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MKS VTS-1B and VTS-2A Vacuum Training System Instruction Manual

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Symbols Used in This Instruction Manual

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

Warning

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

Caution

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

Note

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

Symbols Found on the Unit

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

Definition of Symbols Found on the Unit			
On (Supply) IEC 417, No.5007	Off (Supply) IEC 417, No.5008	Earth (ground) IEC 417, No.5017	Protective earth (ground) IEC 417, No.5019
Frame or chassis IEC 417, No.5020	Equipotentiality IEC 417, No.5021	Direct current IEC 417, No.5031	Alternating current IEC 417, No.5032
Both direct and alternating current IEC 417, No.5033-a	Class II equipment IEC 417, No.5172-a	3~ Three phase alternating current IEC 617-2 No.020206	
Caution, refer to accompanying documents ISO 3864, No.B.3.1	Caution, risk of electric shock ISO 3864, No.B.3.6	Caution, hot surface IEC 417, No.5041	

Table 1: Definition of Symbols Found on the Unit

Safety Procedures and Precautions

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

DO NOT SUBSTITUTE PARTS OR MODIFY INSTRUMENT

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

SERVICE BY QUALIFIED PERSONNEL ONLY

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

USE CAUTION WHEN OPERATING WITH HAZARDOUS MATERIALS

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

PURGE THE INSTRUMENT

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

USE PROPER PROCEDURES WHEN PURGING

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

DO NOT OPERATE IN AN EXPLOSIVE ENVIRONMENT

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

USE PROPER FITTINGS AND TIGHTENING PROCEDURES

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

CHECK FOR LEAK-TIGHT FITTINGS

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

OPERATE AT SAFE INLET PRESSURES

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

INSTALL A SUITABLE BURST DISC

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

KEEP THE UNIT FREE OF CONTAMINANTS

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

ALLOW THE UNIT TO WARM UP

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

Sicherheitshinweise für den Massenflußregler

In dieser Betriebsanleitung vorkommende Symbole

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

Warnung!

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

Vorsicht!

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

Hinweis

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

Erklärung der am Gerät angebrachten Symbole

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

Bedeutung der am Gerät angebrachten Symbole			
Ein (Energie) IEC 417, No.5007	Aus (Energie) IEC 417, No.5008	Erdanschluß IEC 417, No.5017	Schutzleiteranschluß IEC 417, No.5019
Masseanschluß IEC 417, No.5020	Aquipotential- anschluß IEC 417, No.5021	Gleichstrom IEC 417, No.5031	Wechselstrom IEC 417, No.5032
Gleich- oder Wechselstrom IEC 417, No.5033-a	Durchgängige doppelte oder verstärkte Isolierung IEC 417, No.5172-a	3~ Dreileiter- Wechselstrom (Drehstrom) IEC 617-2, No.020206	
Warnung vor einer Gefahrenstelle (Achtung, Dokumen- tation beachten) ISO 3864, No.B.3.1	Warnung vor gefährlicher elektrischer Spannung ISO 3864, No.B.3.6	Höhere Temperatur an leicht zugänglichen Teilen IEC 417, No.5041	

Tabelle 2: Bedeutung der am Gerät angebrachten Symbole

Sicherheitsvorschriften und Vorsichtsmaßnahmen

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

Niemals Teile austauschen oder Änderungen am Gerät vornehmen!

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

Wartung nur durch qualifizierte Fachleute!

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

Vorsicht beim Arbeiten mit gefährlichen Stoffen!

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

Spülen des Gerätes mit Gas!

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

Anweisungen zum Spülen des Gerätes

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

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

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

Anweisungen zum Installieren der Armaturen!

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

Verbindungen auf Undichtigkeiten prüfen!

Überprüfen Sie sorgfältig alle Verbindungen der Vakuumkomponenten auf undichte Stellen.

Gerät nur unter zulässigen Anschlußdrücken betreiben!

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

Geeignete Berstscheibe installieren!

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

Verunreinigungen im Gerät vermeiden!

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

Geräteeinheit auf Arbeitstemperatur bringen!

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

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

Symboles utilisés dans ce manuel d'utilisation

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

Avertissement

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

Attention

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

Remarque

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

Symboles apparaissant sur l'unité

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

Définition des symboles apparaissant sur l'unité			
Marche (sous tension) IEC 417, No.5007	Arrêt (hors tension) IEC 417, No.5008	Terre (masse) IEC 417, No.5017	Terre de protection (masse) IEC 417, No.5019
Masse IEC 417, No.5020	Equipotentialité IEC 417, No.5021	Courant continu IEC 417, No.5031	Courant alternatif IEC 417, No.5032
Courant continu et alternatif IEC 417, No.5033-a	Matériel de classe II IEC 417, No.5172-a	3∼ Courant alternatif triphasé IEC 617-2, No.020206	
Attention : se reporter à la documentation ISO 3864, No.B.3.1	Attention : risque de choc électrique ISO 3864, No.B.3.6	Attention : surface brûlante IEC 417, No.5041	

Tableau 3: Définition des symboles apparaissant sur l'unité

Mesures de sécurité et précautions

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

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

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

DÉPANNAGE UNIQUEMENT PAR DU PERSONNEL QUALIFIÉ

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

PRÉCAUTION EN CAS D'UTILISATION AVEC DES PRODUITS DANGEREUX

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

PURGE DE L'APPAREIL

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

UTILISATION DES PROCÉDURES APPROPRIÉES POUR LA PURGE

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

PAS D'EXPLOITATION DANS UN ENVIRONNEMENT EXPLOSIF

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

UTILISATION D'ÉQUIPEMENTS APPROPRIÉS ET PROCÉDURES DE SERRAGE

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

VÉRIFICATION DE L'ÉTANCHÉITÉ DES CONNEXIONS

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

EXPLOITATION AVEC DES PRESSIONS D’ENTRÉE NON DANGEREUSES

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

INSTALLATION D’UN DISQUE D’ÉCHAPPEMENT ADAPTÉ

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

MAINTIEN DE L’UNITÉ À L’ABRI DES CONTAMINATIONS

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

RESPECT DU TEMPS D’ÉCHAUFFEMENT

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

Medidas de seguridad del controlador de flujo de masa

Símbolos usados en este manual de instrucciones

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

Advertencia

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

Precaución

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

Nota

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

Símbolos hallados en la unidad

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

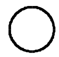
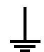
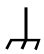
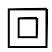
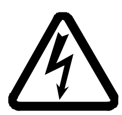
Definición de los símbolos hallados en la unidad			
 Encendido (alimentación eléctrica) IEC 417, N° 5007	 Apagado (alimentación eléctrica) IEC 417, N° 5008	 Puesta a tierra IEC 417, N° 5017	 Protección a tierra IEC 417, N° 5019
 Caja o chasis IEC 417, N° 5020	 Equipotencialidad IEC 417, N° 5021	 Corriente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

