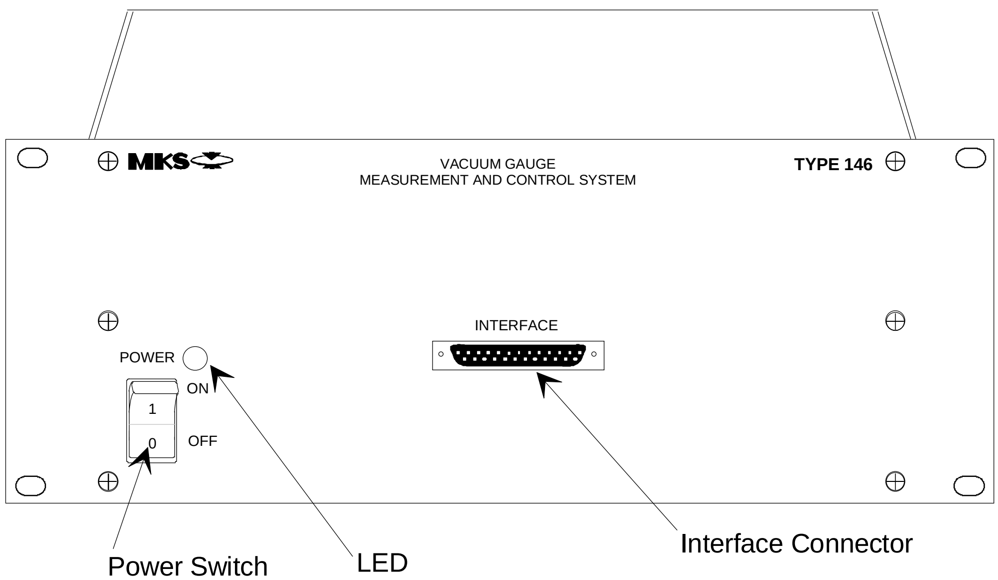


Figure 24: The Front of a Displayless 146 Unit

Connecting to the Displayless 146 Unit

The displayless 146 unit has an Interface connector, located on the front panel, and an RS-232 connector, located on the rear panel. Both connectors support RS-232 communication between the 146 unit and a computer. However, the 146 unit only accepts command messages through one port at a time, though it can report status information on both ports simultaneously. The 146 unit determines which port takes precedence based on the state of pin 4 of the Interface connector. When pin 4 is left open, the device connected to the Interface connector can only receive RS-232 communications that are currently being issued *from* the 146 unit, through the rear panel. Therefore, the RS-232 connector takes precedence. If pin 4 is grounded, the device connected to the Interface connector overrides the rear panel communication link and it can communicate fully with the 146 unit.

Use the RS-232 connector on the rear panel to connect the 146 unit to your system. The Interface connector provides a convenient port to connect a portable computer to the 146 unit should you need to troubleshoot the unit.

The LED

The LED on a displayless 146 unit indicates the status of the unit. When a displayless 146 unit is powered on, the LED condition is as follows:

1. The LED turns red, then changes to green within a few seconds.

   This indicates that all systems are operating properly.

2. The LED turns red and stays red.

   This indicates a power up problem is detected. The error code can be displayed or queried through RS-232 communications.

   A. Turn power to the displayless unit off and then on again.

      If only one non-fatal error condition was detected, the LED turns red and changes to green within a few seconds.

      If more than one non-fatal error condition was detected (such as codes C11, E4, or E10), the LED remains lit. The error code can be displayed or queried through RS-232 communications.

   B. Cycle the power a few more times to allow the unit to cycle through the non-fatal error conditions.

3. After cycling power to the 146 unit several times, the LED still remains red.

   This indicates a fatal error condition (such as E2, E3, E12) is detected. The error code can be displayed or queried through RS-232 communications (if it is still operating).

Note

If querying the error code through RS-232 communications, use the power up status command, described in the *RS-232 Communications* chapter.

How To Establish RS-232 Communications

Connect the RS-232 source to a displayless 146 unit with the correct RS-232 cable. Install the 146 unit into your system using the rear panel connector. Note that the RS-232 cable used for rear panel communications (refer to Table 32, page 77, for the proper MKS part number) differs from the RS-232 cable for front panel communications (MKS p/n CB146-21). All RS-232 commands are supported through either connector. Refer to *Chapter Nine: RS-232 Communications*, page 255, for a complete list of RS-232 commands/requests and the proper protocol for communications.

Refer to Table 32, page 77, for a pinout of the rear panel RS-232 connector. Table 30, page 75, lists the pinout of the front panel Interface connector.

Pins 1 through 5, 7, 8, and 20 on a displayless unit's front panel are involved with RS-232 communications. Pins 4 and 8 are especially worth noting. If pin 4 is left open, the device connected to the 146 unit can only receive RS-232 communications that are currently being issued *from* the 146 unit, through the rear panel. For example, if a status query is sent to the 146 displayless unit, the reply (which includes the header identifying the query), is received. If pin 4 is grounded, the device connected to the 146 instrument overrides the rear panel communication link and it can communicate fully with the 146 unit (that is, it can initiate queries).

Pin 8 can supply a +5V signal, which can be used to power one of several types of remote terminals.

The functions on pins 5 and 20 are special options that must be specifically requested from the factory.

Chapter Four: Operation in Normal Mode

General Information

Figure 25 shows a sample window for Normal Mode. In Normal Mode, all displays show a pressure reading, provided the displays are connected to active sensors and the sensors are reading within their range. If the Control board is installed, the valve control state is displayed (OPEN, AUTO, CLOSE, HOLD, or MANUAL) as well. In our example, the valve control state is set to HOLD.

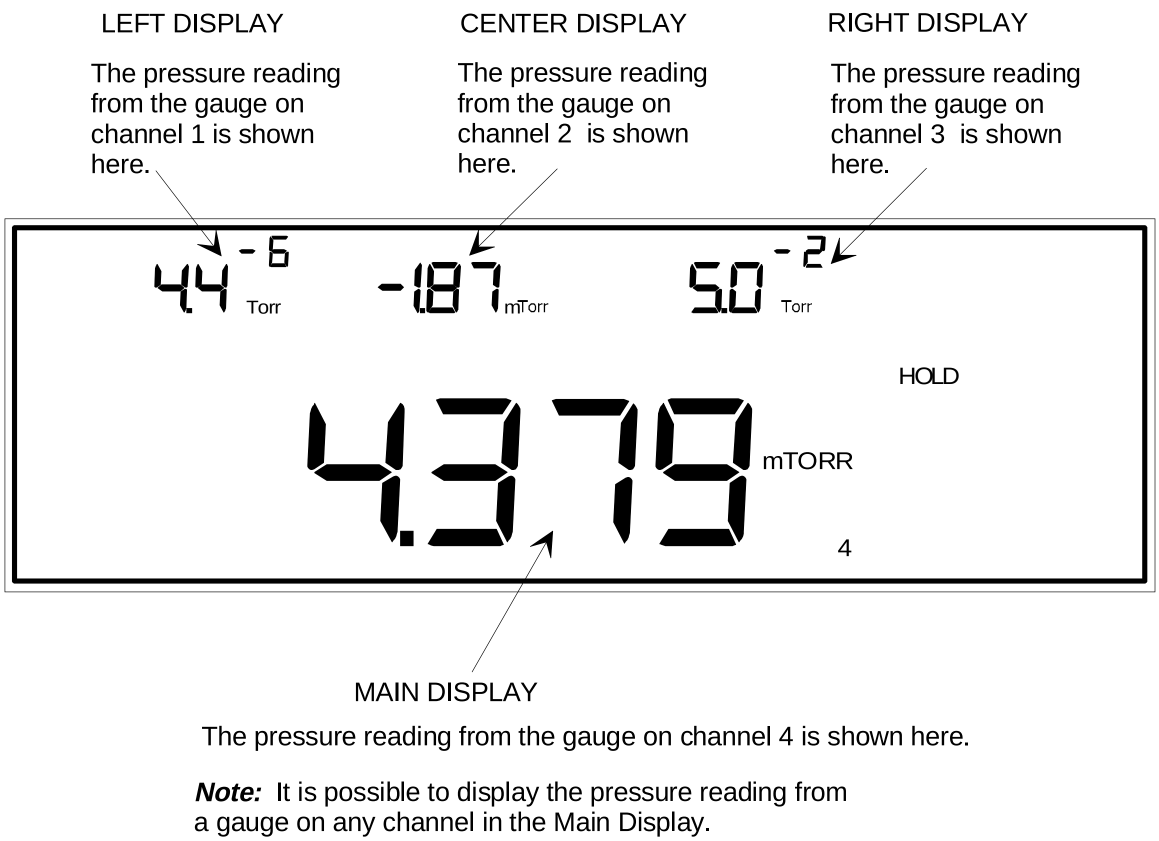


Figure 25: Normal Mode Display

Normal Mode is Used when Performing the Following Procedures

Normal Mode Functions	
Function	**Comments**
View most System Status Information	Displays the pressure readings from up to four different sensors.
Display software version	Lists the software version number.
Switch Channel in the Main Display	Selects what to show in the main display. The choices are channel 1, 2, 3, 4, or dual channel display function 1 or 2.
Turn a Channel ON/OFF	Turns power to a sensor on or off, and turns the sensor's channel on or off. Only the channel (not the sensor power) is turned off for capacitance manometers and mass flow controllers.
Turn an Alarm ON/OFF	Enables/disables standard alarms A and B, and optional alarms C and D.
Zero a Sensor/MFC	Sets the zero pressure point for a sensor.
Toggle the Zero-of-a-Sensor/MFC On and Off	Toggles between undoing the zero, and then re-instating the zero, once a sensor has been zeroed.
Span a Pirani Sensor to Atmosphere	Sets the upper pressure reading of a Pirani sensor equal to 760 Torr or Atmosphere (Atm), whichever is applicable.
Span a Sensor with a Reference	Spans the sensor of a selected channel to the reading of another sensor.
Toggle the Span-of-a -Sensor On and Off	Toggles between undoing the span, and then re-instating the span, once a sensor has been spanned.
Set Lower and Upper Points for Analog Set Point Calculations	Changes the analog set point by adjusting the analog set point input voltage.
Command MFC Open/Close Overrides	Moves an MFC to full open or full close within two seconds when commanded with one of these overrides.
Cancel MFC Open/Close Overrides	Cancels an override that is in effect.
Start Hot Cathode Low/High Power Degassing	Starts low power or high power degassing for a hot cathode which is currently powered on.
Stop HC Degassing	Ends the degassing (low power or high power) function currently underway.

Table 38: Normal Mode Functions

How To Display the Software Version

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Normal Mode.

   The system responds by scrolling through modes.

2. Press the [9/**C**][0/**D**] keys simultaneously.

   The system responds by displaying the software version number in the main display (refer to Figure 26).

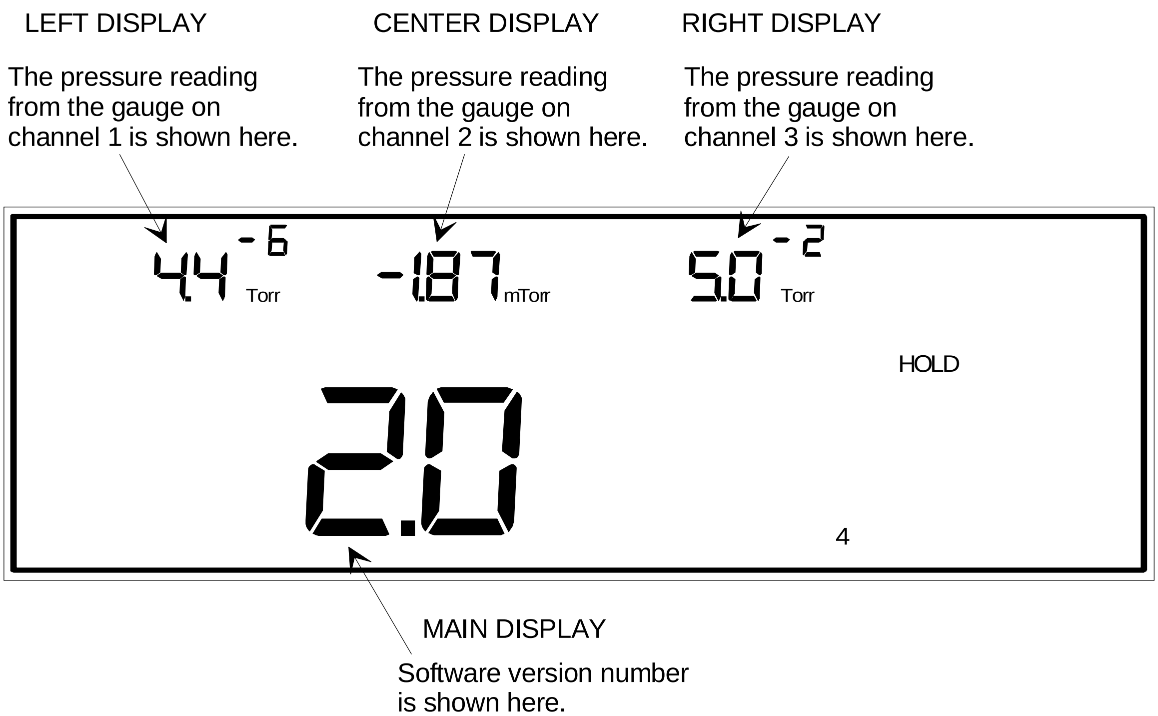


Figure 26: Software Version Number in Normal Mode

3. Press the [QUIET/CANCEL] key.

   The system responds by returning to the previous Normal Mode display.

Note Any key can be pressed to return the window to Normal Mode. However, the 146 unit also executes any command associated with the key.

How To Switch Channels in the Main Display

The system defaults to showing the pressure reading for channel 1 in the main display. The exception to this is if all four channels are used, whereupon the pressure reading for channel 4 appears in the main display. Channel 4 can only be monitored in the main display.

By following the procedure explained below, the pressure reading from any of the four channels can be shown in the main display. Alternately, the main display can be configured for a dual channel display.

The dual channel display feature of the 146 unit automatically switches between two user-selected channels to provide a pressure readout in the main display. The dual channel display can *only* be viewed in the main display. The channel numbers of the two user-selected channels that make up the dual channel display are shown to the right of the main display. When configured for dual channel display, the 146 unit can provide a pressure readout that shows pressure readings over a larger dynamic range than when the main display shows only a single channel's pressure readout.

Two dual channel setups can be configured (Dual Channel 1, and Dual Channel 2). The same channel can be used in both setups. For example, if Dual Channel 1 switches the main display between channels 1 and 4, Dual Channel 2 can still be setup to switch between channels 3 and 4. It does not matter that channel 4 is used in both setups, because only one setup can be used a time.

Note

The Dual Channel feature only effects what is *shown* in the main display. System *control* cannot be governed with two channels.

One of the two channels used in a Dual Channel display can be used for control. Control does *not* switch to the other user-selected channel, however, when the main display *readout* switches to the other channel.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Normal Mode.

   The system responds by scrolling through modes.

2. Press [1], [2], [3], or [4], (to select a channel), or press [DUAL][1] or [DUAL][2], (to select dual channel display feature 1 or 2).

   The system responds by showing the selected channel's pressure reading, or changing to dual channel display, in the main display.

   For example, in Figure 25, page 101, channel 4 is shown in the main display. An example of a dual channel display is shown in Figure 27, page 105.

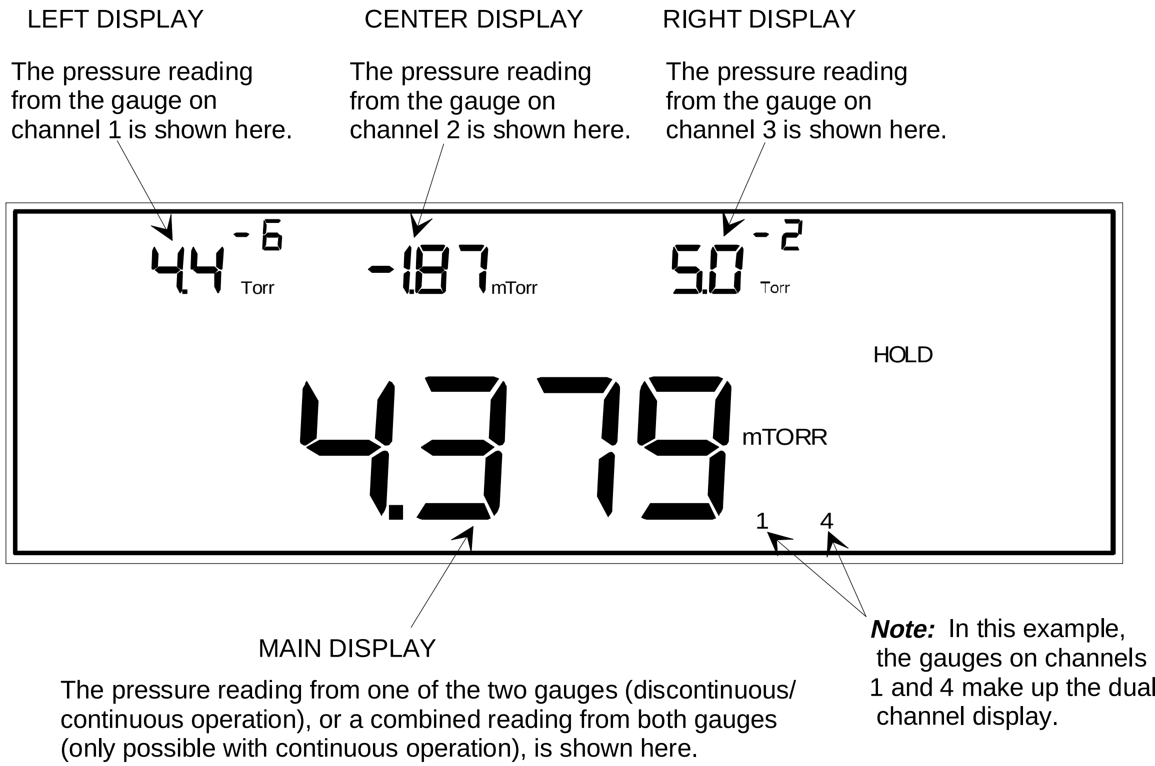


Figure 27: Dual Channel Display in Normal Mode

In a dual channel display, pressure information is shown for a single channel, or for both channels combined. The display is determined by whether the dual channel feature is configured for continuous or discontinuous operation, and whether the pressure is being taken from the upper or lower channel, or the overlapping region between the channels. Refer to *How To Set Up a Dual Channel Readout*, in the *Operation in Setup Mode* chapter, to learn how to select continuous or discontinuous operation in the dual channel display feature.

How To Turn a Channel ON or OFF

The ability to turn off power to sensors is a useful function in several situations. For example, it is a safety procedure against explosion during cryo-pump regeneration with all sensors except capacitance manometers (the danger of explosion does not exist with capacitance manometers). A cold cathode should be powered off above 1 x 10^{-2} Torr otherwise false readings may occur. Generally this is also true for hot cathodes. In addition, a hot cathode gauge may experience damage to its filament at high pressures. Pirani type gauges may need to be powered off if there is a chance their filaments may ignite, or induce a reaction in backfilled gases.

Warning **Turn off all gauges (except capacitance manometers), which are in contact with a cryo-pump, during regeneration procedures. The gauges may cause an explosion if they are not powered down.**

Turning a capacitance manometer or mass flow controller (MFC) on or off is done following the exact same procedure as turning a sensor on or off except that power is still supplied to the MFC or capacitance manometer.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Normal Mode.

   The system responds by scrolling through modes.

2. Press the [ON/LEAD] or [OFF/GAIN] key, followed by [1], [2], [3], or [4].

   The system responds by turning power to the sensor or MFC of the selected channel on (press [ON/LEAD]), or off (press [OFF/GAIN]). If power to a channel is turned off, the display for that channel changes to decimal points to indicate the channel is turned off.

Note ***One exception***: Power to capacitance manometers and MFCs cannot be turned off this way, although their displays can be.

How To Turn an Alarm ON or OFF

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Normal Mode.

   The system responds by scrolling through modes.

2. Press the [ON/LEAD] or [OFF/GAIN] key, followed by [A], [B], [C], or [D].

   The system responds by enabling (press [ON/LEAD]) or disabling (press [OFF/GAIN]), the selected alarm.

Note Alarms A and B are standard with the 146 unit, but alarms C and D are only available if the Auxiliary Output board is installed.

How To Zero a Sensor/MFC

For pressure sensors, zeroing means adjusting the readout for the sensor. The zero point is the pressure at which the instrument displays zero pressure. For capacitance manometers and Pirani type gauges, the zero point is the output voltage at which zero pressure is referenced.

A TC gauge, unlike a capacitance manometer or Pirani type gauge, produces its maximum output at zero pressure. The zero is adjusted by varying the power until a *standard output voltage* is achieved.

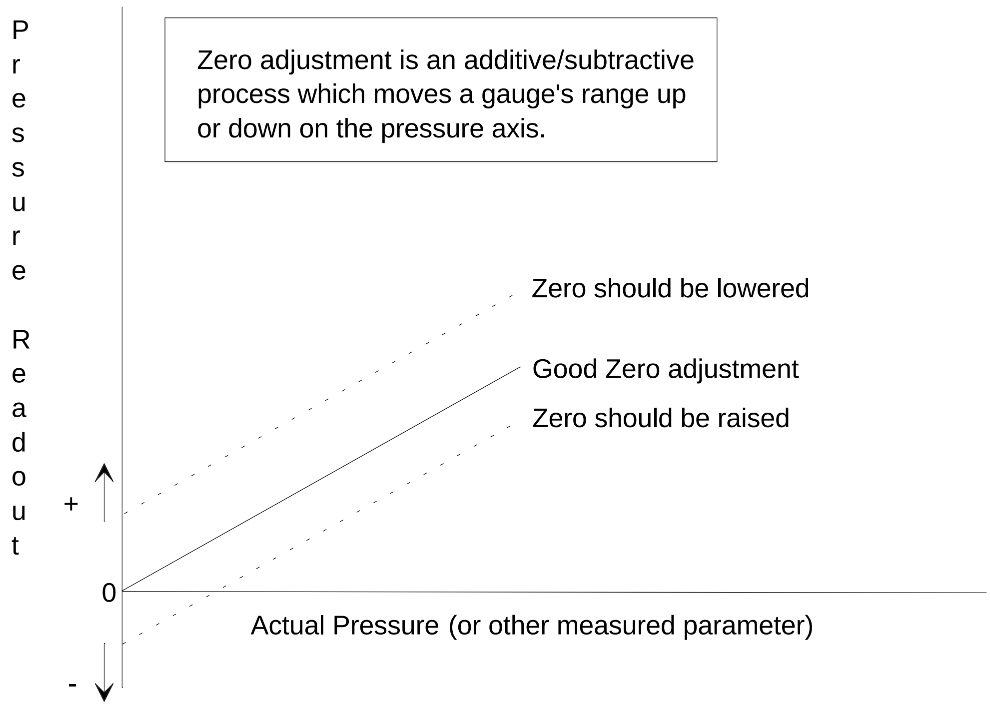


Figure 28: Zeroing a Sensor

For mass flow controllers (MFC), the zero offset is subtracted from the MFC reading and added to the set point output voltage. This is done to accommodate the internal PID control loop in an MFC.

Note

1. Before zeroing an MFC, verify that there is no gas flow through the unit. Two ways to accomplish this involve an upstream valve, or with a digital override (refer to *How To Command an MFC Close Override*, page 121).

2. To zero an MFC, the MFC reading must be close to 0.0. The 146 unit will not perform the zero function if the reading deviates from 0.0 by more than ±10% of the full scale range of the MFC. For example, to zero a 10 sccm unit, the reading must be 0.0 ±1.0 sccm.

1. Pump the gauge down to a pressure below the resolution of the gauge (<0.5 mTorr for a TC gauge). For an MFC, ensure that no gas is flowing through the unit.

2. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Normal Mode.

   The system responds by scrolling through modes.

3. Press the [ZERO/EXP] key, followed by [1], [2], [3], or [4].

   The system responds by zeroing the sensor/MFC of the channel number pressed. The reading in the selected channel's display goes to zero.

Note

1. Zeroing a Pirani sensor preempts the factory set zero. To return to the factory set zero, refer to *How To Perform Sensor Calibration/MFC Setup*, page 190.

2. If there is no sensor for the channel number selected, the system responds by beeping and displaying the CAN'T ZERO error message.

3. If a sensor's zero goes out of its normal range, the 146 unit responds with the CAN'T ZERO error message.

4. Ion gauges cannot be zeroed since they are high vacuum gauges.

5. For the MKS Type 120 gauge, the zeroing occurs in both the sensor and in the 146 unit. If the Type 120 gauge cannot complete the zeroing itself, a CAN'T ZERO message is momentarily displayed and the 146 unit completes the zeroing, provided the 120 gauge is within ±0.8 V of zero.

6. TC gauges ***must*** be zeroed when used for the first time or when replacing the current gauge with a new one.

7. The zero reading for a TC gauge can be toggled on or off. When on, the 146 unit uses the stored zero power level. When off, the stored zero power level is replaced with the factory default power level. Refer to *How To Toggle the Zero On and Off*, page 112, for more information.

8. When replacing a TC-1A gauge with a DV-6M gauge, the system may require two zero commands to achieve a stable zero. This is due to the difference in power levels and thermal response between the two gauges.

Ranges for Zeroing a Sensor	
Sensor Type	**Zero Range**
Type 107 Capacitance Manometer	-0.2 Volts to +0.2 Volts
Type 120 Capacitance Manometer	-0.8 Volts to +0.8 Volts
Linear Capacitance Manometer	-0.3 Volts to +0.3 Volts
Pirani Type Gauges	Gauges can always be zeroed
Cold Cathode Gauges	Gauges cannot be zeroed
Hot Cathode Gauges	Gauges cannot be zeroed
Mass Flow Controller	±0.5 Volts

Table 39: Ranges for Zeroing a Sensor

How To Toggle the Zero On and Off

Once a sensor or MFC has been zeroed, use this procedure to toggle between undoing the zero, and then re-instating the zero again. When the zero is toggled off, the original, unzeroed sensor/MFC reading is displayed. Toggling a sensor's zero on and off is useful as a diagnostic aid or for a transducer calibration check.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Normal Mode.

   The system responds by scrolling through modes.

2. Press the [ZERO/EXP] key, then the [OFF/GAIN] key, followed by [1], [2], [3], or [4].

   The system responds by bypassing the user-defined zero of the sensor/MFC on the selected channel.

Note

1. For the MKS Type 120 capacitance manometer, the zero is bypassed both in the sensor and in the 146 unit.
2. For Pirani gauges, the factory-set zero becomes effective.
3. For TC gauges, the factory default power level is used. The gauge will not yield accurate pressure measurements when the zero is toggled off!

3. Press the [ZERO/EXP] key, then the [ON/LEAD] key, followed by [1], [2], [3], or [4].

   The system responds by undoing the previous command, and restoring the channel's user-defined zero.

Note

1. For the MKS Type 120 capacitance manometer, the zero is restored in both the sensor and in the 146 unit.
2. For Pirani gauges, the user-defined zero is restored.
3. For TC gauges, the stored zero power level is restored.

How To Span a Pirani Type Sensor to Atmosphere

Spanning a Pirani type sensor should only be done at atmosphere. Spanning is done to adjust the upper range of the gauge which may have drifted due to contamination or aging of the sensor. The span adjustment assumes a pressure of 760 Torr (atmospheric pressure), as its reference. Convection gauges display **760 Torr** when spanned, and an HPS Pirani gauge displays **Atm**. This spanning method is usually sufficient to bring the spanned gauge's readings within its stated measurement accuracy. If this is not the case, span the gauge with a reference (refer to *How To How To Span a Sensor with a Reference*, page 115).

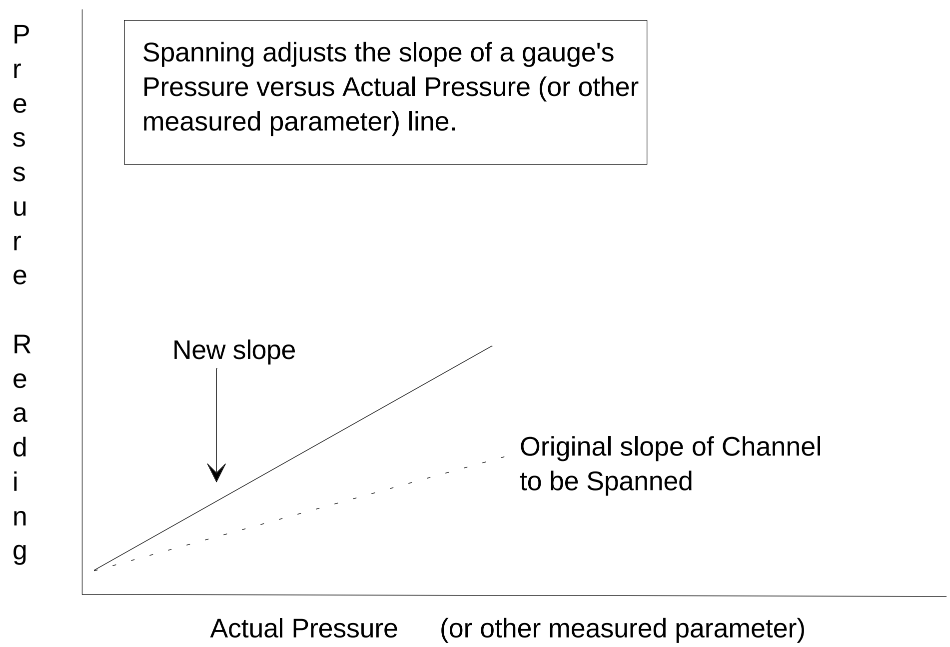


Figure 29: Spanning a Pirani-Type Sensor

Note

1. Spanning a Pirani sensor preempts the factory set span. To return to the factory set span, refer to *How To Perform Sensor Calibration/MFC Setup*, page 190.
2. Because of the high accuracy of capacitance manometers, they are not spanned to atmosphere (which may not be exactly 760 Torr).
3. Ion gauges cannot measure at atmosphere, so they are spanned to a reference within their range.
4. A Pirani sensor cannot be spanned if helium (He) or argon (Ar) is the gas type chosen. The gas must be nitrogen (N_2).

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Normal Mode.

   The system responds by scrolling through modes.

2. Press the [SPAN/.] key, followed by [1], [2], [3], or [4].

   The system responds by spanning the sensor on the selected channel number.

How To Span a Sensor with a Reference

This procedure stores a span constant for a spanned gauge. This makes the upper pressure reading of the spanned gauge agree with the pressure reading of the referenced gauge. Spanning is done with two sensors that are well within their measurement ranges.

Note This procedure does not apply to capacitance manometers.

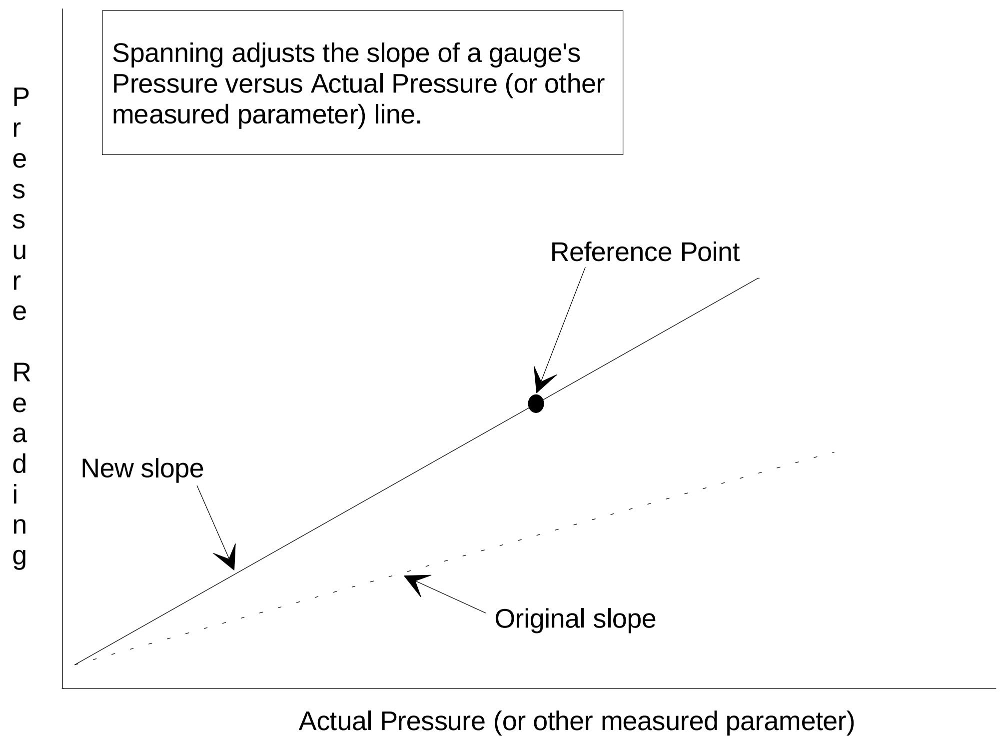


Figure 30: Spanning a Sensor with a Reference

Note

1. Pirani gauges must be reading above 100 Torr, and the reference channel must be within a decade of the Pirani channel for a valid span.
2. When spanning a Pirani gauge, the reference sensor can be anything except an ion gauge. This includes another Pirani.
3. For a successful span of an ion gauge, the reference must be a capacitance manometer. The capacitance manometer must be at least a decade above its zero, reading within one decade (±) of the unspanned ion gauge, and reading at or below 10 mTorr.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Normal Mode.

   The system responds by scrolling through modes.

2. Press [SPAN/.], followed by [5/DUAL], followed by [1], [2], [3], or [4] *(lower range sensor)*, followed by [1], [2], [3], or [4] again *(upper range sensor)*.

   The system responds by spanning the sensor on the first channel, to the reading of the sensor on the second channel.

How To Toggle the Span On and Off

Once a sensor has been spanned, use this procedure to toggle between undoing the span, and then re-instating the span. This procedure does not apply to capacitance manometers. When the span is toggled off, the factory-defined span is used for the display of pressure. Refer to *How To Perform Sensor Calibration/MFC Setup,* page 190, to view whether the factory-defined or user-defined span is in effect.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Normal Mode.

   The system responds by scrolling through modes.

2. Press the [SPAN/.] key, then the [OFF/GAIN] key, followed by [1], [2], [3], or [4].

   The system responds by bypassing the user-defined span for the sensor on the channel number selected.

3. Press the [SPAN/.] key, then the [ON/LEAD] key, followed by [1], [2], [3], or [4].

   The system responds by undoing the previous command, and restoring the channel's user-defined span.

How To Calculate the Analog Set Point

The analog set point input is a linear input sent through the lower connector on the Control board. The input corresponds to an analog set point value (refer to Figure 31). By adjusting the analog set point input voltage, the analog set point is changed. The default settings are for an analog input of 0.0 Volts to correspond to a zero set point, and for a 5 Volt input to define a 1000 Torr set point. The acceptable analog input voltage range is 0 to 10 Volts, with the default full scale voltage set at 5 Volts. The ability to define the set point through an analog input is disabled by default. Refer to *Code 15x: How To Set Up Analog Set Point*, in the *Operation in Setup Mode* chapter for instructions on how to enable the analog set point feature.

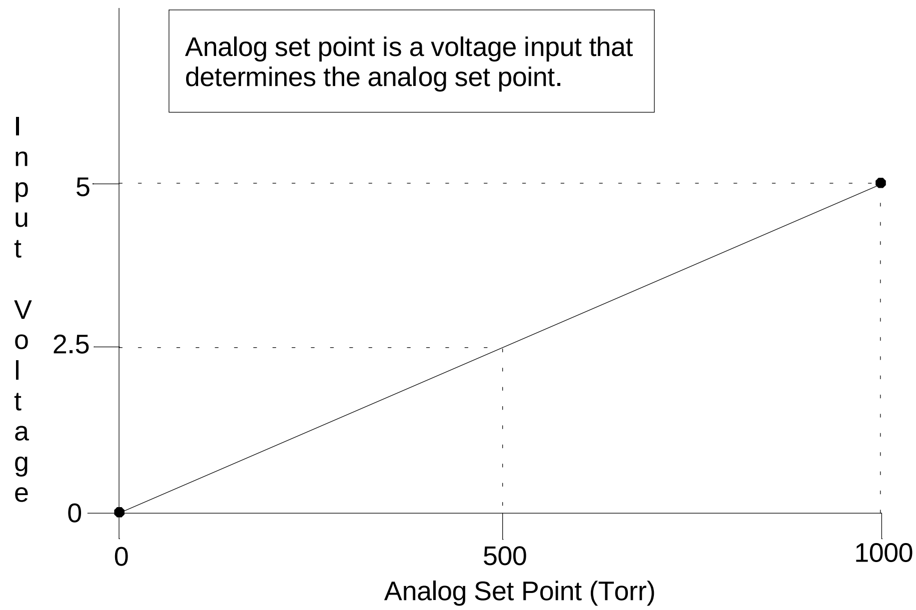


Figure 31: Graph Showing Analog Set Point Defaults

The lower and upper points of the analog input voltage range can be altered (refer to Figure 32, page 119) in Normal and Leakage Modes. By changing either one, or both of these points, the slope of the analog input voltage versus analog set point line is changed. As a result of the change in slope, a fixed input voltage defines a different analog set point. To adjust the lower and upper points in Normal and Leakage Modes, the current analog input voltage must be altered. To change the upper point (not the lower point), independent of the current analog input, refer to *Code 15x: How To Set Up Analog Set Point*, in the *Operation in Setup Mode* chapter.

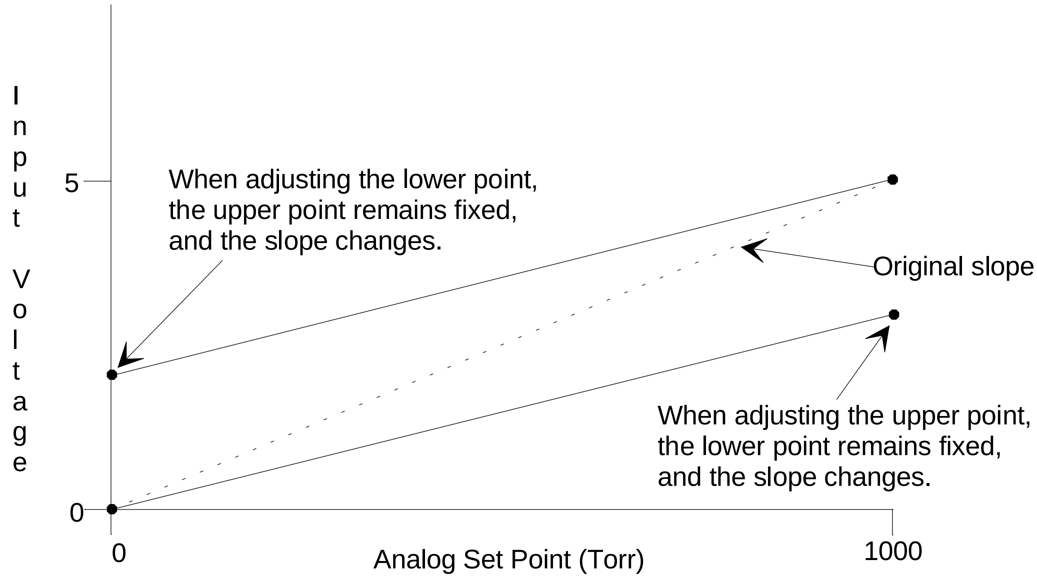


Figure 32: Adjusting Lower and Upper Points for Analog Set Point Calculations

Adjusting the Lower Point of the Analog Set Point Input Voltage Range

The analog set point feature does not need to be enabled to allow a change in the lower point of the analog input voltage range. However, the feature must be enabled to allow the 146 unit to control with an analog set point (refer to *Code 15x: How To Set Up Analog Set Point* in the *Operation in Setup Mode* chapter).

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Normal mode.

   The system responds by scrolling through modes.

2. Provide an analog input equal to the desired low point on the input voltage scale.

3. Press the [ZERO/EXP] key, followed by the [DEGAS/SET POINT] key.

   The system responds by setting the lower point of the analog set point input range equal to the current analog input. The upper point of the input range remains fixed. The slope of the analog input voltage versus analog set point line changes.

Adjusting the Upper Point of The Analog Set Point Input Voltage Range

The analog set point feature does not need to be enabled to allow a change in the upper point of the analog input voltage range. However, the feature must be enabled to allow the 146 unit to control with an analog set point (refer to *Code 15x: How To Set Up Analog Set Point* in the *Operation in Setup Mode* chapter).

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Normal Mode.

   The system responds by scrolling through modes.

2. Provide an analog input equal to the desired full scale voltage input.

3. Press the [SPAN/.] key, followed by the [DEGAS/SET POINT] key.

   The system responds by setting the full scale voltage (the upper point of the analog set point input range), equal to the current analog input. The lower point of the input range remains fixed. The slope of the analog input voltage versus analog set point line changes.

How To Command an MFC Open Override

A mass flow controller (MFC) moves to full open from any position within two seconds when commanded with an open override.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Normal Mode.

   The system responds by scrolling through modes.

2. Press the ⬆ key, followed by [1], [2], [3], or [4].

   The system responds by moving the MFC on the selected channel to full open within 2 seconds.

Note You must use the appropriate CB147-X cable, listed in Table 20, page 64, to enable the MFC override commands. The CB259-5 and CB259-10 cables do not support the open and close override commands. However, using these cables will not damage either unit.

How To Command an MFC Close Override

A mass flow controller (MFC) moves to full close from any position within two seconds when commanded with a close override.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Normal Mode.

   The system responds by scrolling through modes.

2. Press the ▼ key, followed by [1], [2], [3], or [4].

   The system responds by moving the MFC on the selected channel to full close within 2 seconds.

Note

1. The close override provides a fully closed condition, and in most cases can be used to zero the MFC (zero flow).
2. You must use the appropriate CB147-X cable, listed in Table 20, page 64, to enable the MFC override commands. The CB259-5 and CB259-10 cables do not support the open and close override commands. However, using these cables will not damage either unit.

How To Cancel an MFC Open/Close Override

An open or close override is canceled with the same sequence of steps.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Normal Mode.

   The system responds by scrolling through modes.

2. Press either the ▲ or ▼ key, followed by [OFF/GAIN], then [1], [2], [3], or [4].

   The system responds by removing the open or close override for the MFC on the selected channel. The MFC then performs as if no override had been given.

How To Start Hot Cathode Low Power Degassing

During a low power degas, the filament inside the hot cathode stays on, and valid pressure readings continue to be obtained. During low power degas (I^2R resistance heating), all the power remaining (after powering the filament) is delivered to the grid inside the tube. The front panel display for the degassing hot cathode continuously toggles between a pressure reading and **dG** (the degas code).

Note

1. The 146 unit can only perform the degassing procedure on *one* hot cathode gauge at a time. All other channels will continue to function during the degassing procedure.
2. A hot cathode must be on (channel on) in order to degas it.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Normal Mode.

   The system responds by scrolling through modes.

2. Press the [DEGAS/SET POINT] key, then the [ON/LEAD] key, followed by [1], [2], [3], or [4].

   The system responds by turning on the low power degas of the hot cathode on the selected channel, and causing that channel's display to toggle between a pressure reading and dG.

Caution

Damage to a hot cathode gauge can occur if pressure is allowed to get too high. Monitor the pressure, and control it within the specifications stated for the hot cathode gauge.

Degas is only effective if the pressure remains less than 1×10^{-5} Torr.

How To Start Hot Cathode High Power Degassing

During a high power degas, the filament inside the hot cathode is turned off, and all power is delivered to the grid inside the tube. Pressure readings are *not* obtained during a high power degas.

Caution

Only perform a high power degas procedure on a high power hot cathode gauge. Performing a high power degas procedure on a low power gauge may damage the grid within the gauge.

Note

1. The 146 unit can only perform the degassing procedure on *one* hot cathode gauge at a time. All other channels will continue to function during the degassing procedure.
2. A hot cathode must be on (channel on) in order to degas it.

The front panel display for the degassing hot cathode displays **dG** (the degas code) continuously for a high power degas. A hot cathode must be on (channel on) in order to degas it.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Normal Mode.

   The system responds by scrolling through modes.

2. Press the [DEGAS/SET POINT] key, followed by [1], [2], [3], or [4].

   The system responds by turning on the high power degas of the hot cathode on the selected channel, and causing that channel's display to change to **dG** .

Caution

Damage to a hot cathode gauge can occur if pressure is allowed to get too high. Monitor the pressure, and control it within the specifications stated for the hot cathode gauge.

Degas is only effective if the pressure remains less than 1×10^{-5} Torr.

How To Stop Hot Cathode Degassing

When a low power degas is turned off, power to the grid inside the tube is discontinued. The filament remains on and the front panel display shows the pressure reading.

When a high power degas is turned off, power to the grid inside the tube is discontinued (as with a low power degas). The channel re-initializes and the hot cathode filament turns on. The front panel display shows a pressure reading during initialization but this reading should not be considered valid until the display stops flashing (within 1 to 2 seconds).

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Normal Mode.

   The system responds by scrolling through modes.

2. Press the [DEGAS/SET POINT] key, then the [OFF/GAIN] key, followed by [1], [2], [3], or [4].

   The system responds by turning off the degas of the hot cathode on the selected channel.

   A. If the hot cathode had been undergoing a low power degas, its display shows a continuous, valid, pressure reading.

   B. If the hot cathode had been undergoing a high power degas, the gauge re-initializes and its display flashes until initialization is complete (within 2 seconds). The display then shows a continuous, valid, pressure reading.

Chapter Five: Operation in Leakage Mode

General Information

Press the [DISPLAY MODE] key once from Normal Mode to get to Leakage Mode. The word LEAKAGE appears in small letters above the main display.

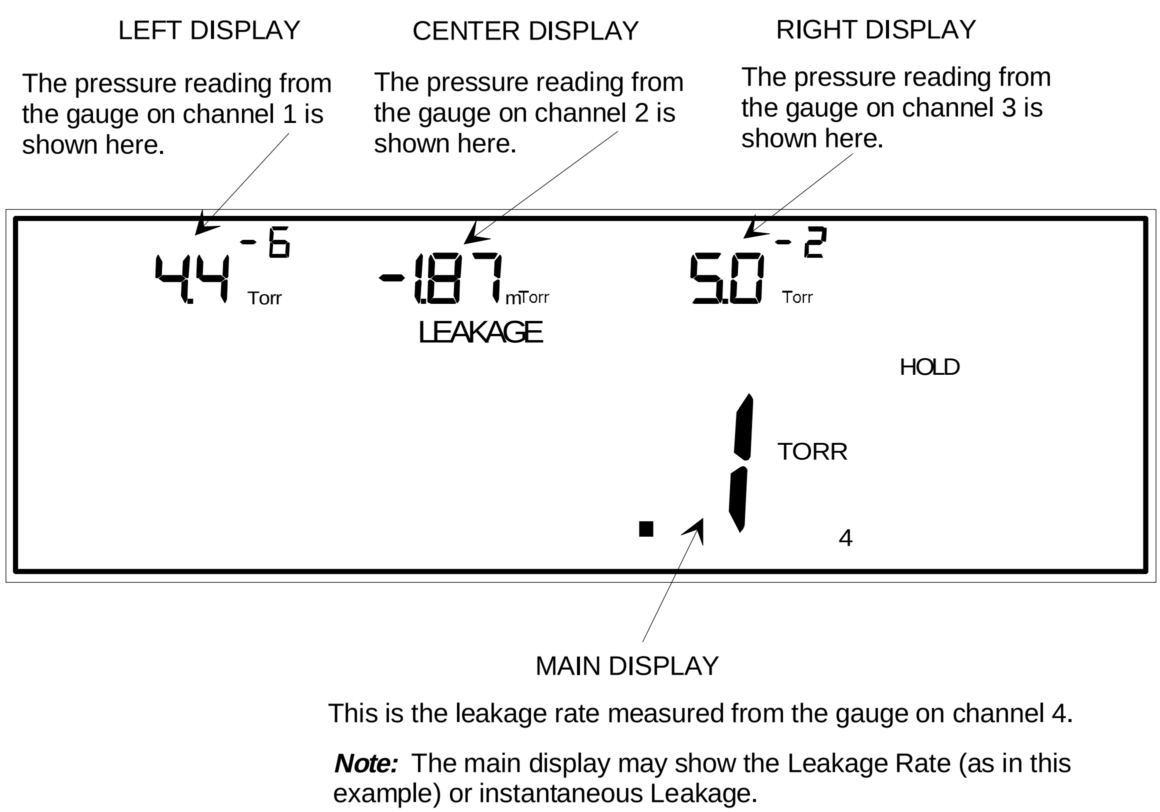


Figure 33: Leakage Mode

Figure 33 shows a sample window for Leakage Mode. In Leakage Mode, all upper displays show a pressure reading, provided the displays are hooked up to active sensors and the sensors are reading within their range. The main display shows either *leakage rate,* or *instantaneous leakage*.