Tabla 4: Definición de los símbolos hallados en la unidad

Procedimientos y precauciones de seguridad

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

NO UTILICE PIEZAS NO ORIGINALES O MODIFIQUE EL INSTRUMENTO

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

LAS REPARACIONES DEBEN SER EFECTUADAS ÚNICAMENTE POR TÉCNICOS AUTORIZADOS

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

TENGA CUIDADO CUANDO TRABAJE CON MATERIALES TÓXICOS

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

PURGUE EL INSTRUMENTO

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

USE PROCEDIMIENTOS ADECUADOS PARA REALIZAR LA PURGA

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

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

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

USE ACCESORIOS ADECUADOS Y REALICE CORRECTAMENTE LOS PROCEDIMIENTOS DE AJUSTE

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

COMPRUEBE QUE LAS CONEXIONES SEAN A PRUEBA DE FUGAS

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

HAGA FUNCIONAR EL INSTRUMENTO CON PRESIONES DE ENTRADA SEGURAS

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

INSTALE UNA CÁPSULA DE SEGURIDAD ADECUADA

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

MANTENGA LA UNIDAD LIBRE DE CONTAMINANTES

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

PERMITA QUE LA UNIDAD SE CALIENTE

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

Chapter One: General Information

Product Description

The MKS Vacuum Training System is a cost-effective and robust tool for learning vacuum and instrumentation fundamentals. The apparatus is designed to provide vivid hands-on experience in:

- Vacuum theory
- Vacuum components
- Gauging practice
- Mass flow control
- Pressure control
- Calibration principles of flow and pressure devices
- Control systems

The apparatus is designed as a representative medium vacuum process system with provisions for manual or automatic pressure control. A Type 146 Cluster Gauge™ Measurement and Control System in combination with the user’s PC provides system setup, control and display of various aspects of system operation. Examples include pressure *vs* time and deviation from set point. A small transparent chamber is incorporated in the system and a variety of accessories can be used to demonstrate the various physical properties of vacuum. A variety of accessory packages are available for the instrument. This manual includes the set up procedures for the High Vacuum and residual gas analyzer (RGA) packages, and exercises that can be performed using the RGA.

The VTS-1 is the standard version of the Vacuum Training System. The VTS-2 offers fully CE compliant components.

How This Manual is Organized

The MKS Vacuum Training System is supplied as a kit of components. This manual provides instructions on how to set up, install and operate the VTS unit.

Before assembling and using your Vacuum Training System please carefully read and familiarize yourself with the manual and the precautionary notes.

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

Chapter Two, *Assembly and Set Up*, explains how to assemble the parts into a standard configuration. Also covered is the set up of the 146 instrument (associated software is described in Chapter Three). Criteria for mechanical pumps compatible with the system are detailed in this chapter.

Chapter Three, *Software*, describes the Remote Terminal Interface (RTI) software (DOS) and MKS146 software (Windows) associated with the 146 instrument.

Chapter Four, *Demonstrations and Exercises*, details a number of classroom uses that can be performed using the Vacuum Training System.

Chapter Five, *Installing the High Vacuum and RGA Upgrades*, explains how to integrate the optional high vacuum, quadrupole Residual Gas Analyzer (RGA) and gas sampling components with the basic Vacuum Training System. Also covered are criteria for the high vacuum pump and operating procedures.

Chapter Six, *Exercises Using the RGA*, details a number of classroom activities using the Quadrupole RGA.

Customer Support

Standard maintenance and repair services are available at all of our regional MKS Calibration and Service Centers, listed on the back cover. If any difficulties arise in the use of your Vacuum Training System, contact any authorized MKS Calibration and Service Center. If it is necessary to return any MKS component to MKS, please obtain an RMA (Return Material Authorization) number from the MKS Calibration and Service Center before shipping. The RMA number expedites handling and ensures proper servicing of your instrument.

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

Questions or comments regarding this manual can be addressed to the MKS Training Department at the address indicated on the cover of this manual.

Chapter Two: Assembly and Set Up

Unpacking and Handling

MKS carefully packs the Vacuum Training System so it reaches you in perfect working order. Upon receiving the unit, however, you should check for defects, cracks, broken connectors, etc., to be certain that the system was not damaged 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 RMA Number from the MKS Service Center before shipping. Please refer to the inside back cover of this manual for a list of MKS Calibration and Service Centers.

Ensure that you have received all of the necessary items by comparing the package contents against the packing list included with your VTS-1 or VTS-2.

Caution **All vacuum components should be handled carefully to avoid contamination, which impairs operation of the system. Avoid leaving fingerprints on the inner and sealing surfaces of the components. Do not expose any components to excessive levels of dust or any other contaminant.**

Mechanical Assembly

This section describes how to assemble the mechanical components. When all components are assembled, they are connected to form the complete system.

Lower Manifold

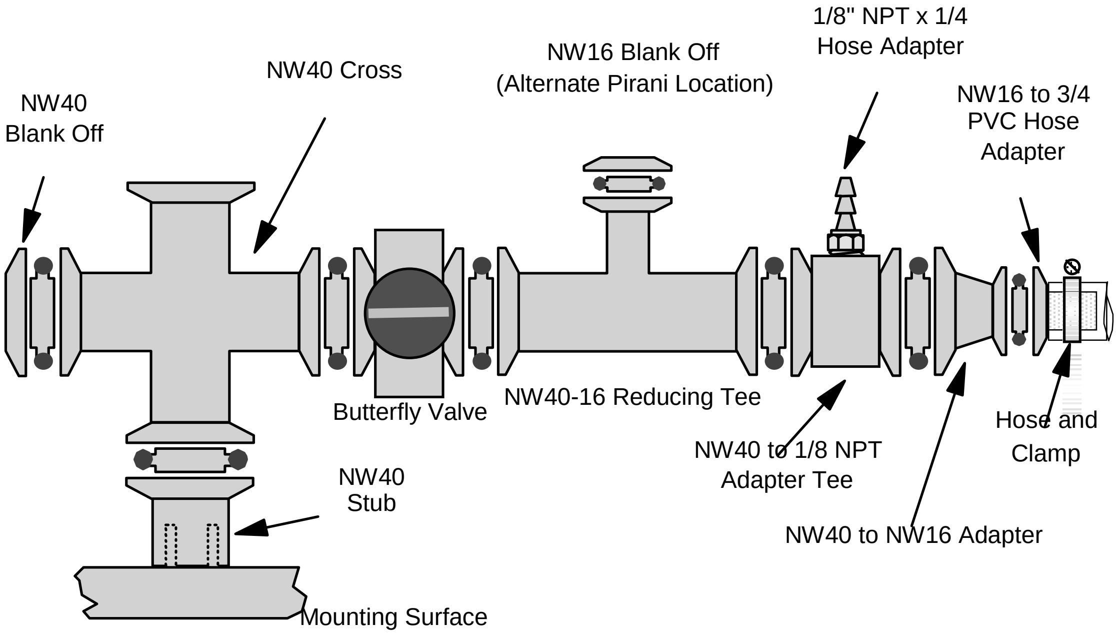


Figure 1: Lower Manifold

Locate the components shown in Figure 1. You also need one wing nut clamp for each connection.

All of the connections are KF style, either NW40 (40 mm) or NW16 (16 mm). Each connection requires two flanges, one center ring assembly consisting of a metal ring with an installed O-ring, and a wing nut clamp. To make the connection, place a center ring in one of the flanges (slip fit) and hold the other flanged component against, and in-line with, the other side of the center ring. Then wrap the hinged wing nut clamp over the joined flanges. The flanges are drawn together by tightening the wing nut, finger tight only. Do not use any grease or lubricant on any of the seal areas.

The NW40 stub can be attached to any convenient surface using 1/4-20 hardware. For permanent mounting, the Vacuum Training System can be attached to a solid table or bench top. For portability, it can be attached to a kitchen hardwood breadboard equipped with rubber feet or to a small cart. However it is mounted, be sure that the system is stable and balanced. If the high vacuum option will be added, please read *Chapter Five: Installing the High Vacuum and RGA Upgrades*, page 77, before proceeding.

Thread the barbed hose adapter into the adapter tee. Teflon® plumbers tape can be used, but the best seals are obtained by lightly coating the first few threads of the hose adapter with clear or white “5-minute” household epoxy cement. Do not use paste-type sealants; they will contaminate the system.

Use the supplied ¾-inch ID wire reinforced PVC hose for the foreline connection to the mechanical pump. Slide the hose over the adapter and use a tubing clamp to secure the hose. Refer to *Pumps*, page 26 for further details.

Throttle Valve and Gauging Section

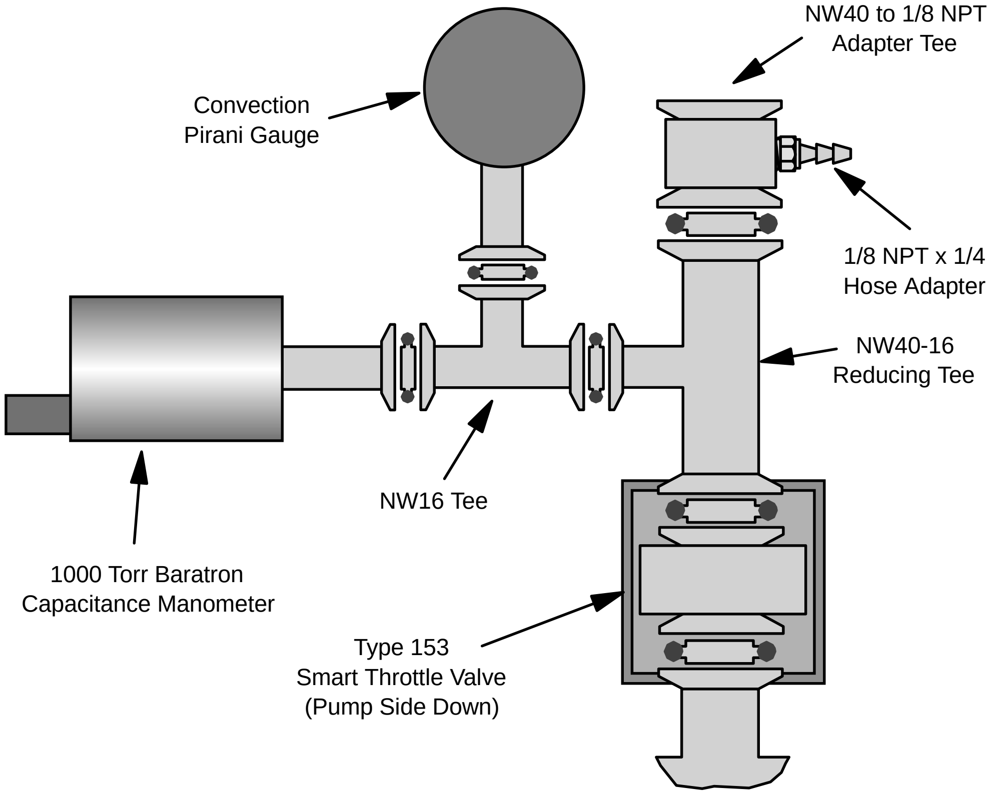


Figure 2: Throttle Valve and Gauges

Locate the components shown in the Figure 2. You also need one wing nut clamp for each connection.

Before mounting the 153 throttle valve:

1. Remove the rear case by unscrewing the two flat-head Allen screws.
2. Locate the Dipswitch bank on the motherboard. Set the switches to the following settings:

   1 ON 2 ON 3 OFF 4 ON 5 OFF 6 ON 7 ON 8 OFF 9 ON 10 OFF

3. Replace the cover
4. Ensure that the HOLD/NORMAL toggle switch is set to NORMAL.
5. Attach the 153 valve to the lower manifold with the “Pump Side” label down.

When mounting the Baratron® transducer, ensure that the ZERO adjustment pot is accessible. When mounting the convection Pirani gauge, ensure that the leveling line on the tube is horizontal.