Leakage rate is the leakage over a user-defined time base. The leakage rate display shows the rate in pressure units/second. For example, the leakage rate may be 3 Torr per 30 seconds, where Torr is the pressure unit, and 30 seconds is the user-defined time base. The display shows the rate as .1 Torr because a rate of 3 Torr/30 seconds equals a rate of 0.1 Torr/second. Refer to

Code 7: How To Set the Display for Leakage Mode, page 222, to learn how to define the time base.

Instantaneous leakage is the difference between the current pressure reading, and the base pressure. The base pressure is the pressure reading on a channel when Leakage Mode was first entered. For example, if the pressure reading on channel 4 was 900 Torr when Leakage mode was first entered (the base pressure), and the current pressure reading is 905 Torr, the instantaneous leakage value is 5 Torr. The base pressure is taken for all channels (not just the one in the main display) when Leakage Mode is entered. As a result, leakage can be viewed for any channel by bringing that channel into the main display.

Leakage Mode is Used when Performing the Following Procedures

Leakage Mode Functions	
Function	**Comments**
View most System Status Information	Displays the pressure readings from up to four different sensors.
Display software version	Lists the software version number.
Switch Channel in the Main Display	Selects what to show in the main display. The choices are channel 1, 2, 3, 4, or dual channel display function 1 or 2.
Turn a Channel ON/OFF	Turns power to a sensor on or off, and turns the sensor's channel on or off. Only the channel (not the sensor power) is turned off for capacitance manometers.
Turn an Alarm ON/OFF	Enables/disables standard alarms A and B, and optional alarms C and D.
Zero a Sensor/MFC	Sets the zero pressure point for a sensor.
Toggle the Zero-of-a-Sensor/MFC On and Off	Toggles between undoing the zero, and then re-instating the zero, once a sensor has been zeroed.
Span a Pirani Sensor to Atmosphere	Sets the upper pressure reading of a Pirani sensor equal to 760 Torr or Atmosphere (Atm), whichever is applicable.
Span a Sensor with a Reference	Spans the sensor of a selected channel to the reading of another sensor.
Toggle the Span-of-a -Sensor On and Off	Toggles between undoing the span, and then re-instating the span, once a sensor has been spanned.
Set Lower and Upper Points for Analog Set Point Calculations	Changes the analog set point by adjusting the analog set point input voltage.
Command MFC Open/Close Overrides	Moves an MFC to full open or full close within two seconds.
Cancel MFC Open/Close Overrides	Cancels an override that is in effect.
Start Hot Cathode Low/High Power Degassing	Starts low power or high power degassing for a hot cathode which is currently powered on.
Stop HC Degassing	Ends the degassing (low power or high power) function currently underway.

Table 40: Leakage Mode Functions

How To Display the Software Version

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Leakage Mode.

   The system responds by scrolling through modes.

2. Press [9/**C**][0/**D**] keys simultaneously.

   The system responds by displaying the software version number in the main display (refer to Figure 34).

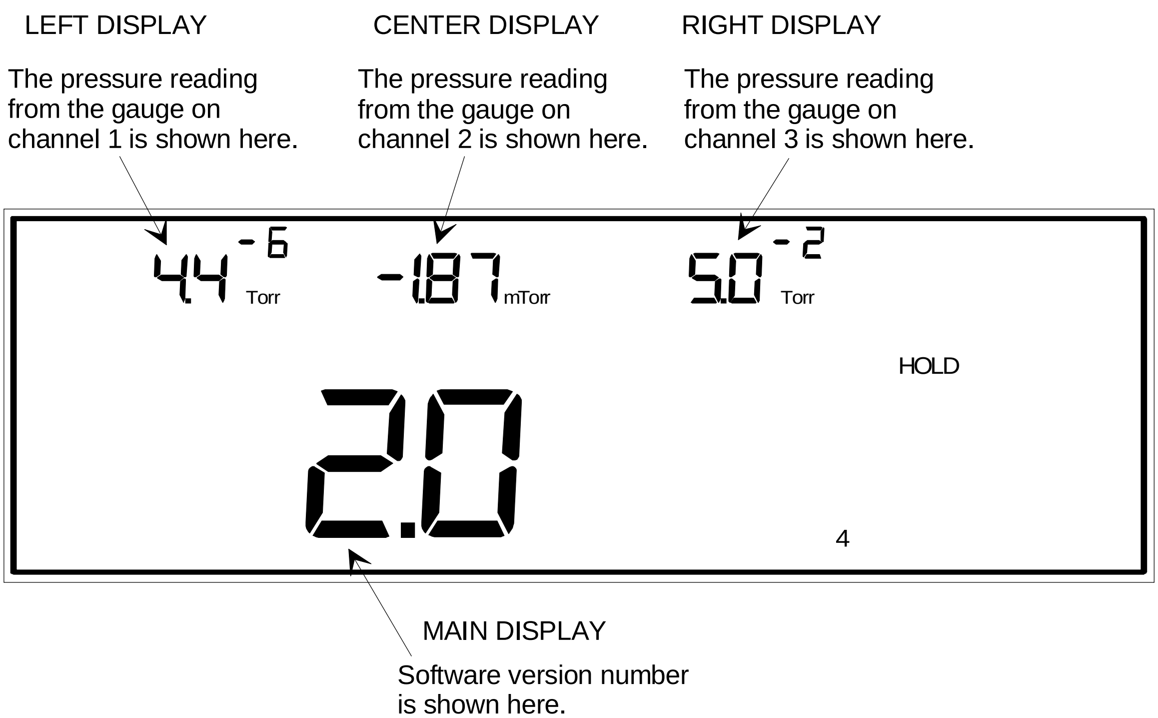


Figure 34: Software Version Number in Leakage Mode

3. Press the [QUIET/CANCEL] key.

   The system responds by returning to Leakage Mode, and displaying the appropriate channel's leakage rate or instantaneous leakage in the main display.

Note Any key can be pressed to return the window to Leakage Mode. However, the 146 unit also executes any command associated with the key.

How To Switch Channels in the Main Display

The system defaults to showing the leakage rate or instantaneous leakage for channel 1 in the main display. The exception to this is if all four channels are used, whereupon the same information for channel 4 appears in the main display. Channel 4 can only be monitored in the main display.

By following the procedure explained below, leakage information from any of the four channels can be shown in the main display. Alternately, the main display can be configured for a dual channel display.

The dual channel display feature of the 146 unit automatically switches between two user-selected channels that show leakage information in the main display. The dual channel display can only be viewed in the main display. The channel numbers of the two user-selected channels, which make up the dual channel display, are shown to the right of the main display.

Two dual channel setups can be configured (Dual Channel 1, and Dual Channel 2). The same channel can be used in both setups. For example, if Dual Channel 1 switches the main display between channels 1 and 4, Dual Channel 2 can still be setup to switch between channels 3 and 4. It does not matter that channel 4 is used in both setups, because only one setup can be used a time.

Note

The Dual Channel feature only effects what is *shown* in the main display. System *control* cannot be governed with two channels.

One of the two channels used in a Dual Channel display can be used for control. Control does *not* switch to the other user-selected channel, however, when the main display *readout* switches to the other channel.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Leakage Mode.

   The system responds by scrolling through modes.

2. Press [1], [2], [3], or [4], (to select a channel), or press [DUAL][1] or [DUAL][2], (to select dual channel display feature 1 or 2).

   The system responds by showing leakage rate or instantaneous leakage in the main display. This is true whether just a single channel is selected for the main display, or if the dual channel display function is selected. Refer to *Code 7: How To Set Up the Main Display for Leakage Mod*e, in the *Operation in Setup Mode* chapter, to learn how to select either leakage rate or instantaneous leakage.

   For example, in Figure 33, page 125, the leakage rate for channel 4 is shown in the main display. An example of a dual channel display is shown in Figure 35, page 130. In this example, the leakage rate for channel 1 or channel 4, or a leakage rate from the two channels combined, is shown in the main display.

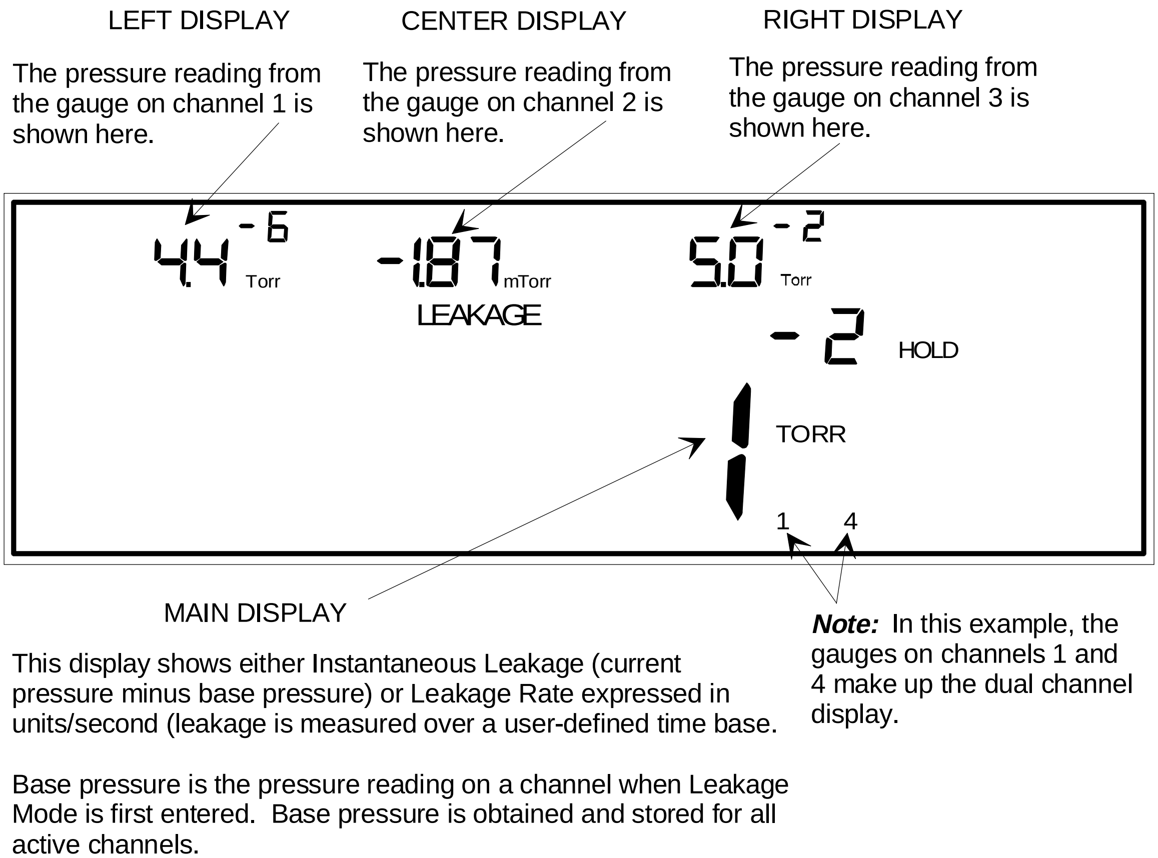


Figure 35: Dual Channel Display in Leakage Mode

In a dual channel display function, leakage information is shown for a single channel, or for both channels combined. The display is determined by whether the dual channel display feature is configured for continuous or discontinuous operation, and whether instantaneous pressure is being taken from the upper or lower channel, or the overlapping region between the channels. Refer to *How To Set Up a Dual Channel Readout*, in the *Operation in Setup Mode* chapter, to learn how to select continuous or discontinuous operation in the dual channel feature.

How To Turn a Channel ON or OFF

The ability to turn off power to sensors is a useful function in several situations. For example, it is a safety procedure against explosion during cryo-pump regeneration with all sensors except capacitance manometers (the danger of explosion does not exist with capacitance manometers). A cold cathode should be powered off above 1 x 10^{-2} Torr, otherwise false readings may occur. Generally this is also true for hot cathodes. In addition, a hot cathode gauge may experience damage to its filament at high pressures. Pirani type gauges may need to be powered off if there is a chance their filaments may ignite, or induce a reaction in backfilled gases.

Warning

Turn off all gauges (except capacitance manometers), which are in contact with a cryo-pump, during regeneration procedures. The gauges may cause an explosion if they are not powered down.

Turning a capacitance manometer or mass flow controller (MFC) on or off is done following the exact same procedure as turning a sensor on or off except that power is still supplied to the capacitance manometer or MFC.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Leakage Mode.

   The system responds by scrolling through modes.

2. Press the [ON/LEAD] or [OFF/GAIN] key, followed by [1], [2], [3], or [4].

   The system responds by turning power to the sensor or MFC of the selected channel on (press [ON/LEAD]), or off (press [OFF/GAIN]). If power to a channel is turned off, the display for that channel changes to decimal points to indicate the channel is turned off.

Note

One exception: Power to capacitance manometers and MFCs cannot be turned off this way, although their displays can be.

How To Turn an Alarm ON or OFF

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Leakage Mode.

   The system responds by scrolling through modes.

2. Press the [ON/LEAD] or [OFF/GAIN] key, followed by [A], [B], [C], or [D].

   The system responds by enabling (press [ON/LEAD]), or disabling (press [OFF/GAIN]), the selected alarm.

Note Alarms A and B are standard with the 146 unit, but alarms C and D are only available if the Auxiliary Output board is installed.

How To Zero a Sensor/MFC

For pressure sensors, zeroing means adjusting the readout for the sensor. The zero point is the pressure at which the instrument displays zero pressure. For capacitance manometers and Pirani type gauges, the zero point is the output voltage at which zero pressure is referenced.

A TC gauge, unlike a capacitance manometer or Pirani type gauge, produces its maximum output at zero pressure. The zero is adjusted by varying the power until a *standard output voltage* is achieved.

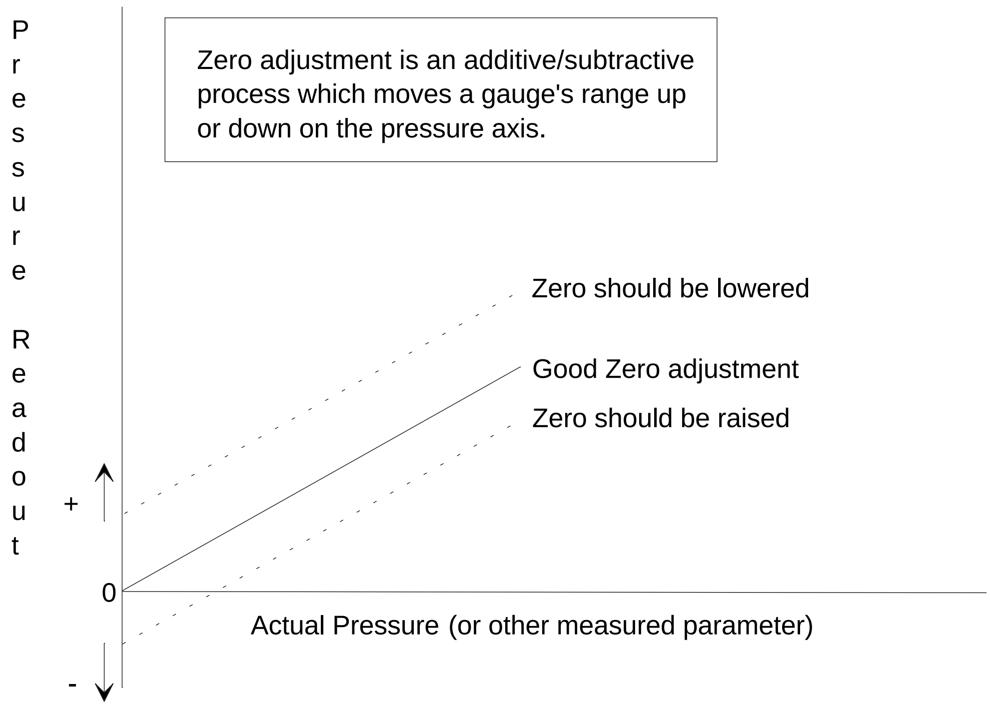


Figure 36: Zeroing a Sensor

For mass flow controllers (MFC), the zero offset is subtracted from the MFC reading and added to the set point output voltage. This is done to accommodate the internal PID control loop in an MFC.

Note

1. Before zeroing an MFC, verify that there is no gas flow through the unit. Two ways to accomplish this involve an upstream valve, or with a digital override (refer to *How To Command an MFC Close Override,* page 146).
2. To zero an MFC, the MFC reading must be close to 0.0. The 146 unit will not perform the zero function if the reading deviates from 0.0 by more than ±10% of the full scale range of the MFC. For example, to zero a 10 sccm unit, the reading must be 0.0 ±1.0 sccm.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Leakage Mode.

   The system responds by scrolling through modes.

2. Press the [ZERO/EXP] key, followed by [1], [2], [3], or [4].

   The system responds by zeroing the sensor/MFC of the channel number pressed. The reading in the selected channel's display goes to zero.

Note

1. Zeroing a Pirani sensor preempts the factory set zero. To return to the factory set zero, refer to *How To Perform Sensor Calibration/MFC Setup,* page 190.

2. If there is no sensor for the channel number selected, the system responds by beeping and displaying the CAN'T ZERO error message.

3. If a sensor's zero goes out of its normal range, the 146 unit responds with the CAN'T ZERO error message.

4. Ion gauges cannot be zeroed since they are high vacuum gauges.

5. For the MKS Type 120 gauge, the zeroing occurs in both the sensor and in the 146 unit. If the Type 120 gauge cannot complete the zeroing itself, a CAN'T ZERO message is momentarily displayed and the 146 unit completes the zeroing, provided the 120 gauge is within ±0.8 V of zero.

6. TC gauges ***must*** be zeroed when used for the first time or when replacing the current gauge with a new one.

7. The zero reading for a TC gauge can be toggled on or off. When on, the 146 unit uses the stored zero power level. When off, the stored zero power level is replaced with the factory default power level. Refer to *How To Toggle the Zero On and Off,* page 137, for more information.

8. When replacing a TC-1A gauge with a DV-6M gauge, the system may require two zero commands to achieve a stable zero. This is due to the difference in power levels and thermal response between the two gauges.

Ranges For Zeroing A Sensor	
Sensor Type	**Zero Range**
Type 107 Capacitance Manometer	-0.2 Volts to +0.2 Volts
Type 120 Capacitance Manometer	-0.8 Volts to +0.8 Volts
Linear Capacitance Manometer	-0.3 Volts to +0.3 Volts
Pirani Type Gauges	Gauges can always be zeroed
Cold Cathode Gauges	Gauges cannot be zeroed
Hot Cathode Gauges	Gauges cannot be zeroed
Mass Flow Controller	±0.5 Volts

Table 41: Ranges for Zeroing a Sensor

How To Toggle the Zero On and Off

Once a sensor or MFC has been zeroed, use this procedure to toggle between undoing the zero, and then re-instating the zero again. When the zero is toggled off, the original, unzeroed sensor/MFC reading is displayed. Toggling a sensor's zero on and off is useful as a diagnostic aid or for a transducer calibration check.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Leakage Mode.

   The system responds by scrolling through modes.

2. Press the [ZERO/EXP] key, then the [OFF/GAIN] key, followed by [1], [2], [3], or [4].

   The system responds by bypassing the user-defined zero of the sensor/MFC on the selected channel.

Note

1. For the MKS Type 120 capacitance manometer, the zero is bypassed both in the sensor and in the 146 unit.
2. For Pirani gauges, the factory-set zero becomes effective.
3. For TC gauges, the factory default power level is used. The gauge will not yield accurate pressure measurements when the zero is toggled off!

3. Press the [ZERO/EXP] key, then the [ON/LEAD] key, followed by [1], [2], [3], or [4].

   The system responds by undoing the previous command, and restoring the channel's user-defined zero.

Note

1. For the MKS Type 120 capacitance manometer, the zero is restored in both the sensor and in the 146 unit.
2. For Pirani gauges, the user-defined zero is restored.
3. For TC gauges, the stored zero power level is restored.

How To Span a Pirani Type Sensor to Atmosphere

Spanning a Pirani type sensor should only be done at atmosphere. Spanning is done to adjust the upper range of the gauge which may have drifted due to contamination or aging of the sensor. The span adjustment assumes a pressure of 760 Torr (atmospheric pressure), as its reference. Convection gauges display **760 Torr** when spanned, and an HPS Pirani gauge displays **Atm**. This spanning method is usually sufficient to bring the spanned gauge's readings within its stated measurement accuracy. If this is not the case, span the gauge with a reference (refer to *How To Span a Sensor with a Reference*, page 140).

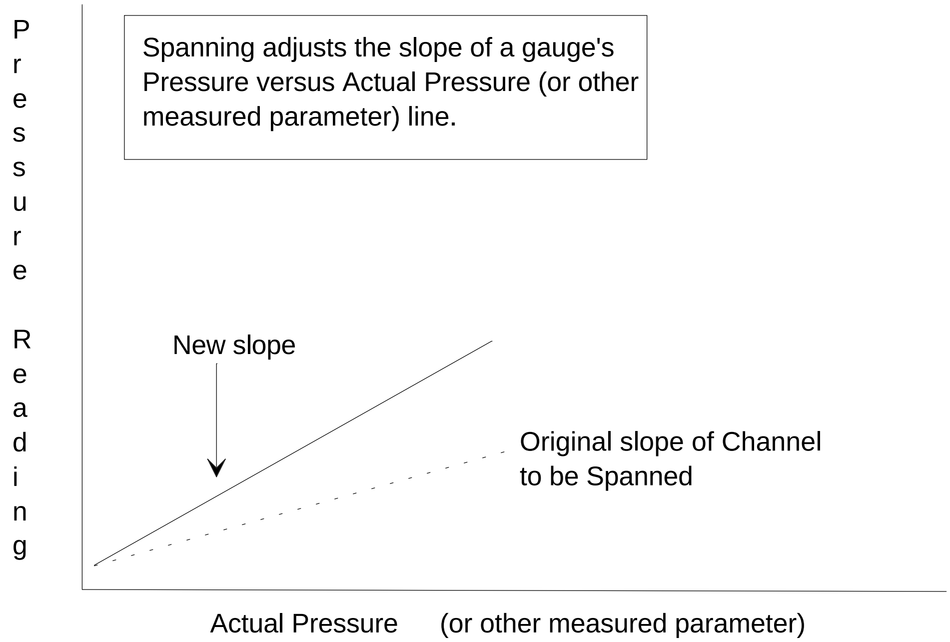


Figure 37: Spanning a Sensor

Note

1. Spanning a Pirani sensor preempts the factory set span. To return to the factory set span, refer to *How To Perform Sensor Calibration/MFC Setup,* page 190.
2. Because of the high accuracy of capacitance manometers, they are not spanned to atmosphere (which may not be exactly 760 Torr).
3. Ion gauges cannot measure at atmosphere, so they are spanned to a reference within their range.
4. A Pirani sensor cannot be spanned if helium (He) is the gas type chosen.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Leakage Mode.

   The system responds by scrolling through modes.

2. Press the [SPAN/.] key, followed by [1], [2], [3], or [4].

   The system responds by spanning the sensor on the selected channel number.

How To Span a Sensor with a Reference

This procedure stores a span constant for a spanned gauge. This makes the upper pressure reading of the spanned gauge agree with the pressure reading of the referenced gauge. Spanning is done with two sensors that are well within their measurement ranges.

Note This procedure does not apply to capacitance manometers.

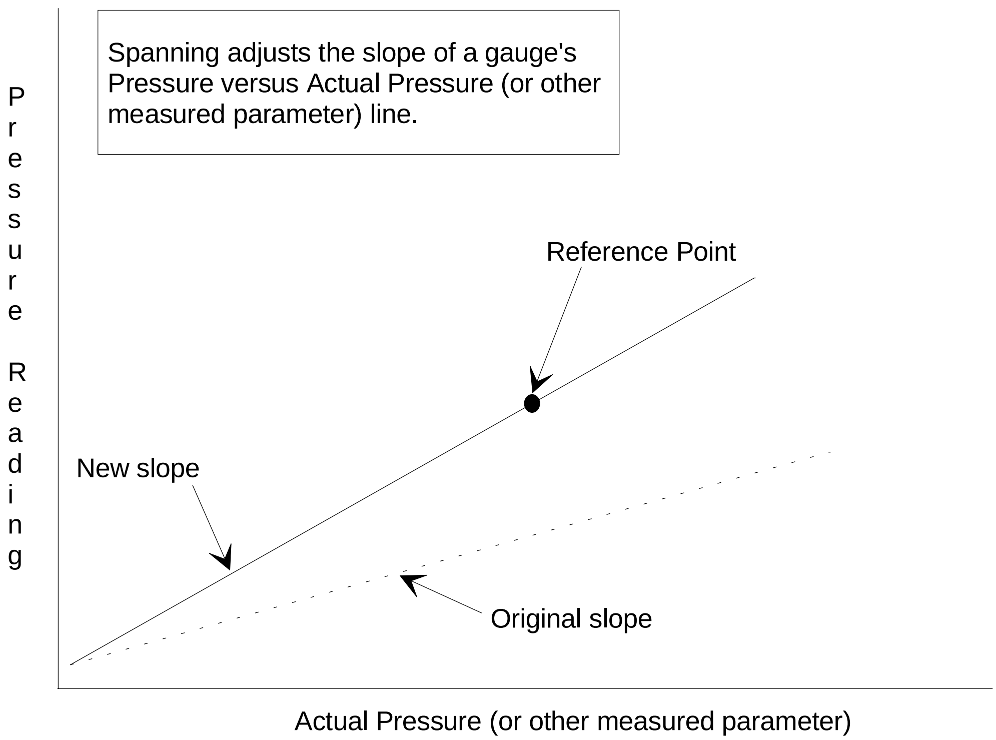


Figure 38: Spanning a Sensor with a Reference

Note

1. Pirani gauges must be reading above 100 Torr, and the reference channel must be within a decade of the Pirani channel for a valid span.
2. When spanning a Pirani gauge, the reference sensor can be anything except an ion gauge. This includes another Pirani.
3. For a successful span of an ion gauge, the reference must be a capacitance manometer. The capacitance manometer must be at least a decade above its zero, reading within one decade (±) of the unspanned ion gauge, and reading at or below 10 mTorr.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Leakage Mode.

   The system responds by scrolling through modes.

2. Press [SPAN/.], followed by [5/DUAL], followed by [1], [2], [3], or [4] *(lower range sensor)*, followed by [1], [2], [3], or [4] again *(upper range sensor)*.

   The system responds by spanning the sensor on the first channel to the reading of the sensor on the second channel.

How To Toggle the Span On and Off

Once a sensor has been spanned, use this procedure to toggle between undoing the span, and then re-instating the span. This procedure does not apply to capacitance manometers. When the span is toggled off, the factory-defined span is used for the display of pressure. Refer to *How To Perform Sensor Calibration/MFC Setup,* page 190, to view whether the factory-defined or user-defined span is in effect.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Leakage Mode.

   The system responds by scrolling through modes.

2. Press the [SPAN/.] key, then the [OFF/GAIN] key, followed by [1], [2], [3], or [4].

   The system responds by bypassing the user-defined span for the sensor on the channel number selected.

3. Press the [SPAN/.] key, then the [ON/LEAD] key, followed by [1], [2], [3], or [4].

   The system responds by undoing the previous command, and restoring the channel's user-defined span.

How To Calculate the Analog Set Point

The analog set point input is a linear input sent through the lower connector on the optional Control board. The input corresponds to an analog set point value (refer to Figure 39). By adjusting the analog set point input voltage, the analog set point is changed. The default settings are for an analog input of 0.0 Volts to correspond to a zero set point, and for a 5 Volt input to define a 1000 Torr set point. The acceptable analog input voltage range is 0 to 10 Volts, with the default full scale voltage set at 5 Volts. The ability to define the set point through an analog input is disabled by default. Refer to *Code 15x: How To Set Up Analog Set Point*, in the *Operation in Setup Mode* chapter for instructions on how to enable the analog set point feature.

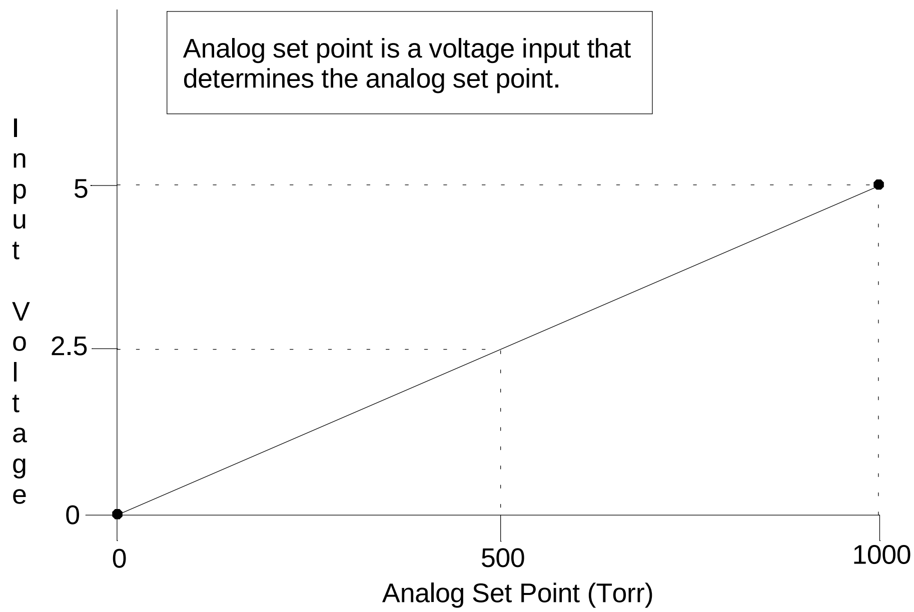


Figure 39: Graph Showing Analog Set Point Defaults

The lower and upper points of the analog input voltage range can be altered (refer to Figure 40, page 144) in Normal and Leakage Modes. By changing either one, or both of these points, the slope of the analog input voltage versus analog set point line is changed. As a result of the change in slope, a fixed input voltage defines a different analog set point. To adjust the lower and upper points in Normal and Leakage Modes, the current analog input voltage must be altered. To change the upper point (not the lower point), independent of the current analog input, refer to *Code 15x: How To Set Up Analog Set Point*, in the *Operation in Setup Mode* chapter.

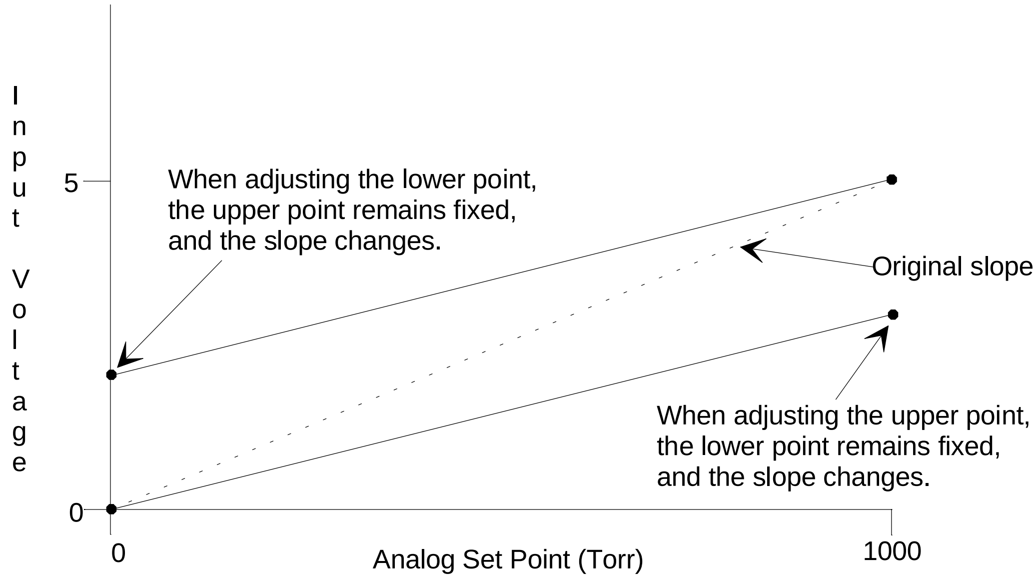


Figure 40: Adjusting the Lower and Upper Points for the Analog Set Point Calculations

Adjusting the Lower Point of the Analog Set Point Input Voltage Range

The analog set point feature does not need to be enabled to allow a change in the lower point of the analog input voltage range. However, the feature must be enabled to allow the 146 unit to control with an analog set point (refer to *Code 15x: How To Set Up Analog Set Point* in the *Operation in Setup Mode* chapter).

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Leakage Mode.

   The system responds by scrolling through modes.

2. Provide an analog input equal to the desired low point on the input voltage scale.

3. Press the [ZERO/EXP] key, followed by the [DEGAS/SET POINT] key.

   The system responds by setting the lower point of the analog set point input range equal to the current analog input. The upper point of the input range remains fixed. The slope of the analog input voltage versus analog set point line changes.

Adjusting the Upper Point of The Analog Set Point Input Voltage Range

The analog set point feature does not need to be enabled to allow a change in the upper point of the analog input voltage range. However, the feature must be enabled to allow the 146 unit to control with an analog set point (refer to *Code 15x: How To Set Up Analog Set Point* in the *Operation in Setup Mode* chapter).

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Leakage mode.

   The system responds by scrolling through modes.

2. Provide an analog input equal to the desired full scale voltage input.

3. Press the [SPAN/.] key, followed by the [DEGAS/SET POINT] key.

   The system responds by setting the full scale voltage (the upper point of the analog set point input range), equal to the current analog input. The lower point of the input range remains fixed. The slope of the analog input voltage versus analog set point line changes.

How To Command an MFC Open Override

A mass flow controller (MFC) moves to full open from any position within two seconds when commanded with an open override.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Leakage Mode.

   The system responds by scrolling through modes.

2. Press the ▲ key, followed by [1], [2], [3], or [4].

   The system responds by moving the MFC on the selected channel to full open within 2 seconds.

Note

You must use the appropriate CB147-X cable, listed in Table 20, page 64, to enable the MFC override commands. The CB259-5 and CB259-10 cables do not support the open and close override commands. However, using these cables will not damage either unit.

How To Command an MFC Close Override

A mass flow controller (MFC) moves to full close from any position within two seconds when commanded with a close override.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Leakage Mode.

   The system responds by scrolling through modes.

2. Press the ▼ key, followed by [1], [2], [3], or [4].

   The system responds by moving the MFC on the selected channel to full close within 2 seconds.

Note

1. The close override provides a fully closed condition, and in most cases can be used to zero the MFC (zero flow).
2. You must use the appropriate CB147-X cable, listed in Table 20, page 64, to enable the MFC override commands. The CB259-5 and CB259-10 cables do not support the open and close override commands. However, using these cables will not damage either unit.

How To Cancel an MFC Open/Close Override

An open or close override is canceled with the same sequence of steps.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Leakage Mode.

   The system responds by scrolling through modes.

2. Press either the ⬆ or ⬇ key, followed by [OFF/GAIN], then [1], [2], [3], or [4].

   The system responds by removing the open or close override for the MFC on the selected channel. The MFC then performs as if no override had been given.

How To Start Hot Cathode Low Power Degassing

During a low power degas, the filament inside the hot cathode stays on, and valid pressure readings continue to be obtained. During low power degas (I^2R), all the power remaining (after powering the filament) is delivered to the grid inside the tube. The front panel display for the degassing hot cathode continuously toggles between a pressure reading and **dG** (the degas code).

Note

1. The 146 unit can only perform the degassing procedure on *one* hot cathode gauge at a time. All other channels will continue to function during the degassing procedure.
2. A hot cathode must be on (channel on) in order to degas it.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Leakage Mode.

   The system responds by scrolling through modes.

2. Press the [DEGAS/SET POINT] key, then the [ON/LEAD] key, followed by [1], [2], [3], or [4].

   The system responds by turning on the low power degas of the hot cathode on the selected channel, and causing that channel's display to toggle between a pressure reading and dG .

Caution

Damage to a hot cathode gauge can occur if pressure is allowed to get too high. Monitor the pressure, and control it within the specifications stated for the hot cathode gauge.

Degas is only effective if the pressure remains less than 1 x 10^{-5} Torr.

How To Start Hot Cathode High Power Degassing

During a high power degas, the filament inside the hot cathode is turned off, and all power is delivered to the grid inside the tube. Pressure readings are *not* obtained during a high power degas.

Caution

Only perform a high power degas procedure on a high power hot cathode gauge. Performing a high power degas procedure on a low power gauge may damage the grid within the gauge.

Note

1. The 146 unit can only perform the degassing procedure on *one* hot cathode gauge at a time. All other channels will continue to function during the degassing procedure.
2. A hot cathode must be on (channel on) in order to degas it.

The front panel display for the degassing hot cathode displays **dG** (the degas code) continuously for a high power degas.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Leakage Mode.

   The system responds by scrolling through modes.

2. Press the [DEGAS/SET POINT] key, followed by [1], [2], [3], or [4].

   The system responds by turning on the high power degas of the hot cathode on the selected channel, and causing that channel's display to change to **dG** .

Caution

Damage to a hot cathode gauge can occur if pressure is allowed to get too high. Monitor the pressure, and control it within the specifications stated for the hot cathode gauge.

Degas is only effective if the pressure remains less than 1 x 10^{-5} Torr.

How To Stop Hot Cathode Degassing

When a low power degas is turned off, power to the grid inside the tube is discontinued. The filament remains on and the front panel display shows the pressure reading.

When a high power degas is turned off, power to the grid inside the tube is discontinued (as with a low power degas). The channel re-initializes and the hot cathode filament turns on. The front panel display shows a pressure reading during initialization but this reading should not be considered valid until the display stops flashing (within 1 to 2 seconds).

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Leakage Mode.

   The system responds by scrolling through modes.

2. Press the [DEGAS/SET POINT] key, then the [OFF/GAIN] key, followed by [1], [2], [3], or [4].

   The system responds by turning off the degas of the hot cathode on the selected channel.

   A. If the hot cathode had been undergoing a low power degas, its display shows a continuous, valid, pressure reading.

   B. If the hot cathode had been undergoing a high power degas, the gauge re-initializes and its display flashes until initialization is complete (within 2 seconds). The display then shows a continuous, valid, pressure reading.

Chapter Six: Operation in Tuning Mode

General Information

Tuning Mode is available only if a Control board is installed (in which case, a valve control legend such as HOLD, is displayed). Press the [DISPLAY MODE] key twice from Normal Mode to scroll to Tuning Mode. The word TUNING appears in small letters above the main display.

Figure 41: Tuning Mode - Original Display, page 152, shows a sample window for Tuning Mode. Tuning Mode allows for fine tuning of seven valve control parameters. Of these seven parameters, three are included in recipes (GAIN, LEAD, and SET POINT), and four are independent valve control parameters (BASE, START, INTEGRAL, and PRESET).

The three control parameters GAIN, LEAD, and SET POINT are associated in a recipe. The default values in these recipes are:

GAIN	10
LEAD	1.5 seconds
SET POINT	0

By changing these default values, you can match the best lead and gain parameters with different set points. In addition, you can associate each recipe with a different control channel (refer to *Code 14x: How To select Polarity and the Control Channel*, in the *Operation in Setup Mode* chapter). In this way, a multi-stepped process can be easily implemented with a predefined recipe (refer to *How To Select the Active Recipe* in the *Operation in Control Mode* chapter).

In addition to these seven valve control parameters, there are several more are accessible from Setup Mode. Refer to *Code 4 (Alpha), Code 13x (Softstart), Code14x (Polarity and Control Channel)*, and *Code 15x (Analog Set Point)*, in the *Operation in Setup Mode* chapter for more information about these additional valve control parameters.

The Front Panel Window

LEFT DISPLAY

This is the current valve position expressed as a percent of the valve control signal output.

This example shows a setting of 20.1% of the valve control signal output.

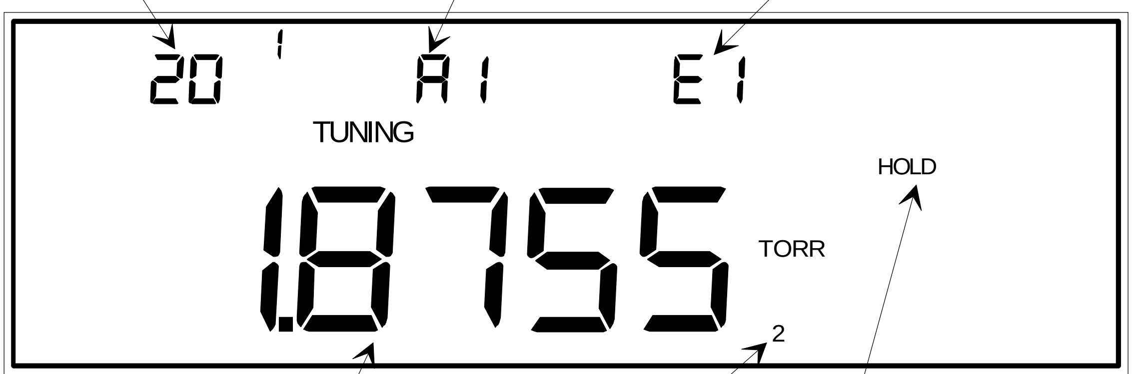
CENTER DISPLAY

This indicates which of the four possible recipes is the active recipe (in this case, it is recipe 1).

Refer to Control Mode to select which recipe is the active recipe.

RIGHT DISPLAY

This indicates which of the four possible recipes is selected for editing (in this case, it is recipe 1).



MAIN DISPLAY

The pressure reading from the gauge on the control channel (in this case, channel 2) is shown here.

Note: The control channel determines which gauge's pressure reading is compared to set point.

Note: This parameter must be HOLD (as in this example), or MANUAL, in order to adjust the valve position shown in the left display.

Figure 41: Tuning Mode - Original Display

Note The first time you enter the Tuning Mode, the window looks like the example above. After activating any of the Tuning parameters, however, the window may appear with a parameter legend displayed when Tuning Mode is entered again. An example of this is shown in Figure 42, page 153. To return to the original Tuning Mode display, press [QUIET/CANCEL].

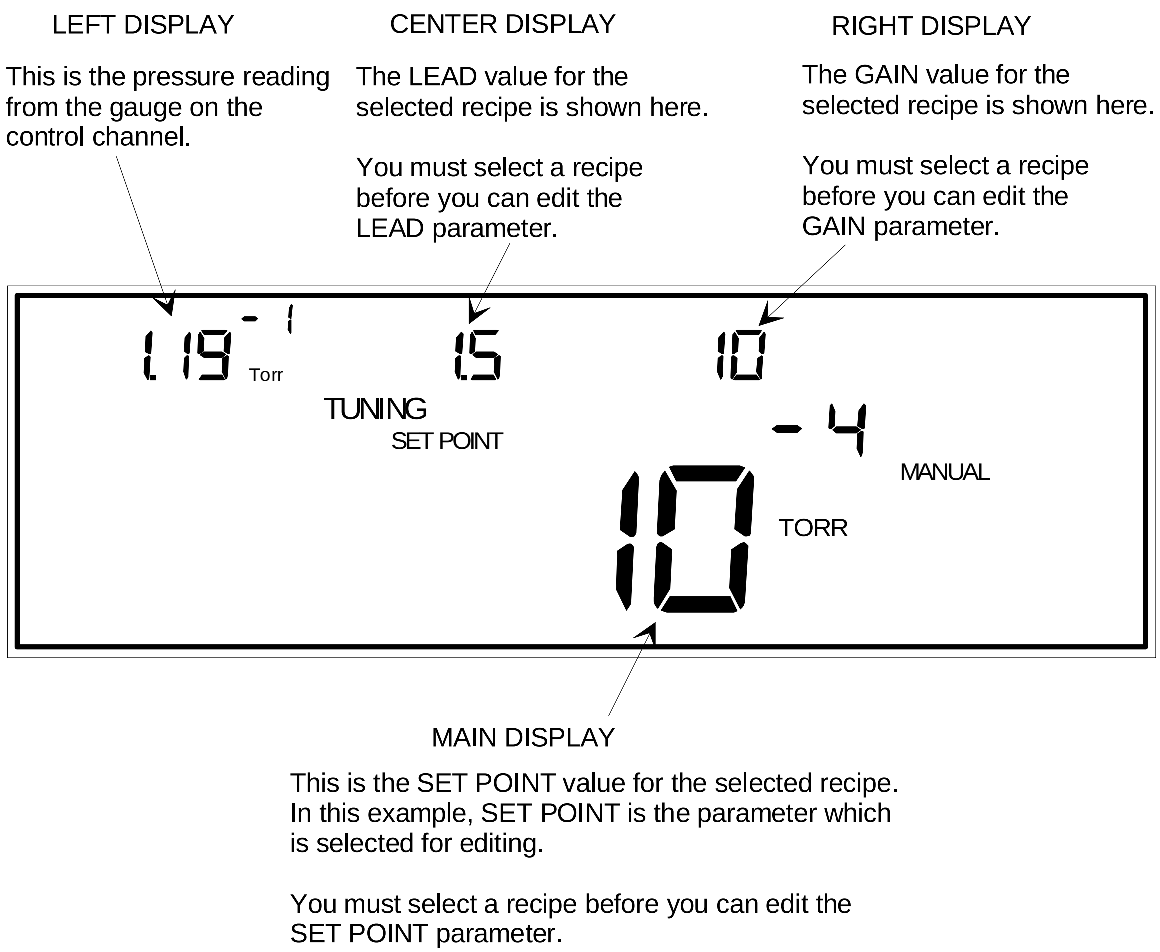


Figure 42: The SET POINT legend displayed in Tuning Mode

The Various Displays in Tuning Mode

In Tuning Mode, the content of the different displays varies depending upon which function you are currently performing. Table 42, page 155, summarizes what is in each display when performing Tuning Mode functions. Italics are used to indicate which displays have editable parameters.

For all parameters *except* Valve Position, the parameter name is displayed when the parameter is editable. For example, the Base parameter is editable when the word **BASE** is displayed, and the Set Point parameter is editable when the words **SET POINT** are displayed. Refer to Figure 1, page 21, to refresh your memory of exactly where the parameter names appear in the front panel window.

The Valve Position parameter is only editable when no other Tuning Mode parameter (BASE, START, INTEGRAL, PRESET, GAIN, LEAD, or SET POINT), is displayed, ***and*** when the Control Mode parameter MANUAL or HOLD is displayed.

Summary of Tuning Mode Displays				
Adjust these Parameters	**Left Display**	**Center Display**	**Right Display**	**Main Display**
Valve Position * (No parameter is displayed)	*Current valve position* * MANUAL/ HOLD must be displayed	Indicates active recipe	*Indicates editable recipe*	Pressure reading from gauge on control channel
Base	Current valve position	*The BASE position for the selected recipe*	"	"
Start	"	*The START position for the selected recipe*	"	"
Integral	"	*The INTEGRAL value for the selected recipe*	"	"
Preset	"	*The PRESET position for the selected recipe*	"	"
Gain	"	The LEAD value for the selected recipe	*The GAIN value for the selected recipe*	"
Lead	"	*The LEAD value for the selected recipe*	The GAIN value for the selected recipe	"
Set Point	Pressure reading from gauge on the control channel	"	"	*The SET POINT value for the selected recipe*
Note: *Italics* are used to indicate displays with editable parameters.				