Finally, attach the brass hose adapter to the tee as described in *Lower Manifold*, page 20.

CF & Compression Adapters and the Glass Chamber

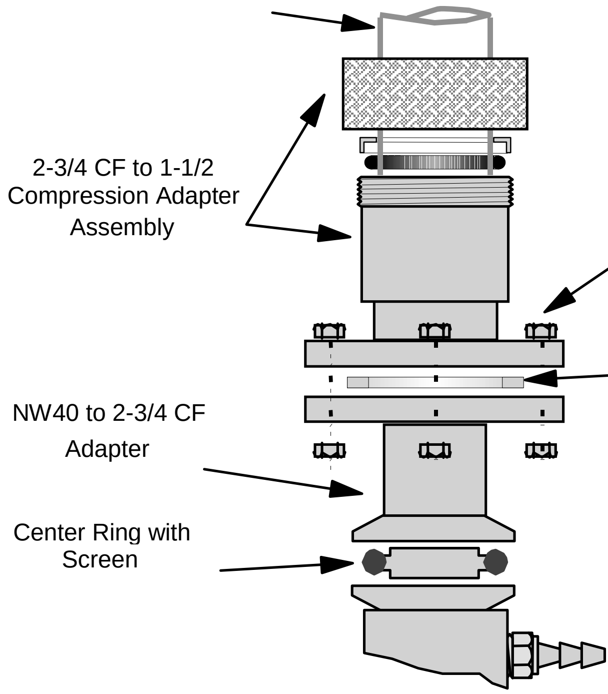


Figure 3: CF & Compression Adapters and the Glass Chamber

Figure 3 shows the assembly of this part of the system.

The NW40 center ring used below the NW40 to 2¾ CF adapter is the center ring with the wire screen insert. The screen helps to prevent any debris that might originate in the chamber area from falling into the system.

A metal sealed CF flange is included with the Vacuum Training System to demonstrate this type of seal. The flanges are joined with six bolt & nut sets and the seal is accomplished with a copper gasket.

6. When removing a gasket from its package, take care not to contaminate it with finger prints.
7. Center the gasket in the lower flange. Align the upper flange with the holes of the lower flange.
8. Insert the bolts (6) and affix a nut to each bolt, finger tight.
9. Tighten each bolt with a wrench. Be sure to evenly tighten the bolts by alternating between bolts, moving diametrically across the flange.

Whenever this flange is taken apart, a new gasket must be inserted to avoid the possibility of leaks.

The glass chamber is attached to the system with the compression fitting.

10. Unscrew the knurled nut and place it on the small end-section tubulation of the chamber.
11. Place the metal ring and O-ring on the chamber tubulation.
12. Slide the tubulation into the body of the compression fitting.
13. Tighten the knurled nut by hand until tight.

Chamber Top End and Shield

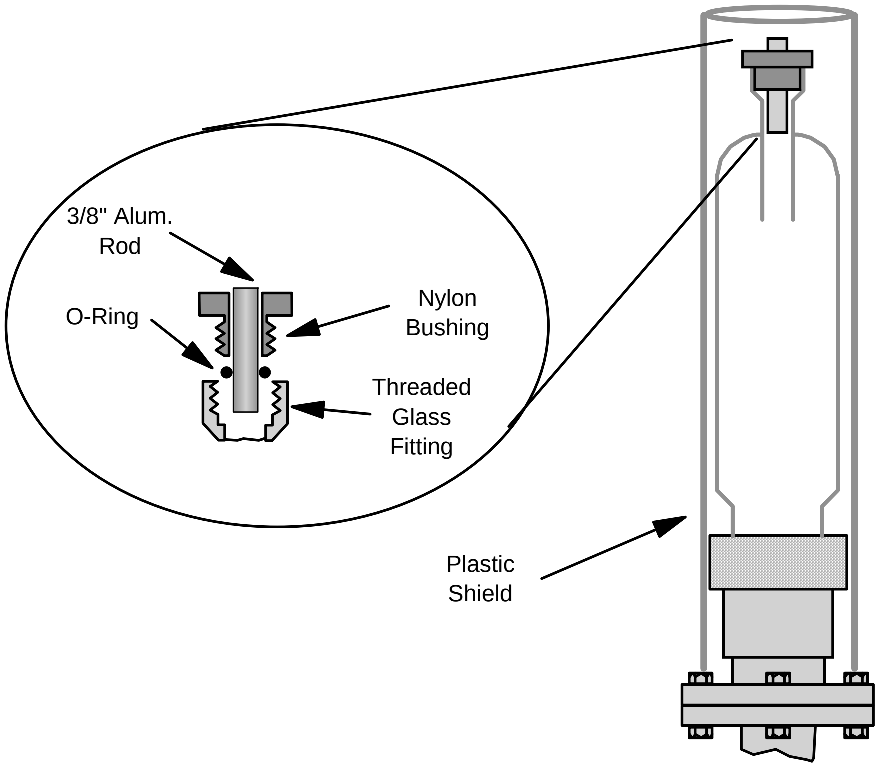


Figure 4: Chamber Top End and Shield

The top end of the chamber includes an 11 mm threaded fitting. Any $^{3}/_{8}$” to $^{13}/_{32}$” diameter cylindrical object can be secured in this fitting with the supplied O-ring and nylon nut. To plug this fitting, use the supplied piece of aluminum rod and assemble as shown in Figure 4. The fitting is also used to hold the digital thermometer as described on page 26. This fitting should only be hand tightened.

Caution **Only hand tighten the 11 mm fitting. Over tightening will damage the fitting and possibly break the glass chamber.**

To preclude to possibility of injury from broken glass while the system is under vacuum, place the plastic shield around the chamber. The shield is placed over the chamber and compression adapter, resting on the CF flange.

Warning **Do not operate the MKS Vacuum Training System without the plastic shield in place around the chamber. The shield is designed to prevent injury in the event of an implosion.**

Mass Flow Controller

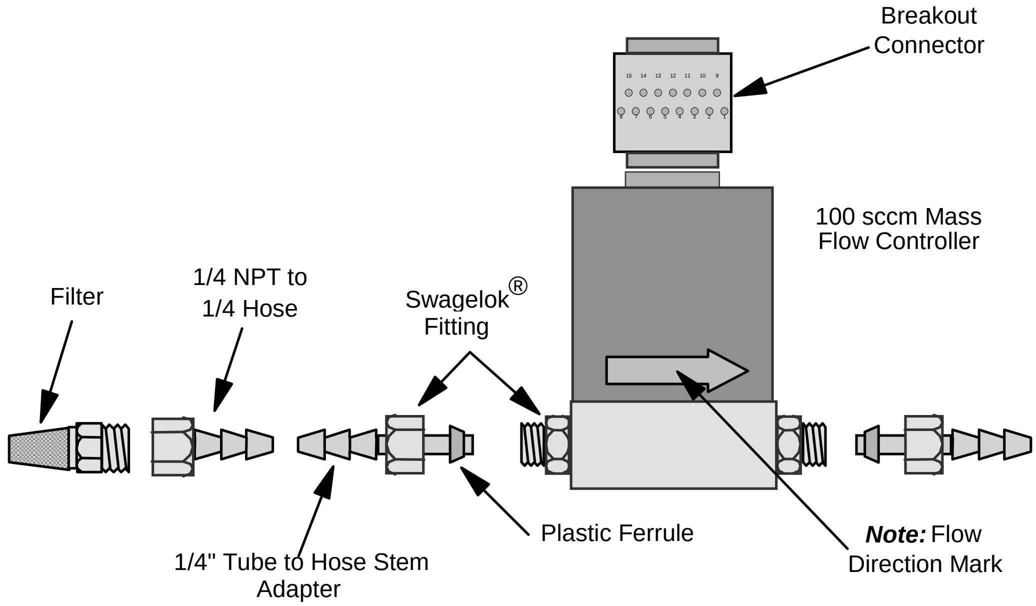


Figure 5: Mass Flow Controller

The MFC's connectors are supplied with fittings that are normally used with metal lines. For flexibility and ease of use in a classroom environment, the Vacuum Training System uses flexible black Norprene® tubing to connect the MFC. Norprene has good qualities under medium vacuum conditions, is easy to attach and remove from the hose barbs, and works well with any of the supplied pinch valves.

Connect the MFC as follows:

14. Remove the plastic fitting covers from the MFC's fittings.
15. Remove each fitting nut and take out the metal ferrules. These are not used.
16. Place a plastic tube to hose stem adapter in each nut and affix a plastic ferrule as shown in Figure 5.
17. Tighten the assembly with a wrench.

Mass flow controllers have internal elements with very small passageways. Any clogging of these passages will cause calibration and operational problems. The sintered metal filter keeps particles out of the MFC. Always keep it in place on the inlet. The filter should be coupled to the MFC with a short piece of tubing.

Access to the MFC's electrical pins is achieved with a breakout connector as shown in Figure 5. Attach this connector only when it is needed for troubleshooting exercises. Please note: since the breakout connector is unshielded, the VTS-2A's MFC is not CE compliant when the breakout connector is attached.

Final Mechanical Assembly

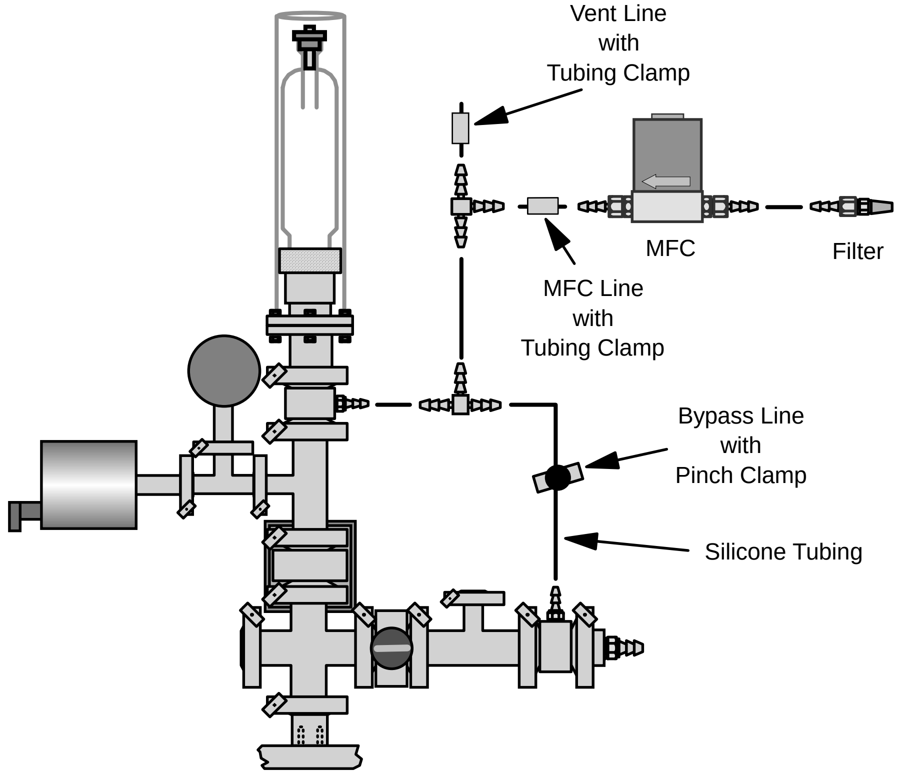


Figure 6: Final Mechanical Assembly

The only remaining steps are to make the final connections using Norprene tubing and plastic tees.

Pinch valves are used for isolation and flow control on these flexible lines. Three styles of valve are supplied with the system:

- Plastic fine-adjusting pinch valves (3 supplied)
- Quick release plastic tubing clamps (3 supplied)
- Metal pinch clamps (3 supplied)

The recommended styles and locations are shown in Figure 6. However, the user may prefer a different valve in any given location. Some exercises require moving or adding valves, or rearranging the tubing.

A fine adjusting pinch valve is desirable on the bypass line.

The clamps on the vent and MFC line should be of the quick release type.

The valve adjacent to the hose connector below the chamber is optional. Closing this valve minimizes the area of elastomer exposed to vacuum, and is therefore useful when the lowest possible pressure is desired.

A sintered metal filter with hose adapter (see page 24) is affixed to the vent line to prevent particulates from being drawn into the system during venting.