Table 42: Summary of Tuning Mode Displays

Tuning Mode is Used when Performing the Following Procedures

Tuning Mode Functions	
Change the valve position	This feature is only functional if the [MANUAL] or [HOLD] legend is displayed. The current valve position becomes editable.
Adjust the Base parameter	Base is defined as the smallest user-defined value for the valve control signal output. In effect, this limits how closed the valve can become. ***Note:*** The Base parameter can override the Softstart parameter.
Adjust the Start parameter	The Start value is used to set the initial position of the valve when the AUTO feature is evoked in Control Mode. The Start value only applies if the valve was at full open or full close just prior to evoking the AUTO feature. ***Note:*** If Softstart is enabled, it can override the Start parameter.
Adjust the Integral parameter	The Integral parameter selects the time constant used for the integral term of the PID control.
Adjust the Preset parameter	The Preset value is used to set the position of the valve when the MANUAL feature is evoked in Control Mode.
Adjust the Gain parameter	Gain can be adjusted, and is associated with the selected recipe.
Adjust the Lead parameter	Lead can be adjusted, and is associated with the selected recipe.
Adjust the Set Point parameter	Set Point can be adjusted, and is associated with the selected recipe.
Edit Control Recipes	There can be up to four recipes, each with its own Set Point, Gain, and Lead parameters. By switching the active recipe (in Control Mode), and selecting the AUTO feature (also in Control Mode), one of these four multi-parameter recipes can be used to position the valve.

Table 43: Tuning Mode Functions

The Two Levels within Tuning Mode

Figure 43, page 158, depicts the differences in functionality and in key operation between the two levels of Tuning Mode.

The Upper Level of Tuning Mode

When Tuning Mode is first entered, it is always operating at the upper level. This is true regardless of whether or not any Tuning Mode parameters (BASE, START, INTEGRAL, PRESET, GAIN, LEAD, or SET POINT), are currently displayed. This level is used to scroll among the parameters and observe their current values, but *no parameter editing* can be done at this level.

It is important to understand that the Valve Position parameter does not have a specific legend as do all other Tuning Mode parameters. In order to select the Valve Position parameter, the *Control Mode* parameter HOLD or MANUAL must be displayed. Additionally, you must move through the *Tuning Mode* parameters until none of the other Tuning Mode parameters are displayed. There are two ways to move to the Valve Position parameter.

One press of the [QUIET/CANCEL] key selects the Valve Position parameter (no Tuning Mode parameters are displayed). Alternately, the Valve Position parameter can be selected by scrolling to it with the arrow keys. As Figure 43, page 158, shows, the Valve Position parameter is positioned between the BASE parameter and the SET POINT parameter. If the BASE parameter legend is displayed, one press of the ↓ selects the Valve Position parameter. If the SET POINT parameter legend is currently displayed, one press of the ↑ selects the Valve Position parameter.

The ↑ and ↓ keys the [QUIET/CANCEL] key, and the [ENTER] key function differently in the two levels of Tuning Mode. On the upper level, the arrow keys scroll through the Tuning Mode parameters BASE, START, INTEGRAL, PRESET, GAIN, LEAD, SET POINT, and Valve Position (remember, there is no Valve Position parameter legend). The [QUIET/CANCEL] key first selects the Valve Position parameter, and if pressed again, returns the 146 unit to Normal Mode. The [ENTER] key selects a parameter for editing and moves to the lower level of Tuning Mode.

The Lower Level of Tuning Mode

The lower level of Tuning Mode is used for parameter editing. To move from the upper level to the lower level, move to the parameter to be edited, then press the [ENTER] key.

On the lower level, the arrow keys increment and decrement the value of the selected parameter. For example, if the GAIN parameter is selected for editing, then the ↑ increases the displayed value for GAIN , and the ↓ decreases it.

On the lower level the [QUIET/CANCEL] key has an additional function. When first pressed, the key returns the editable parameter to its pre-edited value. For example, if GAIN is the editable parameter, and its initial value is 5, the ↑ key increases the value to 6. If the [QUIET/CANCEL] key is pressed, the value for GAIN returns to 5. After this initial operation, the [QUIET/CANCEL] key returns to the upper level.

When still on the lower level, the [ENTER] key causes the 146 unit to accept the value for the currently editable parameter, and returns the unit to the upper level of Tuning Mode.

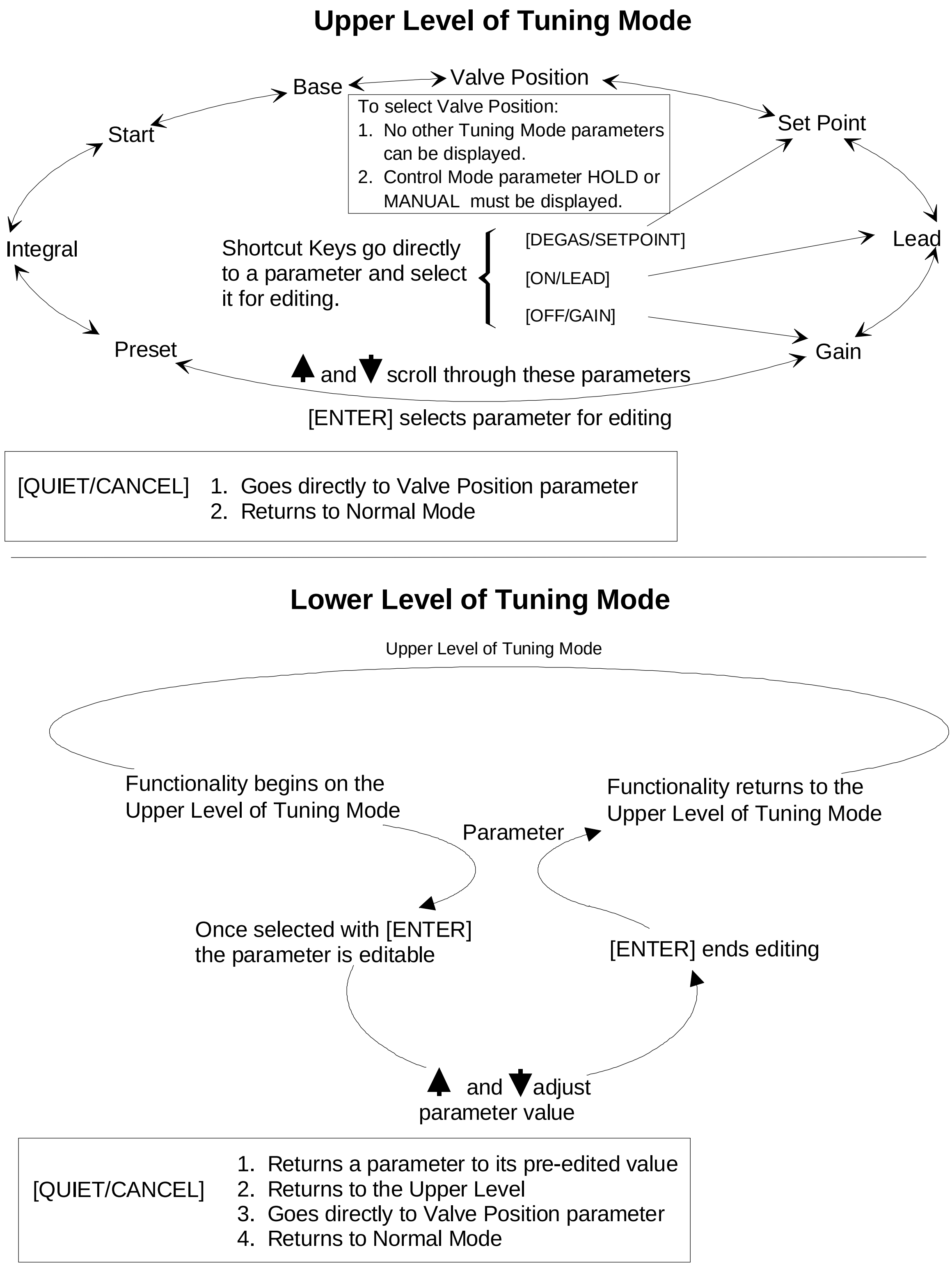


Figure 43: The Two Levels within Tuning Mode

Keys

Table 44 explains the variations in how keys work in Tuning Mode. The Shortcut keys are quick ways of selecting certain parameters. The arrow keys can also be used.

Special Key Functions in Tuning Mode	
Keys	**Key Function**
[+/-]	The [+/-] key moves edit capability one digit to the left in a parameter field. For example, if the value in a parameter field is **123**, and you are using the arrow keys to adjust the **3** digit, the [+/-] key moves the edit capability to the **2** digit. Now, the arrow keys adjust the **2** digit. If the [+/-] key is pressed again, the adjustment control moves to the **1** digit.
[EXP/.]	The [EXP/.] key moves edit capability one digit to the right in a parameter field. For example, if the value in a parameter field is **123**, and the arrow keys are adjusting the **1** digit, the [EXP/.] key moves the edit capability to the **2** digit. Now, the arrow keys adjust the **2** digit. If the [EXP/.] key is pressed again, adjustment control moves to the **3** digit.
[QUIET/CANCEL]	1. Returns a parameter to its pre-edited value (Lower Level only). 2. Selects the Valve Position parameter (Both Levels). 3. Returns the 146 unit to Normal Mode.
⬆ and ⬇	1. Scroll through Tuning Mode parameters (Upper Level). 2. Increase/decrease the value of the editable parameter (Lower Level).
Shortcut Keys	**Key Function**
[QUIET/CANCEL]	Selects the Valve Position parameter, On the Upper level of Tuning Mode. On the Lower level, this key selects the Valve Position parameter *after* it returns any currently editable parameter to its pre-edited value.
[DEGAS/SET POINT]	Selects the SET POINT parameter for updating, and causes it to blink in the main display. The SET POINT legend appears above the main display.
[ON/LEAD]	Selects the LEAD parameter for updating, and causes it to blink in the center display. The LEAD legend appears above the main display.
[OFF/GAIN]	Selects the GAIN parameter for updating, and causes it to blink in the right display. The GAIN legend appears above the main display.

Table 44: Special Key Functions in Tuning Mode

The Deviation Indicator

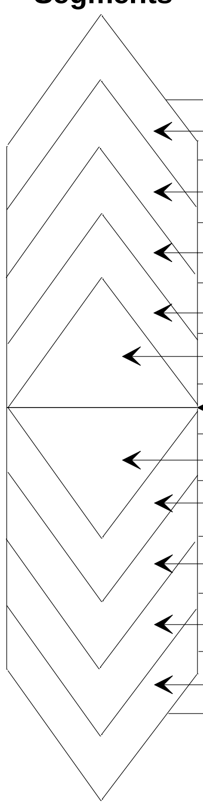
In Tuning Mode there is a deviation indicator which indicates the deviation of the system pressure from set point. The deviation from set point is displayed approximately every one-third second (this is how often the LCD screen is refreshed). The deviation indicator is enabled only if the 146 unit is operating with the AUTO feature turned on (refer to *How To Set the Valve to AUTO Position*, in the *Operation in Control Mode* chapter).

There are ten deviation indicator segments. The five upper segments represent pressure deviation over set point and the five lower segments represent pressure deviation under set point. The 146 unit determines the segment(s) to illuminate according to the following formula:

$$\text{Deviation} = \frac{P}{sp} \qquad \text{Where: } P = \text{pressure},\; sp = \text{set point}$$

Each segment represents a different percent of deviation as shown in Figure 44.

Segments



Deviation	Percent Error
≥ 1.95	> +95%
1.2 to < 1.95	+20 to 95%
1.05 to < 1.2	+5 to 20%
1.01 to <1.05	+1 to 5%
1.002 to < 1.01	+0.2 to 1%
None = 0.998 to <1.002	±0.2%
0.99 to < 0.998	-0.2 to 1%
0.95 to < 0.99	-1 to -5%
0.80 to <0.95	-5 to -20%
0.05 to < 0.80	-20 to -95%
<0.05	> -95%

Figure 44: Deviation Indicator

If the system is operating far below set point, there will be a large change in pressure between screen refreshing because the system will be quickly moving towards set point. Within the one-third second time frame, the deviation could range from - 22% (at the beginning of the time frame), to - 4% (at the end of the time frame). In this case, the middle three segments in the lower half of the deviation indicator light up (refer Figure 44, page 160).

As another example, assume there is pressure oscillation above and below set point. Upper and lower deviation indicator segments light up to indicate over and under pressure readings. In effect, the deviation indicator provides similar information to that provided by an oscilloscope. If the oscillation continues, it is possible that reducing the Gain setting may improve system stability. When the system does stabilize, none of the deviation indicators are lit.

When the Set Point is 0:

If the set point is 0 and the pressure reading is 0, no segments light up.

If the set point is 0 and the pressure is above 0, the uppermost segment lights up.

If the set point is 0 and the pressure is below 0, the lowermost segment lights up.

How To Change the Valve Position

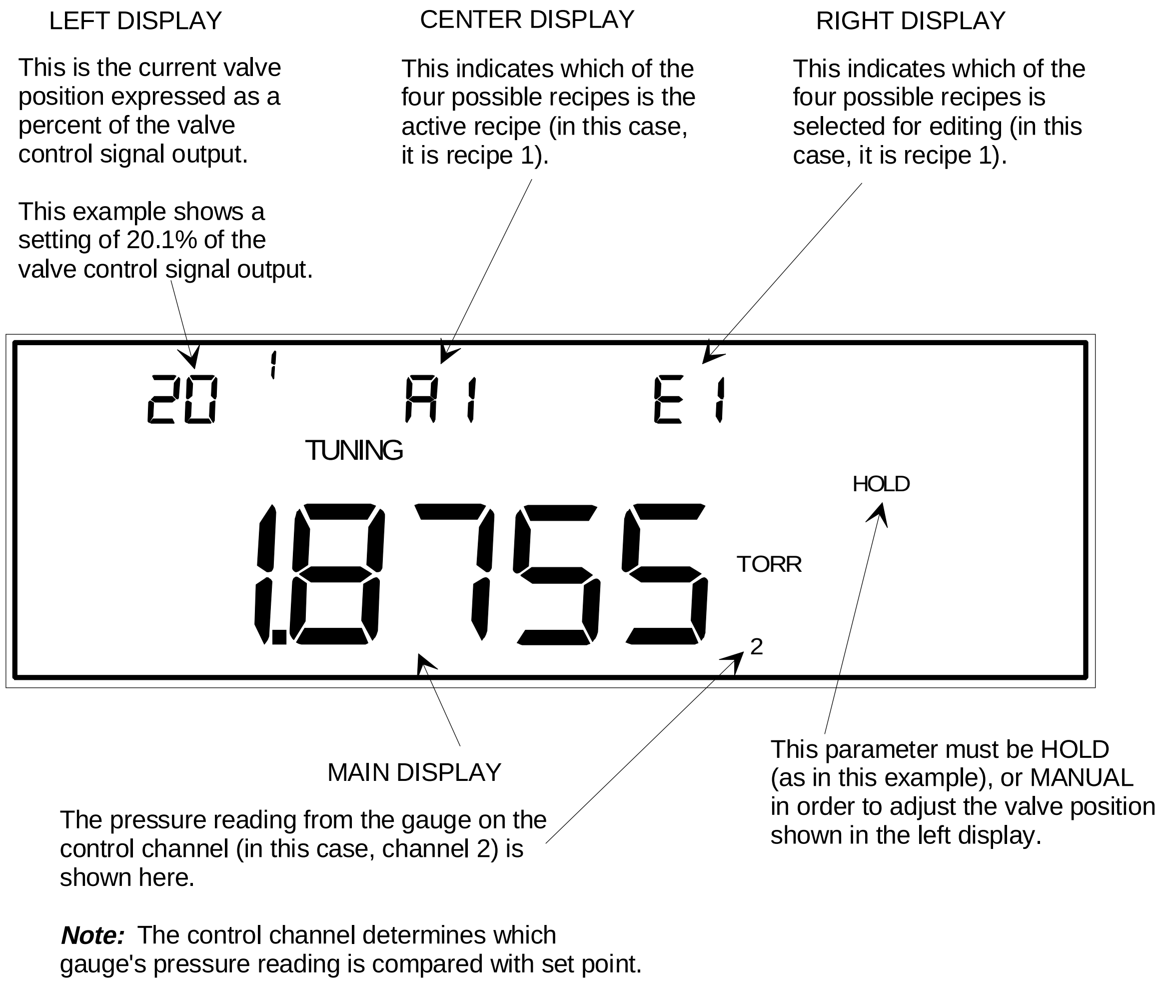


Figure 45: Tuning Mode Display when Adjusting the Valve Position

The Valve Position can only be changed if the MANUAL or HOLD legend is displayed.

The Valve Position is expressed as a percent of the valve control signal output. If the valve is currently in a HOLD position (selected in Control Mode) the HOLD feature is overridden while the Valve Position is changed. After adjusting the Valve Position, the *new* position is maintained in a HOLD status.

Valve Position is a real-time parameter. The new valve position goes into effect as soon as it is adjusted with this procedure.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Tuning Mode.

   The system responds by scrolling through modes.

2. Be sure the correct Tuning Mode window is displayed.

   If any of the Tuning Mode legends is displayed (BASE, START, INTEGRAL, PRESET, GAIN, LEAD, or SET POINT), press the [QUIET/CANCEL] key until the legend is gone.

3. Press the [ENTER] key.

   The system responds by causing the left display to blink.

4. Enter a Valve Position (expressed as a percent of the valve control signal output).

   A new Valve Position may be entered using the number keys. The Valve Position, which is currently displayed, can be adjusted using the arrow keys and the [+/-] key.

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, enter the correct valve position, then press the [ENTER] key.

   The system responds by accepting the valve position. The valve's position changes according to the valve control signal entered here, and is then maintained at this position.

How To Adjust Base

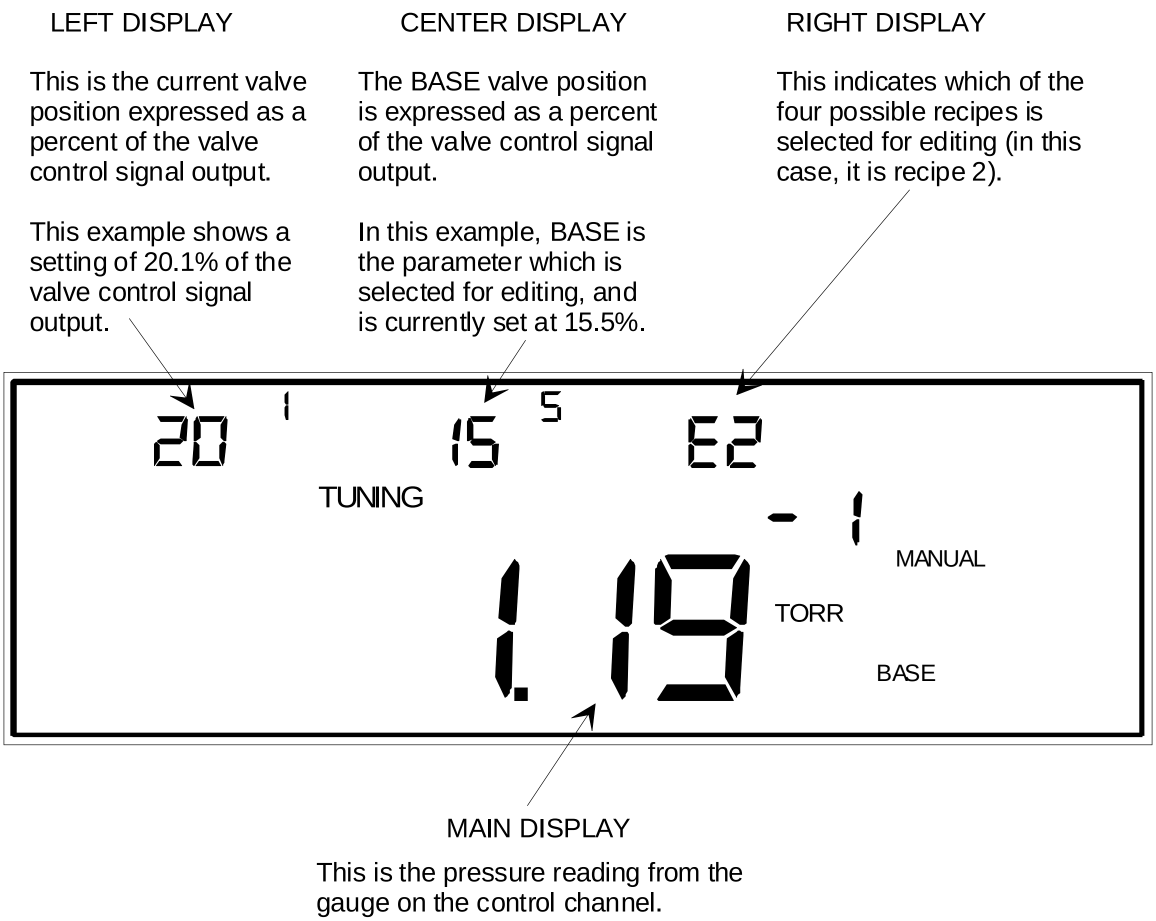


Figure 46: Adjusting the Base Valve Position

Base is a valve control parameter that is expressed as a percent of the valve control signal output. A Base setting of 20 means the valve control signal output should not go below 20% of the full open output. In effect, this means the valve should remain at least 20% open.

For solenoid valves, the Base parameter is frequently adjusted to the point just below where the valve begins to open.

Note The Base parameter can override the Softstart parameter (*Code 13x* in the *Operation in Setup Mode* chapter).

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Tuning Mode.

   The system responds by scrolling through modes.

2. Select the BASE parameter by scrolling through the parameters with the arrow keys.

   The system responds by displaying each of the Tuning parameters as they are scrolled through.

3. Press the [ENTER] key.

   The system responds by causing the center display to blink.

4. Enter the Base value. The range is from 0 to 103% of full open, and the default is 0.

   A. If the center display shows the correct base value, press the [ENTER] key.

   B. If the center display is not correct, use the numeral keys and the arrow keys (for tenths of a percent) to enter the correct Base value, then press the [ENTER] key.

   The system responds by accepting the Base value.

How To Adjust Start

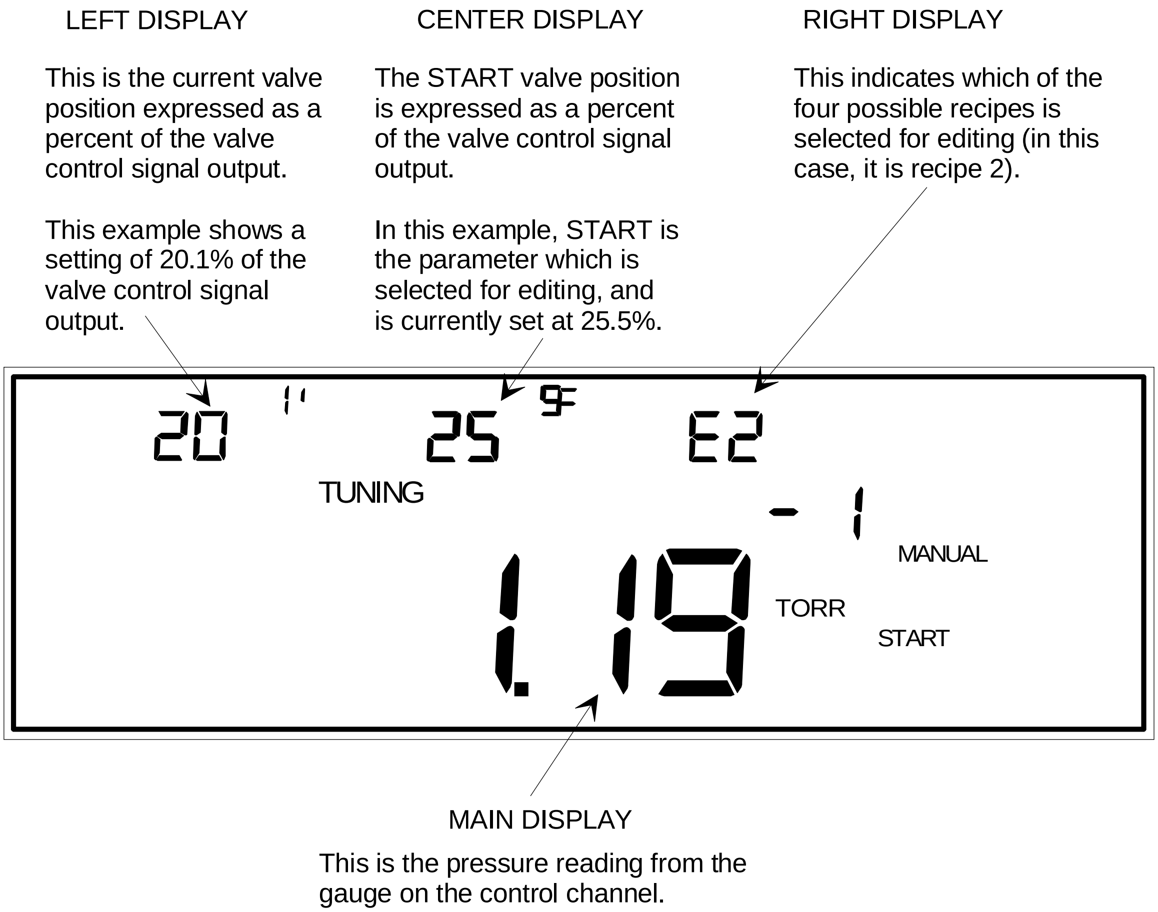


Figure 47: Adjusting the Start Valve Position

Start is a valve position, expressed as a percent of the valve control signal output. The Start value is used to set the initial position of the valve when the AUTO feature is evoked in Control Mode. The Start value only applies if the valve was at full open or full close just prior to evoking the AUTO feature.

Note If the Softstart parameter (*Code 13x* in the *Operation in Setup Mode* chapter), is enabled, it can override the Start parameter.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Tuning Mode.

   The system responds by scrolling through modes.

2. Select the START parameter by scrolling through the parameters with the arrow keys.

   The system responds by displaying each of the Tuning parameters as they are scrolled through.

3. Press the [ENTER] key.

   The system responds by causing the center display to blink.

4. Enter the Start value. The range is from 0 to 103% of full open, and the default is 0.

   A. If the center display shows the correct Start value, press the [ENTER] key.

   B. If the center display is not correct, use the numeral keys and arrow keys to enter the correct Start value, then press the [ENTER] key.

   The system responds by accepting the Start value.

How To Adjust Integral

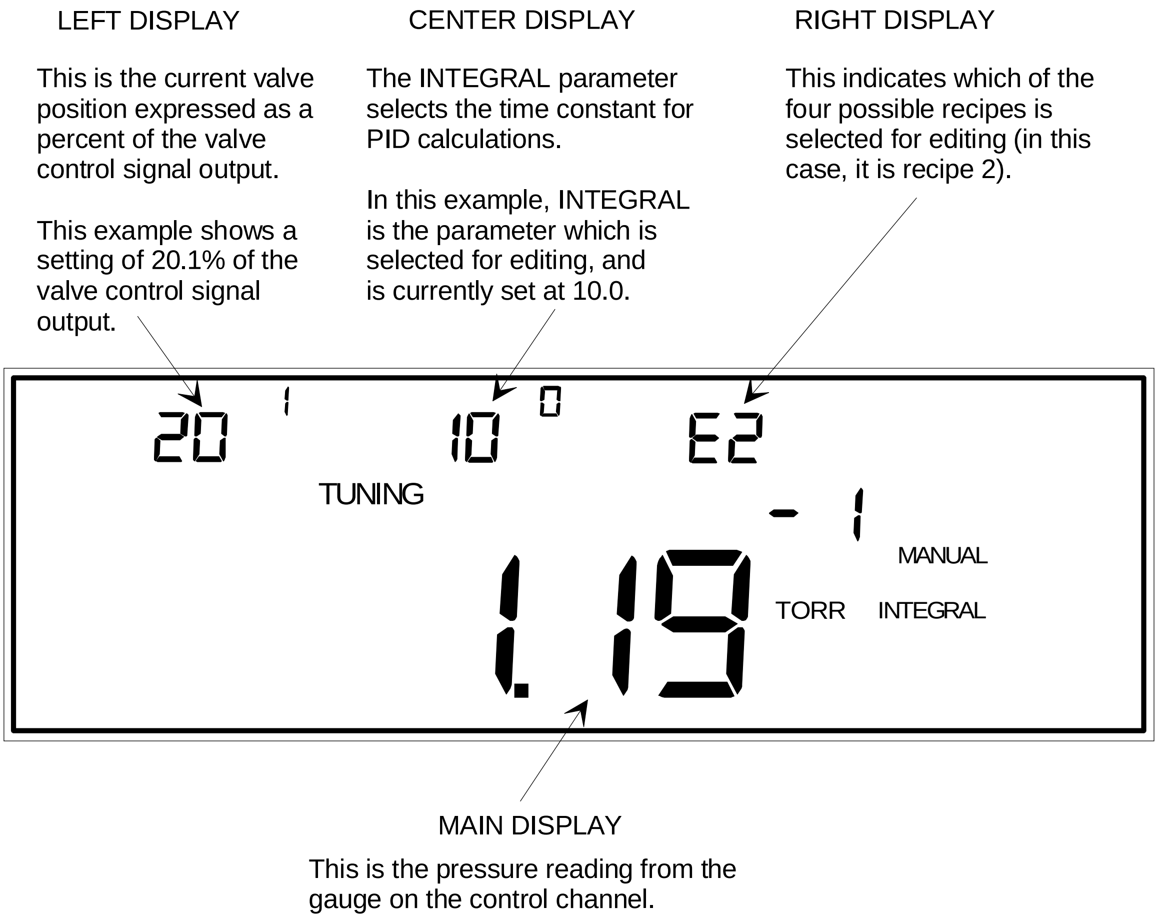


Figure 48: Adjusting the Integral Value

The Integral parameter selects the time constant used for PID calculations.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Tuning Mode.

   The system responds by scrolling through modes.

2. Select the INTEGRAL parameter by scrolling through the parameters with the arrow keys.

   The system responds by displaying each of the Tuning parameters as they are scrolled through.

3. Press the [ENTER] key.

   The system responds by causing the center display to blink.

4. Enter the Integral value. The value must be between 0.02 and 100 (inclusive) seconds, and the default is 0.3 seconds.

    A. If the center display shows the correct Integral value, press the [ENTER] key.

    B. If the center display is not correct, use the numeral keys and arrow keys to enter the correct Integral value, then press the [ENTER] key.

    The system responds by accepting the Integral value.

How To Adjust Preset

LEFT DISPLAY

This is the current valve position expressed as a percent of the valve control signal output.

This example shows a setting of 20.1% of the valve control signal output.

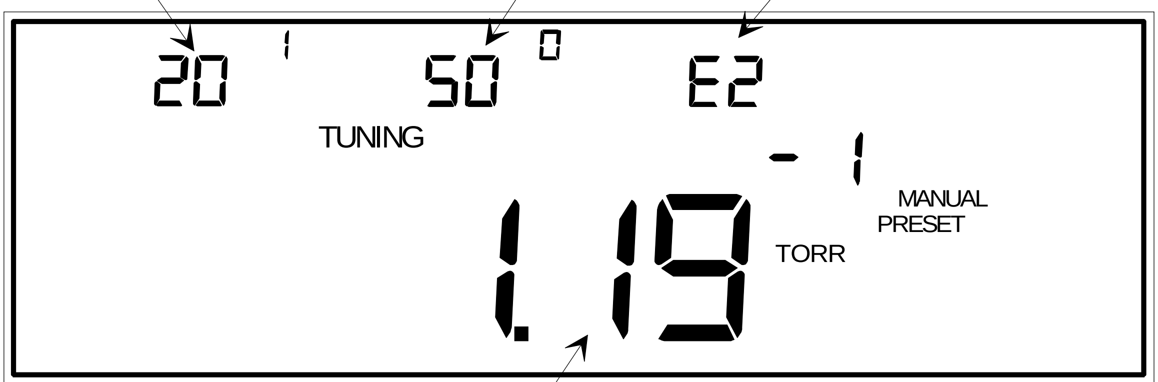
CENTER DISPLAY

The PRESET valve position is expressed as a percent of the valve control signal output.

In this example, PRESET is the parameter which is selected for editing, and is currently set at 50.0%.

RIGHT DISPLAY

This indicates which of the four possible recipes is selected for editing (in this case, it is recipe 2).



MAIN DISPLAY

This is the pressure reading from the gauge on the control channel.

Figure 49: Adjusting the Preset Valve Position

Preset is a valve position, expressed as a percent of the valve control signal output. The Preset value is used to set the position of the valve when the MANUAL feature is evoked in Control Mode.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Tuning Mode.

   The system responds by scrolling through modes.

2. Select the PRESET parameter by scrolling through the parameters with the arrow keys.

   The system responds by displaying each of the Tuning parameters as they are scrolled through.

3. Press the [ENTER] key.

   The system responds by causing the center display to blink.

4. Enter the Preset value. The range is from 0 to 103% of full open, and the default is 99.8%.

   A. If the center display shows the correct Preset value, press the [ENTER] key.

   B. If the center display is not correct, use the numeral keys and arrow keys to enter the correct Preset value, then press the [ENTER] key.

   The system responds by accepting the Preset value.

How To Edit Recipes (Gain, Lead, and Set Point)

Editing a recipe follows the same procedure as editing the gain, lead, and set point parameters separately. It is mentioned here in a separate *How To* section so that you do not have to read the following three *How To* sections to know how to edit a recipe. The instructions can be presented in a more efficient manner than when they are presented as three separate instruction sets.

The 146 unit can store four different recipes. Each recipe contains a gain, lead, and set point value, and an associated control channel (refer to *Code 14x: Select Polarity and Control Channel*, in the *Operation in Setup Mode* chapter to select the control channel). The 146 unit comes with four identical recipes. The default values in these recipes are:

GAIN	10
LEAD	1.5 seconds
SET POINT	0

Channel 1 is the default control channel for all recipes. When the 146 unit is set to control with the AUTO feature (refer to *How To Set the Valve to AUTO position*, in the *Operation in Control Mode* chapter), it controls according to the parameter values of the active recipe (refer to *How To Select the Active Recipe*, also in the *Operation in Control Mode* chapter).

Note It is not necessary to follow this *exact* sequence of steps. The gain, lead, and set point values can be entered in any order.

Recipe parameters (GAIN, LEAD, and SET POINT) are real-time parameters. The new parameter values go into effect as soon as they are adjusted with this procedure.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Tuning Mode.

   The system responds by scrolling through modes.

2. Enter the number of the recipe to be created or edited.

   The system responds by accepting the recipe number.

Note If the MANUAL or HOLD legend is displayed, *and* the right display shows the Edit Recipe parameter (E1, E2, E3, or E4), the left display will blink. The left display is flashing the current control valve position. Since we want to edit the recipe, you may ignore the blinking left display and proceed to the next step.

3. Press the [OFF/GAIN] key.

   The system responds by changing the window parameters, and causing the right display to blink. The GAIN legend is displayed. Refer to Figure 50, page 174, for an example of the front panel window with the GAIN legend displayed.

4. Enter a value for Gain between 0.002 and 10,000 (the default is 10).

   A. If the Gain value is already correct, press the [ENTER] key.

   B. If the Gain value is incorrect, use the [ZERO/EXP] , [+/-] , and numeral keys to enter the correct Gain value, then press the [ENTER] key.

   The system responds by accepting the Gain value.

5. Press the [ON/LEAD] key.

   The system responds by causing the center display to blink. The LEAD legend is displayed. Refer to Figure 51, page 176, for an example of the front panel window with the LEAD legend displayed.

6. Enter a value for Lead between 0.001 and 1000 seconds (the default is 1.5 seconds).

   A. If the Lead value is already correct, press the [ENTER] key.

   B. If the Lead value is incorrect, use the [ZERO/EXP] , [+/-] , and numeral keys to enter the correct Lead value, then press the [ENTER] key.

   The system responds by accepting the Lead value.

7. Press the [DEGAS/SET POINT] key.

   The system responds by moving the pressure reading of the controlling channel from the main display to the left display, and presenting the current Set Point value in the main display. The SET POINT legend is displayed, and the main display blinks. Refer to Figure 52, page 178, for an example of the front panel window with the SET POINT legend displayed.

8. Enter a Set Point value between ± 100,000 (the default is 0).

   A. If the Set Point is already correct, press the [ENTER] key.

   B. If the Set Point is incorrect, use the [ZERO/EXP] , [+/-], and numeral keys to enter the correct Set Point, then press the [ENTER] key.

   The system responds by accepting the Set Point value.

How To Adjust Gain

LEFT DISPLAY

This is the current valve position expressed as a percent of the valve control signal output.

This example shows a setting of 20.1% of the valve control signal output.

CENTER DISPLAY

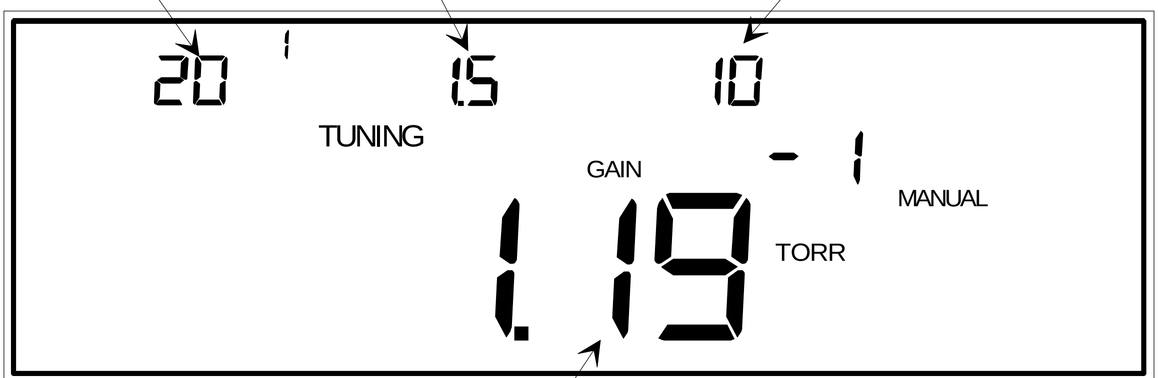
The LEAD value for the selected recipe is shown here.

You must select a recipe before you can edit the LEAD parameter.

RIGHT DISPLAY

The GAIN value for the selected recipe is shown here. In this example, GAIN is the parameter which is selected for editing.

You must select a recipe before you can edit the GAIN parameter.



MAIN DISPLAY

This is the pressure reading from the gauge on the control channel.

Figure 50: Adjusting the Gain Value

Gain is a control parameter. When installed in a control loop, the 146 unit calculates an error signal. The error signal is multiplied by the Gain setting. Thus, when the 146 unit sends out a valve drive signal (based upon the error signal which it received), the valve drive signal is proportional to the Gain setting and the error signal.

Gain is a real-time parameter. The new Gain value goes into effect as soon as it is adjusted with this procedure.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Tuning Mode.

   The system responds by scrolling through modes.

2. Enter the number of the recipe (1 through 4), which is to have the Gain setting adjusted.

   The system responds by accepting the recipe number.

Note If the MANUAL or HOLD legend is displayed, *and* the right display shows the Edit Recipe parameter (E1, E2, E3, or E4), the left display will blink. The left display is flashing the current control valve position. Since we want to edit a recipe, you may ignore the blinking left display and proceed to the next step.

3. Press the [OFF/GAIN] key, ***OR*** scroll through the Tuning Mode parameters with the arrow keys until the GAIN legend is displayed, then press the [ENTER] key.

   The system responds by changing the window parameters, and causing the right display to blink.

4. Enter a value for Gain between 0.002 and 10,000 (the default is 10).

   A. If the Gain value is already correct, press the [ENTER] key.

   B. If the Gain value is incorrect, use the [ZERO/EXP] , [+/-] , and numeral keys to enter the correct Gain value, then press the [ENTER] key.

   The system responds by accepting the Gain value.

How To Adjust Lead

LEFT DISPLAY

This is the current valve position expressed as a percent of the valve control signal output.

This example shows a setting of 20.1% of the valve control signal output.

CENTER DISPLAY

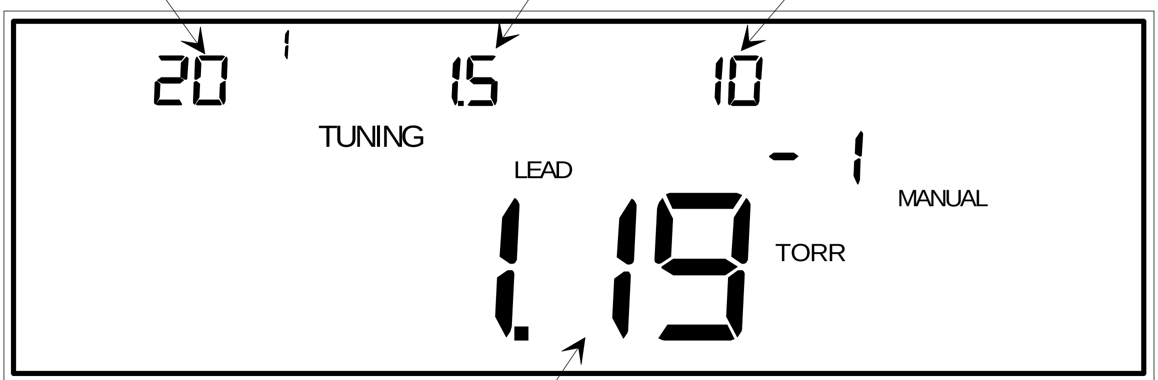
The LEAD value for the selected recipe is shown here. In this example, LEAD is the parameter which is selected for editing.

You must select a recipe before you can edit the LEAD parameter.

RIGHT DISPLAY

The GAIN value for the selected recipe is shown here.

You must select a recipe before you can edit the GAIN parameter.



MAIN DISPLAY

This is the pressure reading from the gauge on the control channel.

Figure 51: Adjusting the Lead Value

The Lead parameter creates a valve drive signal that is proportional to the *rate of change* of the controlling sensor's pressure reading. That is, the Lead value provides anticipation in the system, allowing set point to be reached more quickly.

Lead is a real-time parameter. The new Lead value goes into effect as soon as it is adjusted with this procedure.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Tuning Mode.

   The system responds by scrolling through modes.

2. Enter the number of the recipe (1 through 4), that needs to have the Lead setting adjusted.

   The system responds by accepting the recipe number.

Note

If the MANUAL or HOLD legend is displayed, *and* the right display shows the Edit Recipe parameter (E1, E2, E3, or E4), the left display will blink. The left display is flashing the current control valve position. Since we want to edit a recipe, you may ignore the blinking left display and proceed to the next step.

3. Press the [ON/LEAD] key, ***OR*** scroll through the Tuning Mode parameters with the arrow keys until the LEAD legend is displayed, then press the [ENTER] key.

   The system responds by changing the window parameters, and causing the center display to blink.

4. Enter a value for Lead between 0.001 and 1000 seconds (the default is 1.5 seconds).

   A. If the Lead value is already correct, press the [ENTER] key.

   B. If the Lead value is incorrect, use the [ZERO/EXP] , [+/-] , and numeral keys to enter the correct Lead value, then press the [ENTER] key.

   The system responds by accepting the Lead value.

How To Adjust Set Point

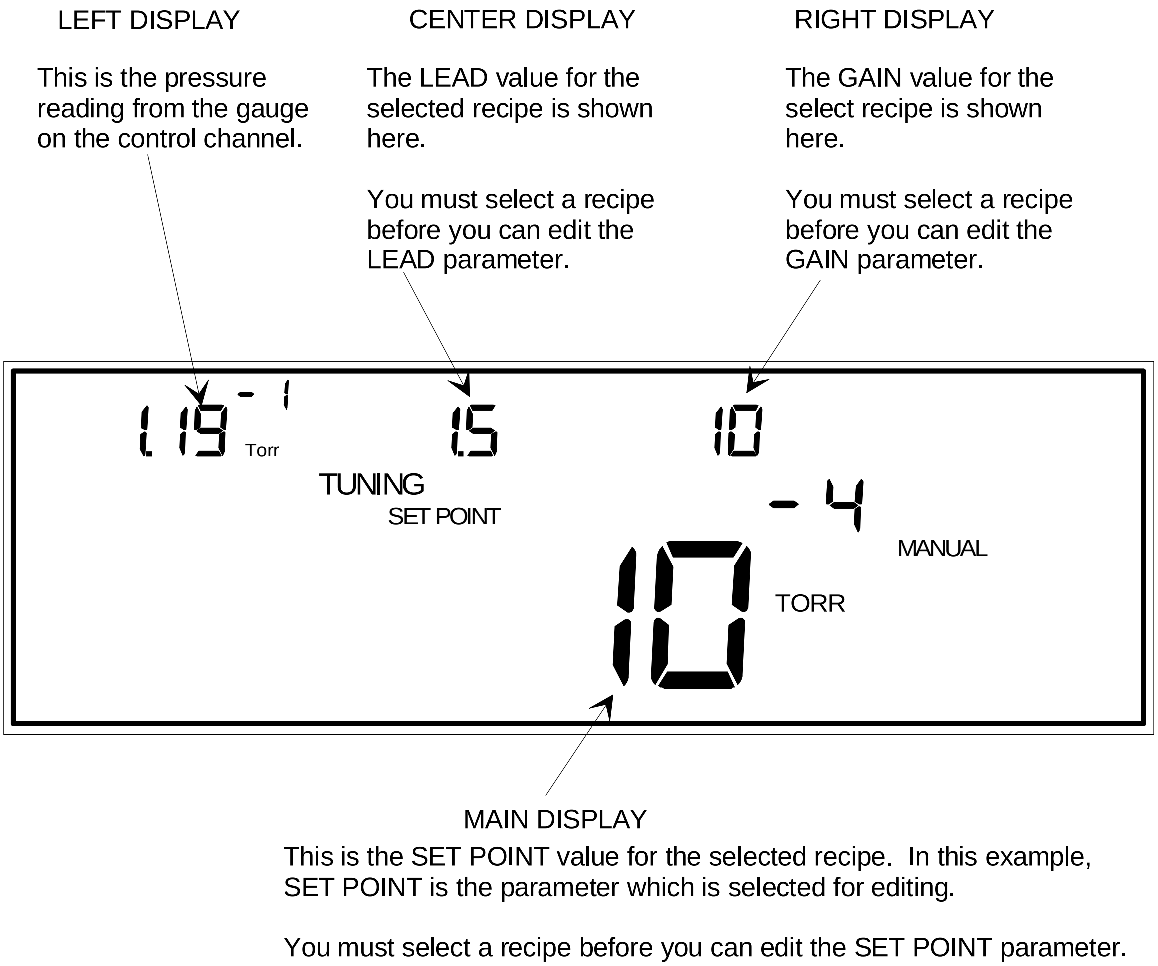


Figure 52: Adjusting the Set Point Value

Set Point is a real-time parameter. The new Set Point value goes into effect as soon as it is adjusted with this procedure.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Tuning Mode.

   The system responds by scrolling through modes.

2. Enter the number of the recipe (1 through 4) which needs to have the Set Point edited.

   The system responds by accepting the recipe number.

Note If the MANUAL or HOLD legend is displayed, *and* the right display shows the Edit Recipe parameter (E1, E2, E3, or E4), the left display will blink. The left display is flashing the current control valve position. Since we want to edit a recipe, you may ignore the blinking left display and proceed to the next step.

3. Press the [DEGAS/SET POINT] key, ***or*** scroll through the Tuning Mode parameters with the arrow keys until the SET POINT legend is displayed, then press the [ENTER] key.