Thermometer

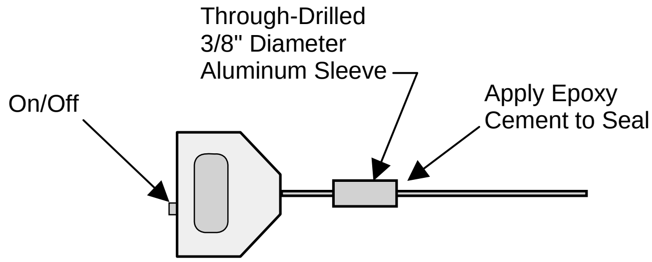


Figure 7: Thermometer Assembly

A fast response digital thermometer is supplied with the Vacuum Training System to monitor chamber temperature. As shown in Figure 7, the thermometer is adapted to fit in the 11 mm chamber fitting using a $^{3}/_{8}$" diameter aluminum sleeve placed over the stem of the thermometer.

The sleeve is assembled to the stem using 2-part epoxy glue. Make sure that each piece is clean, slide the sleeve up to the body of the thermometer, then apply a small amount of epoxy to the stem so that the sleeve will be on the epoxy when the top of the sleeve is about one inch from the thermometer body.

While the glue sets, hold the sleeve in place with clamps or rubber bands. The best attitude for curing is upside down, so the glue remains in the sleeve.

Pumps

The Vacuum Training System works with virtually any two-stage mechanical pump that can achieve a base pressure of 25 milliTorr or better. This is sufficient to bring the manifold to a pressure below the 50 milliTorr maximum zeroing pressure of the 1000 Torr Baratron. In order to handle the gas load in all situations, a free air capacity of at least 2.5 cfm is recommended. A gas ballast provision is useful to minimize oil contamination from water vapor.

Virtually any of the standard industrial 2-stage rotary vane vacuum pumps can be used. A low cost alternative that has worked well with the Vacuum Training System is the type of pump used to evacuate refrigeration systems. These are available through local dealers who support the refrigeration and air conditioning trade. These pumps are made by manufacturers such as Robinaire and J/B Industries, include gas ballast valves, and come with fittings designed to couple to small diameter ($^{1}/_{4}$-inch) rubber refrigeration hose. This small bore tubing impairs the capacity of the pump, causing the VTS to operate improperly. However, the inlets of these pumps can be easily modified to mate with the ¾-inch hose supplied. On the J/B Industries 3 cfm pump, (model DV-85N), the inlet fitting can easily be removed and replaced with common brass fittings from any well stocked hardware store or plumbing supply house. To modify the pump, remove the existing fitting (the pipe thread is sealed with epoxy, so some force is be required to break the bond) and install a $^{3}/_{8}$-inch male to ½-inch female reducer. Then install a ½-inch male pipe thread to ¾-inch hose adapter. Seal the threads with epoxy as described on page 20. Place a metal hose clamp on the tubing to ensure a leak tight connection.

Although a 5-foot length of vacuum hose is supplied with the system, the length should be kept as short as reasonable (3 to 4 ft. if possible) to minimize conductance losses.

Instrumentation Set Up

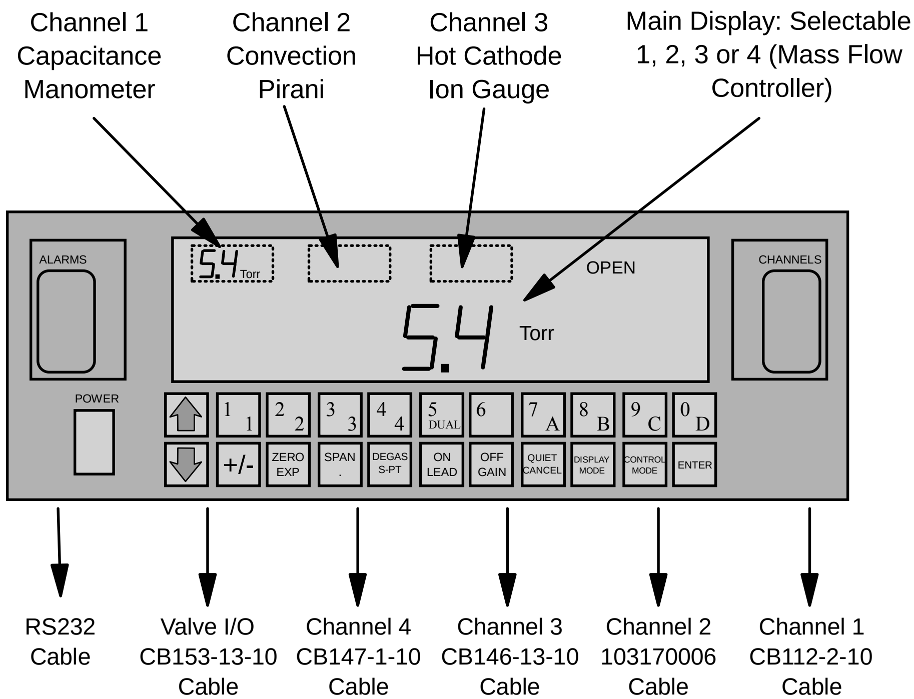


Figure 8: The Front Panel of the 146 Instrument (VTS-1B Cabling is Shown)

The heart of the VTS-1 system's control system is the 146 Cluster Gauge. As supplied, it is configured with control boards for the capacitance manometer, convection Pirani gauge, hot cathode ion gauge and mass flow controller. The channel designations for each of these boards are shown in Figure 8. While the 146 instrument can be operated directly from the front panel, the maximum benefit as a learning tool is realized by interfacing the 146 instrument with an IBM® compatible PC and using the supplied DOS® software package, 146_RTI.

The cables are attached to the rear of the 146 instrument. The assignments for the VTS-1B are shown in Figure 8. Each of the connectors is labeled. Connect the Pirani cable to the upper connector of the Pirani board as this is the only active channel.

Specially shielded cables are provided with the VTS-2A. Part numbers are: CB-153S-13-10 (Smart Throttle Valve), CB147S-1-10 (MFC), CB700S-1-10 (Baratron transducer) and CB146S-37-10 (convection Pirani gauge). No ion gauge cable is provided; the ion gauge channel is only used with the nude ion gauge provided with the optional High Vacuum Modification Package.

The Type 722 Baratron pressure transducer supplied with the VTS-2A is configured with a shielded connector. The Type 722 Baratron pressure transducer supplied with the VTS-1B is connected to the flying leads of the its cable with a terminal block. The connections are as follows:

Green:	+15V (Pin 5)	Black w/ Red:	Pressure Return (Pin 2)
White:	-15V (no connection)	Black w/ Green:	15 V Power Return (Pin 1)
Red:	Pressure Out (Pin 3)	Solid Black:	Chassis Gnd. - secure to case under screw

Pin 4 on the terminal strip is not connected.

Disconnect the hot cathode ion gauge cable, if provided, when that device is not in use, as the cable has a voltage present on the bare collector clip.

Once all devices are connected, plug in the 146 instrument. Power up the unit. After a short initialization period, readings should appear in each of the windows. If a channel shows no indication, activate the channel by pressing ON, then the channel number key. Each channel can be displayed with higher resolution in the main window by pressing the channel number key. For further details on the 146 Cluster Gauge, please refer to its manual.

Chapter Three: Software

The VTS-1B and VTS-2A are supplied with two versions of software. The first is a simple DOS Remote Terminal Interface (RTI). The second is a Windows program that will run with all versions of Windows from Windows 95 through Windows Vista. The following sections describe each of these programs.

Remote Terminal Interface (RTI)

```
MAIN SCREEN       146 Version #312

[A]      alarm on/off
[B]      channel on/off          COMMAND CHOICE: ?
[C]      zero channel
[D]      zero on/off
[E]      span channel
[F]      span on/off
[G]      degas channel
[H]      override MFC valve
[I]      monitor mode
[J]      serial port setup       channel #1     755.7 TORR
[K]      setup mode              channel #2     7.58E+2 TORR
[L]      channel mode            channel #3     OFF (MANUALLY
[M]      tuning mode             channel #4          .03 SCCM
[Q]      quit, return to DOS     alarm A is disabled
                                 alarm B is disabled
```

Figure 9: RTI Main Screen

The Remote Terminal Interface (RTI) is a DOS program used with the 146 instrument and a PC to control the system. This setup permits quick adjustment and monitoring of various system parameters. The program, 146_RTI is supplied on a 3.5" disk. Minimum system requirements are as follows:

80386 or higher computer with DOS Version 5.0 or later

Monochrome or color monitor

4MB of RAM

For a hard drive installation, create a subdirectory and copy the contents of the diskette to that subdirectory. The program requires less than 130 kB of space on the hard disk. No changes to the system configuration are required.

Before starting the program, connect the PC and the 146 instrument with a "straight-through" RS-232 cable. The program is started by typing 146_RTI at the DOS prompt; this establishes communication.

Pressing the F1 key brings up the menu screen shown in Figure 9. To get to any specific menu item, enter the letter associated with that item and press ENTER.

The screens of primary interest for the Vacuum Training System are described in the balance of this chapter. Functions not covered by this manual are described in the manual for the 146 instrument.

RTI Set Up Screen

[K] SETUP

CHANNEL CONFIGURATION

Channel #1 CM: LINEAR	
range: 1000	auto zero reference channel:1
resolution: 10E-1	
autozero operation: DISABLED	
Channel #2 CONVECTION	
gas type: NITROGEN	
autozero operation: DISABLED	
autozero ref. channel: 1	
Channel #3 HOT CATHODE (hi)	
high pressure shutoff: .001	auto power control: DISABLED
gauge factor: 10	auto power threshold: .001
disconnect threshold: 1.E-10	auto power source channel: 1
Channel #4 MFC	
range: 100	co-channel: 1
mode: SETPOINT	autozero operation: DISABLED
setpoint: 0	autozero ref. channel:1

Figure 10: RTI Setup Screen

The Setup menu has several screens associated with it. This is the first screen and the one of interest. The other screens can be accessed by pressing the PAGE UP and PAGE DOWN commands on the computer. Details on the functions of these other screens can be found in the instruction manual for the 146 instrument

This screen is used to set the ranges of each instrument, resolutions and, for the MFC the operational mode and set point. The default settings are shown in Figure 10. Note that the MFC set point can be set for any value from 0 to 100 sccm.

With regard to the convection Pirani gauge, the 146 instrument is programmed with calibration corrections for three gases, nitrogen (air), helium and argon. Only use the helium or argon settings when actually using these gases.

In normal use, when the configuration has been set, the MFC set point is the only menu parameter that changes, as long as the system is used in a manual mode or with downstream pressure control using the Type 153 Throttle Valve. The settings for upstream pressure control are described in the associated exercise, on page 55.

RTI Channel Mode

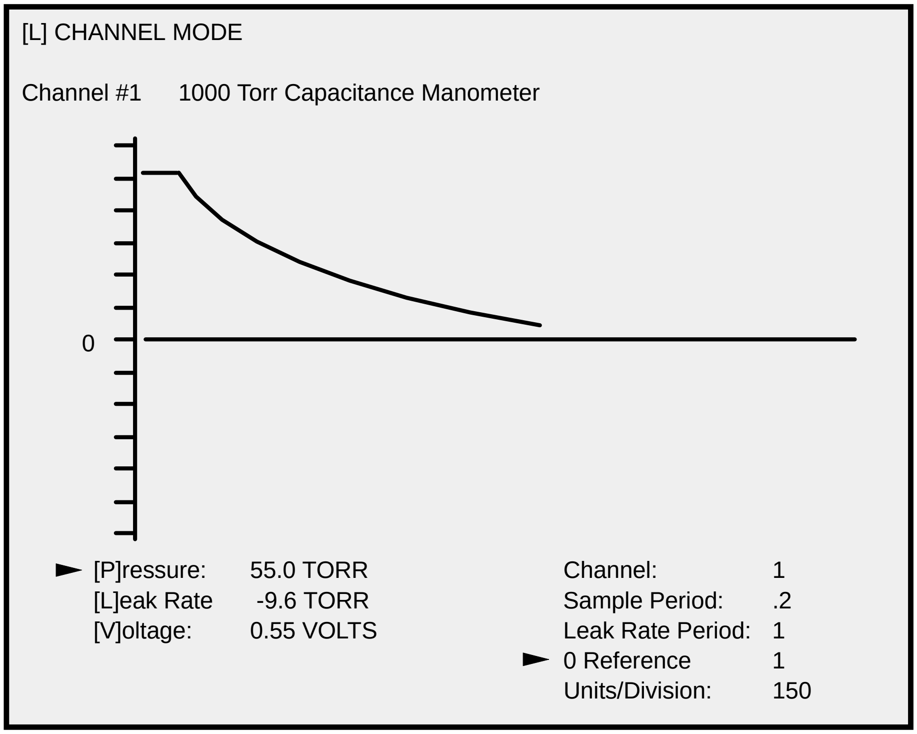


Figure 11: RTI Channel Mode Screen

The Channel Mode screen is accessed by entering L from the Main Menu. The screen is normally used to provide a pressure or flow versus time profile, depending on the device selected. Parameters that are normally adjusted include:

Channel Monitored (1-4)

Sampling Period (in seconds)

0 Reference (pressure or flow corresponding to the central horizontal line)

Vertical Scale Sensitivity (as units per division)

These parameters can be modified by scrolling the arrow using the up/down keys on the computer, entering the new value, and pressing ENTER.