   The system responds by changing the window parameters, and causing the left display to blink.

4. Enter a Set Point value between ±100,000 Torr (the default is 0).

   A. If the Set Point is already correct, press the [ENTER] key.

   B. If the Set Point is incorrect, use the [ZERO/EXP] , [+/-] , and numeral keys to enter the correct Set Point value, then press the [ENTER] key.

   The system responds by accepting the Set Point.

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Chapter Seven: Operation in Setup Mode

General Information

Press the [DISPLAY MODE] key three times from Normal Mode to get to Setup Mode. The word SETUP appears in small letters above the main display.

Figure 53 shows a sample window for Setup Mode. Setup Mode is used to set up the 146 unit to operate according to the needs of a specific control system. For example, in Setup Mode, alarm trip points are entered, and the 146 unit can be set up to read pressure over a range that is spanned by two gauges. All the miscellaneous codes for the 146 instrument are contained within Setup Mode.

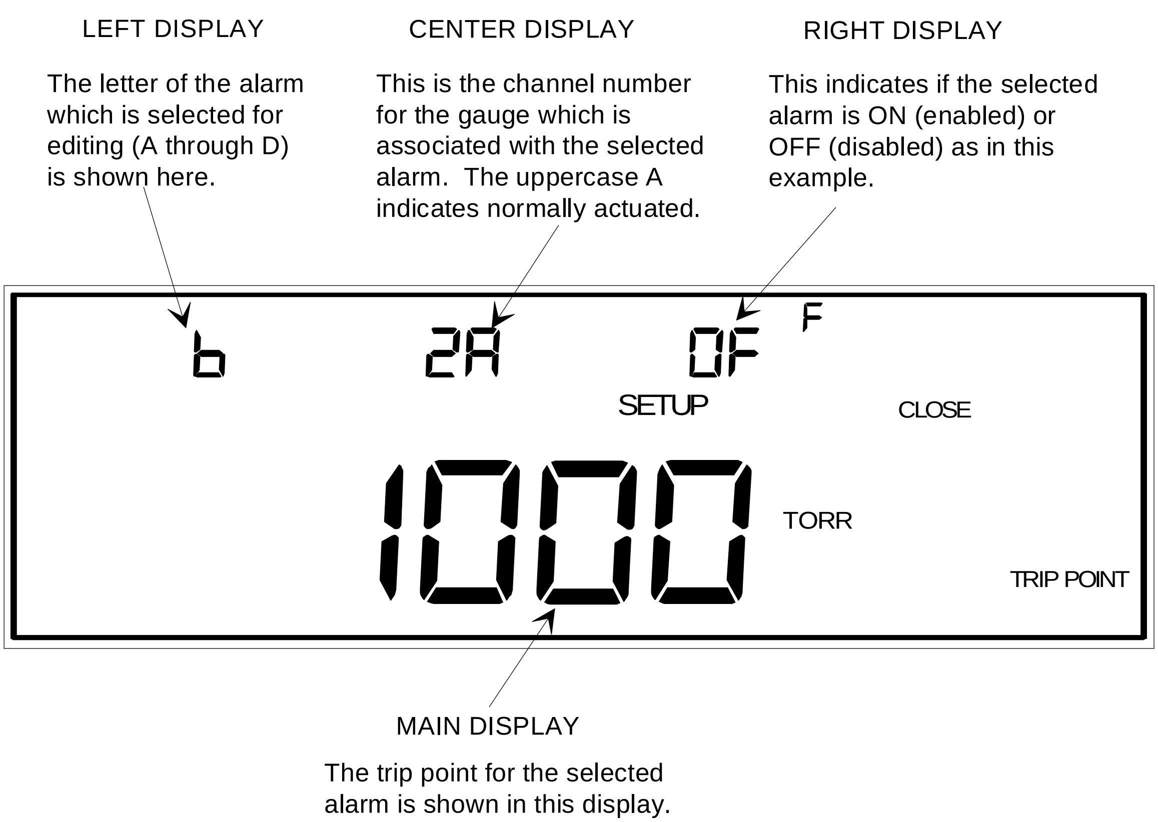


Figure 53: Setup Mode

The Various Displays in Setup Mode

In Setup Mode, the content of the different displays varies depending upon which function you are currently performing. Table 45, page 183, summarizes what is in each display when performing the Setup Mode functions. Table 46, page 184, summarizes the information in the miscellaneous code screens.

For all parameters *except* individual miscellaneous codes, the parameter name is displayed when the parameter is editable. For example, the Alarm Trip Points parameter is editable when the words TRIP POINT are displayed, and the Sensor Calibration parameter is editable when the words SENSOR CAL are displayed. Refer to Figure 1, page 21, to refresh your memory of exactly where the parameter names appear in the front panel window.

Individual miscellaneous codes are indicated by the code number in the left display, and the parameter name **CODE** at the bottom right area of the front panel window.

In the Sensor Calibration function, if a hot cathode is on the selected channel, the letters Hc appear in the right display. Above and to the right of the letters Hc is either the letter H or the letter l . The letter H is used to indicate a high power hot cathode and it is the default setting. The letter l is used to indicate a low power hot cathode (HPS low power, Bayard-Alpert, nude, hot cathode). Refer to *Hot Cathode,* page 55, for instructions on how to change the default setting and accommodate a low power hot cathode.

Summary of Setup Mode Displays				
Function	**Left Display**	**Center Display**	**Right Display**	**Main Display**
Set Alarm Trip Points	Alarm letter	Channel number for alarm	On/Off Alarm	Alarm trip point
Set Up Dual Channels	Dual channel number *and* High/Low switchpoint	Control channel number	Continuous (ct) or discontinuous (dt) or Off, dual channel display	Dual channel switchpoint
Set Up Analog Outputs	Analog Output #	Input channel #	Output scaling method	Pressure = Full scale output or set point
Sensor Calibration	Input channel number	CM: sensor resolution	Type of gauge	CM: sensor range
		P: factory or user-defined zero/ span		P: gas type
		CC: ion gauge disconnect threshold value		CC: combined gauge & GCF
		HC: ion gauge disconnect threshold value	The letter H or l above Hc, indicates high or low powered hot cathode. *Not editable here*	HC: sensitivity
		FC: MFC mode of operation - either (SP) or (to). *Not editable here*		FC: MFC range

Table 45: Summary of Setup Mode Displays

Summary of Setup Mode Codes				
Function	**Left Display**	**Center Display**	**Right Display**	**Main Display**
1 Select Volt/ Pressure/ or Current	Code number	-	HU (high voltage), EC (emission current), or IC (ion current) *Main display must be Volt, or this is unused	Selects Volt or PrES (pressure)
2 Select Pressure Units	Code number	-	-	Selects pressure unit
3 Edit Audio Alarms	Code number	-	-	On or Off audio alarm
4 Adjust Alpha	Code number	-	-	Alpha value
5 Set up RS-232 Port	Code number	Data bits and parity	Data logger or MKS protocol	Baud rate
7 Set up Main Display in Leakage Mode	Code number	-	-	Determine Leakage Mode main display
8 Edit Data Logger Interval	Code number	-	-	Data logger interval value
10x Adjust Display Lag	Code number	-	-	Display lag percent
11x Auto Zero	Code number	-	On/Off Auto Zero	Reference channel number
12x Adjust Ion Gauge Auto Power Control	Code number & channel number for ion gauge	Reference channel number	On/Off auto power control	Trip point for auto power control
13x Adjust Softstart	Code number and recipe number	-	On/Off softstart speed function	Softstart speed
14x Set Polarity & Control Channel	Code number and recipe number	-	Control channel number recipe dependent	Select dir (direct) or rEV (reverse polarity

Table 46: Summary of Setup Mode Codes
(Continued on next page)

Summary of Setup Mode Codes *(Continued)*				
Function	**Left Display**	**Center Display**	**Right Display**	**Main Display**
15x Set up Analog Set Point	Code number and recipe number	Voltage to span analog input	On/Off analog set point	Full scale input voltage
16x Adjust HC High Pressure Shutoff	Code number and channel number	-	Internal fast rate-of-rise shutoff value	High pressure shutoff value
17x Adjust MFC Set Point, Mode, and Co-channel	Code number and channel number	Co-channel, *for Totaling only*	Set Point, Totaling, or Ratio parameter selection	Set Point
18x Select the Type of Convection Gauge	Code number and channel number	-	-	Convection gauge type; Cn for Convectron, CP for CEP

Table 46: Summary of Setup Mode Codes

Setup Mode is Used when Performing the Following Procedures

Setup Mode Procedures	
Action	**Description**
Setting Alarm Trip Points	The trip point is the pressure at which an alarm is tripped. Alarms A and B are standard. Alarms C and D are only available with the Auxiliary Output board.
Sensor Calibration	Sensor calibration is used to customize parameters for different sensor types. For capacitance manometers it allows the sensor range and resolution to be entered (except for Type 107 transducers). For Pirani or convection gauges, it selects the gas type, and is used to determine if the zero and span values are Factory or User defined. For cold cathode gauges, the Gas Correction Factor and disconnect threshold are entered. For hot cathode gauges, sensitivity and the disconnect threshold for sensor reading are entered. For MFCs, the range is entered.
Setting up Dual Channel Display	The 146 unit is set up to display over a range that is spanned by two different sensors.
Setting an Analog Endpoint	This function programs each of the three analog outputs as either linearly scaled (Ln), logarithmically scaled (lo1 - lo9), or as a fixed voltage (SP).

Table 47: Setup Mode Procedures

Setup Mode Functions	
Miscellaneous Codes	**Code Functions**
Code 1: Pressure/Volt/Current Select	Selects pressure, voltage, or current for the main display in Normal and Leakage Modes.
Code 2: Pressure Units	Selects Torr, mbar, or Pascal.
Code 3: Audio Sound	Turns all audio sounds, except the key-press click, On or Off.
Code 4: Alpha (PID Control)	Edits the alpha value (default value is 20).
Code 5: RS-232 Port Configuration	Adjusts RS-232 parameters such as baud rate, protocol, parity, and data bits.
Code 7: Leakage Display Setup	Selects either *instantaneous leakage*, or *leakage rate* for the main display in Leakage Mode.
Code 8: Data Logger Interval	Edits the data logger interval.
Code 10x: Adjust Display Lag	Where x is a channel number. Selects a display sensitivity to accommodate the level of noise in different gas systems.
Code 11x: Auto Zeroing	Where x is a channel number. Auto zeros one channel with a selected reference channel. Enables/disables the Auto Zero feature.
Code 12x: Adjust Ion Gauge Auto Power Control	Where x is a channel number. Adjusts the auto power shutoff pressure and the reference channel for the Ion Gauge Auto Power feature, and enables/disables the feature.
Code 13x: Softstart for Control (PID Control)	Where x is a recipe number. Edits the softstart speed.

Table 48: Setup Mode Functions
(Continued on next page)

Setup Mode Functions *(Continued)*	
Miscellaneous Codes	**Code Functions**
Code 14x: Select Polarity and Control Channel	Where **x** is a channel number. Selects polarity for upstream or downstream control, and selects the control channel.
Code 15x: Analog Set Point Setup (PID Control)	Where **x** is a recipe number. Sets the full scale set point, and the full scale voltage to span for the analog input, and enables/disables the analog set point feature.
Code 16x: Adjust HC High Pressure Shutoff	Where **x** is a channel number. Edits the high pressure shutoff value and the internal fast rate-of-rise shutoff value.
Code 17x: Adjust MFC Set Point, Mode, and Co-channel	Where **x** is a channel number. Selects either the Set Point, Totaling, or Ratio mode of operation, and sets the mass flow set point. When operating in the Totaling mode, you must also choose the co-channel.
Code 18x: Select the Type of Convection Gauge	Selects the type of convection gauge, either Cn for Convectron, or CP for CEP. The Convectron is selected as the initial gauge. This entry is unnecessary for a Pirani gauge.

Table 48: Setup Mode Functions

How To Set Alarm Trip Points

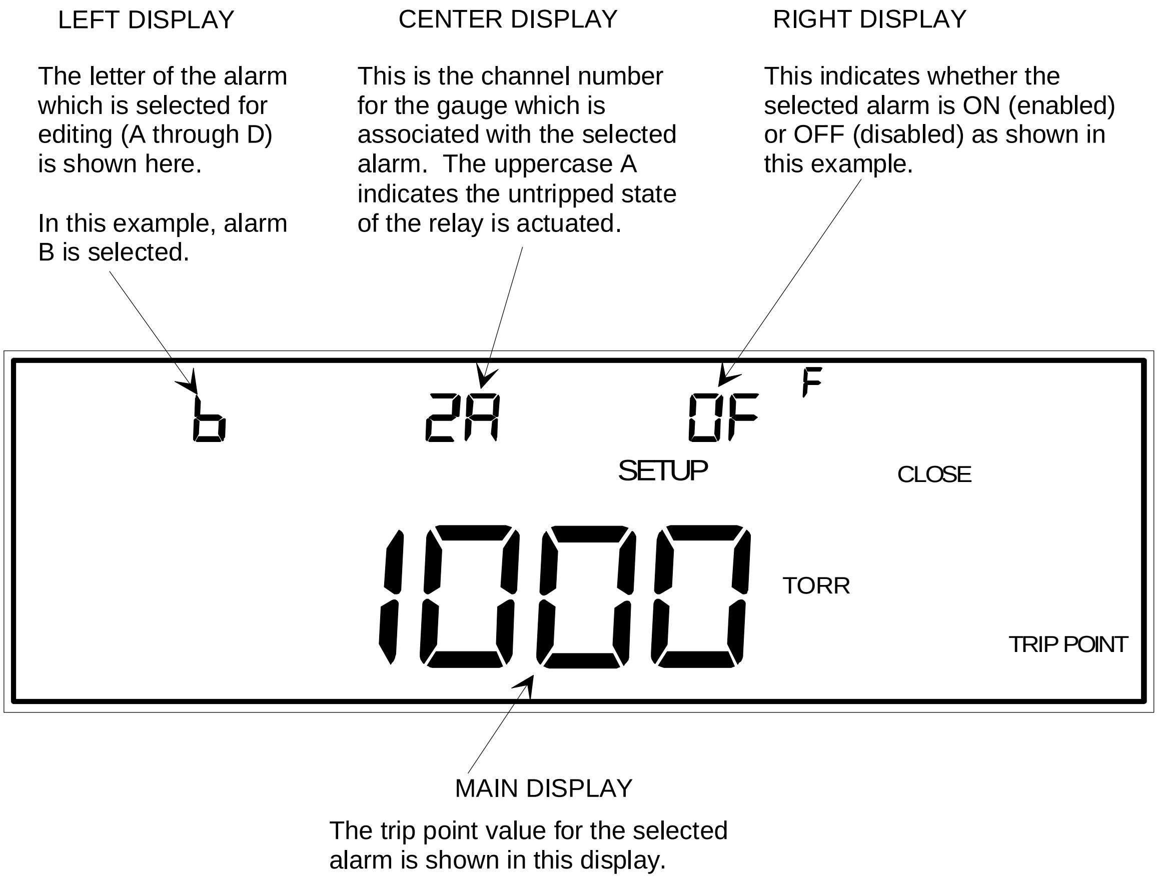


Figure 54: Display for Setting Alarm Trip Points

The trip point is the pressure at which an alarm is tripped. Alarms A and B are standard, but alarms C and D are available only if the optional Auxiliary Output board is installed.

Note Be sure the input channel to the alarm is powered on. You will not be able to configure the alarm unless the input channel is powered on.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Setup Mode.

   The system responds by scrolling through modes.

2. Use the arrow keys to scroll to the TRIP POINT legend.

   The system responds by scrolling through legends.

3. Enter the correct alarm letter in the left display.

   A. If the display is correct, press the [ENTER] key.

   B. If the display is incorrect, press one of the alarm keys ([A], [B], [C], or [D]), then press the [ENTER] key.

   The system responds by accepting the alarm letter entry, and causing the main display to blink.

4. Enter the trip point value in the main display (the default is 1000 Torr).

   A. If the display is correct, press the [ENTER] key.

   B. If the display is incorrect, enter the correct trip point, then press the [ENTER] key.

   The system responds by accepting the trip point, and causing the right display to blink.

5. Turn the alarm On or Off (enable or disable). The default is Off (disable).

   A. If the alarm is set correctly, press the [ENTER] key.

   B. If the alarm is not set correctly, press either the [ON/LEAD] key (to enable) or the [OFF/GAIN] key (to disable), then press the [ENTER] key.

   The system responds by accepting the alarm status, and causing the center display to blink.

6. Enter the channel number to associate with the chosen alarm, and select the relay untripped state. The default channel is channel 1, and the default relay untripped state is actuated.

   Notice, next to the channel number is the letter **A**, or **d**. The letter **A** means the relay untripped state of the alarm relay is actuated, and the letter **d** means the untripped state of the alarm relay is de-actuated. Refer to *Overview of Alarms*, in the *Overview* chapter for more information about relay actuation states.

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, press the correct channel key, (1 through 4) , then use the arrow keys to toggle the relay actuation state between actuated (A), and deactuated (d), then press the [ENTER] key.

   The system responds by accepting the channel number and relay untripped state, and causing the left display to blink. The system is ready to accept a new alarm letter.

How To Perform Sensor Calibration/MFC Setup

Sensor calibration is used to adjust parameters that are specific to different gauge types or to a mass flow controller (MFC). The 146 unit determines which type of sensor is connected to the selected channel, however, the sensor must be powered on for the determination to be accurate. If the sensor is off, the 146 unit reports the last type of sensor connected and powered by that channel.

Sensor calibration allows you to adjust parameters specific to each channel type, as listed in Table 49.

Sensor Configuration Parameters	
Type	**Adjustable Parameters**
Pirani or Convection Gauge	Gas Type Gauge Calibration Parameters: Zero* - factory or user defined Span* - factory or user defined
Hot Cathode Gauge	Sensitivity High Pressure Shutoff Disconnect Threshold
Cold Cathode Gauge	Gauge Correction Factor Disconnect Threshold
Capacitance Manometer	Sensor Range Resolution (*except* Type 107 transducer)
Mass Flow Controller	Range (entered and displayed in sccm)
Thermocouple Gauge	Gas Type

Table 49: Sensor Calibration Parameters for Each Channel Type

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Setup Mode.

   The system responds by scrolling through modes.

2. Use the arrow keys to scroll to the SENSOR CAL legend.

   The system responds by scrolling through legends.

3. Enter a channel number in the left display.

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, press the correct channel number, (1 through 4), then press the [ENTER] key.

   The system responds by accepting the channel number input, changing all the other parameters on the screen to what is appropriate for the selected channel, and causing the main display to blink. Depending upon what kind of sensor is associated with the selected channel, one of three windows is possible.

   In the right display there is a code for the input channel sensor type. Refer to Figure 55 for a list of codes and sensor types.

Code	Sensor/MFC
ln	Linear Capacitance Manometer
107	107 Capacitance Manometer
120	120 Capacitance Manometer
P	Pirani
Cn	Convection
CP	HPS CEP
Hc H	Hot Cathode (high power)
Hc l	Hot Cathode (low power)
cc	Cold Cathode
FC	Mass Flow Controller
1A	MKS TC-1A Thermocouple
d6	Hastings DV-6M Thermocouple

Figure 55: Sensor Codes for Sensor Calibration

This chapter reviews the sensor calibration for each sensor category separately, and then covers the MFCs and thermocouples.

Note

All the instructions in *How To Perform Sensor Calibration* assume that steps 1 through 3 on the previous page have been performed.

Capacitance Manometer

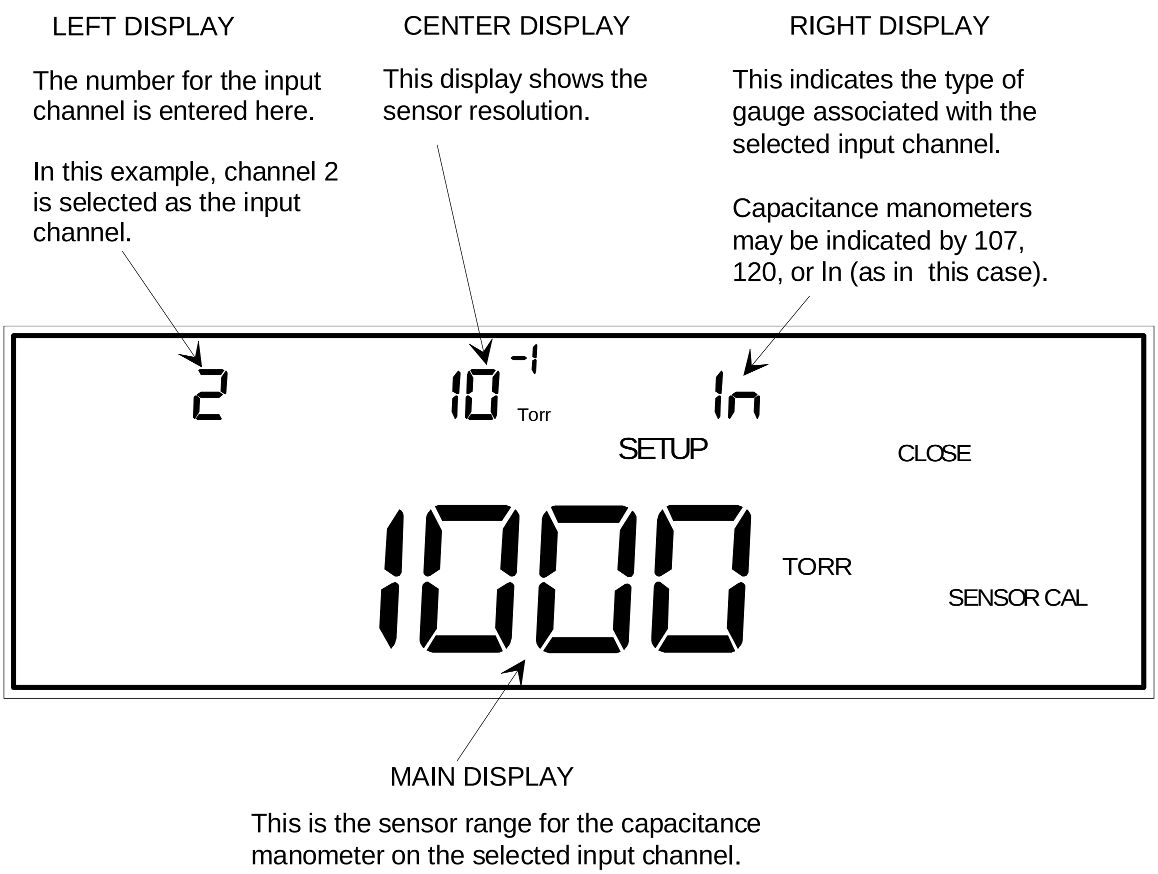


Figure 56: Sensor Calibration for Capacitance Manometers

Refer to *How To Perform Sensor Calibration/MFC Setup*, page 190, for steps 1 through 3.

Capacitance manometers may be listed as **107, 120** or **ln** in the right display.

4. Enter the span for the sensor in the main display.

   The span range is

   Type 107: 940 to 1060 Torr.

   Type 120 or linear capacitance manometer: 0.0009 to 100,000 Torr.

   The default span for *all* capacitance manometers is 1000 Torr.

   A. If the main display is correct, press the [ENTER] key.

   B. If the display is incorrect, enter the correct sensor span, then press the [ENTER] key.

   The system responds by accepting the span value, and blinking the center display.

Note For a 6 decade MKS Type 107 gauge, the range is adjustable ± 6% only.

5. Enter the sensor resolution in the center display.

   Sensor resolution is the smallest pressure that can be displayed above or below zero. The sensor resolution *range* for a Type 120 gauge or linear capacitance manometer is ±7 decades.

   The default resolution for *all* capacitance manometers is 10^{-1}.

   A. If the display is correct, then press the [ENTER] key.

   B. If the display is incorrect, enter the correct sensor resolution, then press the [ENTER] key.

   The system responds by accepting the sensor resolution.

Pirani and Convection Gauges

LEFT DISPLAY

The number for the input channel is entered here.

In this example, channel 2 is selected as the input channel.

CENTER DISPLAY

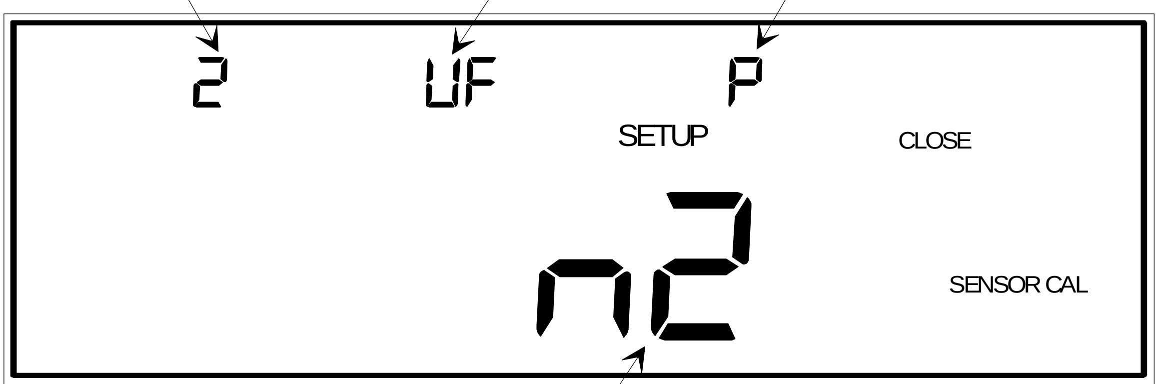
This indicates either a Factory (F), or User (U) defined ZERO (left character) and SPAN (right character).

In this case, the ZERO is User-defined, and the SPAN is Factory-defined.

RIGHT DISPLAY

This indicates the type of gauge associated with the selected input channel.

The codes are P for Pirani (shown in this example) Cn for Convectron, and CP for HPS CEP.



MAIN DISPLAY

There are three gas types which may be selected:
n2 (nitrogen, as in this case), HE (helium), and Ar (argon).

Figure 57: Calibration for Pirani and Convection Gauges

The sensor type codes are **P** for Pirani, **Cn** for Convectron, and **CP** for HPS CEP (Convection Enhanced Pirani). Sensor type, whether Pirani or convection, is automatically determined when a channel is initialized. However, the 146 unit cannot distinguish between the two convection gauges: Convectron and CEP. The default convection gauge selection is the Convectron gauge. If you are using a CEP gauge, you must change the convection gauge type to CEP. No additional commands are required if you are using either a Convectron gauge or a standard Pirani gauge.

The display also lists the type of gas selected, either **n2** (nitrogen), **HE** (helium), or **Ar** (argon).

Refer to *How To Perform Sensor Calibration/MFC Setup*, page 190, for steps 1 through 3.

4. Verify that the 146 unit has correctly determined the sensor type. If the sensor type is incorrect, use the arrow keys to change the sensor type entry. If you have a convection gauge, use Code 18x to verify the type of gauge.

   The 146 unit cannot distinguish between a Convectron gauge and an HPS CEP gauge. If you are using an HPS CEP gauge you must select it using Code 18x, as described in *Code 18x: How To Select the Convection Gauge*, page 245.

Note Turn the channel off before you attempt to change the convection gauge type. The command will not be accepted if the channel is on.

   A. If the display is correct, then press the [ENTER] key.

   B. If the display is incorrect, scroll to the correct sensor type, then press the [ENTER] key.

   The system responds by accepting the sensor type, and blinking the right display.

5. Use the arrow keys to select the gas type (n2 for nitrogen, HE for helium, and Ar for argon). The default gas type is nitrogen.

   A. If the display is correct, then press the [ENTER] key.

   B. If the display is incorrect, scroll to the correct gas type, then press the [ENTER] key.

   The system responds by accepting the gas type, and blinking the center display.

6. Confirm if the zero (left) and span (right) parameters are correctly listed as Factory-defined or User-defined. The default is Factory-defined zero and span.

   A. If the display is correct, then press the [ENTER] key.

   B. If the display is incorrect, press the [ZERO/EXP] or [SPAN/.] keys to toggle the left and right parameters (respectively), between F (Factory-defined) and U (User-defined) zero and span values, then press the [ENTER] key.

   The system responds by accepting the zero and span parameter definitions.

Note Zeroing or spanning a Pirani or convection gauge in Normal or Leakage Mode, switches the center display to U (User defined).

Cold Cathode

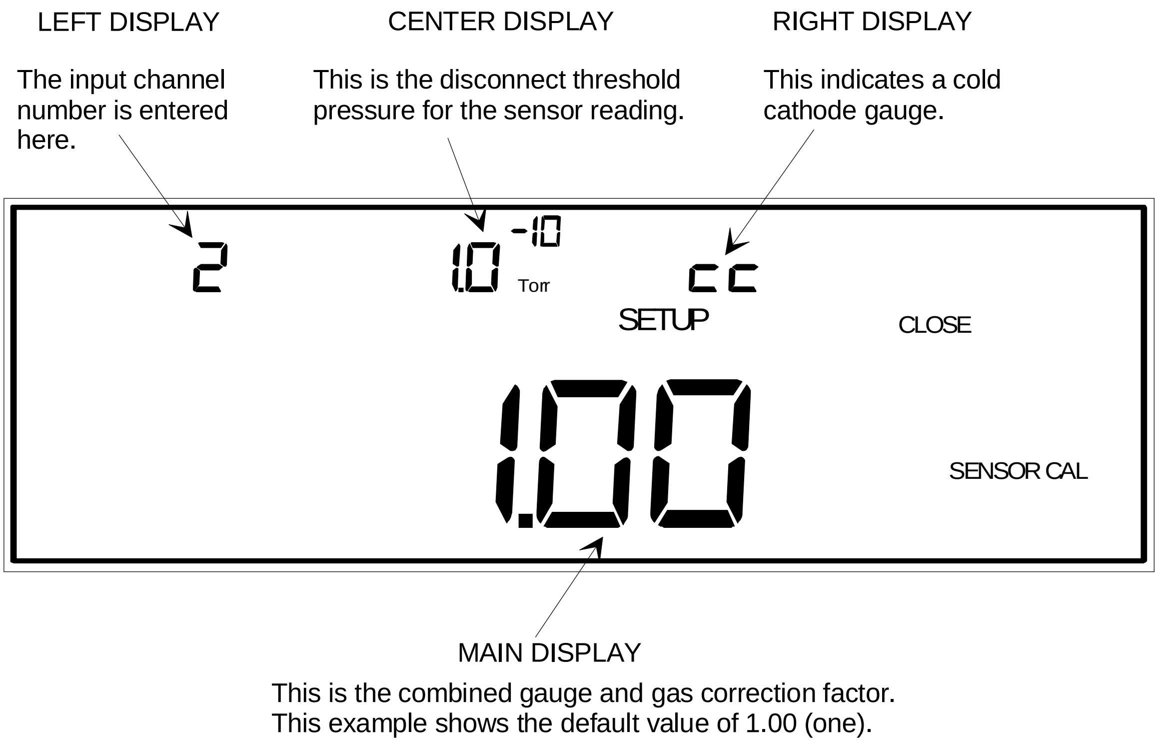


Figure 58: Sensor Calibration for Cold Cathode Gauges

Refer to *How To Perform Sensor Calibration/MFC Setup*, page 190, for steps 1 through 3.

A cold cathode sensor is indicated by the code **cc.**

4. Enter a combined gauge and gas correction factor (GCF).

   A. If the display is correct, press the [ENTER] key.

   B. If the display is incorrect, enter another value, then press the [ENTER] key.

   The exact value for the combined gauge and GCF depends upon the type of gas used, and it must also allow for some variability in the gauge itself.

   The system responds by accepting the entered value, and causing the center display to blink.

Note

1. The default value for the gauge/gas correction factor is 1.00.
2. In the 146 unit, the combined gauge/GCF value (between 0 and 10, excluding 0), is used as a multiplier. Therefore, it functions as a span adjustment factor.

5. Enter a disconnect threshold for the sensor in the center display.

   A. If the display is correct, press the [ENTER] key.

   B. If the display is incorrect, enter the correct disconnect threshold, then press the [ENTER] key.

   The system responds by accepting the new disconnect threshold.

Note

When this feature is enabled, and the sensor pressure reading drops below the disconnect threshold value entered here, an alarm sounds. The factory configuration value for the sensor disconnect threshold is -1.0, to disable the feature.

Do not enable this feature if your pressure signal is noisy in its low range. The noise may cause the pressure reading to drop below the disconnect pressure momentarily; the 146 unit will power down the sensor and report a disconnected sensor status for the channel.

Hot Cathode

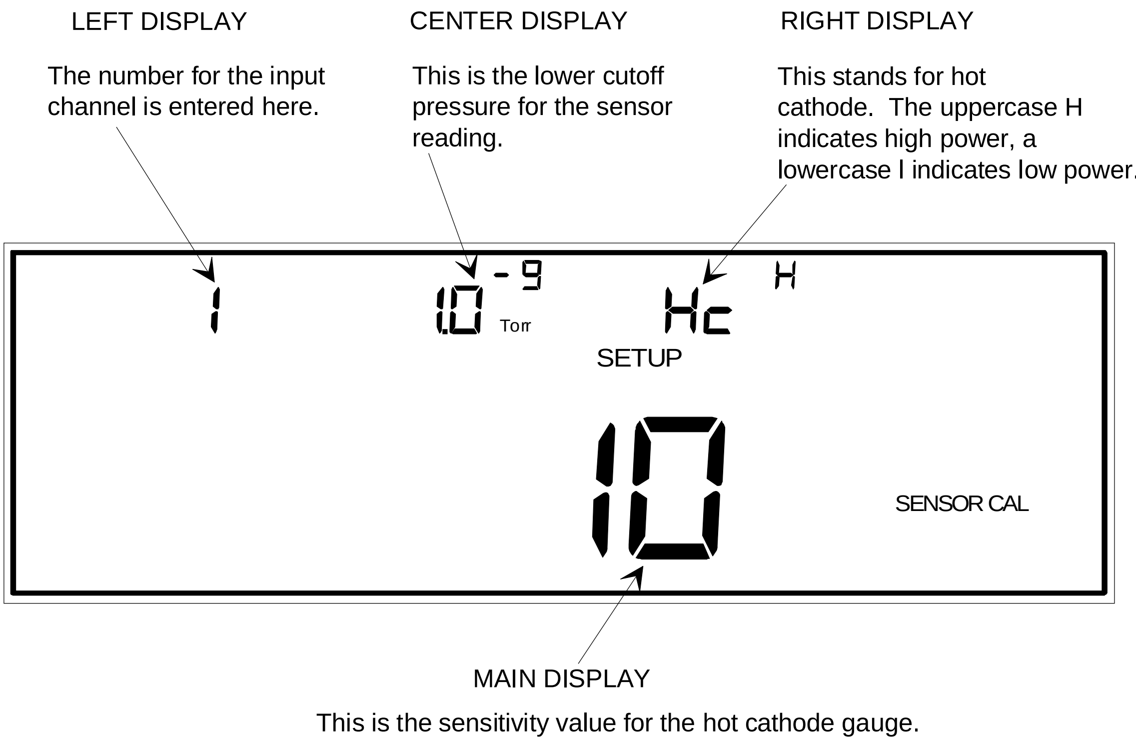


Figure 59: Sensor Calibration for Hot Cathode Gauges

A hot cathode sensor is indicated by the code **Hc.** In addition, above and to the right of the **Hc** code, is either the letter **H** or the letter **l** . The letter **H** is used to indicate a high power hot cathode and it is the default setting. The letter **l** is used to indicate a low power hot cathode (HPS low power, Bayard-Alpert, nude, hot cathode). Refer to *Configuring the Hot Cathode Board for a Low Power Hot Cathode*, page 57, for instructions on how to change the default setting and accommodate a low power hot cathode.

Refer to *How To Perform Sensor Calibration/MFC Setup*, page 190, for steps 1 through 3.

4. Enter a sensitivity value.

   A. If the display is correct, press the [ENTER] key.

   B. If the display is incorrect, enter another value, then press the [ENTER] key.

   The system responds by accepting the entered value, and causing the center display to blink.

Note

1. The default value for sensitivity is 10.
2. The sensitivity value must be in the range of 0.011 to 100.

5. Enter a disconnect threshold for the sensor in the center display.

   A. If the display is correct, press the [ENTER] key.

   B. If the display is incorrect, enter the correct disconnect threshold, then press the [ENTER] key.

   The system responds by accepting the new disconnect threshold. The factory configuration has this feature disabled (the disconnect threshold is set to -1.0).

Note

When this feature is enabled, and the sensor pressure reading drops below the disconnect threshold value entered here, an alarm sounds. The factory configuration value for the sensor disconnect threshold is -1.0, to disable the feature.

Do not enable this feature if your pressure signal is noisy in its low range. The noise may cause the pressure reading to drop below the disconnect pressure momentarily; the 146 unit will power down the sensor and report a disconnected sensor status for the channel.

Mass Flow Controller

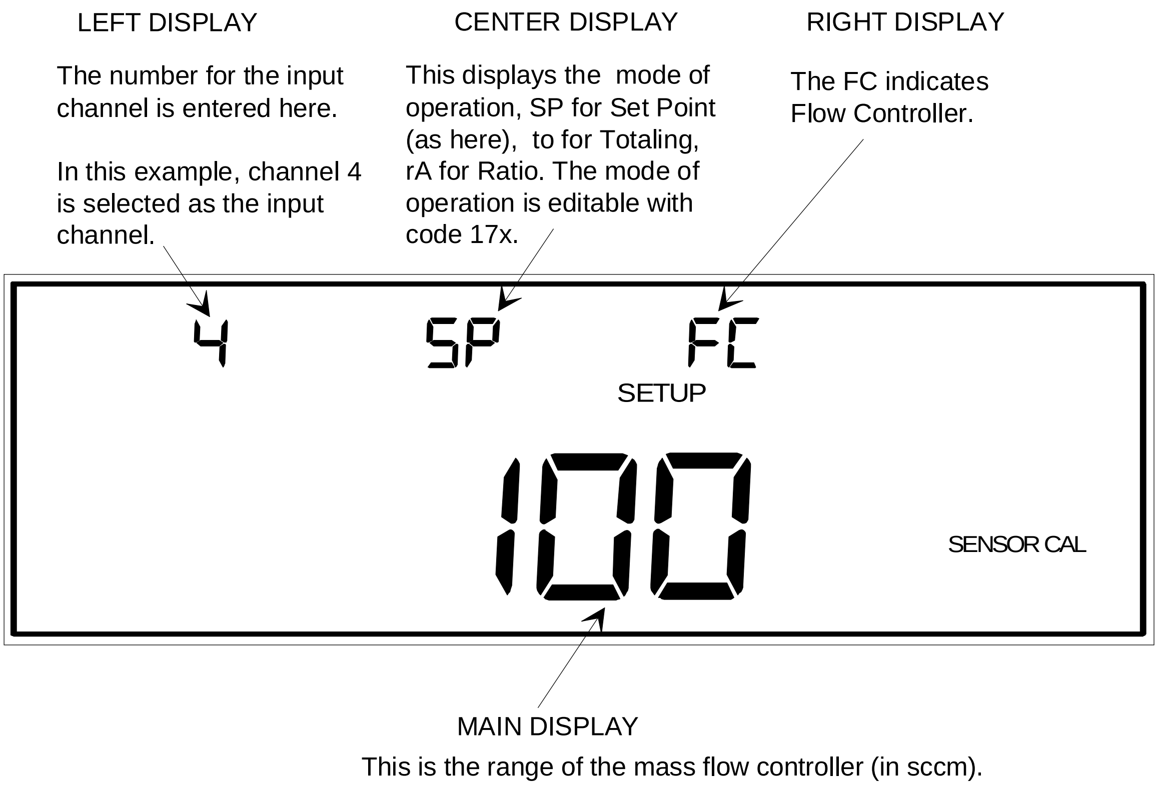


Figure 60: Sensor Calibration for Mass Flow Controllers

An MFC is indicated by the code **FC** in the right display. The three modes of operation for an MFC are *Set Point*, *Totaling* and *Ratio*. The different modes are indicated by codes in the center display: **SP** for the Set Point mode; **to** for the Totaling mode; and **rA** for the Ratio mode. To change the mode of operation, refer to *Code 17x: How To Set Up the MFC,* page 241.

The only editable parameter in the MFC sensor calibration display is the range of the MFC.

Note

1. The range of the mass flow controller must be entered in sccm (standard cubic centimeters per minute). You cannot change the units to slm (standard liters per minute).
2. The mode of operation, displayed in the center display, cannot be changed through this screen. Refer to *Code 17x: How To Set Up the MFC,* page 241, to change the operating mode.

Refer to *How To Perform Sensor Calibration/MFC Setup*, page 190, for steps 1 through 3.

4. Enter the range of the MFC, in sccm.

   The default is 1000 sccm. The range is 0.0002 sccm to 1×10^5 sccm.

   A. If the display is correct, press the [ENTER] key.

   B. If the display is incorrect, enter the correct range, then press the [ENTER] key.

   The system responds by accepting the new value.

Thermocouple

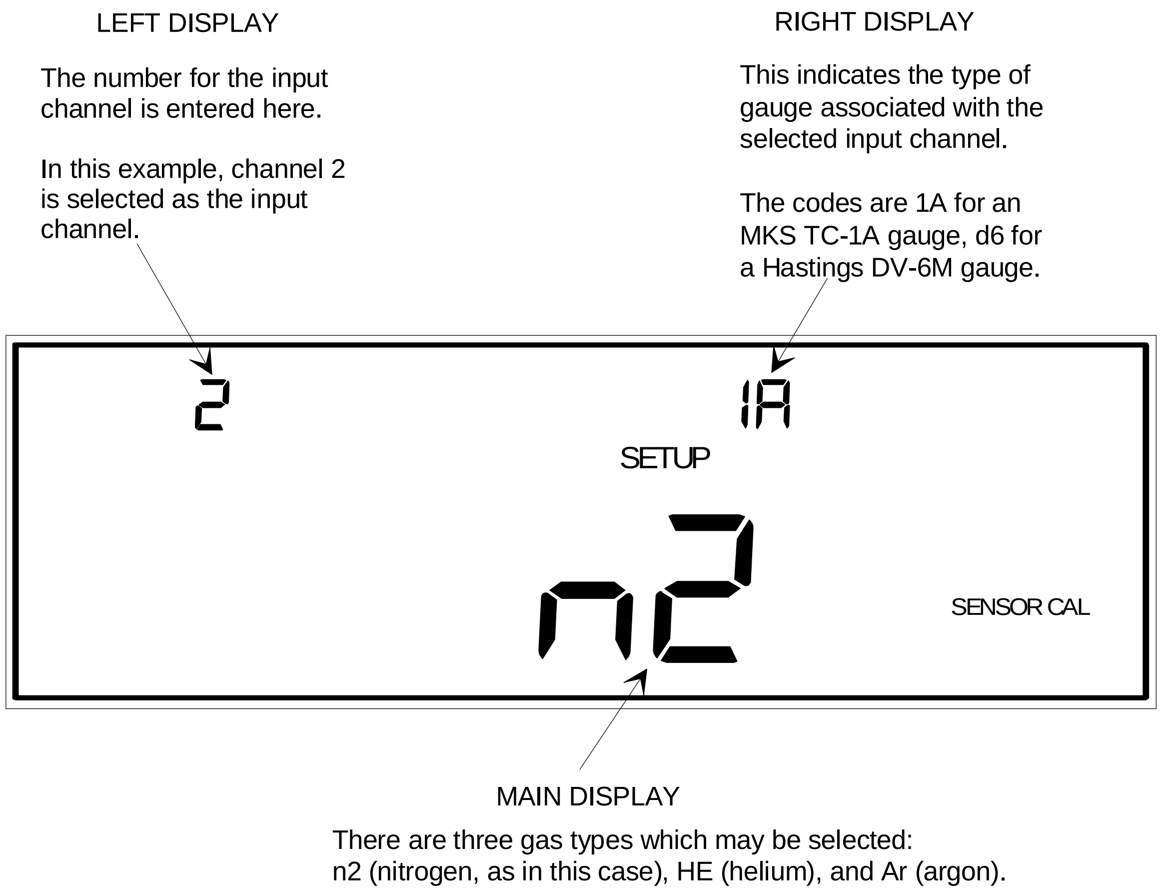


Figure 61: Sensor Calibration for Thermocouples

The thermocouple gauge codes are **1A** for the MKS TC-1A, and **d6** for the Hastings DV-6M gauge. The gauge type is automatically determined when a channel is initialized.

Note The thermocouple type, displayed in the right hand display, cannot be changed through this screen. The 146 unit determines the thermocouple type when the channel is powered on.

The display also lists the type of gas selected, either **n2** (nitrogen), **HE** (helium), or **Ar** (argon).

Refer to *How To Perform Sensor Calibration/MFC Setup*, page 190, for steps 1 through 3.

4. Verify that the 146 unit has correctly determined the gauge type. The gauge type is displayed in the right display.

5. Use the arrow keys to select the gas type (n2 for nitrogen, HE for helium, and Ar for argon), listed in the main display. The default gas type is nitrogen.

   A. If the display is correct, then press the [ENTER] key.

   B. If the display is incorrect, scroll to the correct gas type, then press the [ENTER] key.

   The system responds by accepting the gas type, and blinking the center display.

How To Set Up a Dual Channel Display

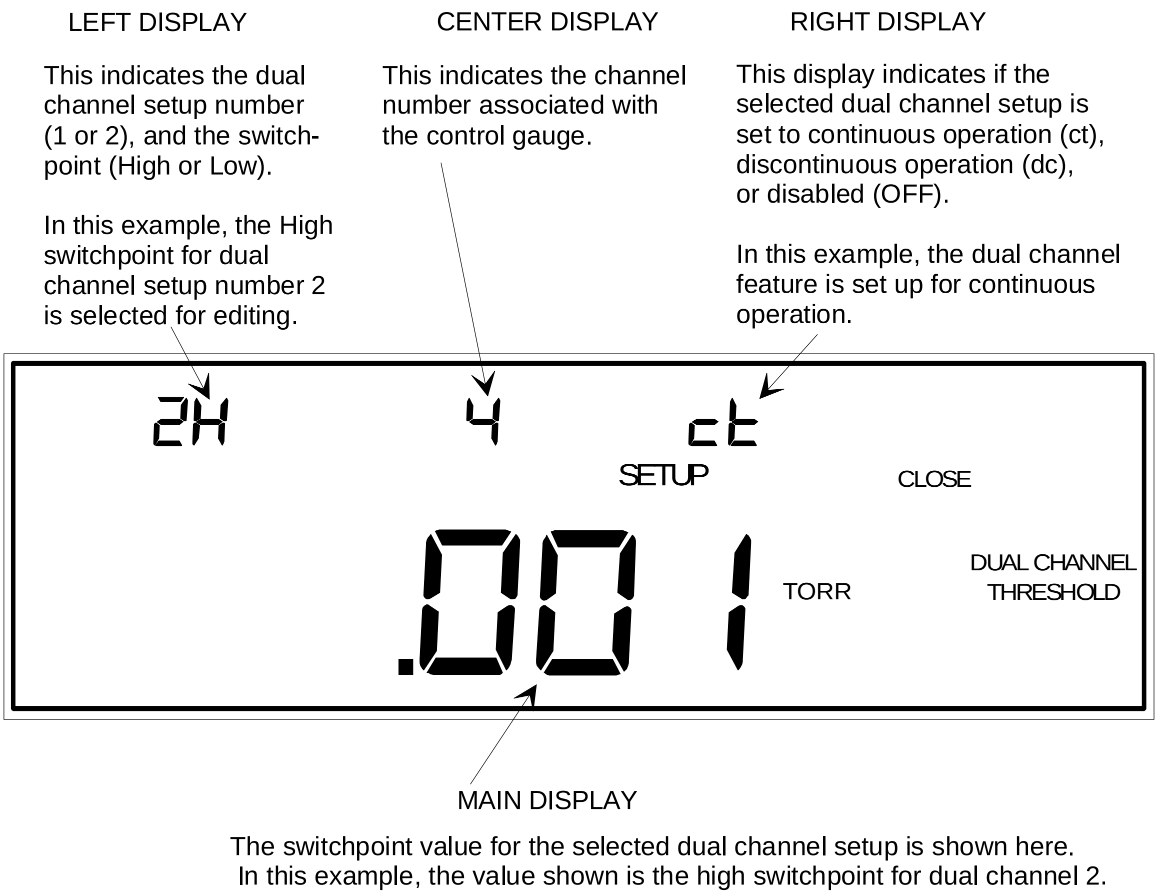


Figure 62: Setting Up Dual Channel Displays

The dual channel display function can be activated in Normal and Leakage Modes (refer to *How To Switch Channels in the Main Display*, in either the *Operation in Normal Mode*, or *Leakage Mode* chapters). The dual channel function allows the 146 unit to display pressure readings from one of two associated sensors. One sensor controls over a low range, and the other sensor controls over the high range.

There are two switchpoints associated with the dual channel threshold function (high and low). A switchpoint is the pressure at which the pressure reading display switches from one sensor to another. When the pressure is above the high switchpoint, the upper channel is used for display. When the pressure is below the low switchpoint, the lower channel is used for display. The pressure range between the switchpoints provides hysteresis, and is used to create a single pressure display.

Use the [+/-] key to toggle between the two switchpoints in the left display. The 146 instrument has default high and low switchpoint values which are different for different sensor types. Enter a 0 in the switchpoint field (center display), to enable the default values. Table 50, page 205, summarizes the default values.

Note

There are no default values supplied for a hot cathode gauge. If 0 is entered for a switchpoint, the system accepts the value of 0. The default values for a cold cathode gauge are good values to reference when determining the best switchpoint values for a hot cathode gauge.

Default Values For Dual Channel Displays

The default value is enabled when 0 is entered *except* where indicated by an **X** .
The **X** indicates where the system accepts a value of 0 for the switchpoint.

The upper number is the high switchpoint
The lower number is the low switchpoint

Hi Dual Channel Sensor (min. resolution for CM)	Lo Dual Channel Sensor (max. range for CM)					
	Cold Cathode	Hot Cathode	0.1 Torr CM	1 Torr CM	10 Torr CM	100 Torr CM
HPS Pirani	9 mT 1 mT	**X**	100 mT 10 mT	1 T 100 mT	10 T 1 T	**X**
G.P. Convectron HPS CEP	9 mT 1 mT	**X**	100 mT 10 mT	1 T 100 mT	10 T 1 T	100 T 10 T
0.001 mT Linear CM	1 mT 0.1 mT	**X**	**X**	**X**	10 T 1 T	**X**
0.01 mT Linear CM	1 mT 0.1 mT	**X**	100 mT 50 mT	**X**	**X**	**X**
0.1 mT Linear CM	3 mT 0.3 mT	**X**	100 mT 50 mT	1 T 0.5 T	**X**	**X**
1 mT Linear CM	9 mT 1 mT	**X**	100 mT 50 mT	1 T 0.5 T	10 T 5 T	**X**
10 mT Linear CM	**X**	**X**	100 mT 50 mT	1 T 0.5 T	10 T 5 T	100 T 50 T
100 mT Linear CM	**X**	**X**	100 mT 50 mT	1 T 0.5 T	10 T 5 T	100 T 50 T
107 CM	9 mT 1 mT	**X**	100 mT 50 mT	1 T 0.5 T	10 T 5 T	100 T 50 T

Table 50: Default Values for Dual Channel Displays

Two Types of Dual Channel Operation - Continuous and Discontinuous

Continuous operation means the 146 unit smoothly transitions the pressure readout (in the main display), from one sensor to another over the pressure range where they overlap. This is done by creating a percent gradient which gives the lower range sensor's reading a greater weight in calculations at the lower end of the overlapping range, and the upper sensor's reading a greater weight at the higher end of the overlapping range. The range is delimited by user-defined switchpoints.

Discontinuous operation means the 146 instrument switches the pressure readout from one sensor to the other at the user-defined high and low switchpoints. The readout shows output from only one sensor at a time. The sensor outputs are not combined over the area where the sensors' ranges overlap.

The dual channel display function can be enabled or disabled.

Note The following instruction sequence is the same for setting either the low or high switchpoint setting.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Setup Mode.

   The system responds by scrolling through modes.

2. Use the arrow keys to scroll to the DUAL CHANNEL THRESHOLD legend.

   The system responds by displaying dual channel parameters.

3. Select either H(high) or L(low) switchpoint in the left display, with the [+/-] key.

   The system responds by toggling between the high and low switchpoints.

4. Enter the dual channel number (1 or 2), which is *also* in the left display, then press the [ENTER] key.

   The system responds by accepting the channel number, and causing the main display to blink.

5. Enter the switchpoint value. The range for both the upper and lower switchpoints is a floating point value between 0 and 25,000 inclusive. The default is 0.

Note A general rule of thumb is that the high and low switchpoints should differ by at least a factor of ten. It is possible to enter values with less of a difference, but then there is a risk of getting a negative slope when the unit is set for continuous operation. If the difference is too large, the data displayed may be unreliable. What is considered "too large" depends upon the type of gauges used.

A. If the main display is correct, press the [ENTER] key.

B. If the main display is not correct, enter the correct switchpoint value, then press the [ENTER] key.

The system responds by accepting the switchpoint value, and causing the right display to blink.

6. Select a type of dual channel operation, (ct for continuous, dt for discontinuous, and OFF to disable the function). The default is off (disabled).

   A. If the right display is correct, press the [ENTER] key.

   B. If the right display is not correct, use the arrow keys to scroll through the three selections of dual channel operation.

   The system responds by accepting the type of dual channel operation, and causing the center display to blink.

7. Enter the channel number associated with the control sensor. The default is channel 1 for both the upper and lower sensors.

   A. If the center display is correct, press the [ENTER] key.

   B. If the center display is not correct, enter the correct channel number (1 through 4), then press the [ENTER] key.

   The system responds by accepting the channel number entered.

Note If you are setting the low switchpoint, the controlling sensor is the one that controls at the lower range. If you are setting the high switchpoint, the controlling sensor is the one that controls at the higher range.

How To Configure an Analog Output

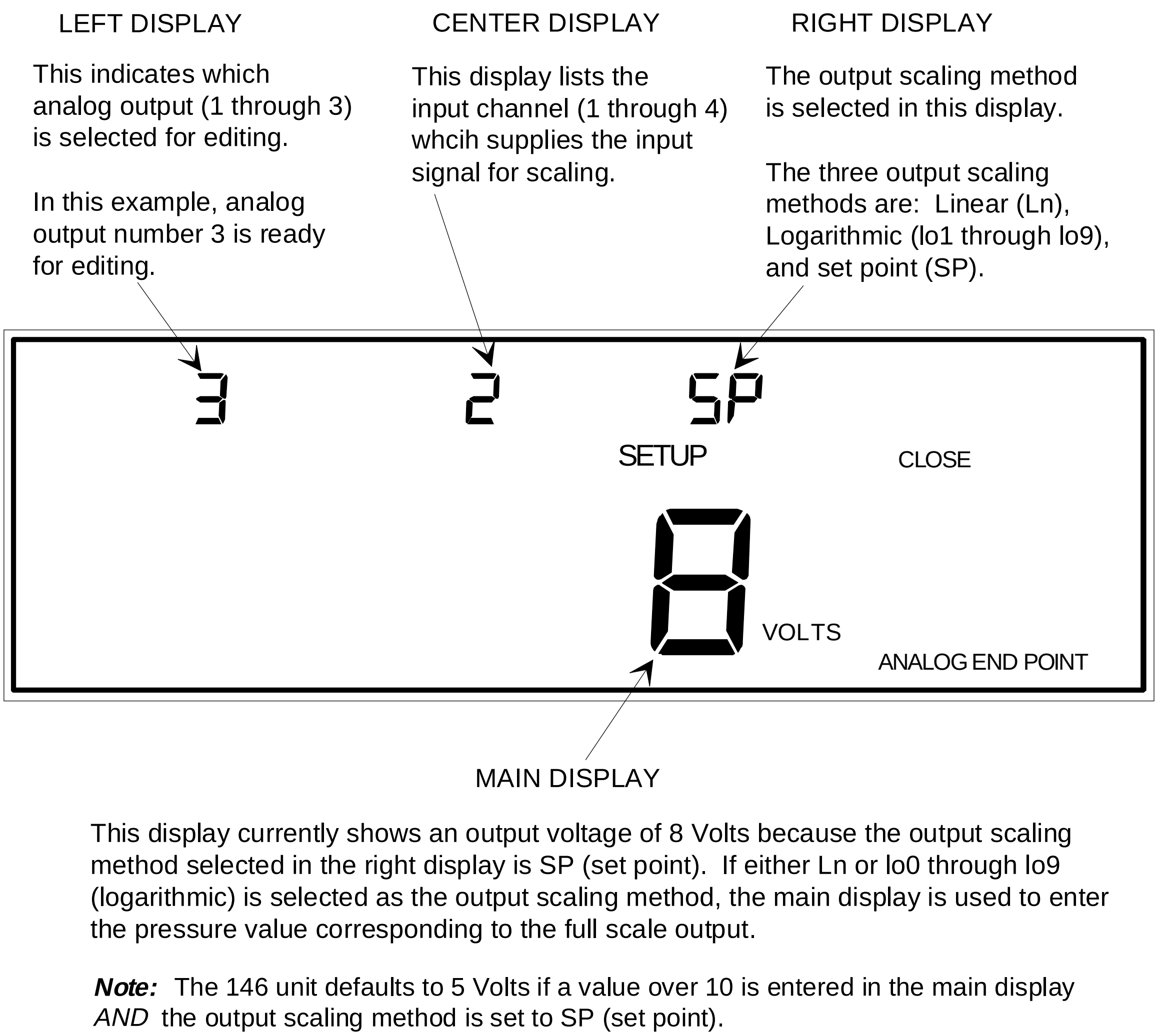


Figure 63: Display for Configuring an Analog Output

The 146 unit supports up to three analog outputs: one on the CPU board; and two on the Auxiliary Output board. Each of these outputs may be programmed as either linearly scaled (**Ln**), logarithmically scaled (**lo1 - lo9**), or as a set point (**SP**). In the case of linear or logarithmic scaling, the full scale output of 10 V is made to correspond to a pressure.

Linear Scaling

In linear scaling, the voltage versus pressure curve is linear over its entire length. Refer to Figure 64 for a scalar representation of voltage versus pressure.

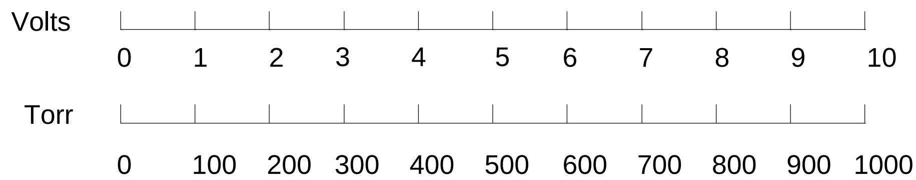


Figure 64: Linear: Voltage versus Pressure

Logarithmic Scaling

In logarithmic scaling, the voltage versus pressure curve is logarithmic over its upper portion, and linear over its lower portion. The boundary between linear and logarithmic scaling is determined by the selection of LO1 through LO9. The *numerals 1 through 9* represent the number of logarithmic decades in the output. Each logarithmic decade is equal to 1 Volt. As an example, you want the full scale voltage of 10 Volts to correspond to 20 Torr, and you want three decades of logarithmic output. To accomplish this, select LO3. Refer to Figure 65 for a scalar representation of voltage versus pressure with three decades of logarithmic output.

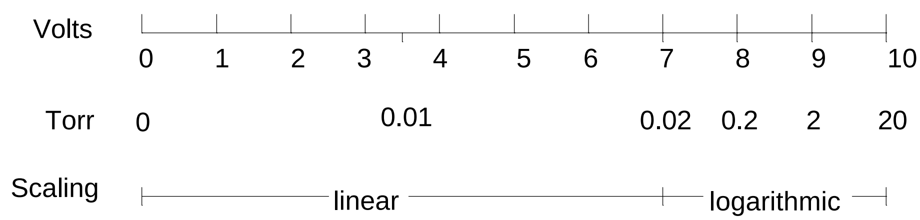


Figure 65: Linear and Logarithmic: Voltage versus Pressure

Set Point

In the case of a set point (select SP in the right display), a fixed voltage is sent from the 146 unit, regardless of the pressure readings received.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Setup Mode.

   The system responds by scrolling through modes.

2. Use the arrow keys to scroll to the ANALOG END POINT legend.

3. Enter the number for the analog output to be modified.

   A. If the left display is correct, press the [ENTER] key.

   B. If the left display is not correct, enter the correct analog output number (1 through 3), then press the [ENTER] key.

   The system responds by accepting the analog output number, and causing the main display to blink.

4. Enter the pressure value corresponding to full scale voltage ***OR*** the voltage for set point (0 to 10 Volts), if that is the input method to be used.

   A. If the main display is correct, press the [ENTER] key.

   B. If the main display is not correct, enter the correct pressure value, then press the [ENTER] key.

Note

The pressure units remain the same, even if the value entered is intended to be a fixed set point voltage.

5. Select the output scaling method to be used.

   A. If the right display is correct, press the [ENTER] key.

   B. If the right display is not correct, use the arrow keys to select the output scaling method, then press the [ENTER] key.

   If **ln** or **lo1-lo9** is selected, the system responds by accepting the output scaling method, and causing the center display to blink.

   If **SP** is selected, the center display goes blank, the units in the main display change to VOLTS , and the left display blinks. If the value entered in the main display is greater than 10, the system defaults to 5 Volts.

6. Select the input channel (1 through 4, 5 for dual channel 1, or 6 for dual channel 2) which supplies the input signal for scaling.

   A. If the center display is correct, press the [ENTER] key.

   B. If the center display is not correct, enter the correct input channel (1 through 4, 5 for dual channel 1, or 6 for dual channel 2), then press the [ENTER] key.

   The system responds by accepting the input channel number.

Note

The same channel may be used for more than one analog output.

How To Adjust Miscellaneous Codes

There are many miscellaneous parameters that can be modified with the miscellaneous code functions. Some miscellaneous codes refer to PID control and are, therefore, only in effect if the Control board is installed.

The parameters in the miscellaneous code functions can be either selected or edited. The procedures for parameter selection or editing are listed in Table 51.

How To Adjust Miscellaneous Codes	
To select a parameter choice	Use the [▲] and [▼] keys to scroll through the choices in a parameter list. The [ENTER] key causes the 146 unit to accept whichever parameter choice is currently selected.
For entry of a numeric value	Use the numeral keys, the [+/-] key, the arrow keys, [ZERO/EXP], or [SPAN/.].
To toggle a display between On and Off	Use the [ON/LEAD] and [OFF/GAIN] keys.

Table 51: How To Adjust Miscellaneous Codes

Code 1: How To Select Pressure/Volt/Current

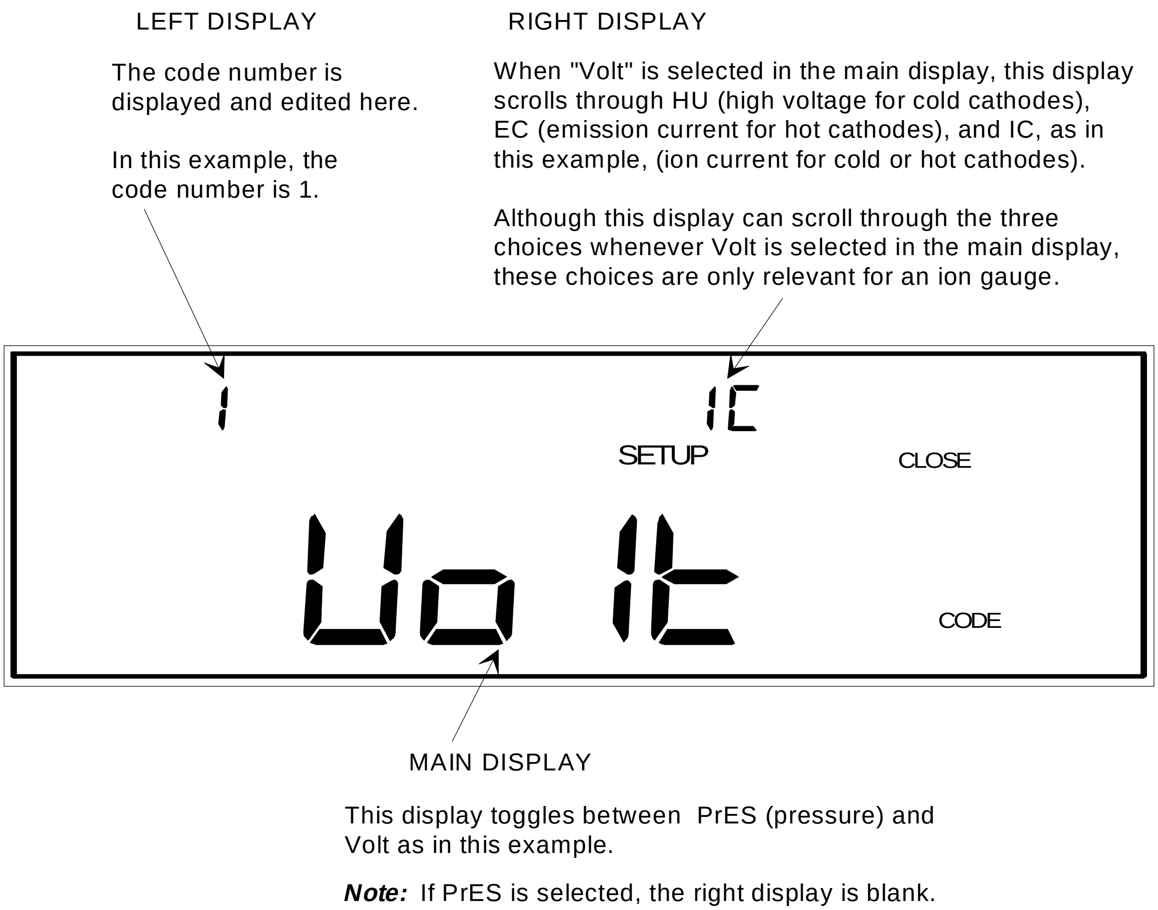


Figure 66: Code 1 Display

This function determines whether pressure (PrES), or voltage (Volt), is shown in the main display in Normal and Leakage Modes. The other three displays in Normal and Leakage Modes continue to show pressure readings. The selections made in this function only effect the channel shown in the main display in Normal or Leakage Modes, and do not effect RS-232 functions.

If pressure (PrES) is selected in the main display in the Code 1 function, there are no parameters to edit. The pressure selection (PrES) is available for all gauge types.

The voltage (Volt) selection is also available for any gauge type, but the editable parameter in the Code 1 right display only applies to ion gauges. If voltage (Volt) is selected, the right display flashes and there is an additional choice to make *if an ion gauge is on the channel shown in the main display in Normal or Leakage Modes*. If any other gauge type is on the main display channel (in Normal or Leakage modes), the choices available in the flashing right display are irrelevant. The right display scrolls through the following choices: high voltage (HU), ion current (IC), and emission current (EC).

The high voltage (HU) selection only applies to cold cathodes (CC). The high voltage, which is being applied to the cold cathode, is shown in the main display in Normal and Leakage Modes. This display can be used for several purposes, such as a diagnostic aid. For example, if the cold cathode is shorted, a very low voltage is displayed. If the pressure is very high (above 1 Torr), there may be enough gas available to prevent any high voltage conduction, therefore a full high voltage is applied to the cold cathode (and shown in the main display).

Note If the HU (high voltage) selection is chosen for a hot cathode, then 0 (zero) is shown in the main display in Normal and Leakage Modes.

The Ion Current (IC) selection applies to both hot and cold cathodes. Ion current is sometimes referred to as the *collector current*. This display shows the current that is present at the collector inside an ion gauge.

The Emission Current (EC) selection only applies to hot cathodes (HC). The emission current is maintained at 1 milliampere when the pressure is below 1 x 10^{-4} Torr. At pressures higher than 1 x 10^{-4} Torr, the emission current is maintained at 100 microamperes. This reduced emission current level helps to extend the life of a hot cathode gauge.

Note If the EC (Emission Current) selection is chosen for a cold cathode, a 0 (zero) is shown in the main display in Normal and Leakage Modes.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Setup Mode.

   The system responds by scrolling through modes.

2. Use the arrow keys to scroll to the CODE legend.

   The system responds by causing the left display to blink.

3. Enter the number **1** and press the [ENTER] key.

   The system responds by displaying the appropriate parameters for code 1, and causing the main display to blink.

4. Select PrES or Volt in the main display (the default is pressure).

   A. If the display is correct, then press the [ENTER] key.

   B. If the display is not correct, press one of the arrow keys, then press the [ENTER] key.

   The system responds by accepting the parameter value.

Note If PrES is selected, the right window becomes blank and the Code 1 function is finished.

5. If Volt is selected, the right display blinks. Select HU (high voltage for cold cathodes), IC (ion current for ion gauges), or EC (emission current for hot cathodes).

Note This parameter is irrelevant if a gauge other than an ion gauge is selected as the main display channel in Normal or Leakage Modes. Press the [ENTER] key.

A. If the display is correct for an ion gauge, press the [ENTER] key.

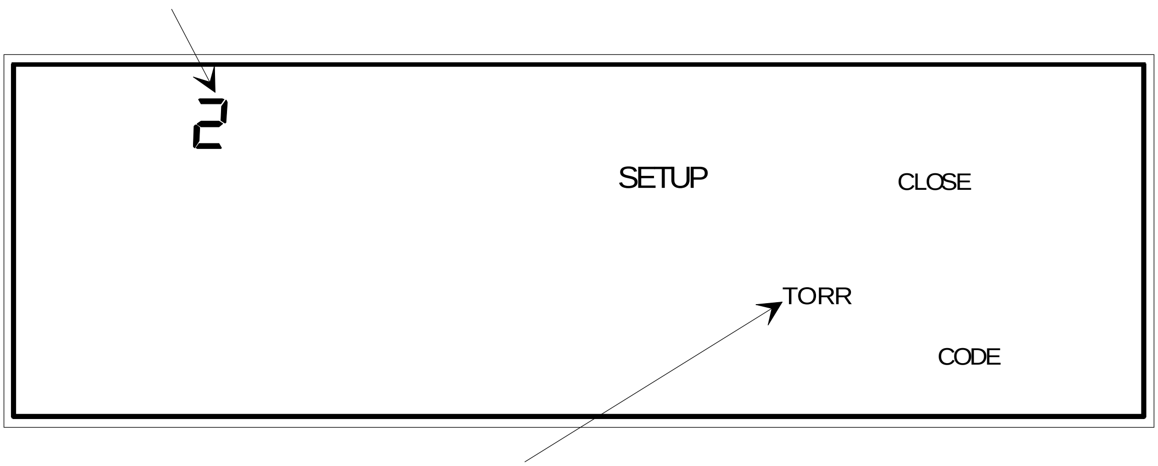
B. If the display is not correct for an ion gauge, use the [↑] and [↓] (arrow keys) to scroll to the correct selection, then press the [ENTER] key.

The system responds by accepting the configuration choice for the main display in Normal or Leakage Modes.

Code 2: How To Select Pressure Units

LEFT DISPLAY

The code number is displayed and edited here.
In this example, the code number is 2.



MAIN DISPLAY

The arrow keys are used to scroll among the three choices for pressure units.
The choices are: PASCAL, mBAR, and TORR (as in this example).

Figure 67: Code 2 Display

This function selects the units for pressure readings shown in all displays, and for all parameter entries. The choices are: Torr, Pascal, and millibar (mbar).

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Setup Mode.

   The system responds by scrolling through modes.

2. Use the arrow keys to scroll to the CODE legend.

   The system responds by causing the left display to blink.

3. Enter the number **2** and press the [ENTER] key.

   The system responds by displaying the appropriate parameters for code 2. One of the three pressure units available for the main display (Torr, Pascal, or mbar), blinks.

4. Use the arrow keys to select a pressure unit. The default is Torr.

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, scroll to the correct pressure unit (mBAR, TORR, or PASCAL) with an arrow key, then press the [ENTER] key.

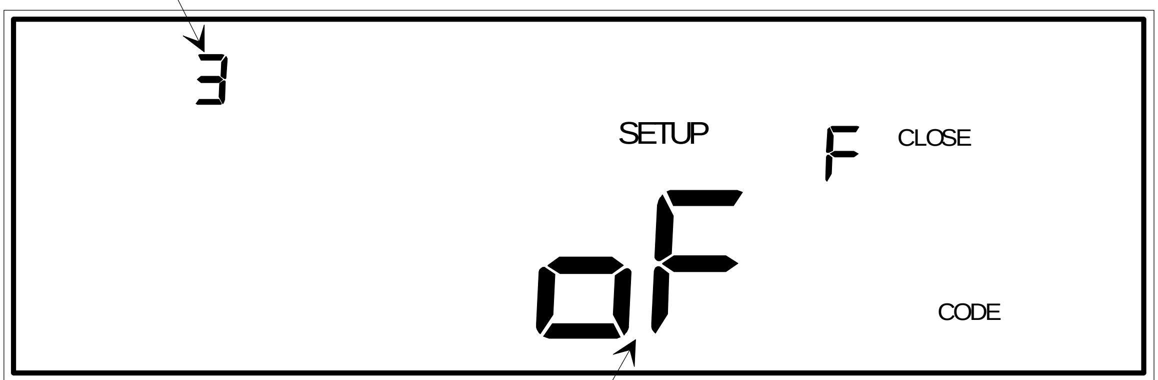
   The system responds by accepting the pressure unit.

Code 3: How To Adjust Audio Alarms

LEFT DISPLAY

The code number is
displayed and edited here.

In this example, the
code number is 3.



MAIN DISPLAY

This display toggles between on (turn the audio alarm on),
and oFF (turn the audio alarm off) as shown in this example.

Figure 68: Code 3 Display

The Audio Alarm function turns On/Off some of the beeper sounds made by the 146 unit. If turned Off, the only remaining sound from the beeper is the key-press click.

Note The Audio Alarm function should be set to Off for displayless units since these units have no front panel keypad.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Setup Mode.

   The system responds by scrolling through modes.

2. Use the arrow keys to scroll to the CODE legend.

   The system responds by causing the left display to blink.

3. Enter the number **3** and press the [ENTER] key.

   The system responds by displaying the appropriate parameters for code 3, and causing the main display to blink.

4. Select On or Off in the main display (the default is On).

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, press either the [ON/LEAD] (to turn sounds On), or [OFF/GAIN] (to turn sounds Off), then press the [ENTER] key.

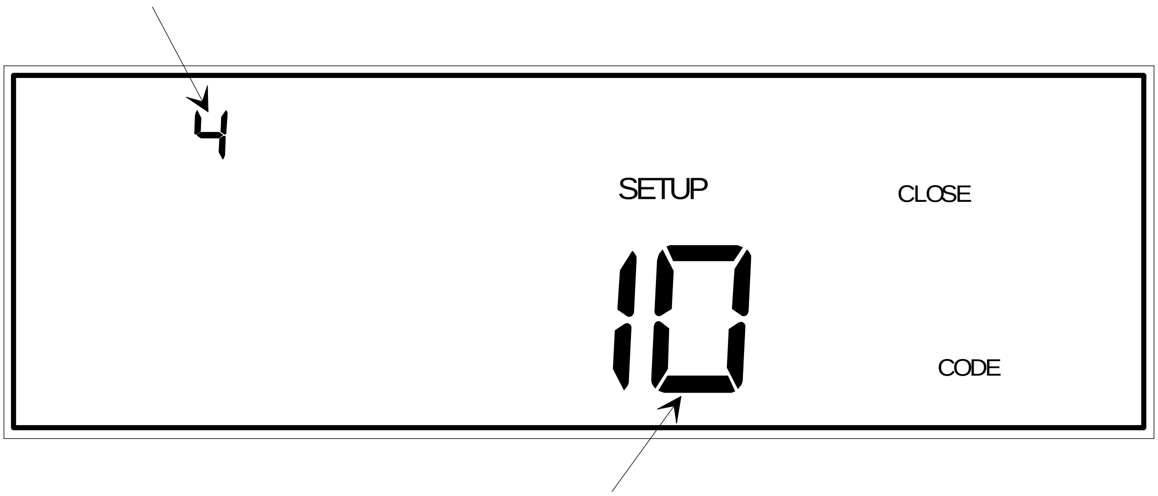
   The system responds by turning the alarm audio tone on or off.

Code 4: How To Adjust Alpha (PID Control)

LEFT DISPLAY

The code number is
displayed and edited here.

In this example, the
code number is 4.



MAIN DISPLAY

This display is used to edit the
alpha value (for PID control).

Figure 69: Code 4 Display

This function requires the Control board.

Alpha is a control parameter that helps reduce the amplification of noise, which is an inherent problem in PID control algorithm calculations. The noise itself is inherent in control systems. With a low Alpha value, the lead's response time is slower. With a higher Alpha value, the lead may be overly sensitive to noise. Unless there is a *well understood* reason for changing the Alpha value, it should remain at its default value of 20.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Setup Mode.

   The system responds by scrolling through modes.

2. Use the arrow keys to scroll to the CODE legend.

   The system responds by causing the left display to blink.

3. Enter the number **4** and press the [ENTER] key.

   The system responds by displaying the appropriate parameters for code 4, and causing the main display to blink.

4. Enter an appropriate Alpha value, between 5 and 99 (the default is 20).

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, enter the correct value, then press the [ENTER] key.

   The system responds by accepting the Alpha value.

Code 5: How To Configure the RS-232 Port

LEFT DISPLAY

The code number is displayed and edited here.

In this example, the code number is 5.

CENTER DISPLAY

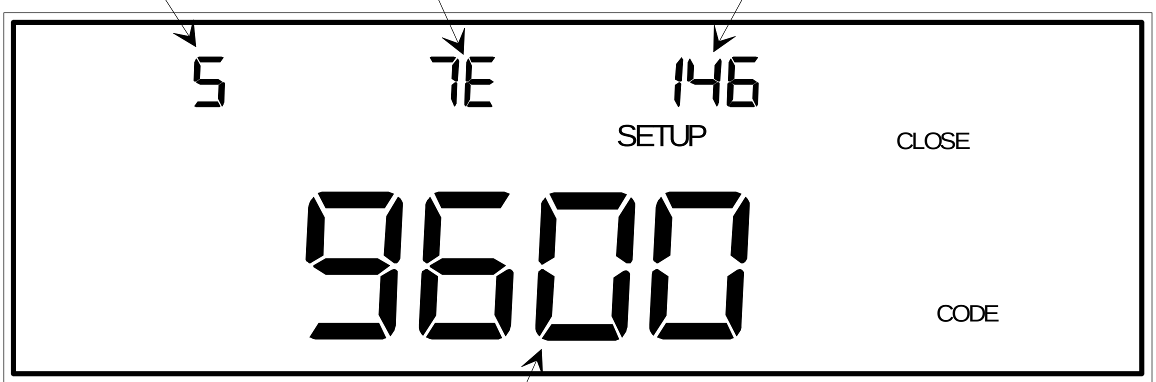
The left character represents the number of data bits. The choices are 7 or 8.

The right character represents parity. The choices are: E (even), o (odd), and n (no).

In this example, the number of data bits is 7 and the parity is even.

RIGHT DISPLAY

This display toggles between dl (data logger protocol), and 146 (MKS protocol). In this example, 146 protocol is selected.



MAIN DISPLAY

The baud rate is selected in this display.
In this example, the baud rate is 9600.

Figure 70: Code 5 Display

This function is used to set up the RS-232 port. The features that can be adjusted are the baud rate (300, 1200, 2400, 4800, or 9600), parity (odd, even, or no), data bits (7 or 8), and communication protocol (MKS protocol or data logger). Refer to *Code 8: How To Edit the Data Logger Interval*, page 224, for the set up of the data logger interval.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Setup Mode.

   The system responds by scrolling through modes.

2. Use the arrow keys to scroll to the CODE legend.

   The system responds by causing the left display to blink.

3. Enter the number **5** and press the [ENTER] key.

   The system responds by displaying the appropriate parameters for code 5, and causing the main display to blink.

4. Use the [↑] or [↓] key to select the correct baud rate (the default is 9600).

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, use the arrow keys to scroll to the correct baud rate, then press the [ENTER] key.

   The system responds by accepting the baud rate, and causing the right parameter to blink.

5. Select the correct protocol (the default is MKS protocol).

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, use the arrow keys to select the correct protocol, then press the [ENTER] key. The choices for protocol are 146 (MKS Protocol) and dl (data logger).

   The system responds by accepting the protocol, and causing the center display to blink.

6. Enter the number of data bits (7 or 8), and parity (even, odd, or no). The defaults are 7 data bits, and even parity.

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, press the [7] or [8] key to enter the number of data bits, then use the arrow keys to scroll through the three parity choices. Press the [ENTER] key.

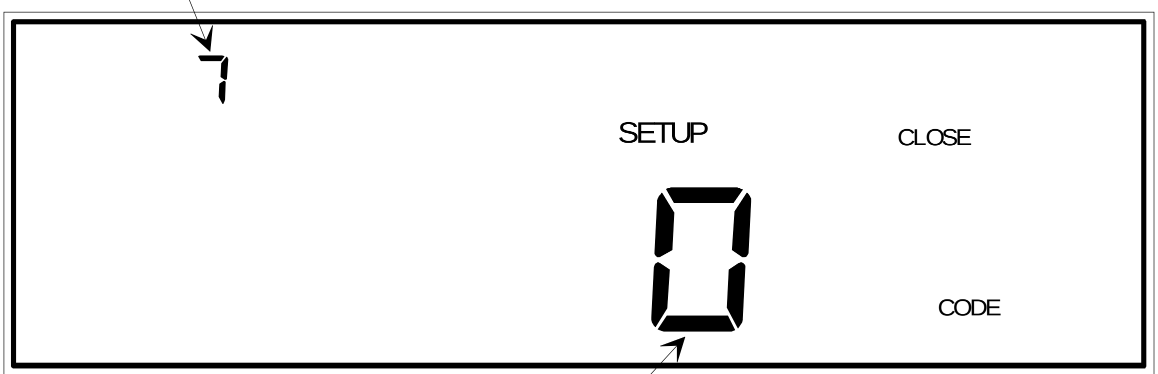
   The system responds by accepting the number of data bits and parity choices.

Code 7: How To Set the Display for Leakage Mode

LEFT DISPLAY

The code number is
displayed and edited here.

In this example, the
code number is 7.



MAIN DISPLAY

Code 7 is used to determine what is shown in the main display when the 146 unit is in the Leakage Mode.

If a number between 1 and 60 is entered here, the main display in Leakage Mode will show a leakage rate value. The number entered here represents the time base for the leakage rate calculations.

If a 0 is entered here, as in this example, the main display in Leakage Mode will show instantaneous leakage. Instantaneous leakage is the difference between the current pressure reading and what the pressure reading was when Leakage Mode was entered.

Figure 71: Code 7 Display

This function determines what is shown in the main display in Leakage Mode. The two choices are *instantaneous leakage* (enter 0 in this function), and *leakage rate* (enter a number between 1 and 60 in this function). Instantaneous leakage is the pressure change since entering Leakage Mode, and leakage rate is the actual rate of change of the pressure.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Setup Mode.

   The system responds by scrolling through modes.

2. Use the arrow keys to scroll to the CODE legend.

   The system responds by causing the left display to blink.

3. Enter the number **7** and press the [ENTER] key.

   The system responds by displaying the appropriate parameters for code 7, and causing the main display to blink.

4. Enter the leakage rate time base **OR** 0 for instantaneous leakage. The default value of 0 configures the 146 unit for instantaneous leakage display.

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, enter 0 for instantaneous leakage, or a number from 1 to 60 (seconds) to define the time base for leakage rate calculations, then press the [ENTER] key.

   The system responds by accepting the value entered.

Code 8: How To Edit the Data Logger Interval

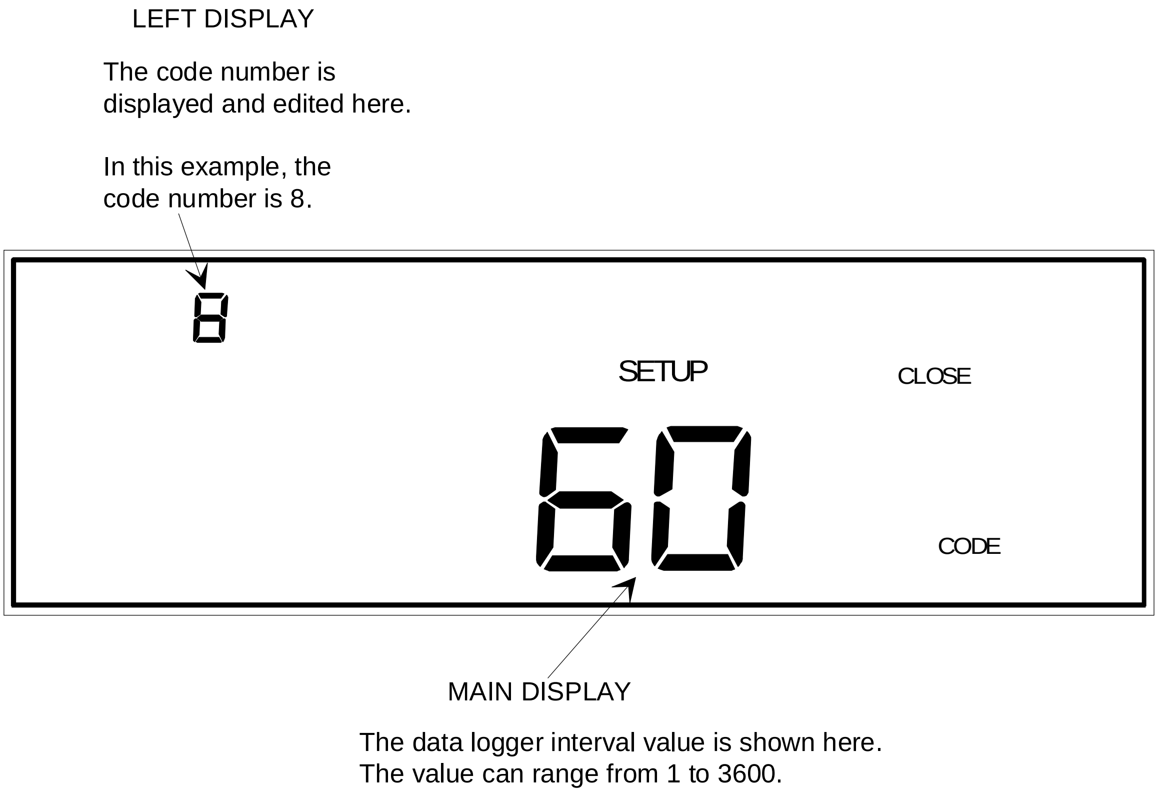


Figure 72: Code 8 Display

The data logger interval is the time period (from 1 to 3600 seconds), for the periodic output of pressure readings. The default is 60 seconds. The pressure reading outputs are for all four channels, and are sent via the RS-232 port. The data logger interval may be selected at any time, regardless of the currently selected protocol. Refer to *Code 5: How To Configure the* RS-232 Port, page 220, to select a protocol.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Setup Mode.

   The system responds by scrolling through modes.

2. Use the arrow keys to scroll to the CODE legend.

   The system responds by causing the left display to blink.

3. Enter the number **8** and press the [ENTER] key.

   The system responds by displaying the appropriate parameters for code 8, and causing the main display to blink.

4. Enter the value for the data logger interval (1 through 3600 seconds, inclusive).

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, use the numeral keys to enter a value between 1 and 3600, then press the [ENTER] key.

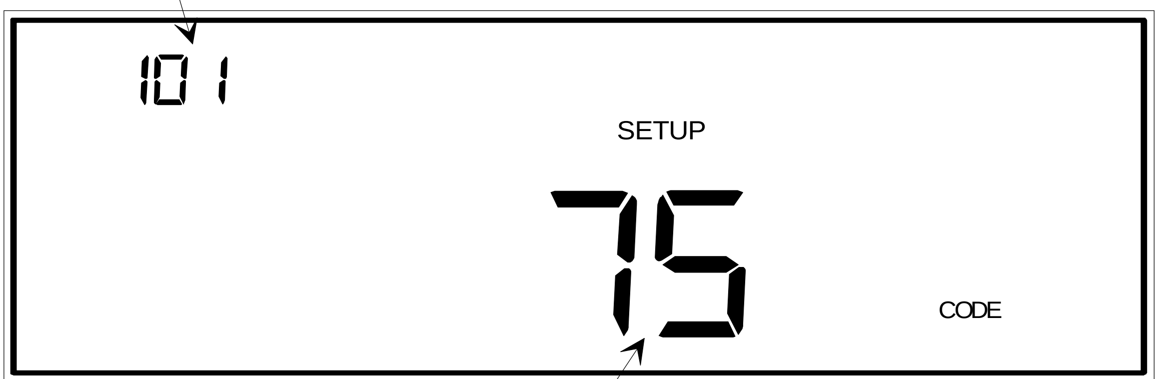
   The system responds by accepting the data logger interval value.

Code 10x: How To Adjust the Display Lag

LEFT DISPLAY

The code number is displayed
and edited here.

In this example, the code number
is 10x, where x represents the
channel number of the display
to be edited.



MAIN DISPLAY

This is the display lag percent. The range for the lag percent
is 1 to 100, where 100% is the highest display sensitivity. Use
a high display sensitivity for very quiet applications only.

Figure 73: Code 10x Display

The **x** in the code number represents a channel number. Code 10 adjusts the display sensitivity for a channel. When sensitivity is increased, any noise on the selected channel becomes more apparent in the display. Therefore, for noisy applications a low sensitivity value is best. Sensitivity is entered as a percent; the range is 1% to 100%.

The percent value is the weight of the instantaneous pressure (or flow) reading that is used to calculate the pressure (or flow) value that is displayed. For example, a value of 100% causes the display to show the actual measured pressure (or flow) since 100% weight is given to the instantaneous value. A value of 90% gives a 90% weight to the instantaneous pressure (or flow) reading and a 10% weight to the previous reading. Both weights are included in the calculation to determine the displayed pressure or flow reading.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Setup Mode.

   The system responds by scrolling through modes.

2. Use the arrow keys to scroll to the CODE legend.

   The system responds by causing the left display to blink.

3. Enter the number **10x** (where **x** represents a channel number), and press the [ENTER] key.

   The system responds by displaying the appropriate parameters for code 10x, and causing the main display to blink.

4. Enter the sensitivity percent (the default is 100% for all sensors, and 25% for an MFC).

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, enter the correct sensitivity percent (1 through 100%), and then press the [ENTER] key.

   The system responds by immediately adjusting the sensitivity for the selected channel.

Note

1. A 100% setting results in an instantaneous display of pressure or flow changes. Lower settings cause the displayed reading to lag the instantaneous reading.
2. The lag is for display purposes and RS-232 pressure queries only. Real-time data is used for all other internal functions (such as relays, analog output, and control).

Code 11x: How To Turn Auto Zeroing ON or OFF

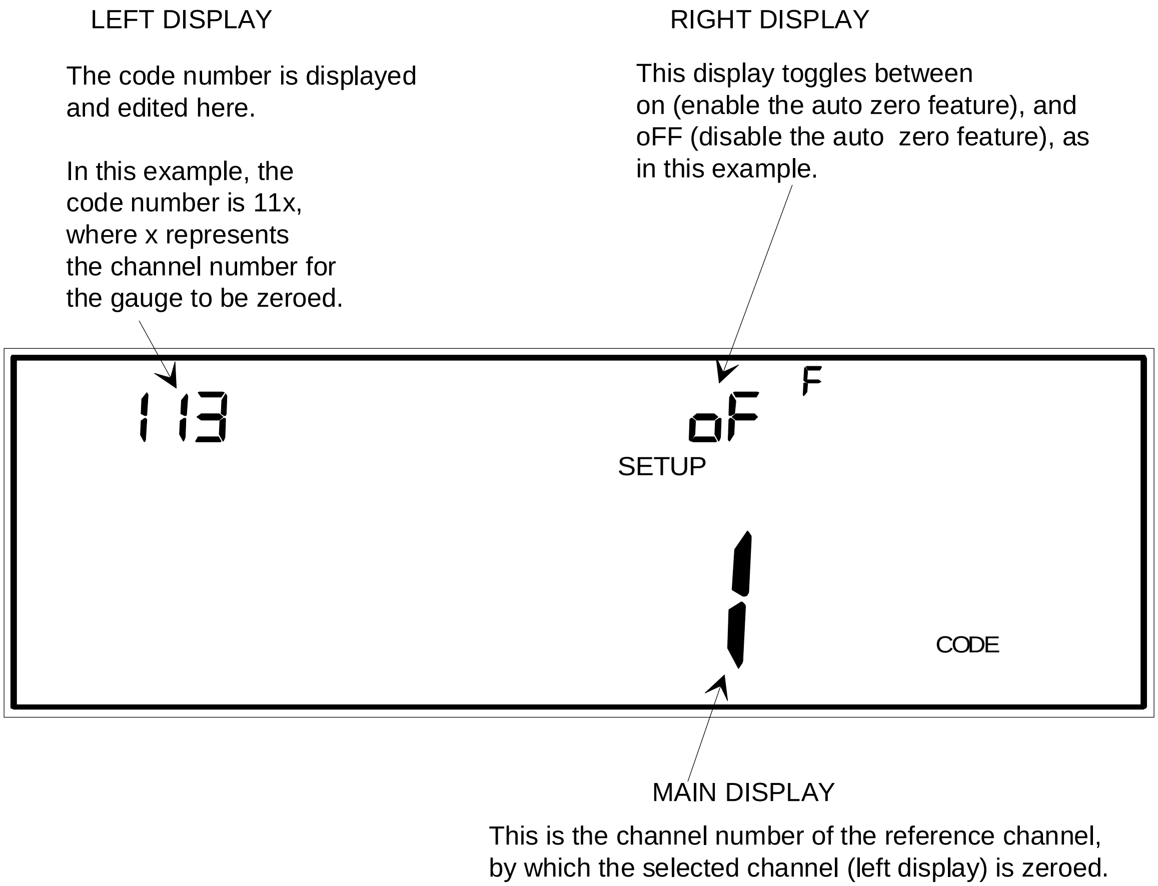


Figure 74: Code 11x Display

The **x** in the code number represents a channel number. When the Auto Zero feature is set up and enabled, one channel (defined as the reference channel) automatically zeros a second channel (defined as the selected channel). The selected channel is continually zeroed as long as the reference channel's pressure is below the selected channel's minimum resolution. The zeroing operation is suspended whenever the reference channel's condition is not measuring, and during the first 10 seconds after the reference channel is turned on.

The Auto Zero function overrides any user-defined zero previously set. If a new user-defined zero is then implemented, it overrides the effects of the Auto Zero function. If the Auto Zero feature is disabled, the 146 unit uses the last zero defined (by Auto Zero or user-defined, and via the front panel, RS-232, or rear panel remote zero).

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Setup Mode.

   The system responds by scrolling through modes.

2. Use the arrow keys to scroll to the CODE legend.

   The system responds by causing the left display to blink.

3. Enter the number **11x** (where **x** represents the channel number of the gauge to be zeroed), and press the [ENTER] key.

   The system responds by showing code 11x in the left display, and causing the main display to blink.

4. Enter the reference channel number (the default is channel 1).

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, enter the correct reference channel number (1 through 4), and press the [ENTER] key.

   The system responds by accepting the reference channel number and causing the right display to blink.

5. Select On or Off to Enable or Disable the Auto Zero function.

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, use the [ON/LEAD] or [OFF/GAIN] key to enable or disable the Auto Zero function, then press the [ENTER] key.

   The system responds by enabling or disabling the Auto Zero function for the specified reference and selected channels.

Code 12x: How To Adjust the Auto Power Control

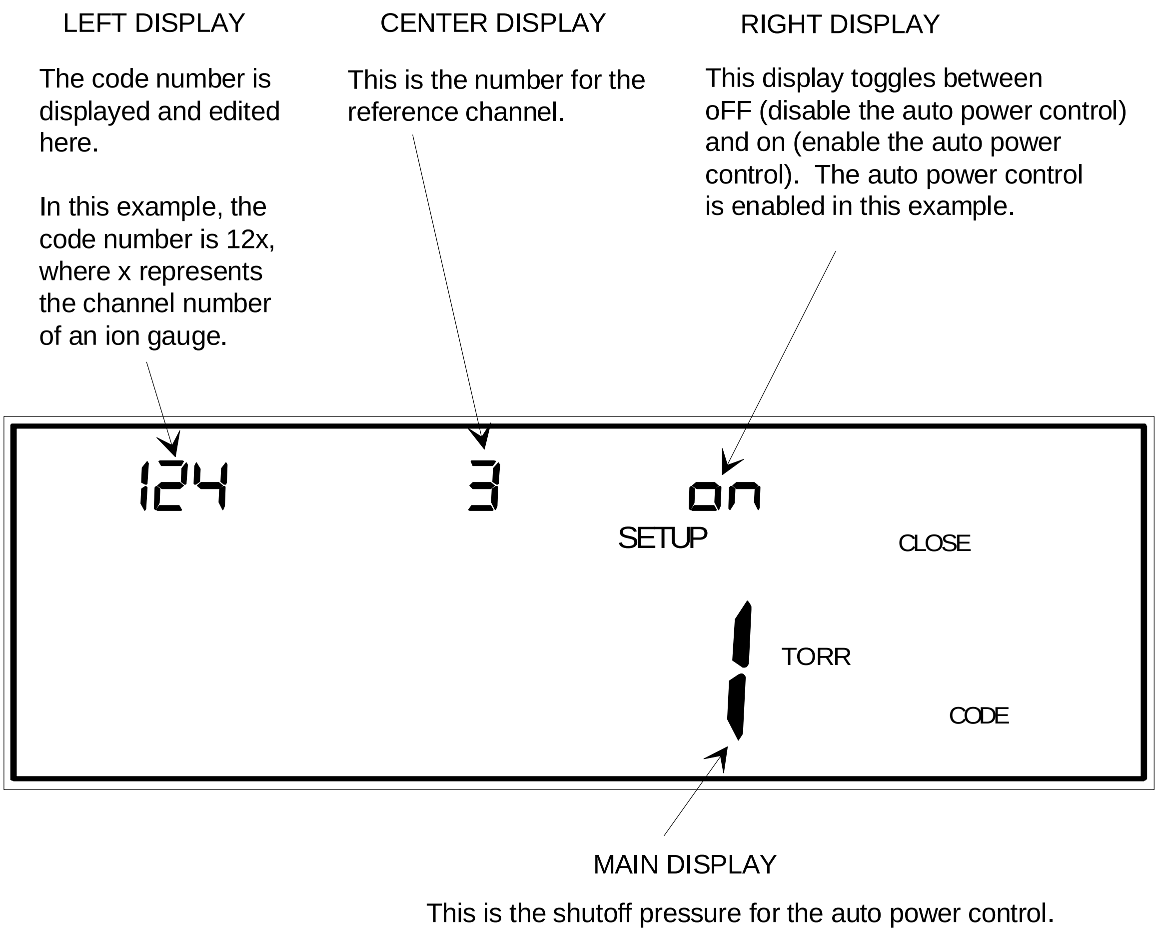


Figure 75: Code 12x Display

This function applies to ion gauges only.

The **x** in the code number represents the channel number associated with the ion gauge. This function is used to turn the power to an ion gauge on or off automatically with respect to a pressure reading from a reference channel. The parameters which can be adjusted with this function are the switchpoint (the pressure at which the gauge is powered off), selection of the reference channel, and enabling/disabling (turning on or off) the Automatic Power On/Off feature itself.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Setup Mode.

   The system responds by scrolling through modes.

2. Use the arrow keys to scroll to the CODE legend.

   The system responds by causing the left display to blink.

3. Enter the number **12x** (where **x** represents the channel number for the ion gauge), and press the [ENTER] key.

   The system responds by displaying the appropriate parameters for code 12x, and causing the main display to blink.

4. Enter the switchpoint pressure (the default is 0.001 Torr).

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, enter the correct switchpoint (0 through 35,000 Torr), and press the [ENTER] key.

   The system responds by accepting the switchpoint value, and causing the right display to blink.

5. Select on or off in the right display (the default is off).

   When this function is enabled (on), a channel can still be turned off manually. If turned off manually, a channel must be manually turned back on again before it can be autopowered.

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, use the [ON/LEAD] or [OFF/GAIN] key to enable or disable the Automatic Power On/Off feature. Press the [ENTER] key to select the action.

   The system responds by enabling or disabling the Automatic Power On/Off feature for the selected ion gauge channel, and causing the center display to blink.

6. Enter the reference channel number (the default is channel 1).

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, enter the correct reference channel number (1 through 4), then press the [ENTER] key.

   The system responds by accepting the reference channel number.

Code 13x: How To Adjust Softstart for Control

LEFT DISPLAY

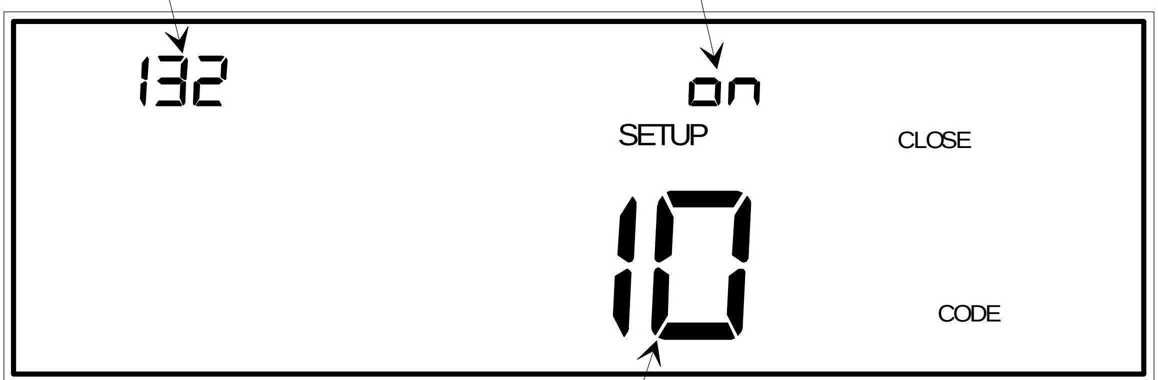
The code number is displayed and edited here.

In this example, the code number is 13x, where x represents the number of the recipe whose softstart value is listed in the main display. In this example, the recipe number is 2.

RIGHT DISPLAY

This display toggles between oFF (disable the softstart speed feature for the selected recipe), and on (enable the softstart speed feature). This example shows the softstart speed enabled.

The status of the softstart feature, either enabled or disabled, applies to all recipes.



MAIN DISPLAY

The softstart speed value is edited here. The value entered here only effects the selected recipe.

Figure 76: Code 13x Display

This function requires the Control board.

The **x** in the code number represents a recipe number. The softstart speed is used when adjusting the control valve, and is the time period for which the valve drive signal (and thus the valve position) can go from 0 to 100%. Each recipe can have a different softstart speed—the value shown in the main display applies to the selected recipe only. The right display indicates the status of the softstart function; whether it is enabled or disabled. The softstart status applies to all recipes.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Setup Mode.

   The system responds by scrolling through modes.

2. Use the arrow keys to scroll to the CODE legend.

   The system responds by causing the left display to blink.

3. Enter the number **13x** (where **x** represents a recipe number), and press the [ENTER] key.

   The system responds by displaying the appropriate parameters for code 13x, and causing the main display to blink.

4. Enter the softstart speed value. The range is 1 to 99 seconds, and the default is 10 seconds.

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, enter the correct softstart speed value (1 to 99), then press the [ENTER] key.

   The system responds by accepting the softstart speed value, and causing the right display to blink.

Note The softstart speed is common to *all* recipes.

5. Select On or Off in the right display (the default is Off).

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, use the [ON/LEAD] or [OFF/GAIN] key to enable or disable the Softstart Control feature for the selected recipe, then press the [ENTER] key.

   The system responds by enabling or disabling the Softstart Control feature for the selected recipe.

Code 14x: How To Select Control Settings

LEFT DISPLAY

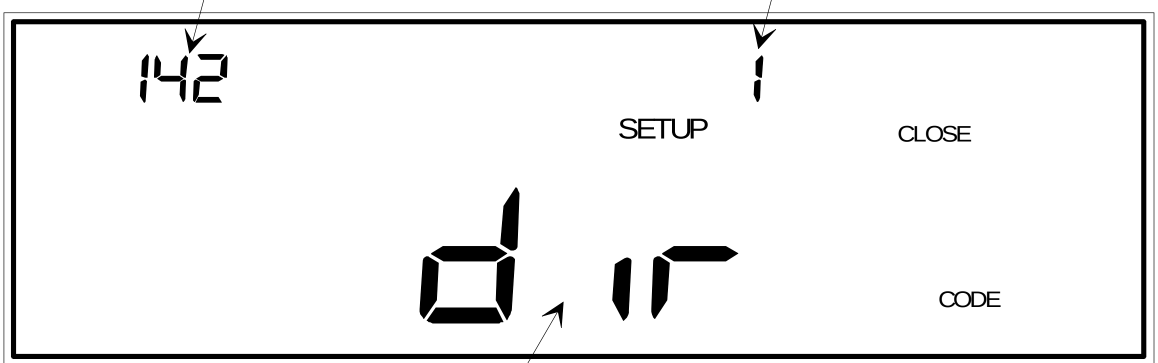
The code number is displayed and edited here.

This number represents the code number and the number for the recipe which you want to edit. In this example, recipe 2 is selected for editing.

RIGHT DISPLAY

The input channel number for the control loop of the selected recipe is entered here.

In this example, input channel 1 provides the input in recipe 2.



MAIN DISPLAY

This display toggles between rEV (reverse) and dir (direct) polarity.

Note: The polarity applies to *all* recipes, regardless of which recipe is selected in the left display.

Figure 77: Code 14x Display

This function requires the Control board.

The **x** in the code number represents a recipe number. This function selects the polarity (direct or reverse), and the input channel used for control. By changing the input channel and then editing a recipe (refer to *How To Edit Recipes*, in the *Operation in Tuning Mode* chapter), a different input channel can be associated with each recipe.

Note The polarity feature applies to *all* recipes, not just the selected recipe.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Setup Mode.

   The system responds by scrolling through modes.

2. Use the arrow keys to scroll to the CODE legend.

   The system responds by causing the left display to blink.

3. Enter the number **14x** (where **x** represents a recipe number, the default recipe is 1), and press the [ENTER] key.

   The system responds by displaying the appropriate parameters for code 14x, and causing the main display to blink.

4. Select dir (direct) or rEV (reverse) polarity. The default is direct polarity.

   For upstream control, the rEV (reverse) polarity is used to decrease the upstream valve's output as pressure rises in the process chamber. For downstream control, the dir (direct) polarity is used to increase the downstream valve's output as pressure rises in the process chamber. This polarity setting applies to all recipes.

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, use the arrow keys to select the correct polarity direction, then press the [ENTER] key.

   The system responds by accepting the polarity direction, and causing the right display to blink.

Note Although the polarity can be modified within any recipe, only the last entered polarity is saved and used for all recipes.

5. Enter the input channel number (the default is input channel 1).

   The input channel provides the signal that is fed into the control loop. The channel chosen becomes associated with the selected recipe. The default entry for all recipes is input channel 1.

Note The two Dual Channels cannot be used as input channels.

Either *one* of the two channels used in Dual Channel display, however, can be used as an input channel.

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, enter the correct channel number (1 through 4), then press the [ENTER] key.

   The system responds by accepting the input channel.

Code 15x: How To Set Up the Analog Set Point

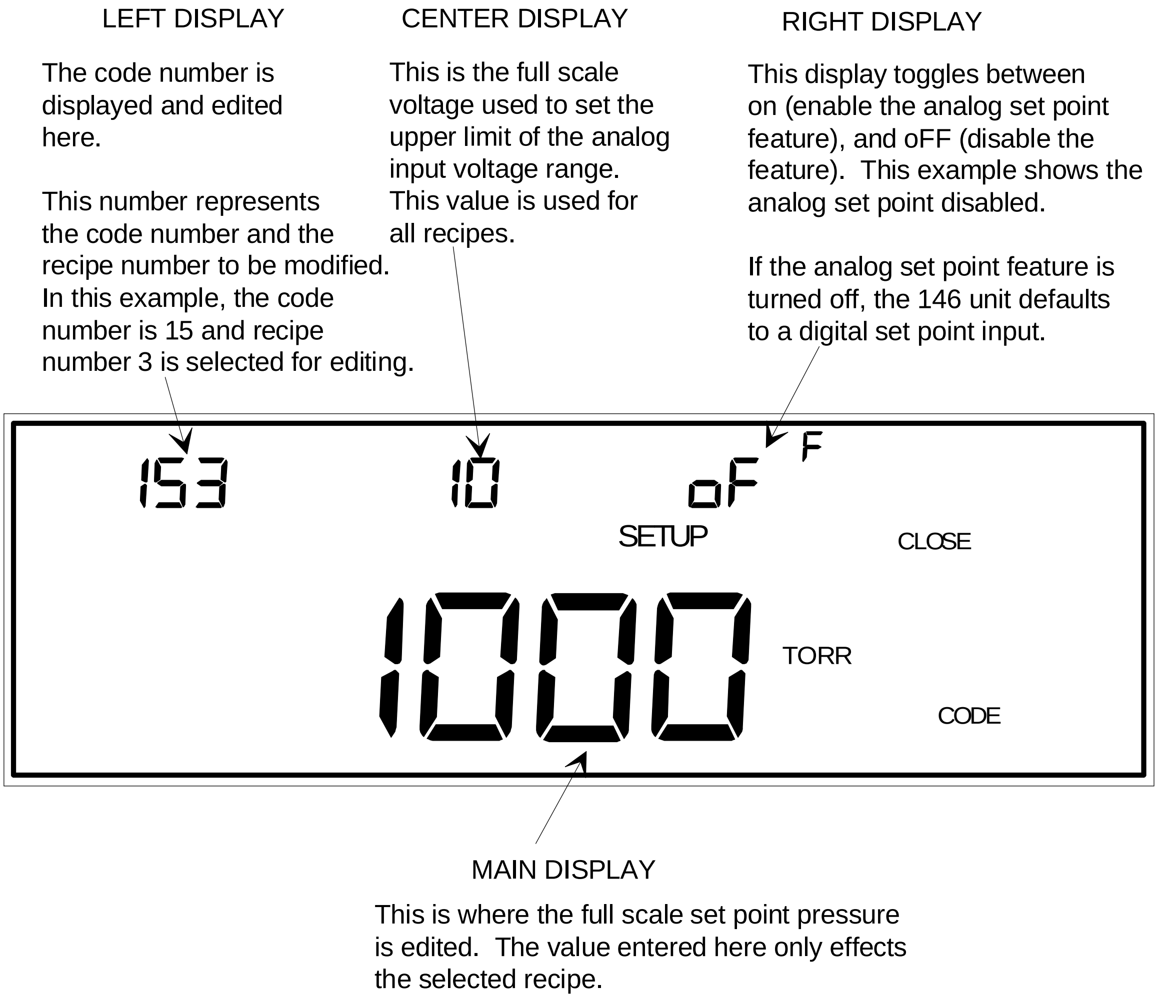


Figure 78: Code 15x Display

This function requires the Control board.

The **x** in the code number represents a recipe number. Each recipe can be configured with a different full scale set point pressure value, set in the main display. The set point signal input is configured as an analog or digital input in the right display of this function. All parameters adjusted in this function *except* the parameter edited in the center display (full scale voltage to set the upper limit of the analog input voltage range), are specific to each recipe. The full scale voltage for analog input is common to all recipes.

The analog set point input is a linear input sent through the lower connector on the Control board. The input corresponds to an analog set point value (refer to Figure 79, page 237). By adjusting the analog set point input voltage, the analog set point is changed. The default settings are for an analog input of 0 Volts to correspond to a 0 set point, and for a 5 Volt input to define a

1000 Torr set point. The acceptable analog input voltage range is 0 to 10 Volts, with the default full scale voltage set at 5 Volts. The full scale set point pressure can range from 0 to 100,00 Torr; 1000 Torr is the default. The ability to define the set point through an analog input is disabled by default.

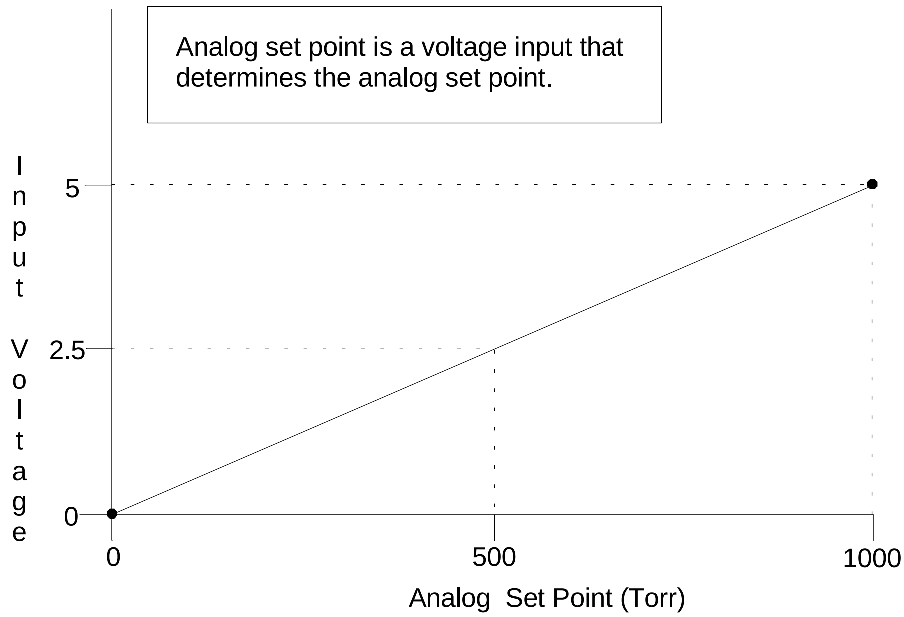


Figure 79: Graph Showing Analog Set Point Defaults

The lower and upper points of the analog input voltage range can be altered in Normal and Leakage Modes, however to do so the current analog input voltage must be altered. To change the upper point (not the lower point), independent of the current analog input, use Code 15x.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Setup Mode.

   The system responds by scrolling through modes.

2. Use the arrow keys to scroll to the CODE legend.

   The system responds by causing the left display to blink.

3. Enter the number **15x** (where **x** represents the recipe number), and press the [ENTER] key.

   The system responds by displaying the appropriate parameters for code 15x, and causing the main display to blink.

4. Enter the full scale set point pressure value from 0 to 100,000 Torr (the default is 1000 Torr).

   A. If the display is correct, press the [ENTER] key.

B. If the display is not correct, enter the correct full scale set point, then press the [ENTER] key.

The system responds by accepting the full scale pressure value, associating it with the selected recipe, and causing the right display to blink.

5. Select On or Off in the right display (the default is Off) to enable/disable the Analog Set Point feature.

A. If the display is correct, press the [ENTER] key.

B. If the display is not correct, use the [ON/LEAD] (to enable), or [OFF/GAIN] (to disable) key, the analog set point feature for the selected recipe, then press the [ENTER] key.

The system responds by enabling or disabling the analog set point feature for the selected recipe, and causing the center display to blink.

Note If the analog set point feature is turned off in a recipe, the system defaults to a digital set point input for that recipe. The digital set point can be entered via the front panel or RS-232 communications.

6. Enter the full scale voltage to set the upper limit of the analog input voltage range (the default is 5 Volts).

A. If the display is correct, press the [ENTER] key.

B. If the display is not correct, enter the correct full scale voltage (up to 10 Volts), and press the [ENTER] key.

The system responds by accepting the full scale voltage value and using it to set the upper point on the analog set point slope.

The slope of the line in the analog voltage input versus analog set point graph determines the value of the analog set point. Changing the value of the upper point on the line changes the slope of the line. Figure 39, page 143, illustrates how the Analog Set Point feature determines set point, and Refer to Figure 40, page 144, shows how adjusting the lower or upper points of the analog input voltage range effect the set point value.

Note

1. The full scale voltage can also be modified in Normal and Leakage Modes. Refer to *How To Set Lower and Upper Points for Analog Set Point Calculations* in Normal and Leakage Modes.
2. Although the full scale voltage can be modified within any recipe, only the last entered voltage is saved and used for all recipes.

Code 16x: How To Set the HC Shutoff Features

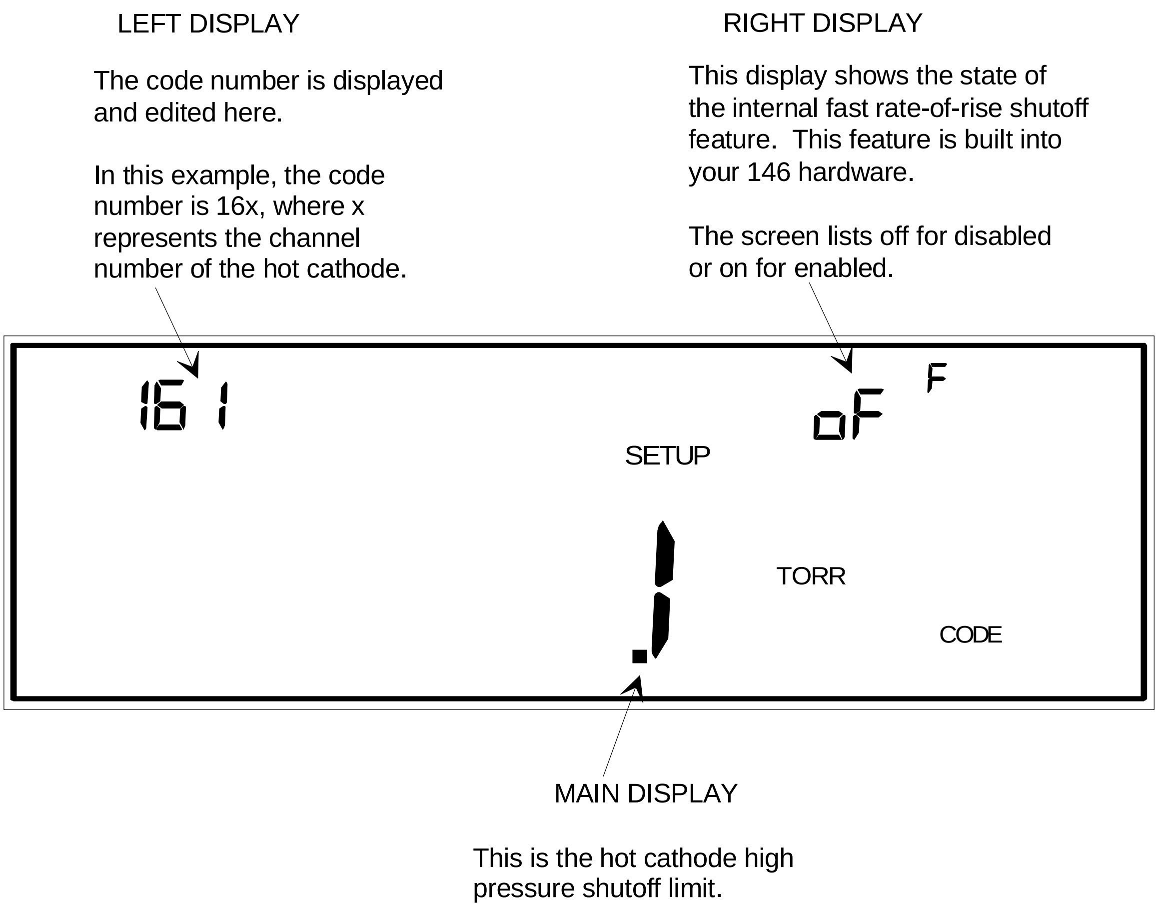


Figure 80: Code 16x Display

This function applies to hot cathode gauges only.

The **x** in the code number represents the channel number for the hot cathode. The user-defined high pressure shutoff value is used to protect a hot cathode from potential damage if the pressure rises too high. When the gauge is turned off with this function, three dots (**. . .**) appear in the hot cathode channel display. The gauge must be turned back on manually.

The internal fast rate-of-rise shutoff feature is built into the hardware of the 146 unit. It monitors the pressure signal for a rapid increase. Most gauges are shut down around 10 to 100 mT in the event of a rapid pressure rise, and the error code E1 appears in the hot cathode channel display. To turn the hot cathode back on, the channel must first be turned off. When turned off, three dots (**. . .**) appear in the hot cathode channel display. The channel can then be turned back on.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Setup Mode.

   The system responds by scrolling through modes.

2. Use the arrow keys to scroll to the CODE legend.

   The system responds by causing the left display to blink.

3. Enter the number **16x** (where **x** represents the hot cathode channel number), and press the [ENTER] key.

   The system responds by displaying the appropriate parameters for code 16x, and causing the main display to blink.

4. Enter the hot cathode high pressure shutoff value.

   The default value is 1 x 10^{-3} Torr and the range is 1.001 x 10^{-5} Torr to 1 Torr.

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, enter the correct high pressure shutoff value, then press the [ENTER] key.

   The system responds by accepting the high pressure shutoff value.

5. Set the internal fast rate-of-rise shutoff feature. The factory configuration has this feature disabled. To enable the feature, press the [ON/LEAD] key.

Note

Only enable the internal fast rate-of-rise shutoff feature if your pressure signal is stable. A noisy pressure signal may exceed the rate-of rise-value momentarily causing the 146 unit to turn off the hot cathode gauge

Caution

Enabling the internal fast rate-of-rise shutoff feature will make the 146 unit more sensitive to electrostatic discharge (ESD). Transient signals may be interpreted as a fast pressure change that would cause the 146 unit to turn off power to the hot cathode gauge. When this feature is enabled*, the 146 unit DOES NOT COMPLY with the Low-Voltage Directive (EN61010-1: 1993) requirement for CE certification.*

The 146 unit is configured at the factory with this feature disabled.

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, press the [ON/LEAD] key to enable or the [OFF/GAIN] key to disable the feature.

   The system responds by enabling or disabling the internal fast rate-of-rise shutoff feature.

Code 17x: How To Set Up the MFC

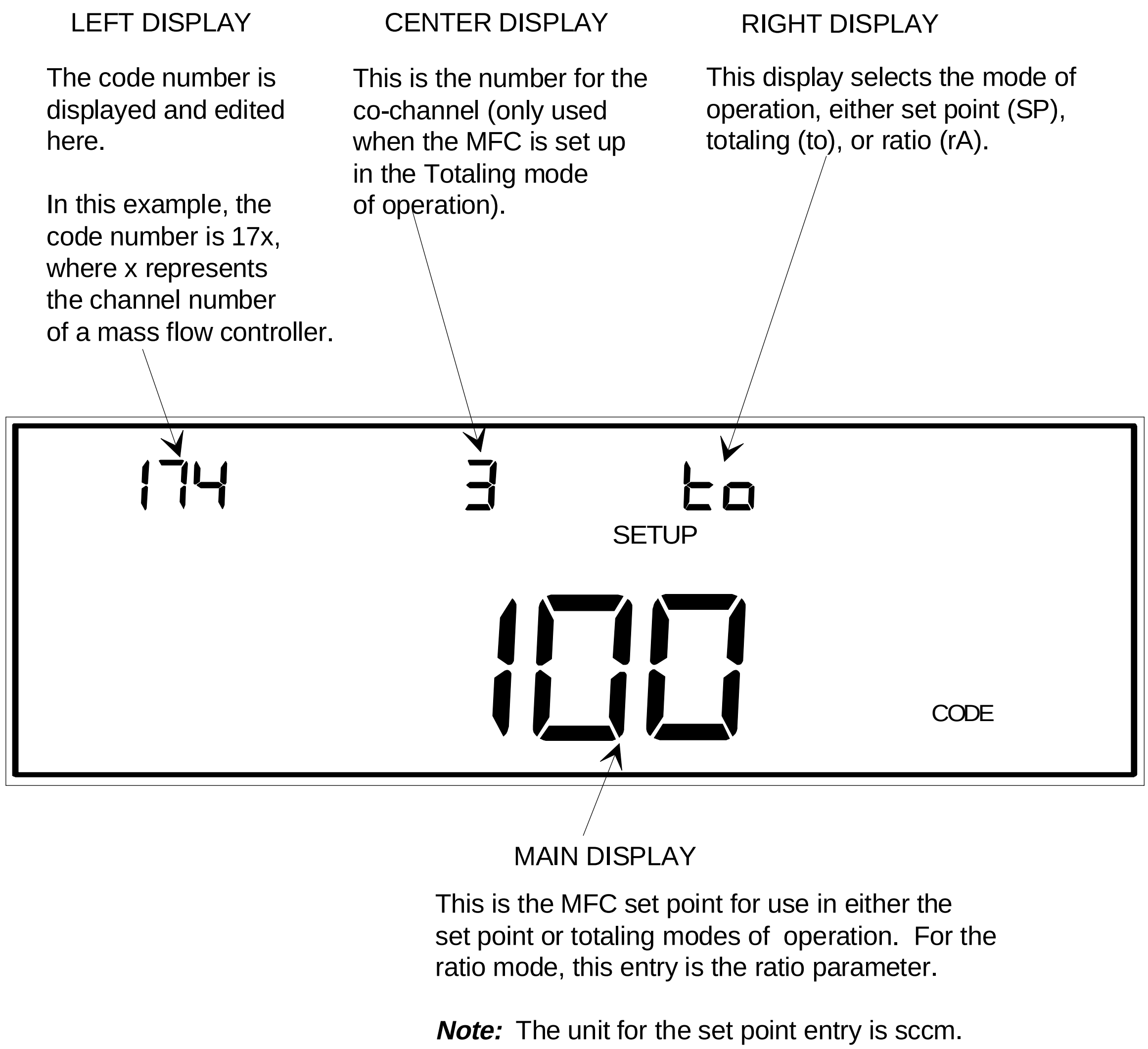


Figure 81: Code 17x Display

The **x** in the code number represents the channel number for the mass flow controller (MFC). The three modes of operation for an MFC are *Set Point*, *Totaling*, and *Ratio*. The different modes are indicated by codes in the right display: **SP** for Set Point; **to** for Totaling; and **rA** for Ratio.

Set Point Mode of Operation

When using the Set Point mode of operation, the 146 unit sends out a voltage corresponding to a user-defined set point (in sccm). The set point voltage takes into account any zero offset which may have resulted from zeroing the MFC, to ensure that the MFC controls to the desired flow rate. The 146 unit can operate up to four MFCs. Each MFC operating in Set Point mode has a set point value assigned to it.

Totaling Mode of Operation

When using the Totaling mode of operation, two MFCs operate in conjunction with each other. One MFC (defined as the co-channel), operates according to a fixed set point. The other MFC, defined as the totaling MFC, adjusts its output voltage to maintain a user-defined total flow rate (set point) for the system. For example, you want to maintain a flow rate of 100 sccm. Enter a set point of 100 sccm and set the co-channel to a fixed flow rate of 20 sccm. The totaling MFC will subtract 20 (flow rate of the co-channel) from 100 (the set point) and adjust its voltage to produce a flow rate of 80 sccm. Therefore, the total flow rate will be 100 (20 + 80). As with the Set Point mode of operation, the 146 accounts for any zero offset.

Ratio Mode of Operation

In the Ratio mode of operation, the 146 instrument is capable of controlling up to four MFCs simultaneously. The 146 uses a pressure control signal (PCS), or a total flow signal, as feedback. The Ratio mode uses a logical control channel to execute the PID control algorithm and achieve the desired gas ratio. The logical control channel (control channel 0) is present even if no Control board is installed. The 146 unit calculates the control signal to correct the gas ratio and sends the signal to all MFCs configured for Ratio control.

Two possible control methods exist within Ratio mode: control with a *pressure* measuring control channel, and control with a *flow* measuring (MFC) control channel.

The ratio controllers maintain the *gas ratio,* and the 146 instrument maintains the absolute *pressure* by controlling the *total flow*.

Essentially, the Ratio mode of operation scales and proportions the 0 to 10 Volt control signal among the MFCs configured for Ratio mode, based on their chosen ratio set points. The set points can range from 0 to 200%. Since most MFCs accept a 0 to 5 Volt signal, the control signal for a given MFC is always scaled by ½, then multiplied by the ratio set point percent:

$$\text{MFC control signal} = \tfrac{1}{2}\,(\text{control signal})(\text{ratio set point }\%/100)$$

Example 1: Assume you have two MFCs configured for ratio control and you change the control set point to 100%. Each MFC has a set point of 50%. The PID control algorithm determines that full scale flow is required to meet the new set point, so the equation becomes:

$$\text{MFC control signal} = \tfrac{1}{2}\,(10\text{ Volts})(50\%/100) = 2.5\text{ Volts}$$

Each MFC would receive a 2.5 Volt control signal.

Example 2: If the control algorithm determined that the change necessitates a 60% flow rate, the equation becomes:

$$\text{MFC control signal} = \tfrac{1}{2}\,(6\text{ Volts})(50\%) = 1.5\text{ Volts}$$

Each MFC would receive a 1.5 Volt control signal.

Example 3: Assume that you have three MFCs with ratio set points of 10%, 30%, and 60%. The PID algorithm determines that a 75% control signal is required to meet the control set point. The 146 instrument calculates the control signal for each MFC:

$$\text{MFC 1} = \tfrac{1}{2}\,(7.5\text{ Volts})(10\%) = 0.375\text{ Volts}$$

$$\text{MFC 2} = \tfrac{1}{2}\,(7.5\text{ Volts})(30\%) = 1.125\text{ Volts}$$

$$\text{MFC 3} = \tfrac{1}{2}\,(7.5\text{ Volts})(60\%) = 2.25\text{ Volts}$$

The total control signal is 3.75 Volts (75% of 5 Volts).

Pressure Measuring Control

When using a pressure measuring control channel, up to three MFCs can be configured to function in a pressure control loop. In this case, the total flow of the three MFCs determines the pressure, however, the percent of gas through each MFC remains constant. For example, if the ratio set points for the three MFCs are 30%, 30%, and 40% and pressure rises in the system, the gas flow through each MFC decreases but the 30%, 30%, 40% relationship remains intact.

Flow Measuring Control

When using a flow measuring control channel, an MFC channel is selected as the control input channel. The Ratio mode MFCs follow the controlling MFC with their respective proportions of flow as set by their Ratio mode set points.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Setup Mode.

   The system responds by scrolling through modes.

2. Use the arrow keys to scroll to the CODE legend.

   The system responds by causing the left display to blink.

3. Enter the number **17x** (where **x** represents an MFC channel number), and press the [ENTER] key.

   The system responds by displaying the appropriate parameters for code 17x, and causing the main display to blink.

4. Enter the set point flow rate (the range is ± 10% of the MFC range) if using Set Point or Totaling mode, or enter the ratio set point percent (0 to 200%) if using Ratio mode.

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, enter the correct set point, then press the [ENTER] key.

   The system responds by accepting the set point value and causing the right display to blink.

5. Use the arrow keys to scroll through the modes of operation (**SP** for Set Point, **to** for Totaling, and **rA** for Ratio)

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, press an arrow key and then press the [ENTER] key.

   If Set Point (SP) is selected, no more input is required for code 17x. When the selected MFC is controlling, it controls according to the new set point.

   If Totaling (to) is selected, the system responds by displaying a blinking channel number in the center display.

   If Ratio (rA) is selected, no additional input is required. The MFC will control to a flow rate equal to the PID output signal times the ratio selected the main display.

6. If Totaling mode (to) was selected, enter the channel number for the co-channel (it must be an MFC).

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, enter the correct co-channel number, and press the [ENTER] key.

      The system responds by accepting the co-channel number. When the totaling MFC is controlling, its output voltage is adjusted in order to accommodate the output of the co-channel MFC, and to control with a total flow rate equal to the user-defined set point.

Code 18x: How To Select the Convection Gauge

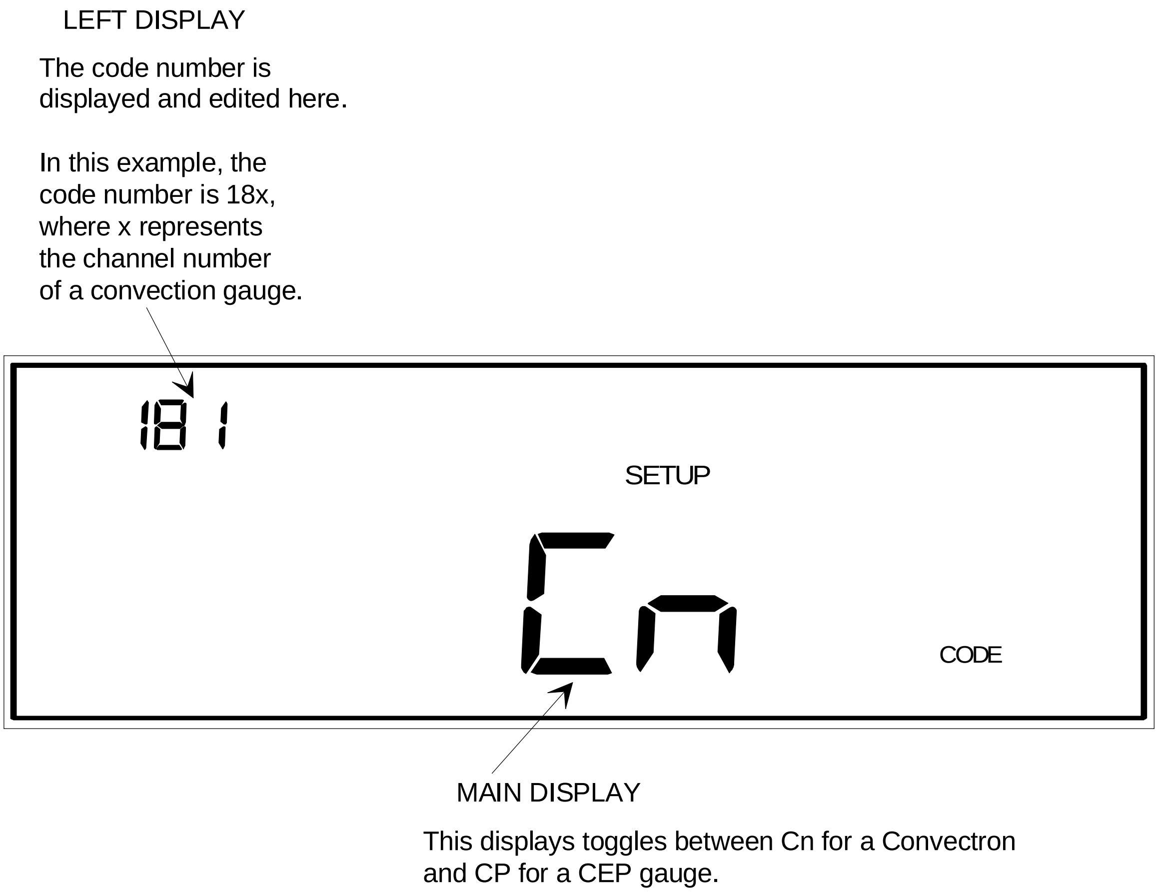


Figure 82: Code 18x Display

The 146 instrument now supports the HPS Convection Enhanced Pirani (CEP) gauge. This gauge replaces the Alcatel PI 3C gauge.

When the 146 instrument detects the type of gauge attached to each channel, it can distinguish between a Pirani and convection gauge. However, it cannot distinguish between the two convection gauges: the Granville-Phillips Convectron® gauge and the HPS CEP gauge. The default convection gauge selection is the Convectron gauge. If you are using a CEP gauge, you must change the convection gauge type to CEP. No additional commands are required if you are using either a Convectron gauge or a standard Pirani gauge.

Note Turn the channel off before you attempt to change the convection gauge type. The command will not be accepted if the channel is on.

1. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in the Setup Mode.

   The system responds by scrolling through the modes.

2. Use the arrow keys to scroll to the CODE legend.

   The system responds by causing the left display to blink.

3. Enter the number **18x** (where **x** represents the convection gauge channel number), and press the [ENTER] key.

   The system responds by displaying the abbreviation for the type of convection gauge installed and blinking the main display entry.

4. Use the arrow keys to toggle between the convection gauge abbreviations:

   Cn for a Convectron gauge

   CP for a CEP gauge

   A. If the display is correct, press the [ENTER] key.

   B. If the display is not correct, press an arrow key to toggle to the correct gauge type and then press the [ENTER] key.

   The system responds by accepting the new convection gauge type.

Chapter Eight: Operation in Control Mode

General Information

Toggle in and out of this mode by pressing the [CONTROL MODE] key.

Note The Control Mode functions only if a Control board is installed.

Figure 83, page 248, shows an example of the Control Mode window. Control Mode functions are used to operate a valve in one of several ways:

Manual

Open

Close

Hold

Auto

The HOLD selection halts the valve in its current position. The AUTO selection automatically controls the position of the valve according to one of four user-defined recipes.

Control Mode is Used when Performing the Following Procedures

Control Mode Functions	
Select an Active Recipe	The active recipe is used to control the valve when the AUTO feature is selected.
Valve Positions	
Move the valve to open (OPEN)	The valve output signal is set to 100%.
Control the valve automatically (AUTO)	The valve is controlled according to a selected recipe.
Move the valve to closed (CLOSE)	The valve output signal is set to zero.
Hold the valve in its current position (HOLD)	This feature freezes the valve in its current position.
Move the valve to a preset position (MANUAL)	The valve is moved to a preset position. The preset position is entered in Tuning Mode.

Table 52: Control Mode Functions

LEFT DISPLAY

This is the current valve position, expressed as a percent of the valve control signal output.

This example shows a setting of 20.1% of the valve control signal output.

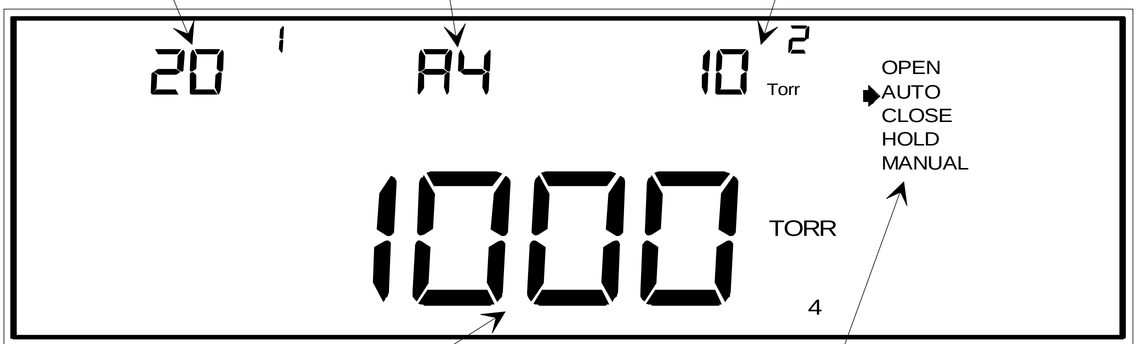
CENTER DISPLAY

The active recipe is selected in this display.

In this example, recipe 4 is the active recipe.

RIGHT DISPLAY

The set point for the active recipe is entered here. OR, if an analog set point is being used, the analog set point value is displayed here.



MAIN DISPLAY

The current pressure reading from the control channel is displayed here.

This is a list of valve control positions. The arrow keys on the keyboard scroll the selecting arrow through the list of valve positions.

In this example, AUTO is selected, so the 146 unit will control according to the control parameters in the active recipe (recipe 4 in this example).

Figure 83: Control Mode Screen

The Deviation Indicator

In Control Mode there is a deviation indicator which indicates the deviation of the system pressure from set point. The deviation from set point is displayed approximately every one-third second (this is how often the LCD screen is refreshed). The deviation indicator is enabled only if the 146 unit is operating with the Auto feature turned on (refer to *How To Set the Valve to AUTO* Position, page 252).

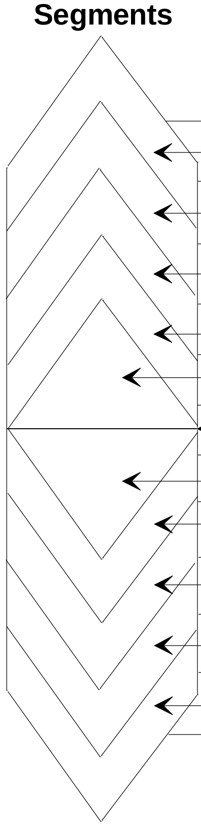
There are ten deviation indicator segments on the front panel (refer to Figure 12, page 43). Five segments represent pressure over set point and five represent pressure under set point. The 146 unit determines the segment(s) to illuminate according to the following formula:

$$\text{Deviation} = \frac{P}{sp}$$

where: P = pressure
sp = set point

Each segment represents a different percent of deviation as shown in Figure 84.

Segments



Deviation	Percent Error
≥ 1.95	> +95%
1.2 to < 1.95	+20 to 95%
1.05 to < 1.2	+5 to 20%
1.01 to <1.05	+1 to 5%
1.002 to < 1.01	+0.2 to 1%
None = 0.998 to <1.002	±0.2%
0.99 to < 0.998	-0.2 to 1%
0.95 to < 0.99	-1 to -5%
0.80 to <0.95	-5 to -20%
0.05 to < 0.80	-20 to -95%
<0.05	> -95%

Figure 84: Deviation Indicator

If the system is operating far below set point, there will be a large change in pressure between screen refreshing because the system will be quickly moving towards set point. Within the one-third second time frame, the deviation could range from -22% (at the beginning of the time frame), to -4% (at the end of the time frame). In this case, the middle three segments in the lower half of the deviation indicator light up (refer to Figure 84, page 249).

Another example is when the pressure oscillates above and below set point. Upper and lower deviation indicator segments light up to indicate over and under pressure readings. In effect, the deviation indicator provides similar information to that provided by an oscilloscope. If the oscillation continues, it is possible that reducing the Gain setting may improve system stability. When the system does stabilize, none of the deviation indicators are lit.

When the Set Point is 0:

If the set point is 0 and the pressure reading is 0, no segments light up.

If the set point is 0 and the pressure is above 0, the uppermost segment lights up.

If the set point is 0 and the pressure is below 0, the lowermost segment lights up.

The Rear Panel Override Indicator

The Valve Position parameters (Open, Auto, Close, Hold, and Manual), and the Active Recipe parameter can be selected through the front panel keyboard. The Open, Close, Manual, and Active Recipe parameters can also be selected through the bottom connector on the Control board (digital control lines). A front panel selection can be overridden by a rear panel digital input. A small arrow appears to the left of the parameter when a rear panel override occurs. Refer to Figure 12, page 43, to see where the Control Mode parameters and their associated override arrows are located.

For example, if the Valve Position parameter AUTO is selected with the front panel keypad, the AUTO legend is displayed in the front panel window. If the Valve Position parameter CLOSE is selected through the rear panel, this selection overrides the front panel keypad selection. The AUTO legend continues to be displayed, but the CLOSE legend is also displayed. Additionally, a small arrow is shown to the left of the CLOSE legend, to indicate a rear panel override is in effect.

An Active Recipe override is indicated by displaying a small arrow next to the AUTO legend. For example, if the 146 unit is currently operating with the AUTO parameter selected, and the active recipe is recipe 1, the AUTO legend is displayed. If the active recipe is changed to recipe 2 through the rear panel, the AUTO legend remains lit, but a small arrow now appears to the left of it.

How To Select the Active Recipe

Up to four user-defined recipes, each containing gain, lead, and set point values, can be edited in Tuning Mode. This function determines which of the four recipes is the active recipe. The active recipe is the recipe that regulates the control valve when the AUTO feature is selected in Control Mode.

1. Press the [CONTROL MODE] key.

   The system responds by entering Control Mode.

2. Press the [1], [2], [3], or [4] key to select a recipe (the default is recipe 1).

   The system responds by making the selected recipe the active recipe. The selected recipe number appears next to the letter **A** (for Active) in the center display.

How To Set the Valve to OPEN Position

This command sequence adjusts the valve control signal output to full output. Generally, this means the valve goes to a full open position.

1. Press the [CONTROL MODE] key.

   The system responds by entering Control Mode.

2. Scroll to the OPEN legend with the arrow keys.

   The system responds by scrolling the small arrow in the window display.

3. Press the [ENTER] key.

   The system responds by changing the valve control signal output to 100 %. As a result, the valve's position generally goes to full open.

How To Set the Valve to AUTO Position

This feature operates the valve according to the control parameters in the active recipe. The control parameters include gain, lead, and set point.

1. Press the [CONTROL MODE] key.

   The system responds by entering Control Mode.

2. Scroll to the AUTO legend with the arrow keys.

   The system responds by scrolling the small arrow in the window display.

3. Press the [ENTER] key.

   The system responds by operating the valve according to the control parameters of the active recipe.

How To Set the Valve to CLOSE Position

This command sequence adjusts the valve control signal output to 0. Generally, this means the valve goes to a fully closed position.

1. Press the [CONTROL MODE] key.

   The system responds by entering Control Mode.

2. Scroll to the CLOSE legend with the arrow keys.

   The system responds by scrolling the small arrow in the window display.

3. Press the [ENTER] key.

   The system responds by setting the valve control signal output to 0. As a result, the valve's position generally goes to full close.

How To Set the Valve to HOLD Position

This function is used to hold the valve control signal output at its current value. This has the effect of holding the control valve in its current position. The valve position can then be modified in Tuning Mode by changing the valve control signal output. Once changed, the new valve position is maintained as a fixed position.

1. Press the [CONTROL MODE] key.

   The system responds by entering Control Mode.

2. Scroll to the HOLD legend with the arrow keys.

   The system responds by scrolling the small arrow in the window display.

3. Press the [ENTER] key.

   The system responds by holding the valve control signal output at its current value.

How To Set the Valve to MANUAL Position

When this feature is evoked, the valve control signal output immediately changes to the value selected in the *How To Adjust Preset*, in the *Operation in Tuning Mode* chapter. This has the effect of altering the valve position until it is held at the position dictated by the preset value.

Note The rate at which the valve changes position is a function of the valve dynamics. The valve control signal output, and the 146 window displays, however, are changed immediately when the MANUAL feature is evoked.

1. Press the [CONTROL MODE] key.

   The system responds by entering Control Mode.

2. Scroll to the MANUAL legend with the arrow keys.

   The system responds by scrolling the small arrow in the window display.

3. Press the [ENTER] key.

The system responds by immediately changing the valve control signal output to the value entered in the preset function (refer to *How To Adjust Preset*, in the *Operation in Tuning Mode* chapter).

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Chapter Nine: RS-232 Communications

General Information

The 146 unit is programmed to communicate with any host computer equipped with an RS-232 serial port, and an RS-232 cable. The 146 instrument is configured as a DTE (Data Terminal Equipment) device, and uses a 9-pin male Type "D" IBM AT® configuration connector. All standard baud rates are accepted up to a baud rate of 9600. The 146 unit supports 7 or 8 bit data format, and any parity option (even, odd, or no). Commands sent via the RS-232 port allow full control of all 146 functions remotely. The parameters, and inquiries of parameters and readings, are both changeable.

RS-232 Communication Parameters		
Parameter	**Initial Setting**	**Options**
Baud Rate	9600	300, 1200, 2400, 4800
Parity	Even	Odd, No
Number of Data Bits	7	8
Number of Stop Bits	1	*Cannot be changed*
End-of-Line Delimiter	CR	*Cannot be changed*
Protocol	MKS	Data Logger

Table 53: RS-232 Communication Parameters

Refer to *Code 5: How To Configure the RS-232 Port*, in *Chapter Seven: Operation in Setup Mode*, for instructions on changing the communication parameters.

Note The communication parameters cannot be changed on a displayless 146 unit.

How To Establish RS-232 Communications

Use the RS-232 connector on the rear panel to connect the 146 unit to your computer. Be sure to use the correct RS-232 cable.

Displayless units have an RS-232 connector on both the front and rear panels. Note that the RS-232 cable used for rear panel communications (refer to Table 32, page 77, for the proper MKS part number) is *not* the same as the RS-232 cable used for the front panel (MKS p/n CB146-21).

MKS RS-232 Protocol

Command formats sent by the Host computer

Messages sent by the host computer to the 146 unit are either *commands* that instruct the instrument to change an operating parameter, or *requests* that prompt the instrument to report status information. The following table shows the format of RS-232 command messages that are sent from the host computer to the 146 unit. Specific commands are described in *Command Messages,* page 259.

Note Use UPPERCASE letters for all messages. Messages entered in lowercase will generate an “invalid command” error.

Channel Numbering

The 146 unit can hold up to five plug-in boards and supports up to four input channels and one process control channel. The input channels include capacitance manometers, Pirani gauges, convection gauges, hot cathode gauges (maximum of two), cold cathode gauges, thermocouple gauges, and mass flow controllers. The unit supports one process control channel. The analog output(s) does not require channel space. The channel numbering sequence depends on the position of the plug-in board in the 146 unit. The input and output channels are numbered separately.

The 146 unit assigns the channel numbers upon power up. For example, using the board configuration shown in Figure 4, page 27, the Pirani board in slot 1 would be assigned input channel 1 (upper connector) and input channel 2 (lower connector). The Capacitance Manometer board in the adjacent slot would use input channel 3. The Cold Cathode board in slot 3 would be assigned input channel 4. The Auxiliary Output board in slot 4 provides two additional relays and two additional analog outputs. Neither relays nor analog outputs are allocated channel numbers. The Control board in slot 5 would use the one process control channel.

If the Capacitance Manometer board is removed from slot 2, the Cold Cathode board (previously input channel 4) would become input channel 3, and all user defined parameters for the cold cathode would change to default values. The parameters associated with input channels 1 and 2 remain unchanged because the channel numbers assigned to the Pirani board would have remained unchanged.

<table>
<tr><th colspan="10">RS-232 Command Message Format</th></tr>
<tr><td rowspan="4">@</td><td colspan="2">Command Category</td><td rowspan="4">Command Number</td><td rowspan="4">Parameter</td><td colspan="3">Data
(one of the following)</td><td colspan="2">Checksum
Optional</td></tr>
<tr><td rowspan="3">Byte 1</td><td rowspan="3">Byte 2</td><td>:</td><td>up to 20 data bytes</td><td>CR</td><td rowspan="3">Byte 1</td><td rowspan="3">Byte 2</td></tr>
<tr><td>?</td><td colspan="2">CR</td></tr>
<tr><td colspan="3">CR</td></tr>
<tr><th colspan="10">Description</th></tr>
<tr><td colspan="3">@</td><td colspan="7">The “@” character is always the first character in a message</td></tr>
<tr><td colspan="3">2 ASCII Bytes</td><td colspan="7">These two bytes represent the Command Category</td></tr>
<tr><td colspan="3">1 ASCII Byte</td><td colspan="7">This byte represents the Command Number</td></tr>
<tr><td colspan="3">1 ASCII Byte</td><td colspan="7">This is the Parameter Byte—it may be one of the following:
Channel Number (1 through 4, 5 for dual channel 1, or 6 for dual channel 2)
Alarm (A through D)
Recipe Number (1 through 4)</td></tr>
<tr><td colspan="3">Data</td><td colspan="7">This can be variable length ASCII data up to 20 bytes
For data input, use a colon (:) followed by the data, terminated with CR
For a data request, use a question mark (?) followed by CR
For no data, use a carriage return (CR) by itself</td></tr>
<tr><td colspan="3">2 Byte Checksum</td><td colspan="7">This is optional Note: To use the optional checksum bytes, you must set the number of data bits to 8. The initial number of data bits is 7.</td></tr>
</table>

Table 54: RS-232 Command Message Format

General Guidelines for RS-232 Messages

- All commands are sent and received as ASCII strings *except* for the checksum, which is binary.
- All commands *must* include a parameter byte, even if it has no significance. Any character, including a space, can be supplied in its place.
- The checksum bytes are ignored, unless the checksum mode is enabled.

  The checksum is the sum of all the ASCII values in the message. It includes everything preceding it, beginning with the “at” character (@), and ending with the carriage return (CR). The checksum command needs no checksum value of its own. If the checksum is enabled, the 146 unit expects a checksum for all commands and returns a proper checksum. The checksum is sent with the low byte first. The number of data bits must be set to 8 when the checksum is enabled. The 146 unit is initially configured with the checksum disabled. Refer to *Miscellaneous Messages,* page 273, to enable the checksum.
- UPPERCASE letters must be used in all command messages.
- Floating point data fields may be entered in either scientific notation or fixed notation.

  For example, to set the disconnect threshold to 1 x 10^{-10} on channel 1, the 146 instrument accepts either of the following *commands*:

a) @0651:.0000000001<CR>

b) @0651:1E-10<CR>

where:

<CR> is a carriage return

Also, it is possible to specify the form that all RS-232 *responses* (from the 146 unit) are in, by sending the following command:

@508*x*:<option><CR>

where:

x is anything

<option> is E (for scientific notation) or D (for fixed notation)

<CR> is a carriage return

Note This command is ***not saved*** at power down and must be re-initialized after each power up.

Command Messages

This section describes all of the RS-232 commands that can be received by the 146 unit. The commands in this section are grouped by function. Refer to *Appendix G: Board Specific Commands,* page 315, for a list of commands organized by *plug-in board* type.

Should an incorrect command message be sent, the 146 unit will return an error message. The error messages, and their causes, are discussed in *Error Messages,* page 287.

Power Control Messages

The power control messages enable you to turn the power to a channel on or off; to activate the Auto Power feature; and to perform a hot cathode degas procedure.

Power Control Messages										
Message Description	Message Format									
	@	command category		command number	Parameter	Data			*Optional checksum*	
Channel Power	@	0	8	1	1, 2, 3, or 4 (channel #)	:	ON = on OFF = off	CR	*c1*	*c2*
Channel Auto Control (ion gauges only)	@	0	8	2	1, 2, 3, or 4 (channel #)	:	E = Enable D = Disable	CR	*c1*	*c2*
Auto Power Reference Channel	@	0	8	3	1, 2, 3, or 4 (channel #)	:	Reference channel #	CR	*c1*	*c2*
Auto Power Shutoff Pressure	@	0	8	4	1, 2, 3, or 4 (channel #)	:	ASCII value (-1 to 1 Torr)	CR	*c1*	*c2*
Hot Cathode Degas	@	0	8	5	1, 2, 3, or 4 (channel #)	:	L = Lo power H = Hi power O = Off	CR	*c1*	*c2*

Table 55: Power Control Messages

Table 58 lists the chapter that explains the function performed by each message.

Chapter References for Power Control Messages	
Function	**Chapter**
Channel Power	*Chapter Four: Operation in Normal Mode*
Channel Auto Control *(ion gauges only)*	*Chapter Seven: Operation in Setup Mode*
Auto Power Reference Channel	*Chapter Seven: Operation in Setup Mode*
Auto Power Shutoff Pressure	*Chapter Seven: Operation in Setup Mode*
Hot Cathode Degas	*Chapter Four: Operation in Normal Mode*

Table 56: Chapter References for Power Control Messages

Calibration Messages

Depending upon the type of sensor, calibration may involve adjusting the zero, the span, or both the zero and span.

Calibration Messages											
Message Description	Message Format										
	@	command category		command number	Parameter	Data				*Optional checksum*	
Zero Channel	@	0	5	1	1, 2, 3, or 4 (channel #) **or** S (set point)	CR				*c1*	*c2*
Define Lower Analog Set Point Input	@	0	5	2	*Any character*	:	Min. Voltage in ASCII	CR		*c1*	*c2*
Span Channel	@	0	5	3	1, 2, 3, or 4 (channel #) **or** S (set point)	CR				*c1*	*c2*
Define Upper Analog Set Point Input	@	0	5	4	*Any character*	:	Max Voltage in ASCII	CR		*c1*	*c2*
Span Channel with reference	@	0	5	5	1, 2, 3, or 4 (channel #)	:	1, 2, 3, or 4 (channel #)	CR		*c1*	*c2*
Zero On/Off	@	0	5	6	1, 2, 3, or 4 (channel #) **or** S (set point)	:	ON = On OFF = Off	CR		*c1*	*c2*
Span On/Off	@	0	5	7	1, 2, 3, or 4 (channel #) **or** S (set point)	:	ON = On OFF = Off	CR		*c1*	*c2*
Enable Auto Zero	@	0	5	8	1, 2, 3, or 4 (channel #)	:	E = Enable D = Disable	CR		*c1*	*c2*
Select Auto Zero Reference Channel	@	0	5	9	1, 2, 3, or 4 (channel #)	:	1, 2, 3, or 4	CR		*c1*	*c2*

Table 57: Calibration Messages

Table 58 lists the chapter that explains the function performed by each message.

Chapter References for Calibration Messages	
Function	**Chapter**
Zero Channel	*Chapter Four: Operation in Normal Mode*
Define Lower Analog Set Point Input	*Chapter Five: Operation in Leakage Mode*
Span Channel	*Chapter Four: Operation in Normal Mode*
Define Upper Analog Set Point Input	*Chapter Five: Operation in Leakage Mode*
Span Channel with reference	*Chapter Four: Operation in Normal Mode*
Zero On/Off	*Chapter Four: Operation in Normal Mode*
Span On/Off	*Chapter Four: Operation in Normal Mode*
Enable Auto Zero	*Chapter Seven: Operation in Setup Mode*
Select Auto Zero Reference Channel	*Chapter Seven: Operation in Setup Mode*

Table 58: Chapter References for the Power Control Messages

Sensor Configuration Messages

The sensor configuration messages set the parameters specific to each type of channel. For example, you must set the gas type for a Pirani or convection gauge. Table 60, page 264, lists the parameters for each gauge type.

Sensor Configuration Messages											
Message Description	Message Format										
	@	command category		command number	Parameter	Data				*Optional checksum*	
Channel Range	@	0	6	1	1, 2, 3, or 4 (channel #)	:	ASCII value	CR		*c1*	*c2*
Channel Resolution	@	0	6	2	1, 2, 3, or 4 (channel #)	:	ASCII value that represents the resolution as a power of 10	CR		*c1*	*c2*
Channel Gas Type	@	0	6	3	1, 2, 3, or 4 (channel #)	:	N = Nitrogen A = Argon H = Helium	CR		*c1*	*c2*
Channel Gauge Factor/Sensitivity	@	0	6	4	1, 2, 3, or 4 (channel #)	:	ASCII value	CR		*c1*	*c2*
Ion Gauge Disconnect Threshold	@	0	6	5	1, 2, 3, or 4 (channel #)	:	ASCII value	CR		*c1*	*c2*
Hot Cathode High Pressure Shutoff	@	0	6	6	1, 2, 3, or 4 (channel #)	:	ASCII value	CR		*c1*	*c2*
Hot Cathode Fast Pressure Rate of Rise Shutoff	@	0	6	7	1, 2, 3, or 4 (channel #)	:	E = Enabled D = Disabled	CR		*c1*	*c2*
Convection Gauge Type	@	0	6	8	1, 2, 3, or 4 (channel #)	:	4 = GP Convectron 5 = HPS Convection	CR		*c1*	*c2*

Table 59: Sensor Configuration Messages

Table 61, page 264, lists the chapter that explains the function performed by each message.

Sensor Configuration Parameters for Each Gauge Type	
Gauge Type	**Configuration Parameter**
Pirani or Convection	Gas Type Convection Gauge Type (convection gauges only)
Hot Cathode	Sensitivity High Pressure Shutoff Disconnect Threshold
Cold Cathode	Gauge Correction Factor Disconnect Threshold
Capacitance Manometer	Sensor Range Resolution (except Type 107 unit)
Mass Flow Controller	Range
Thermocouple	Thermocouple Type (detected at power up) Gas Type

Table 60: Sensor Configuration Parameters for Each Gauge Type

Chapter References for Sensor Configuration Messages	
Function	**Chapter**
Channel Range	*Chapter Seven: Operation in Setup Mode*
Channel Resolution	*Chapter Seven: Operation in Setup Mode*
Channel Gas Type	*Chapter Seven: Operation in Setup Mode*
Channel Gauge Factor/Sensitivity	*Chapter Seven: Operation in Setup Mode*
Ion Gauge Disconnect Threshold	*Chapter Seven: Operation in Setup Mode*
Hot Cathode High Pressure Shutoff	*Chapter Seven: Operation in Setup Mode*
Hot Cathode Fast Pressure Rate of Rise Shutoff	*Chapter Seven: Operation in Setup Mode*

Table 61: Chapter References for Sensor Configuration Messages

Mass Flow Controller Messages

The Mass Flow Controller board enables the 146 unit to communicate with mass flow controllers to regulate the flow of gas into a system.

Mass Flow Controller Messages											
Message Description	Message Format										
	@	command category		command number	Parameter	Data				*Optional checksum*	
Mode of Operation	@	1	0	1	1, 2, 3, or 4 (channel #)	:	R = Ratio S = Set Point T = Totaling	CR		*c1*	*c2*
Adjust Set Point	@	1	0	2	1, 2, 3, or 4 (channel #)	:	0.0002 to 1×10^5 sccm	CR		*c1*	*c2*
Totaling Co-channel	@	1	0	3	1, 2, 3, or 4 (channel #)	:	1, 2, 3, or 4 (co-channel #)	CR		*c1*	*c2*
Open/Close/Cancel Override	@	1	0	4	1, 2, 3, or 4 (channel #)	:	O = Open C = Close N = Cancel	CR		*c1*	*c2*

Table 62: Mass Flow Controller Messages

Table 63 lists the chapter that explains the function performed by each message.

Chapter References for Mass Flow Controller Messages	
Function	**Chapter**
Mode of Operation	*Chapter Seven: Operation in Setup Mode*
Adjust Set Point	*Chapter Seven: Operation in Setup Mode*
Totaling Co-channel	*Chapter Seven: Operation in Setup Mode*
Open/Close/Cancel Override	*Chapter Seven: Operation in Setup Mode*

Table 63: Chapter References for Mass Flow Controller Messages

Dual Channel Setup Messages

The dual channel feature allows the 146 unit to report pressure from one of two associated sensors. One sensor controls over a low range; the other sensor controls over the high range.

Dual Channel Setup Messages										
Message Description	Message Format									
	@	command category		command number	Parameter	Data			*Optional checksum*	
Select Dual Channel	@	0	9	1	1 or 2 (dual chan. #)	:	UL where U = Upper # L = Lower #	CR	*c1*	*c2*
Dual Channel Threshold HI	@	0	9	2	1 or 2 (dual chan. #)	:	0 to 25,000, inclusive	CR	*c1*	*c2*
Dual Channel Threshold LO	@	0	9	3	1 or 2 (dual chan. #)	:	0 to 25,000, inclusive	CR	*c1*	*c2*
Dual Channel Mode	@	0	9	4	1 or 2 (dual chan. #)	:	OFF = off CNT = continuous DSC = Discontinuous	CR	*c1*	*c2*

Table 64: Dual Channel Setup Messages

Table 65 lists the chapter that explains the function performed by each message.

Chapter References for Dual Channel Setup Messages	
Function	**Chapter**
Mode of Operation	*Chapter Seven: Operation in Setup Mode*
Adjust Set Point	*Chapter Seven: Operation in Setup Mode*
Totaling Co-channel	*Chapter Seven: Operation in Setup Mode*
Open/Close/Cancel Override	*Chapter Four: Operation in Normal Mode*

Table 65: Chapter References for Dual Channel Setup Messages

Alarm Trip Point Messages

The trip point defines the pressure at which an alarm is tripped. Trip Point A and B are standard; Trip Point C and D are available on the Auxiliary Output board.

Alarm Messages										
Message Description	Message Format									
	@	command category		command number	Parameter	Data			*Optionalc hecksum*	
Alarm Enable	@	0	1	1	A, B, C, or D	:	E = Enable D = Disable	CR	*c1*	*c2*
Trip Point Value	@	0	1	2	A, B, C, or D	:	±100,000 Torr	CR	*c1*	*c2*
Alarm Association	@	0	1	3	A, B, C, or D	:	1, 2, 3, or 4 (channel #)	CR	*c1*	*c2*
Unlatch Currently Alarmed Relays	@	0	1	4	*Any character*	CR			*c1*	*c2*
Status Alert	@	0	1	5	*Any character*	:	E = Enable D = Disable	CR	*c1*	*c2*
Untripped State of Unlatched Relay	@	0	1	6	A, B, C, or D	:	A = Actuated D = Deactuated	CR	*c1*	*c2*

Table 66: Alarm Messages

Table 67 lists the chapter that explains the function performed by each message.

Chapter References for Alarm Messages	
Function	**Chapter**
Alarm Enable	*Chapter Seven: Operation in Setup Mode*
Alarm Trip Point	*Chapter Seven: Operation in Setup Mode*
Alarm Association	*Chapter Seven: Operation in Setup Mode*
Unlatch Currently Alarmed Relays	*Applies to RS-232 messages only—see below*
Status Alert	*Applies to RS-232 messages only—see below*
Untripped State of Unlatched Relay	*Chapter Seven: Operation in Setup Mode*

Table 67: Chapter References for Alarm Messages

Unlatch Currently Alarmed Relays

Refer to *Chapter Three: Overview,* for a description of the latching state. There are two ways to unlatch currently alarmed relays; either send the RS-232 command, or set a TTL signal high (the latch pins are located on the General I/O connector). This action releases the latch on the alarm so the relay can resume normal operation. If the pressure is within the defined operating range, the alarm will resume its untripped state. If the pressure is outside of the defined operating range, the alarm will resume its tripped state. The state of the relay latching pin (high or low) determines whether the alarm will become latched. If the pin is high the latching state is deactivated; if the pin is low the latching state is activated.

Status Alert

When the status alert function is enabled, the 146 unit automatically sends a message to the host computer whenever an alarm is tripped.

Analog Output Messages

The 146 unit supports one analog output on the CPU board and two additional analog outputs provided by the Auxiliary Output board.

Analog Output Messages											
Message Description	Message Format										
	@	command category		command number	Parameter	Data				*Optional checksum*	
Channel Output Type	@	0	7	1	1, 2, or 3 (analog output #)	:	LN = Linear LO1 - LO9 = Log 1 - Log 9 SP = Set Point	CR		*c1*	*c2*
Input Channel Selection	@	0	7	2	1, 2, or 3 (analog output #)	:	channel # 1, 2, 3, 4, 5 (dual 1), or 6 (dual 2)	CR		*c1*	*c2*
Full Scale Pressure (for 10 V output)	@	0	7	3	1, 2, or 3 (analog output #)	:	Value in ASCII	CR		*c1*	*c2*

Table 68: Analog Output Messages

Table 69 lists the chapter that explains the function performed by each message.

Chapter References for Analog Output Messages	
Function	**Chapter**
Channel Output Type	*Chapter Seven: Operation in Setup Mode*
Input Channel Selection	*Chapter Seven: Operation in Setup Mode*
Full Scale Pressure (for 10 V output)	*Chapter Seven: Operation in Setup Mode*

Table 69: Chapter References for Analog Output Messages

Control Messages

The control messages are separated into three categories: General; Control Adjust; and Recipe Specific messages.

Note The General and Control Adjust messages support Control Channel 0, which is a virtual control channel used by the MFC board for Ratio flow control. A "virtual" channel exists in software only; it does not require a physical board to function. Refer to *Mass Flow Control*, page 93, for information on Ratio control for flow controllers.

General Control Messages										
Message Description	Message Format									
	@	command category		command number	Parameter (Control channel)	Data			*Optional checksum*	
Select Control Mode	@	0	2	1	0,* 1	:	A = Auto O = Open C = Close H = Hold M = Manual	CR	*c1*	*c2*
Select Active Recipe	@	0	2	2	0,* 1	:	1, 2, 3, or 4 (recipe #)	CR	*c1*	*c2*
Select Controller Polarity	@	0	2	3	0,* 1	:	D = Direct R = Reverse	CR	*c1*	*c2*
**Control channel 0 is a virtual control channel used in conjunction with Mass Flow Controllers*										

Table 70: General Control Messages

Table 71 lists the chapter that explains the function performed by each message.

Chapter References for General Control Messages	
Function	**Chapter**
Select Control Mode	*Chapter Eight: Operation in Control Mode*
Select Active Recipe	*Chapter Eight: Operation in Control Mode*
Select Controller Polarity	*Chapter Seven: Operation in Setup Mode*

Table 71: Chapter References for General Control Messages

Control Adjust Messages											
Message Description	Message Format										
	@	command category		command number	Parameter (Control channel)	Data			*Optional checksum*		
Adjust Integral	@	0	3	1	0,* 1	:	0.01 to 100 seconds	CR	*c1*	*c2*
Adjust Base	@	0	3	2	0,* 1	:	0 to 103 (% of full open)	CR	*c1*	*c2*
Adjust Start	@	0	3	3	0,* 1	:	0 to 103 (% of full open)	CR	*c1*	*c2*
Adjust Alpha	@	0	3	4	0,* 1	:	5 to 99, inclusive	CR	*c1*	*c2*
Adjust Preset	@	0	3	5	0,* 1	:	0 to 103 (% of full open)	CR	*c1*	*c2*
Adjust Output	@	0	3	6	0,* 1	:	0 to 100% inclusive	CR	*c1*	*c2*
Adjust Softstart Speed	@	0	3	7	0,* 1	:	1.0 to 990 seconds	CR	*c1*	*c2*
Analog Set Point F.S.	@	0	3	8	0,* 1	:	0 to 10 Volts	CR	*c1*	*c2*
** Control channel 0 is a virtual control channel used in conjunction with Mass Flow Controllers*											

Table 72: Control Adjust Messages

Table 73 lists the chapter that explains the function performed by each message.

Chapter References for Control Adjust Messages	
Function	**Chapter**
Adjust Integral	*Chapter Six: Operation in Tuning Mode*
Adjust Base	*Chapter Six: Operation in Tuning Mode*
Adjust Start	*Chapter Six: Operation in Tuning Mode*
Adjust Alpha	*Chapter Seven: Operation in Setup Mode*
Adjust Preset	*Chapter Six: Operation in Tuning Mode*
Adjust Output	*Chapter Seven: Operation in Setup Mode*
Adjust Softstart Speed	*Chapter Seven: Operation in Setup Mode*
Analog Set Point F.S.	*Chapter Seven: Operation in Setup Mode*

Table 73: Chapter References for Control Adjust Messages

Recipe Specific Messages										
Message Description	Message Format									
	@	command category		command number	Parameter	Data			*Optional checksum*	
Adjust Set Point	@	0	4	1	1, 2, 3, or 4 (recipe #)	:	±100,000 Torr	CR	*c1*	*c2*
Adjust Lead	@	0	4	2	1, 2, 3, or 4 (recipe #)	:	0.001 to 1000	CR	*c1*	*c2*
Adjust Gain	@	0	4	3	1, 2, 3, or 4 (recipe #)	:	0.001 to 10,000	CR	*c1*	*c2*
Select Softstart	@	0	4	4	1, 2, 3, or 4 (recipe #)	:	E = Enable D = Disable	CR	*c1*	*c2*
Select Analog Set Point	@	0	4	5	1, 2, 3, or 4 (recipe #)	:	D = Digital A = Analog	CR	*c1*	*c2*
Adjust Analog Set Point Range	@	0	4	6	1, 2, 3, or 4 (recipe #)	:	0 to 100,000 Torr	CR	*c1*	*c2*
Select Control Channel	@	0	4	7	1, 2, 3, or 4 (recipe #)	:	1, 2, 3, or 4 (channel #)	CR	*c1*	*c2*

Table 74: Recipe Specific Messages

Table 75 lists the chapter that explains the function performed by each message.

Chapter References for Recipe Specific Messages	
Function	**Chapter**
Adjust Set Point	*Chapter Six: Operation in Tuning Mode*
Adjust Lead	*Chapter Six: Operation in Tuning Mode*
Adjust Gain	*Chapter Six: Operation in Tuning Mode*
Adjust Softstart	*Chapter Seven: Operation in Setup Mode*
Adjust Analog Set Point	*Chapter Seven: Operation in Setup Mode*
Adjust Analog Set Point Range	*Chapter Seven: Operation in Setup Mode*
Select Control Channel	*Chapter Seven: Operation in Setup Mode*

Table 75: Chapter References for Recipe Specific Messages

Miscellaneous Messages

These messages enable you to set a variety of global parameters.

Miscellaneous Messages										
Message Description	Message Format									
	@	command category		command number	Parameter	Data			*Optional checksum*	
Audio Alarm	@	5	0	1	*	:	E = Enable D = Disable	CR	*c1*	*c2*
Front Panel Lockout	@	5	0	2	*	:	U = Unlock L = Lock	CR	*c1*	*c2*
Select Pressure Units	@	5	0	3	*	:	T = Torr P = Pascal B = mBar	CR	*c1*	*c2*
Enable Checksum	@	5	0	5	*	:	E = Enable D = Disable	CR		
Save to EEPROM	@	5	0	6	*			CR		
Leak Rate Period	@	5	0	7	*	:	ASCII value	CR	*c1*	*c2*
Select Format	@	5	0	8	*	:	E = Scientific D = Fixed	CR	*c1*	*c2*
* *Any character may be entered since the parameter field has no significance in the message*										

Table 76: Miscellaneous Messages

Table 77, page 274, lists the chapter that explains the function performed by each message.

Chapter References for Miscellaneous Messages	
Function	**Chapter**
Audio Alarm	*Chapter Seven: Operation in Setup Mode*
Front Panel Lockout	*Chapter Three: Operation in Overview Mode*
Select Pressure Units	*Chapter Seven: Operation in Setup Mode*
Optional Checksum	*Applies to RS-232 messages only—see below*
Save to EEPROM	*Applies to RS-232 messages only—see below*
Leak Rate Period	Refer to *How To Determine the Leak Rate,* page 280
Select Format	*Applies to RS-232 messages only—see below*

Table 77: Chapter References for Miscellaneous Messages

Optional Checksum

The 146 unit can communicate with a host computer with or without using checksum bytes. The checksum is the sum of all the ASCII values in the message. It includes all characters in the message; from the "at" character (@) through the carriage return (CR). The checksum itself is not calculated into the checksum value.

When the checksum is enabled, the 146 unit expects to receive a checksum for all incoming messages. In return it sends a checksum value with each response. The checksum is sent with the low byte first. The 146 unit is shipped with the checksum feature disabled.

Note

The number of data bits must be set to 8 when the checksum is enabled. Refer to *How To Configure the RS-232 Port,* in *Chapter Seven: Operation in Setup Mode,* for information on changing the communication parameters.

The communication parameters on a displayless 146 unit cannot be changed. Refer to Table 53, page 255, for a listing of the default communication parameters.

Save To EEPROM Command

The 146 unit saves information to its EEPROM immediately upon receiving this command. During front panel operation, the 146 unit saves the information when you exit either the Setup or Tuning modes.

How To Select the Response Format

You can specify whether the response sent by the 146 unit is in scientific notation or fixed format. The initial configuration is fixed. The 146 unit will *accept* messages in either format, regardless of the format selected for its response messages. To configure the 146 unit to respond in scientific notation, issue the command:

@508•:E<CR>

where • = represents a blank space
E = for scientific notation (D selects fixed notation)

Note You must re-issue this command after each power up since it is *not stored* at power down.

Read Only Messages

The read only messages prompt the 146 unit to return information. You cannot change the value or setting of any read only parameter. The read only messages are divided into read only data messages and read only status messages.

Read Only Data Messages									
Message Description	Message Format								
	@	command category		command number	Parameter	Data		*Optional checksum*	
Channel Pressure	@	6	0	1	channel # 1, 2, 3, 4, 5 (dual 1), or 6 (dual 2)	?	CR	*c1*	*c2*
Channel Pressure with Time Stamp	@	6	0	2	channel # 1, 2, 3, 4, 5 (dual 1), or 6 (dual 2)	?	CR	*c1*	*c2*
Channel Voltage	@	6	0	3	channel # 1, 2, 3, 4, 5 (dual 1), or 6 (dual 2)	?	CR	*c1*	*c2*
Ion Current	@	6	0	4	channel # 1, 2, 3, 4, 5 (dual 1), or 6 (dual 2)	?	CR	*c1*	*c2*
Emission Current	@	6	0	5	channel # 1, 2, 3, 4, 5 (dual 1), or 6 (dual 2)	?	CR	*c1*	*c2*
Pressure Leak Rate	@	6	0	6	channel # 1, 2, 3, 4, 5 (dual 1), or 6 (dual 2)	?	CR	*c1*	*c2*
Analog Set Point	@	6	0	7	*Any character*	?	CR	*c1*	*c2*
Channel Condition *This is the best message to use when checking the pressure reading*	@	6	0	8	channel # 1, 2, 3, 4, 5 (dual 1), or 6 (dual 2)	?	CR	*c1*	*c2*
Power Up Status	@	6	0	9	*Any character*	?	CR	*c1*	*c2*

Table 78: Read Only Data Messages
(Continued on next page)

Read Only Data Messages *(Continued)*									
Message Description	Message Format								
	@	command category		command number	Parameter	Data		*Optional checksum*	
Relay Status	@	6	0	A	A, B, C, or D	?	CR	*c1*	*c2*
Alarm Status	@	6	0	B	A, B, C, or D	?	CR	*c1*	*c2*
Current Control Mode	@	6	0	C	*Any character*	?	CR	*c1*	*c2*
Current Recipe	@	6	0	D	*Any character*	?	CR	*c1*	*c2*
Current PID Set Point	@	6	0	E	*Any character*	?	CR	*c1*	*c2*
PCS Output	@	6	0	F	*Any character*	?	CR	*c1*	*c2*

Table 78: Read Only Data Messages

Response Format for Read Only Data Messages		
Message	**Response***	**Description**
Channel Condition	@608X:<status><pres>	where x is 1 through 6 <pres> is an empty field unless <status> is A or B, then <pres> is an ASCII string <status> is: A = On; G = High power degas B = low power degas; H = Initializing C = Underranged; I = Zeroing D = Overranged; J = Bad sensor E = Manually off; K = Disconnected F = Auto off; L = Channel not installed
Relay Status	@60A:<para><status>	where <para> A, B, C, or D <status> is E = Enabled D = Disabled T = Tripped

Table 79: Response Format for Read Only Data Messages
(Continued on next page)

Response Format for Read Only Data Messages *(Continued)*			
Message	**Response***	**Description**	
Alarm Status	@60B:<para><status>	where <para>	A, B, C, or D
		<status> is	E = Enabled D = Disabled T = Tripped
Control Mode	@60C:<over><mode>	where <over> is:	0 = No override 1 = Override enabled
		<mode> is:	
		A = Auto O = Open C = Close	M = Manual H = Hold
Current Recipe	@60D:<over><recipe>	where <over> is:	0 = No override 1 = Override enabled
		<recipe> is:	An ASCII string, from 1 to 4
PID Set Point	@60E:<type><sp>	where <type> is:	analog set point digital set point
		<sp> is:	An ASCII string
** All response messages terminate in a CR as the end-of-line delimiter*			

Table 79: Response Format for Read Only Data Messages

Chapter References for Read Only Data Messages	
Function	**Chapter**
Channel Pressure	*Chapter Four: Operation in Normal Mode*
Channel Pressure with Time Stamp	*Applies to RS-232 messages only—see below*
Channel Voltage	*Chapter Seven: Operation in Setup Mode*
Ion Current	*Chapter Seven: Operation in Setup Mode*
Emission Current	*Chapter Seven: Operation in Setup Mode*
Pressure Leak Rate	*Chapter Seven: Operation in Setup Mode*

Table 80: Chapter References for Read Only Data Messages

Chapter References for Read Only Data Messages	
Function	**Chapter**
Analog Set Point	*Chapter Seven: Operation in Setup Mode*
Channel Status	*Applies to RS-232 messages only—see below*
Power Up Status	*Chapter Four: Operation in Normal Mode*
Relay Status	*Chapter Three: Overview*
Alarm Status	*Chapter Seven: Operation in Setup Mode*
Current Control Mode	*Chapter Eight: Operation in Control Mode*
Current Recipe	*Chapter Eight: Operation in Control Mode*
Current PID Set Point	*Chapter Eight: Operation in Control Mode*
PCS Output	*Chapter Three: Overview*

Table 80: Chapter References for Read Only Data Messages

How To Report the Channel Reading with Time Stamp

The 146 instrument can report the channel's reading with the time difference between readings. A 16-bit counter tracks the elapsed time in 10 millisecond increments. The counter increments by one count every 10 milliseconds, until it reaches a count of 65535 (approximately 65 seconds). The counter then wraps around and begins counting from 0 again. To calculate the elapsed time between readings, subtract the time stamp of the first reading from the time stamp of the second reading.

For example, you query the channel reading on channel 3, and the 146 responds with:

```
@6023:133 4261 <CR>
```

to indicate a pressure of 133 at the time equivalent to 4261 counts.

The next time you check the reading with time stamp, the 146 instrument responds with:

```
@6023:129 18784 <CR>
```

The time between the readings is:

$$18784 - 4261 = 14523 \text{ counts}$$

Therefore, the time elapsed between readings is approximately 14.5 seconds.

How To Check the Status of an Alarm or a Relay

There are separate read only messages to report the status of an alarm and the status of a relay. The status message reports whether the alarm or relay is enabled, disabled, or tripped.

To determine the status of an alarm or a relay, send the message:

@60#X?<CR>

where # = is A for a relay or B for an alarm

where X = is the alarm letter (A, B, C, or D)

The 146 responds with:

`@60#X:S <CR>`

where S = is relay or alarm state: E = Enabled; D = Disabled; T = Tripped

How To Determine the Leak Rate

The 146 instrument can calculate the leak rate of a sensor. The leak rate reflects the amount of leakage over a user-defined time period, expressed as pressure units per second. For example, if the pressure is measured in Torr and you have selected a time base of 30 seconds, the leak rate will be reported as Torr per 30 seconds. The leak rate period entry is global and applies to all channels.

The leak rate is calculated as a moving average using the most recent measurements. The 146 instrument continually replaces the oldest value with the latest value and recalculates the new leak rate. Initially, when you enter the leak rate period, you must wait until the time period has elapsed before querying the 146 instrument to report the leak rate.

The range is from 1 to 60 seconds; the default value is 1.

To determine the leak rate, you must first specify the time period, for example, 30 seconds:

@507•:30 <CR>

where • = represents a blank space

To request the leak rate on channel 5, enter:

@6065? <CR>

Following the example above, the 146 instrument responds with:

`@6065:2 <CR>`

This response indicates that a 2 Torr difference in pressure has occurred over 30 seconds.

How To Check the Channel Status

The channel status message reports the channel's pressure if the channel is currently on or currently performing a low power degas. Otherwise, the response will indicate the condition of the channel—initializing, zeroing, underranged, overranged, off (either manual or auto), high power degas, disconnected, sensor problem, or not installed. Since the channel status message reports complete information on the channel's condition, it is the best command to use when you query the pressure reading.

To check the channel pressure, enter:

@608C?<CR>

where C = is the channel number 1, 2, 3, 4, 5 (dual 1), or 6 (dual 2)

The 146 instrument responds with:

`@608C:<status><reading> <CR>`

where <`status`> is: = A for On
B for low power degas
C for underranged
D for overranged
E for manually off
F for auto off
G for high power degas
H for initializing
I for zeroing
J for bad sensor
K for disconnected
L for channel not installed

<`reading` > is: = an empty field unless <status> is A (on) or B (low power degas), then this field contains an ASCII string representing the channel's reading

For example, the following response indicates a disconnected sensor on channel 2:

`@6082:K <CR>`

How To Check the Power Up Status

Send a power up status message if the 146 instrument encounters a power up problem. The response will report the cause; either a configuration, calibration, or memory problem. To query the power up status enter:

@609•?<CR>

• = represents a blank space

the 146 instrument responds with:

`@609•:XX <CR>`

where • = represents a blank space
XX = represents the status, in a hexadecimal number, as described in Table 81

Response to a Power Up Status Message		
Bit	**Value (in Hexadecimal)**	**Cause**
—	00	No errors
0	01	Bad factory calibration
1	02	Bad user configuration
2	04	Bad zero calibration
3	08	New configuration
4	10	Bad ROM (Read Only memory)
5	20	Bad RAM (Random Access memory)
6	40	Reserved
7	80	Reserved

Table 81: Response to a Power Up Status Message

The response values are additive, so that one response reports all power up problems. The response consists of two digits; the first digit represents the value of bit 4 through bit 7 and the second digit represents the value of bit 0 through bit 3. For example, a response of 28 (hexadecimal) indicates that the unit has detected a new configuration (08) *and* a RAM problem (20). If the zero calibration (04) was lost as well, the response would be 2C (hexadecimal).

Read Only Status Messages									
Message Description	Message Format								
	@	command category		command number	Parameter	Data		*Optional checksum*	
Software Version	@	7	0	1	*	?	CR	*c1*	*c2*
Channel Status	@	7	0	2	*	?	CR	*c1*	*c2*
Alarm Status	@	7	0	3	*	?	CR	*c1*	*c2*
Configuration Setup	@	7	0	4	*	?	CR	*c1*	*c2*
Rear Panel Status	@	7	0	5	*	?	CR	*c1*	*c2*
Reference Voltage	@	7	0	6	*	?	CR	*c1*	*c2*
** Any character may be entered since the parameter field has no significance in the message*									

Table 82: Read Only Status Messages

Response Format for the Read Only Status Messages			
Message	**Response**	**Description**	
Software Version	<version> CR	where <version> represents the software version number	
Channel Status	C1:<text>LF CR C2:<text> LF CR C3:<text> LF CR C4:<text> LF CR	where <text> is: ON = Sensor normal OFF = Manual off AOFF = Auto off DCNT = Disconnected OVER = Overranged	 UNDR = Underranged INIT = Initializing ZERO = Zeroing E1 = Channel error # - - - - = Channel not installed
Alarm Status	AA:<text>LF CR AB:<text> LF CR AC:<text> LF CR AD:<text> LF CR	where <text> is: ENAB = Alarm Enabled ENAL = In alarmed state	 ENLT = Just latched DSBL = Alarm disabled - - - - = Channel not installed

Table 83: Response Format for the Read Only Status Messages
(Continued on next page)

Response Format for the Read Only Status Messages *(Continued)*		
Message	**Response**	**Description**
Configuration (slot status at power up)	Sx<text> LF CR	where x is 1 through 5 <text> is: CC-- = Cold Cathode CLN = Linear Cap. Man. C107 = Type 107 Cap. Man. C120 = Type 120 Cap. Man. CNCN = Convection, dual channel PRCN = Pirani/Convection C- - - = Cap. Man. board, no sensor CN - - = Convection, single channel CNPR = Convection/Pirani CNTL = Control board AUXO = Auxiliary Output board - - - - = Empty slot PR - - = Pirani, single channel PRPR = Pirani, dual channel MFC - Mass Flow Controller HCL - = Hot Cathode, low power HCH - = Hot Cathode, high power 1A - - = Thermocouple board

Table 83: Response Format for the Read Only Status Messages

Response Format for the Read Only Status Messages *(Continued)*		
Message	**Response**	**Description**
Rear Panel Status		
Remote zero channel 1	RZ1:<text> LF CR	where <text> is L for low (Ground)
Remote zero channel 2	RZ2:<text> LF CR	H for high (5 Volts)
Remote zero channel 3	RZ3:<text> LF CR	
Remote zero channel 4	RZ4:<text> LF CR	
Latch relay A	LTA:<text> LF CR	
Latch relay B	LTB:<text> LF CR	
Latch relay C	LTC:<text> LF CR	
Latch relay D	LTD:<text> LF CR	
Front panel lockout	FPL:<text> LF CR	
Open valve	OM:<text> LF CR	
Manual valve control	MM:<text> LF CR	
Close valve	CM:<text> LF CR	
Set point B	SPB:<text> LF CR	
Set point C	SPC:<text> LF CR	
Set point D	SPD:<text> LF CR	
Calibration Data (ASCII)	<text> LF CR	where <text> is a six character value for the voltage in standard fixed point format. The second character from the left is the decimal point.
	<text> LF CR	
	<text> LF CR	
	<text> LF CR	
	<text> LF CR	
** All response messages terminate in a CR as the end-of-line delimiter*		

Table 83: Response Format for the Read Only Status Messages

Table 84 lists the chapter that explains the function performed by each message.

Chapter References for Read Only Status Messages	
Function	**Chapter**
Software Version	*Chapter Four: Operation in Normal Mode*
Channel Status	*Chapter Four: Operation in Normal Mode*
Alarm Status	*Chapter Three: Overview*
Configuration Setup	*Chapter Three: Overview*
Rear Panel Status	*Chapter Three: Overview*
Calibration Data	*Chapter Seven: Operation in Setup Mode*

Table 84: Chapter References for Read Only Status Messages

How To Determine The Software Version

To request the software version, enter:

@701•?<CR>

• = represents a blank space

the 146 instrument responds with:

`@701•:XX <CR>`

where • = represents the software version, for example, 4.0

Error Messages

If the 146 instrument cannot execute a command, it will respond with an error message.

Error Code Summary	
Error Code	**Description**
E111	Unrecognized command
E112	Inappropriate command
E122	Invalid data field
E131	Bad checksum

Table 85: Error Code Summary

E111: Unrecognized Command

An "unrecognized command" error message will occur if the command syntax is incorrect. The 146 instrument cannot interpret the command string. The syntax error is located in the first four bytes of the command.

E112: Inappropriate Command

The 146 instrument will return an "inappropriate command" error message if the command cannot be executed on the selected channel or at this time. Examples of inappropriate commands include attempting to:

- Read a channel that is turned off
- Zero an ion gauge (*Ion gauges cannot be zeroed*)
- Read a channel that is out-of-range
- Read a hot cathode gauge that is performing a high power degas
- Perform a degas procedure on a channel that is not connected to a hot cathode gauge
- Span a Pirani gauge that has the gas type set to argon or helium *(A Pirani can only be spanned if the gas type is set to nitrogen.)*
- Enter the Auto (or PID) control mode with the recipe select command set to "none"

E122: Invalid Data Field

An "invalid data field" error message indicates a problem with the data field of the command string. The data field can contain a maximum of 26 characters. If your data field exceeds 26 characters, the 146 instrument will return an invalid command error message. Other possible causes of an invalid command error message include an invalid data range, or a data field that contains numbers instead of letters, or vice versa.

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Chapter Ten: Maintenance

General Information

The Type 146 instrument is virtually maintenance free, however, a few common sense notes are included here.

- Periodically check for wear on the cables and inspect the enclosure for visible signs of damage.
- The 146 unit's environment should be kept dust free.
- If a substantial change is made to the gas system, verify that the maximum potential difference between grounds is limited to 3.5 Volts to prevent noise.

How To Clean the Front Panel

- The front panel may be washed with mild soap and water, and a non-abrasive cloth.

 How To Determine The Software Version

How To Replace the Fuses

Warning **Be sure the power cord is DISCONNECTED before proceeding with the next step.**

1. Select the proper fuses.

   All units should have two fuses installed to fuse both sides of the line.

   A. Refer to Figure 4, page 27, for the location of the fuses.

   B. Refer to Table 86 for proper fuse selection.

Voltage Range and Fuse Selection		
Setting	**Nominal Voltage Range**	**Fuses (250V IEC)**
115 VAC	100 to 120 VAC	1.6A(T)
230 VAC	220 to 240 VAC	1.0A (T)

Table 86: Voltage Range and Fuse Selection

2. Check the setting of the AC line voltage select switch.

   A. Refer to Figure 4, page 27, for the location of the switch.

   B. Use a small straight screwdriver to set the switch to the left position for operation in the 115V range, or to the right position for operation in the 230V range.

Chapter Eleven: Troubleshooting

The Diagnostics Feature

The 146 unit comes with a basic diagnostics feature. This feature is used to command the 146 unit to perform specific self-tests and display the test results in the front panel window.

Starting the Diagnostics Feature

1. Press and hold both arrow keys [▲] and [▼] together, for about 3 seconds when powering up the 146 unit. When the arrow keys are released, the display changes to the initial diagnostics screen display.

   The system responds by performing its normal initialization procedure and providing a full LCD test display in the front panel window.

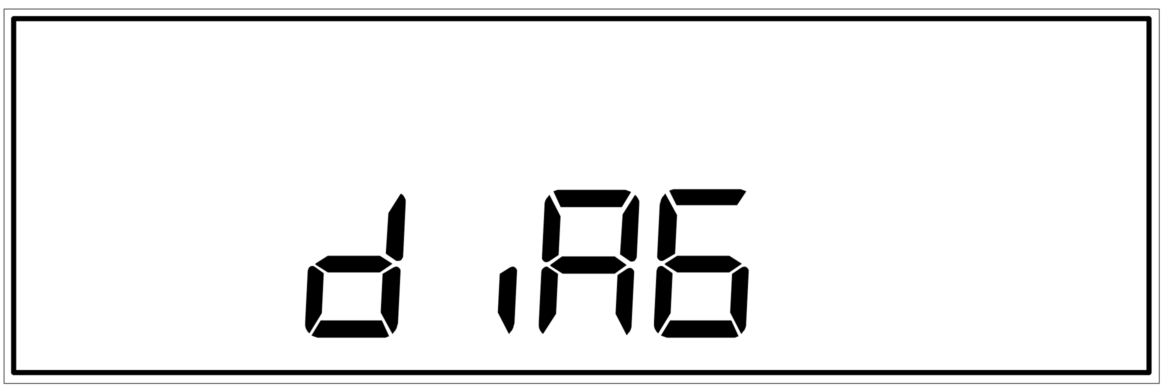

Figure 85: Initial Diagnostics Screen Display

Performing 146 Instrument Self Tests

All tests *except* Codes 5x, 6x, and 7x, are initiated by entering a code number and pressing the [ENTER] key. The 146 unit responds by performing the selected self-test.

If the self-test for any code *except* Codes 1 and 2 fails, the display remains as it was before the self-test was initiated. For example, if the display currently is showing the word **PASS** (as in Figure 86, page 292), and a Code 6 test is done, the display continues to show the word **PASS** if the Code 6 self-test failed. Codes 1 and 2 test the 146 unit RAM and PROM respectively. These tests should always come up with a PASS test result because if either the RAM or PROM is bad, the 146 unit displays error codes upon power up, and will not initiate the diagnostics feature at all.

There are three general message codes that may appear in the main display. One general message code is **nA** for non-applicable. This appears when a test is being run inappropriately. The general message code **ni** stands for not installed. For example, if the Code 6x test is being run to test one of the analog outputs on the Analog Output board, and the Analog Output board is not installed in the 146 unit, then the **ni** general message code is displayed. General message code **Err** is displayed for an inappropriate key sequence. When this message is displayed, press the [QUIET/CANCEL] key to return to the initial diagnostics screen display.

To Exit the Diagnostics screens:

1. Press [1/1] , then [0/D] , and then the [ENTER] key.

   The system responds by exiting the Diagnostics screens.

Code 1: RAM Test

1. Press the [1/1] key and then the [ENTER] key.

   The system should respond by performing a RAM test and displaying PASS. An example of the PASS display shown in Figure 86.

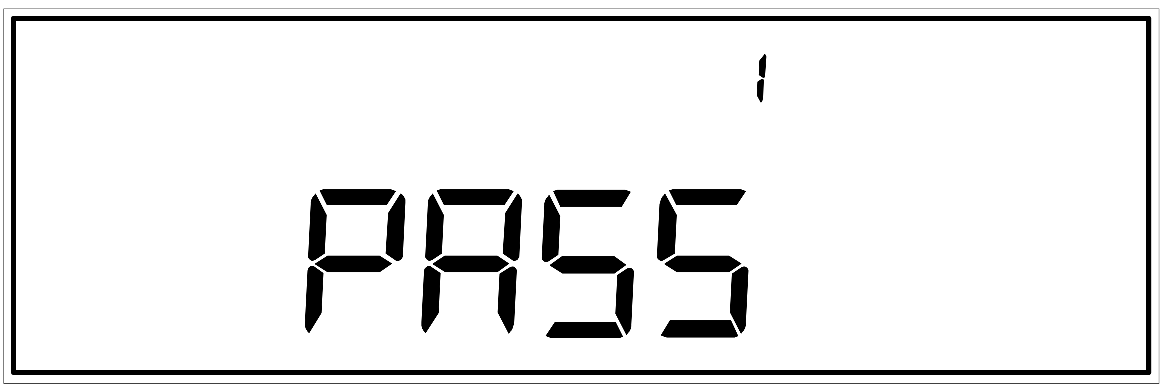

Figure 86: PASS Test Result Display from RAM Self-Test

Code 2: PROM Test

1. Press the [2/2] key and then the [ENTER] key.

   The system should respond by performing a checksum verification and displaying PASS. The display is the same as shown in Figure 86, page 292.

Note Codes 1 and 2 are the same tests the 146 unit performs as part of the normal power up procedure. If either of the tests fails at power up, an error code is displayed (E2 for PROM failure, and E3 for RAM failure).

Code 3: Display Test

1. Press the [3/3] key and then the [ENTER] key.

   The system should respond by providing a full LCD test display. This is the same display that appears during a normal power up. Refer to Figure 12, page 43, to see what the full display looks like.

   The full LCD display is shown for less than 3 seconds, and then the unit returns to the initial diagnostics screen display.

Code 4: Check all Keys

1. Press the [4/4] key and then the [ENTER] key.

   The system should respond by clearing the window and showing the number four (4) in the right display. All keys on the keypad can now be tested. To test a key simply press it. For example, if the [1/1] key is pressed, the number 1 appears in the main display. If the [2/2] key is pressed, the number 2 appears in the main display. The following chart lists what is shown in the main display for every key on the keypad. Figures 87 and 88 provide examples of some keypad test results.

To Exit Code 4

1. Press the [⬆] and [⬇] keys simultaneously.

   The system responds by returning to the initial diagnostics screen display.

Diagnostics Code 4 Key Test Results	
Key Pressed	**What Appears in the Main Display**
[*the number keys*] [1/1] through [0/D]	The corresponding number For example, pressing the [1/1] key displays the number 1, pressing the [0/D] key displays the number 0.
⬆	The word **UP**
⬇	The abbreviation **dn** (for down)
[+/-]	The word **SIGn** (as shown in Figure 87, page 295)
[ZERO/EXP]	The abbreviation **EP** (for exponent)
[SPAN/.]	Three decimal points **...**
[DEGAS/SET POINT]	The abbreviation **SP** (for set point)
[ON/LEAD]	The word **on**
[OFF/GAIN]	The word **oFF**
[QUIET/CANCEL]	The word **SHHH** (as shown in Figure 88, page 295)
[DISPLAY MODE]	The abbreviation **dISP** (for Display mode)
[CONTROL MODE]	The abbreviation **cont** (for Control mode)
[ENTER]	The abbreviation **Ent** (for enter)

Table 87: Diagnostics Code 4 Key Press Results

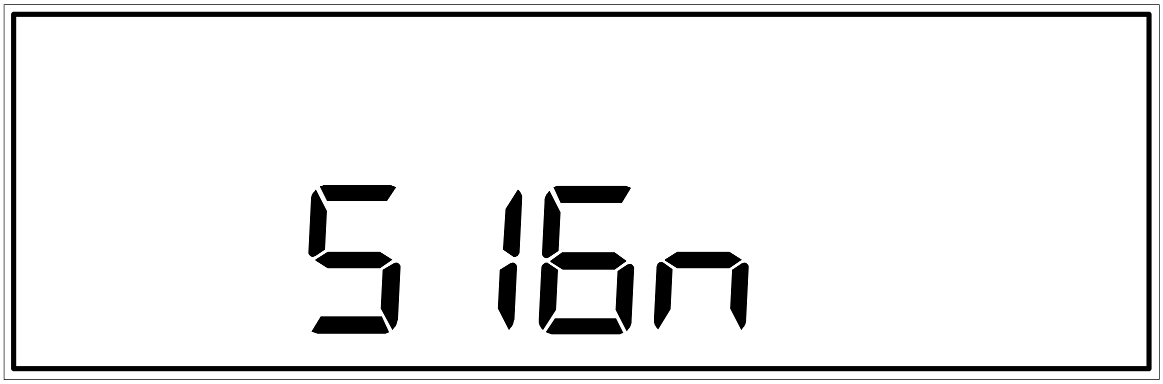

Figure 87: The Keypad Test Result for the [+/-] Key

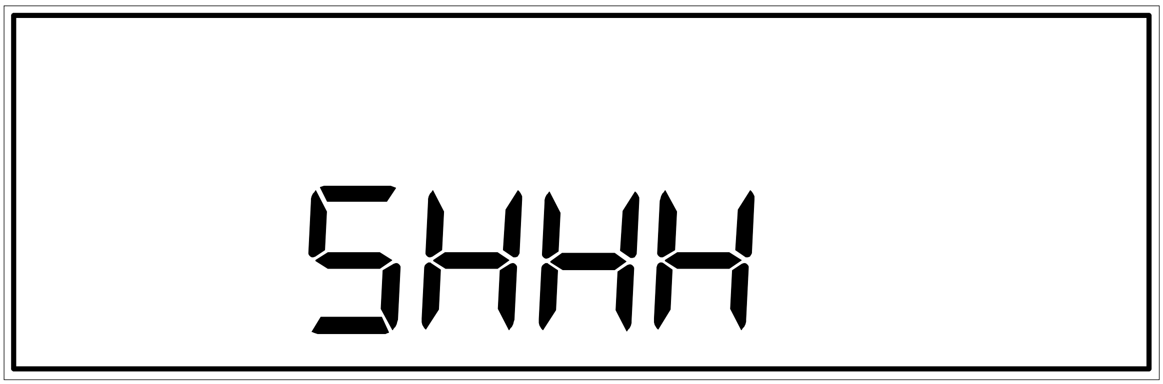

Figure 88: The Keypad Test Result for the [QUIET/CANCEL] Key

Code 5: Beeper Test

1. Press the [5/DUAL] key and then the [ENTER] key.

   The system should respond by sounding one beep, and placing the number 5 in the right display.

Code 5x: Relay Test

The x in the code represents the relay letter A through D. To perform a relay test on relay A, press the [5/DUAL] key, followed by the [7/A] key.

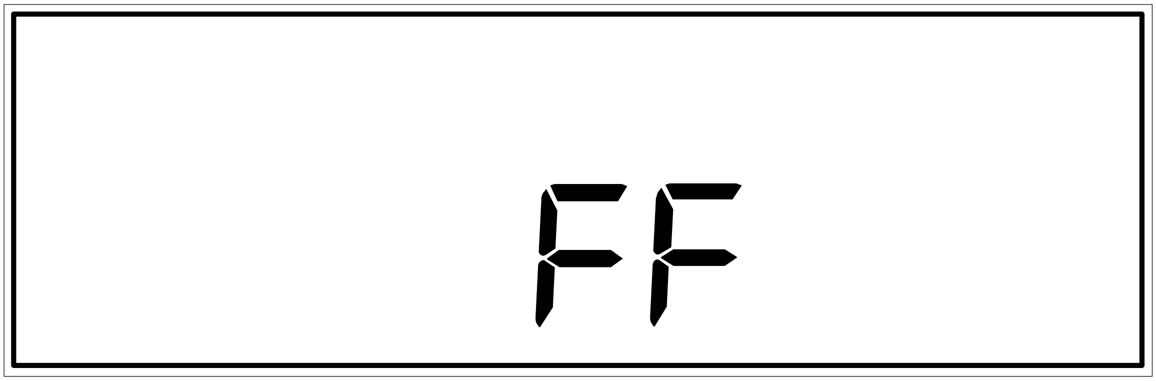

Figure 89: Rear Panel Output Test Display When all Bits are High

Steps 2 and 3 in this instruction set, can be performed in reverse order.

1. Press the [5/DUAL] key, followed by a number key (A through D).

   The system should respond by displaying the number 5 followed by the letter key selected. For example, if the letter key [7/A] is selected, the center display shows **5A** .

2. Press the [ON/LEAD] key.

   The system should respond by turning the selected relay on and displaying the word **on** .

   When turned on, a normally open contact is closed (energized). A normally closed contact is opened (energized).

3. Press the [OFF/GAIN] key.

   The system should respond by turning the selected relay off and displaying the word **oFF** . A small “click” sound can be heard as the relay switches from on to off.

   When turned off, a normally open contact is opened (de-energized). A normally closed contact is closed (de-energized).

To Exit Code 5x

1. Press the [QUIET/CANCEL] key.

   The system responds by returning to the initial diagnostics screen display.

Code 6: Rear Panel Status

1. Press the [6] key and then the [ENTER] key.

   The 146 unit's processor should respond by reading the inputs for 8 bits (remote zero 1 through 4, and latches A through D) on the General I/O connector, and displaying the sum of the hexadecimal values which are assigned to each bit when the bit is high. Refer to Table 88 for a listing of the hexadecimal values assigned to each bit when it is high (when low, the bits are assigned a value of 0).

   The sum of the hexadecimal values is shown in the main display. For example, if Remote Zero 1 and Latch A are low, they are assigned a value of 0. The other inputs are assigned the hexadecimal values shown. The 146 unit totals all values. The sum is EE (hexadecimal for 238). If all bits are high, the sum is FF (hexadecimal for 255), as shown in Figure 89, page 296.

Hexadecimal Values Assigned to the General I/O Connector Input Bits	
Bit Definition	**Hexadecimal Value if Bit is High**
Remote Zero 1	01
Remote Zero 2	02
Remote Zero 3	04
Remote Zero 4	08
Latch A	10
Latch B	20
Latch C	40
Latch D	80

Table 88: Hexadecimal Values Assigned to General I/O Connector Input Bits

Code 6x: Analog Outputs Check

The x in the code represents the analog output number (1 through 3).

1. Press the [6] key, followed by an analog output number (1 through 3).

   The system should respond by placing the analog output number (1 through 3) in the center display, and the analog output abbreviation **AnAl** in the main display.

   The analog output is normally proportional to pressure. The 146 unit sends a square wave to make the output go back and forth between 0 and 10 Volts. An output detection device must be used to detect if the analog output is indeed fluctuating between 0 and 10 Volts.

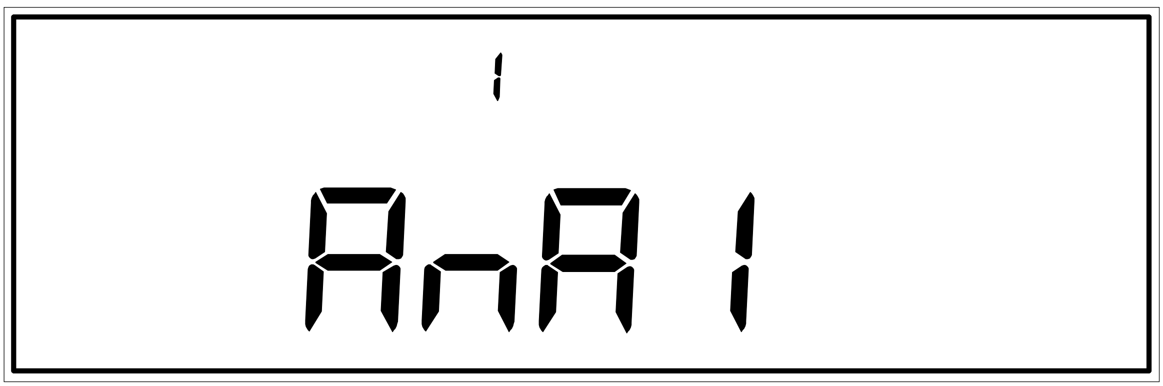

Figure 90: Analog Output Test Display

Code 7x: Response Time for Fail-Safe Feature

The x in the code represents the Auxiliary Output board relay letter (C or D).

Relays C and D on the Auxiliary Output board are associated with the 146 instrument's Fail-Safe feature. When the 146 unit is powered on, the Fail-Safe feature is activated. When Code 7x is used, the processor sends a relay setup command to relays C, D, and then checks to see if the relays have responded. If the relays do not respond, the abbreviation **Err** (for Error), appears in the main display. If the relays do respond, the Fail-Safe feature continues, and the Code 7x function determines the Fail-Safe system response time.

The Fail-Safe feature includes a timed hardware reset. The hardware reset causes relays C and D to go to default positions. During normal operation of the 146 unit, the processor prevents the timed hardware reset from executing by sending out an interrupt pulse every 10 milliseconds. If the 146 unit's software crashes, the interrupt pulse stops and the timed hardware reset executes, causing relays C and D to go to default positions.

Code 7x is used to determine if the Fail-Safe system is operating, and its response time. The response time is the amount of time which passes between when an interrupt pulse is received by the hardware reset, and when relays C and D can be set to default. The response time should be about 12 msec. ± 1 msec.

1. Press the [7/a] key, followed by either [9/C] (for Relay C), or [0/D] (for Relay D).

   The system responds by displaying the Fail-Safe feature response time in milliseconds.

Code 9999: Factory Calibration

MKS Instruments performs factory calibration procedures on the 146 instrument. Part of the calibration procedure involves entering Code 9999 while the 146 unit is attached to other instrumentation. When 9999 is entered, the abbreviation CAL appears in the main display. Nothing further can be done with this code because the 146 unit is not attached to the appropriate calibration instrumentation. The 146 unit must be powered off to exit Code 9999.

Caution

1. **If the code 9999 is shown in the main display, the Fail-Safe feature has failed its self-test. Return the 146 unit to MKS for repair.**
2. **If the number 26 appears in the main display, the relays did not go to their default values within 26 milliseconds (the maximum time on the counter). Return the 146 unit to MKS for repair.**

Appendix A: Product Specifications

Physical Specifications

Analog Output	Standard: 0 to 10 VDC on single channel, linear or log Optional: 0 to 10 VDC on 2 additional channels, linear or log
Closed-Loop Pressure Control (optional)	One channel (selectable) PID control for use with MKS Type 248 Proportioning Valve or MKS Type 153 Exhaust Throttle Valve
Compatible Instruments	Capacitance Manometers Any capacitance manometer providing 0 to ± 10 VDC output; MKS Types 107, 120, 122, 124, 127, 128, 220, 221, 223, 224, 225, 390 or 690 with 270, 622, 623, 624, 625, 626, 627, 628, 700 Series or 800 Series. Cold Cathode Gauge Tubes HPS Division Cold Cathode Gauge Tubes Convection Gauge Tubes HPS Division Convection Enhanced Pirani Granville-Phillips Convectron Hot Cathode Gauge Tubes[1] HPS Division Hot Cathode Gauge Tubes including thoriated iridium and tungsten filament gauges in nude or glass envelope configuration, and the HPS low power, nude, Bayard-Alpert Tube Mass Flow Controllers MKS MFCs except for Types 1749 and 1759 Pirani gauge tubes HPS Division Pirani gauge tubes Thermocouple Gauges[2] MKS TC-1A Hastings DV-6M

(Continued on next page)

[1] Only hot cathode gauges with nude tubes are CE compliant. Hot cathode gauges with glass tubes do not pass CE testing.

[2] Units equipped with a Dual Thermocouple board will not carry the CE mark since there are no CE compliant thermocouple gauges to connect to the board.

Physical Specifications *(Continued)*

Digital Output	RS-232
Input Power Required	100 to 120 VAC or 220 to 240 VAC, 50/60 Hz
Mounting	½ rack; 9" W x 3½" H x 12" D (24.1 cm x 8.9 cm x 30.5 cm)
Power Supply Output	± 15 VDC @ 2 Amps
Simultaneous Display	1 channel with 4½ place LCD readout (with exponent) 3 channels with 2½ place LCD readouts (with exponents)
Trip Point Relays	Standard: 2 alarm relay outputs (28 Volts max.) Optional: 2 additional alarm relay outputs (120 VAC max.)

Electrical Specifications

CE Mark Compliance[3] Electromagnetic Compatibility[4] Low-Voltage Requirements Installation Category Pollution Degree Product Safety and Liability	 EMC Directive 89/336/EEC Low-Voltage Directive 73/23/EEC II, according to EN 61010-1 2, according to IEC 664 Product Safety Directive 92/59/EEC
Power Requirement 115 VAC setting 230 VAC setting	 100 to 120 VAC, nominal 220 to 240 VAC, nominal
Power Consumption	150 VA, maximum
Fuse Ratings 115 V 230 V	 1.6A(T) 1.0A(T)

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

[3] CE compliance depends on the actual configuration of your 146 unit. Some configurations are not CE compliant.

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

Appendix B: Parts List/Accessories

Gauge Cables

Gauge Cables	
Gauge Type	**Cable**
Capacitance Manometer:	
107B	CB107-1-10
120	CB120-1-10
122A/124/223/224/225/622/623/624/625	CB112-2-10
127A/128/626/627/628	CB259-5-10
220	CB112-10-10
221	CB112-14-10
390 or 690 with a 270	CB112-6-10
700 Series	Consult factory
800 Series	Consult factory
Cold Cathode: 10421000*x* (where *x* = fitting type)	100006171 for all types
Convection:	
HPS Convection Enhanced Pirani (CEP)	CB146-37
Granville-Phillips Convectron	CB146-14
Adapter cable for G.P. Convectron cable	CB146-1
Hot Cathode:	
HPS low power, nude, Bayard-Alpert (B/A) KF40 or 2¾ CF	For glass envelope tubes CB146-13
	For glass envelope tubes & external power CB146-16
MKS Hot Cathode Gauges nude or B/A, thoriated iridium or tungsten filament, Types IG-xx, RG75, & NRC563	For nude hot cathode tube CB146-19
Pirani: 10315001*x* (where *x* = fitting type)	CB146-15 for all types
Thermocouple:	
TC-1A	CB146-6-10
Extension cable (26 to 100 ft)	CB146-7-XX
DV-6M	CB146-8-10

Mass Flow Controller Cables

Mass Flow Controller Cables		
Mass Flow Controllers	**Cable**	
All MKS MFCs *except* Types 1749 and 1759	Cable for MFCs w/ Edge Card connector	CB147-7
	Cable for MFCs w/ 15-pin Type "D" connector	CB147-1
	Cable for MFCs w/ 9-pin Type "D" connector	CB147-12

Control Valve Cables

Control Valve Cables	
Control Valves	**Cable**
Type 148, 248	CB251-2-10
Type 153 (not powered by the 146 unit)	CB153-4-10
Type 153 (not powered by the 146 unit)	CB153-13-10
Type 154	CB251-2-10 (with CB248-1-5 adapter)

Power Supply/Readout Cables

Power Supply/Readout Cables	
Power Supply/Readout	**Cable**
Type 147 Four Channel Flow, with CRT	CB147-3
Type 246 Single Channel Flow	CB246-3
Type 247 Four Channel Flow	CB247-9

Accessories

Accessories	
Item	**Part Number**
Rack Mounting Kit	114090
RS-232 cable for displayless units	CB146-21

Appendix C: RS-232 Error Codes

Error Code Summary

If the 146 instrument cannot execute a command, it will respond with an error message. The error codes are summarized in Refer to Table 89.

RS-232 Error Code Summary	
Error Code	**Description**
E111	Unrecognized command
E112	Inappropriate command
E122	Invalid data field
E131	Bad checksum

Table 89: RS-232 Error Code Summary

E111: Unrecognized Command

An "unrecognized command" error message will occur if the command syntax is incorrect. The 146 instrument cannot interpret the command string. The syntax error is located in the first four bytes of the command.

E112: Inappropriate Command

The 146 instrument will return an "inappropriate command" error message if the command cannot be executed on the selected channel or at this time. Examples of inappropriate commands include attempting to:

- Read a channel that is turned off
- Zero an ion gauge (*Ion gauges cannot be zeroed*)
- Read a channel that is out-of-range
- Read a hot cathode gauge that is performing a high power degas
- Perform a degas procedure on a channel that is not connected to a hot cathode gauge
- Span a Pirani gauge that has the gas type set to argon or helium *(A Pirani can only be spanned if the gas type is set to nitrogen.)*
- Enter the Auto (or PID) control mode with the recipe select command set to "none"

E122: Invalid Data Field

An “invalid data field” error message indicates a problem with the data field of the command string. The data field can contain a maximum of 26 characters. If your data field exceeds 26 characters, the 146 instrument will return an invalid command error message. Other possible causes of an invalid command error message include an invalid data range, or a data field that contains numbers instead of letters, or vice versa.

Appendix D: Front Panel Error/Status Messages

Description

1. E stands for Error.
2. C stands for Caution, or a non-vital problem.
3. Input channel errors appear in their respective displays.
4. Output channel and system errors appear in the main display.

Description of Front Panel Error/Status Messages	
Display/Error Code	**Error**
A blank display	No channel/board installed
A blinking display	Calibration error
INVALID *legend*	Invalid keystroke
1 long beep	Invalid command
2 short beeps	Keypad timeout
" . "	Channel auto-powered off A single decimal point is displayed for any cold cathode channel that is turned off with the Ion Gauge Auto Power feature. This distinguishes it from a user-commanded turn off condition.
" _ _ _ _ "	Underrange sensor (lower segments of display are turned on) Underrange conditions depend upon which sensor is associated with the channel. A differential capacitance manometer goes underrange when the reference port pressure exceeds the measurement port pressure by the full scale of the sensor. For Pirani gauges, zeroing the sensor can bring the instrument within range.
" - - - - "	Overrange sensor (upper segments of display are turned on) Overrange conditions depend upon which sensor is associated with the channel. Generally, a sensor goes overrange when the pressure exceeds the measurement range of the sensor.
" .. " or " .... "	Channel turned off (all decimal points in the display are turned on) If any channels were off when the 146 unit was powered down, they remain off when the unit is powered up. The channel must be turned on to resume pressure measurement.

Table 90: Description of Front Panel Error/Status Messages
(Continued on next page)

Description of Front Panel Error/Status Messages *(Continued)*	
Display/Error Code	**Error**
E0	Disconnected sensor If any sensor becomes disconnected from a powered channel, the NO SENSOR legend appears on the right side of the window, and the channel's pressure reading is replaced with **E0**.
E1	Bad sensor A sensor is considered bad if it is unable to provide pressure information. This determination is sensor dependent. A Pirani type gauge with an open filament, an MKS Type 120 sensor which cannot range switch or which has a non-verified change in gain, and MKS Type 107 six decade transducer with corrupted EEPROM data, are the detectable bad sensors.
E2	PROM checksum error
E3	RAM failure
E4	User EEPROM checksum failure
E8	EEPROM Cal reference failure (non-recoverable)
E9	Set point input out of range
E10	Wrong EEPROM format
E12	System recovery failure
C5	Cannot turn off channel with associated alarms enabled
C6	Cannot turn off channel with associated control channel in AUTO
C7	Cannot shut off reference channel of an auto powered ion gauge
C11	New hardware configuration detected

Table 90: Description of Front Panel Error/Status Messages

To Override C Error Codes (C5, C6, C7, and C11):

All of the **C** error codes are overridden by pressing the [ENTER] key.

Codes Displayed at Power Up:

If there has been a configuration change in the 146 unit (C11), or an E4 or E10 condition is present, the 146 instrument displays an error code upon power up. When power is recycled (turned off and then on again), the unit clears the non-fatal error code. If there is only one non-fatal error, the unit powers up and initializes normally. If however, a second error condition exists, then the error code for the second error condition is displayed. By cycling the power a few times, all non-fatal error codes are displayed and then cleared.

Appendix E: Instrument Default Values

Default Values

Active recipe	1
Alarm Relays	
Untripped alarm state	Actuated
Channel assignment (all alarms)	1
Trip point default	1000 Torr (range ± 105,000 Torr)
Alarm status	Disabled
Latch state	Off
Alarms - Audio	On
Alpha	20
Analog Output End Point	
Value	1000 Torr
Type	Linear
Channel association	1
Analog Set Point	
Zero voltage	0.0 Volts
Full scale voltage	5 Volts
Setting	1000 Torr (range 0 to 100,000 Torr)
Status	Disabled
Overrange	Input > 10.3 Volts
Underrange	Input < -10.3 Volts
Base	0 (range 0 to 103% of full open)
Baud Rate	9600

Capacitance Manometer	
Span	1000 Torr
Resolution	10^{-1}
Cold Cathode	
Gauge & GCF	1
Disconnect Threshold	1.0^{-10} Torr
Control Channel	1
Control Valve Position	CLOSE
Data Bits	7 bit
Data Logger Interval	60 seconds
Dual Channel	
Continuity status	Off
Upper channel number	1
Lower channel number	1
Upper threshold value	0 (range 0 and 25,000 inclusive)
Lower threshold value	0 (range 0 and 25,000 inclusive)
Gain	10 (range 0.001 to 10,000)
Hot Cathode	
Disconnect Threshold	1.0^{-10} Torr
Internal High Pressure Fast Shutoff	Disabled
Sensitivity	10
Integral	0.3 (range 0.01 to 100 seconds)
Lead	1.5 seconds (range 0.001 to 1000 seconds)
Leakage Time Base	0 (= instantaneous leakage)
Mass Flow Controller Range	1000 sccm
Parity	Even
Pirani	
ZERO and SPAN	Factory-defined
Gas type	Nitrogen

Polarity	Direct
Preset	99.8% (range 0 to 103% of full open)
Protocol	MKS Protocol
Set Point	0 (range ± 100,000 Torr)
Softstart Speed value Status	 10 (range 1.0 to 990 seconds) Disabled
SPAN (for all recipes)	1
Start	0 (range 0 to 103% of full open)
Unit	Torr

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Appendix F: Underrange and Overrange Values

Underrange and Overrange Values

Sensor Type	Gas Type	Overrange Value	UnderrangeValue
Cold Cathode		1.05×10^{-2} Torr	1.05×10^{-12} Torr
Hot Cathode		1.05×10^{-2} Torr	1.05×10^{-12} Torr
HPS Pirani	Nitrogen Helium Argon	1050 Torr 57.75 Torr 1108.8 Torr	1.05×10^{-5} Torr 1.05×10^{-5} Torr 1.05×10^{-5} Torr
Convectron	Nitrogen Helium Argon	1060.5 Torr 57.75 Torr 1108.8 Torr	1.05×10^{-5} Torr 1.05×10^{-5} Torr 1.05×10^{-5} Torr
HPS CEP	Nitrogen Helium Argon		
107 Capacitance Manometer		*Varies* - 1100 Torr or upper limit of sensor, whichever is less	Varies with sensor
120 Capacitance Manometer		+105% of sensor range	-105% of sensor range
All other Linear Capacitance Manometers		+105% of sensor range	-105% of sensor range
Thermocouple			
MFC			

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Appendix G: Board Specific Commands

General Information

This appendix organizes the 146 commands by *plug-in board* type. It lists all the commands necessary to operate each type of sensor. The plug-in boards covered include:

- Capacitance Manometer
- Pirani/Convection
- Cold Cathode
- Hot Cathode
- Mass Flow Controller
- Thermocouple
- Auxiliary Output
- Control

The commands are arranged in four groups: power, configuration, calibration, and status. Refer to the body of the manual for an explanation of each command. Although this appendix lists the RS-232 commands, the information applies to commands that are entered through both RS-232 and front panel operations.

Capacitance Manometer Messages

The 146 supports a wide variety of MKS capacitance manometers. Refer to Table 9, page 49, for a complete list of transducers.

Capacitance Manometer Messages			
Function	**Description**	**Command**	**Range and Restrictions**
Power	Channel power	@081<para>:<state>	<para> is the channel number 1, 2, 3, or 4 <state> is ON for on; OFF for off Sensor must be installed
Configuration	Sensor full scale	@061<para>:<fs>	<para> is the channel number 1, 2, 3, or 4 <fs> 0.001 to 100,000 Torr equivalent Sensor must be installed Sensor type must be linear or Type 120
	Sensor resolution	@062<para>:<res>	<para> is the channel number 1, 2, 3, or 4 <res> is an ASCII value that represents the resolution as a power of 10, from +7 to -7. Sensor type must be linear or Type 120
Calibration	Zero function	@056<para>:<state>	<para> is the channel number 1, 2, 3, or 4 <state> is ON for on; OFF for off Sensor must be installed
	Zero channel	@051<para>	<para> is the channel number 1, 2, 3, or 4 *Command only* Zero function must be on
	Auto zero function	@058<para>:<state>	<para> is the channel number 1, 2, 3, or 4 <state> is E for enabled; D for disabled
	Select auto zero reference sensor	@059<para>:<ref>	<para> is the channel number 1, 2, 3, or 4 <ref> is the reference channel number Both sensors must be installed

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Capacitance Manometer Messages *(Continued)*			
Function	**Description**	**Command**	**Range and Restrictions**
Status	Report channel reading	@601<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - Sensor must be installed
	Report reading with time stamp	@602<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - Sensor must be installed
	Report sensor voltage	@603<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - Sensor must be installed
	Report channel condition	@608<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - Sensor must be installed

Pirani/Convection Messages

The 146 unit can identify the gauge as a Pirani or convection gauge. If the gauge is identified as a convection gauge, you must further identify the gauge as either a Granville-Phillips Convectron gauge or an HPS Convection Enhanced Pirani (CEP) gauge.

Pirani/Convection Messages

Function	**Description**	**Command**	**Range and Restrictions**
Power	Channel power	@081<para>:<state>	<para> is the channel number 1, 2, 3, or 4 <state> is ON for on; OFF for off Sensor must be installed
Configuration	Gas type	@063<para>:<gas>	<para> is the channel number 1, 2, 3, or 4 <gas> is N for nitrogen H for helium A for argon
	Convection gauge type	@068<para>:<type>	<para> is the channel number 1, 2, 3, or 4 <type> 4 for GP Convectron 5 for HPS convection

(Continued on next page)

Pirani/Convection Messages *(Continued)*

Function	**Description**	**Command**	**Range and Restrictions**
Calibration	Zero function	@056<para>:<state>	<para> is the channel number 1, 2, 3, or 4 <state> is ON for on; OFF for off Sensor must be installed
	Zero channel	@051<para>	<para> is the channel number 1, 2, 3, or 4 *Command only* Sensor must be in range or underrange Zero function must be on
	Auto zero function	@058<para>:<state>	<para> is the channel number 1, 2, 3, or 4 <state> is E for enabled; D for disabled
	Auto zero reference sensor	@059<para>:<ref>	<para> is the channel number 1, 2, 3, or 4 <ref> is the reference channel number Sensors must be installed.
	Span function	@057<para>:<state>	<para> is the channel number 1, 2, 3, or 4 <state> is ON for on; OFF for off
	Span	@053<para>	<para> is the channel number 1, 2, 3, or 4 *Command only* - Span function must be enabled
	Span with reference	@055<para>:<ref>	<para> is the channel number 1, 2, 3, or 4 <ref> is the reference channel number Span function must be on
Status	Report channel condition	@608<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - Sensor must be installed
	Report reading with time stamp	@602<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - Sensor must be installed
	Report channel reading	@601<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - Sensor must be installed
	Report sensor voltage	@603<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - Sensor must be installed

Cold Cathode Messages

The 146 unit supports up to four cold cathode gauges.

Cold Cathode Messages			
Function	**Description**	**Command**	**Range and Restrictions**
Power	Channel power	@081<para>:<state>	<para> is the channel number 1, 2, 3, or 4 <state> is ON for on; OFF for off Sensor must be installed
	Auto power function	@082<para>:<state>	<para> is the channel number 1, 2, 3, or 4 <state> is E for enabled; D for disabled
	Auto power reference	@083<para>:<ref>	<para> is the channel number 1, 2, 3, or 4 <ref> is the reference channel ID
	Auto power shutoff pressure	@084<para>:<pres>	<para> is the channel number 1, 2, 3, or 4 <pres> is the shutoff pressure, in ASCII
Configuration	Gauge factor	@064<para>:<fact>	<para> is the channel number 1, 2, 3, or 4 <fact> is a numeric ASCII string
	Disconnect pressure	@065<para>:<pres>	<para> is the channel number 1, 2, 3, or 4 <pres> is the disconnect pressure, in ASCII
Calibration	Span function	@057<para>:<state>	<para> is the channel number 1, 2, 3, or 4 <state> ON for on; OFF for off Sensor must be installed
	Span with reference	@055<para>:<ref>	<para> is the channel number 1, 2, 3, or 4 <ref> is the reference channel number Span function must be on
	Span	@053<para>	<para> is the channel number 1, 2, 3, or 4 *Command only* - Span function must be on

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Cold Cathode Messages *(Continued)*			
Function	**Description**	**Command**	**Range and Restrictions**
Status	Report channel condition	@608<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - Sensor must be installed
	Report reading with time stamp	@602<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - Sensor must be installed
	Report channel reading	@601<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - Sensor must be installed
	Report sensor voltage	@603<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - Sensor must be installed
	Report sensor ion current	@604<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - Sensor must be installed

Hot Cathode Messages

The 146 unit supports up to four hot cathode gauges.

Hot Cathode Messages			
Function	**Description**	**Command**	**Range and Restrictions**
Power	Channel power	@081<para>:<state>	<para> is the channel number 1, 2, 3, or 4 <state> is ON for on; OFF for off Sensor must be installed
	Auto power function	@082<para>:<state>	<para> is the channel number 1, 2, 3, or 4 <state> is E for enabled; D for disabled
	Auto power reference	@083<para>:<ref>	<para> is the channel number 1, 2, 3, or 4 <ref> is the reference channel number
	Auto power shutoff pressure	@084<para>:<pres>	<para> is the channel number 1, 2, 3, or 4 <pres> is the shutoff pressure, in ASCII
	Degas	@085<para>:<dgas>	<para> is the channel number 1, 2, 3, or 4 <dgas> is: H for high power degas L for low power degas O for degas function off
Configuration	Select gauge factor	@064<para>:<fact >	<para> is the channel number 1, 2, 3, or 4 <fact> is a numeric ASCII string
	Disconnect pressure	@065<para>:<pres>	<para> is the channel number 1, 2, 3, or 4 <pres> is the disconnect pressure, in ASCII
	High pressure shutoff	@066<para>:<pres>	<para> is the channel number 1, 2, 3, or 4 <pres> is the shutoff pressure, in ASCII
	Fail-Safe function	@067<para>:<state>	<para> is the channel number 1, 2, 3, or 4 <state> is E for enabled; D for disabled

(Continued on next page)

Hot Cathode Messages (*Continued*)			
Function	**Description**	**Command**	**Range and Restrictions**
Calibration	Span function	@057<para>:<state>	<para> is the channel number 1, 2, 3, or 4 <state> is ON for on; OFF for off Sensor must be installed
	Span with reference	@055<para>:<ref>	<para> is the channel number 1, 2, 3, or 4 <ref> is the reference channel number Span function must be on
	Span	@053<para>	<para> is the channel number 1, 2, 3, or 4 *Command only* - Span function must be on
Status	Report channel condition	@608<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - Sensor must be installed
	Report reading with time stamp	@602<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - Sensor must be installed
	Report channel reading	@601<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - Sensor must be installed
	Report sensor ion current	@604<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - Sensor must be installed
	Report sensor emission current	@605<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - Sensor must be installed

Mass Flow Controller Messages

The 146 instrument supports all MKS mass flow controllers, and equivalent flow controllers.

Mass Flow Controller Messages			
Function	**Description**	**Command**	**Range and Restrictions**
Power	Channel power	@081<para>:<state>	<para> is the channel number 1, 2, 3, or 4 <state> is ON for on; OFF for off MFC must be installed
Configuration	MFC range	@061<para>:<rng>	<para> is the channel number 1, 2, 3, or 4 <rng> is a number between 0.0002 sccm to 1×10^5 sccm
	Operating mode	@101<para>:<mode>	<para> is the channel number 1, 2, 3, or 4 <mode> is R for Ratio S for Set Point T for Totaling
	Set Point value	@102<para>:<value>	<para> is the channel number 1, 2, 3, or 4 <value> is from ±105% MFC F.S. range
	Totaling co-channel	@103<para>:<chan>	<para> is the channel number 1, 2, 3, or 4 <chan> is the co-channel number
	Override	@104<para>:<cmd>	<para> is the channel number 1, 2, 3, or 4 <cmd> is O for Open C for Close N for Cancel
Calibration	Zero function	@056<para>:<state>	<para> is the channel number 1, 2, 3, or 4 <state> is ON for on; OFF for off Sensor must be installed
	Zero channel	@051<para>	<para> is the channel number 1, 2, 3, or 4 *Command only* Sensor must be in range or underrange Zero function must be on

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Mass Flow Controller Messages			
Function	**Description**	**Command**	**Range and Restrictions**
Status	Report MFC status	@608<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - MFC must be installed
	Report MFC flow rate	@601<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - MFC must be installed
	Report MFC flow rate with time stamp	@602<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - MFC must be installed
	Report MFC voltage	@603<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - MFC must be installed

Thermocouple Messages

The 146 instrument supports the MKS TC-1A and the Hastings DV-6M thermocouples.

Thermocouple Messages			
Function	**Description**	**Command**	**Range and Restrictions**
Power	Channel power	@081<para>:<state>	<para> is the channel number 1, 2, 3, or 4 <state> is ON for on; OFF for off Sensor must be installed
Configuration	Gas Type	@063<para>:<gas>	<para> is the channel number 1, 2, 3, or 4 <gas> is N for nitrogen; H for helium; A for argon
Calibration	Zero function	@056<para>:<state>	<para> is the channel number 1, 2, 3, or 4 <state> is ON for on; OFF for off Sensor must be installed
	Zero channel	@051<para>	<para> is the channel number 1, 2, 3, or 4 *Command only* Sensor must be in range or underrange Zero function must be on
	Auto zero function	@058<para>:<state>	<para> is the channel number 1, 2, 3, or 4 <state> is E for enabled; D for disabled
	Auto zero reference sensor	@059<para>:<ref>	<para> is the channel number 1, 2, 3, or 4 <ref> is the ref. channel number Sensors must be installed
Status	Report sensor status	@608<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - Sensor must be installed
	Report sensor reading	@601<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - Sensor must be installed
	Report reading with time stamp	@602<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - Sensor must be installed
	Report sensor voltage	@603<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - Sensor must be installed
	Report channel condition	@608<para>?	<para> is the channel number 1, 2, 3, or 4 *Request only* - Sensor must be installed

Auxiliary Output Messages

The Auxiliary Output board provides two relays (in addition to relays A and B, available on the General I/O connector), and two analog outputs (in addition to the single analog output provided by the General I/O connector).

Auxiliary Output Messages			
Function	**Description**	**Command**	**Range and Restrictions**
Alarms	Alarm enable	@011<para>:<data>	<para> is the alarm letter (A through D) <data> is E for enabled; D for disabled
	Trip point value	@012<para>:<data>	<para> is the alarm letter (A through D) <data> is the trip point pressure, from -100000 to 100000 Torr, inclusive
	Alarm association	@013<para>:<chan>	<para> is any character (no significance) <chan> is the input channel (1, 2, 3, or 4)
	Unlatch currently alarmed relays	@014<para>	<para> is any character (no significance)
	Status alert	@015<para>:<state>	<para> is any character (no significance) <state> is E for enabled; D for disabled
	Untripped state of unlatched relay	@016<chan>:<state>	<chan> is the alarm letter (A through D) <state> is A for actuated; D for deactuated
	Relay Status	@60A<alarm>?	<alarm> is the alarm letter Request only Response: E = Enabled, D = Disabled, T = Tripped
	Alarm Status	@60B<alarm>?	<alarm> is the alarm letter Request only Response: E = Enabled, D = Disabled, T = Tripped

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Auxiliary Output Messages (*Continued*)			
Function	**Description**	**Command**	**Range and Restrictions**
Analog Outputs	Channel Output Type	@071<para>:<type>	<para> is the analog output (1, 2, or 3) <type> is LN for linear LO1 to LO9 for log 1 to log 9 SP for set point
	Input Channel Selection	@072<para>:<chan>	<para> is the analog output (1, 2, or 3) <chan> is the input channel (1, 2, 3, 4, 5 (dual 1), or 6 (dual 2))
	FS Pressure (10 V output)	@073<para>:<pres>	<para> is the analog output (1, 2, or 3) <pres> is the full scale pressure

Control Messages

The Control board allows you to use the 146 as a closed-loop controller. The control messages are separated into three categories: General; Control Adjust; and Recipe Specific messages.

Control Messages			
Function	**Description**	**Command**	**Range and Restrictions**
General Control	Control mode	@021<para>:<mode>	<para> is channel number (0*, 1) <mode> is A for auto O for open C for close H for hold M for manual
	Active recipe	@022<para>:<data>	<para> is control channel number (0*, 1) <data> is the recipe number 1, 2, 3, or 4
	Controller Polarity	@023<para>:<data>	<para> is control channel number (0*, 1) <data> is D for direct; R for reverse
Current Setting	Control Mode	@60C<para>?	<para> is control channel number (0*, 1)
	Current Recipe	@60D<para>?	<para> is control channel number (0*, 1)
	Current PID Set Point	@60E<para>?	<para> is control channel number (0*, 1)
	PCS Output	@60F<para>?	<para> is control channel number (0*, 1)
** Control channel 0 is a virtual control channel used in conjunction with Mass Flow Controllers*			

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Control Messages ***(Continued)***			
Function	**Description**	**Command**	**Range and Restrictions**
Control Adjust	Integral	@031<para>:<data>	<para> is control channel number (0*, 1) <data> is from 0.01 to 100 seconds
	Base	@032<para>:<data>	<para> is control channel number (0*, 1) <data> is from 0 to 103 (% of full open)
	Start	@033<para>:<data>	<para> is control channel number (0*, 1) <data> is from 0 to 103 (% of full open)
	Alpha	@034<para>:<data>	<para> is control channel number (0*, 1) <data> is from 5 to 99, inclusive
	Preset	@035<para>:<data>	<para> is control channel number (0*, 1) <data> is from 0 to 103 (% of full open)
	Output	@036<para>:<data>	<para> is control channel number (0*, 1) <data> is from 0 to 100% inclusive
	Softstart speed	@037<para>:<data>	<para> is control channel number (0*, 1) <data> is from 1.0 to 990 seconds
	Set point F.S.	@038<para>:<data>	<para> is control channel number (0*, 1) <data> is from 0 to 10 Volts
Recipe Specific	Set point value	@041<para>:<pres>	<para> is the recipe number, 1, 2, 3, or 4 <pres> is from ±100,000 Torr
	Lead	@042<para>:<lead>	<para> is the recipe number, 1, 2, 3, or 4 <lead> is from 0.001 to 1000 seconds
	Gain	@043<para>:<gain>	<para> is the recipe number, 1, 2, 3, or 4 <gain> is from 0.001 to 10,000
	Softstart	@044<para>:<pres>	<para> is the recipe number, 1, 2, 3, or 4 <pres> is from 1.0 to 990 seconds
	Select analog set point	@045<para>:<state>	<para> is the recipe number, 1, 2, 3, or 4 <state> is E for enabled; D for disabled
	Analog set point range	@046<para>:<rng>	<para> is the recipe number, 1, 2, 3, or 4 <rng> is 0 to 100,000 Torr
	Control Channel	@047<para>:<chan>	<para> is the recipe number, 1, 2, 3, or 4 <chan> is the input channel, 1, 2, 3, or 4
** Control channel 0 is a virtual control channel used in conjunction with Mass Flow Controllers*			

Index

K

L

M

N

O

P

R

S