The Leak Rate Period is the period used to calculate a pressure change/time number. The period is normally 1 second. The pressure rise rate in Torr/sec is displayed in the left hand column.

The display at the lower left shows the current reading in the selected units (Torr in this example) and the actual output voltage of the transducer being monitored. By entering the bracketed letter, the pressure (the default), the leak rate (in Torr/sec), or transducer output voltage can be displayed on the graph.

Figure 11 depicts a pressure versus time profile as the system is being evacuated from atmosphere. The current pressure (the end of the trace) is 55 Torr. The screen does not scroll - when the trace reaches the right hand side, it restarts from the left.

RTI Tuning Mode: Screen 1 (Display)

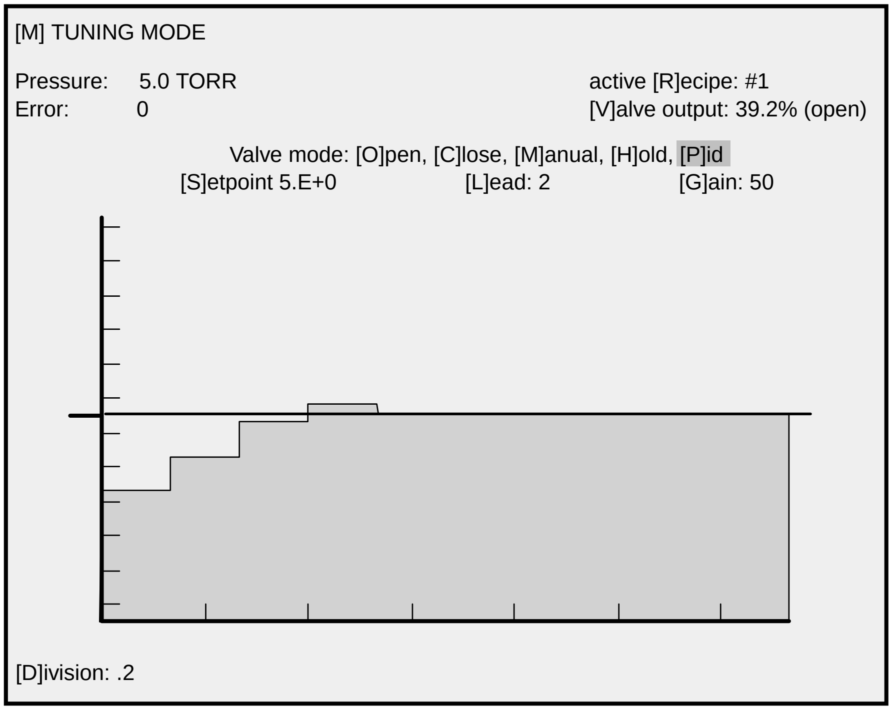


Figure 12: RTI Tuning Mode Screen 1

The Tuning Mode consists of two screens. The first screen is shown in Figure 12. This screen shows deviation from set point when the system is being automatically controlled. The screen is also used to set the mode of operation of the 153 valve. When doing demonstrations and exercises where automatic pressure control is not desired, the valve should be set to [O]pen. When doing exercises where there is automatic pressure control, the valve is set to [P]id (closed loop *P*roportional, *I*ntegral, *D*erivative control). The set point can be entered with the [S]etpoint command and tuning parameters are established with the [L]ead and [G]ain commands.

Actual pressure as measured by the control channel is shown at the upper left along with the deviation that exists between the actual and set point pressures.

Valve output as a percentage of full open is shown at the upper right. In a couple of the exercises we will see how this changes under varying circumstances.

Set point is the center line of the plot. Vertical sensitivity is controlled by the [D]ivision command.

Several recipes can be preprogrammed into the 146 instrument using the second screen in this mode. Any of the recipes can be called up by using the [R]ecipe command. Defaults are shown on page 33.

RTI Tuning Mode: Screen 2 (Set Up)

[M] TUNING MODE

CONTROL SETUP SCREEN

RECIPE:	1	2	3	4
setpoint	5			
lead	2			
gain	50			
softstart	DISABLED			
control channel	1			
analog setpoint	disabled			
analog setpoint range	1000			

integral:	.3	alpha:	20
base:	0	polarity:	DIRECT
start:	0	softstart speed:	1
preset:	99.8	analog setpt. full scale:	5

Figure 13: RTI Tuning Mode Screen 2

Figure 13 shows the default parameters for the Tuning Mode setup. Here it is assumed that the capacitance manometer on channel 1 is the controlling device. Desired set point, lead and gain settings can be entered for each recipe. Any recipe can be overridden by entering a new value on Screen 1.

The "DIRECT" polarity is for downstream control using the 153 Throttle Valve. If upstream control is desired (see page 55), change this entry to "REVERSE".

Windows MKS146

Program Installation and Setup Overview

The software is contained in two zip files (Disk 1 and Disk 2). Unzip these into a common folder and click on the setup program SETUP.EXE. The program will install as:

C:\Program Files\MKS146

Before the program can be run, the 146 instrument must be connected to the PC via a "straight-through" RS-232 cable. Upon opening the program, a splash screen appears. Clicking on the splash screen will open the main screen. If the communication parameters are not correct, a dialog box will appear. The communications parameters are 9600 baud, even parity, 7 data bits, and 1 stop bit. Also, select the proper communications port.

When communication has been established, the opening screen with toolbar will appear as shown in Figure 14.

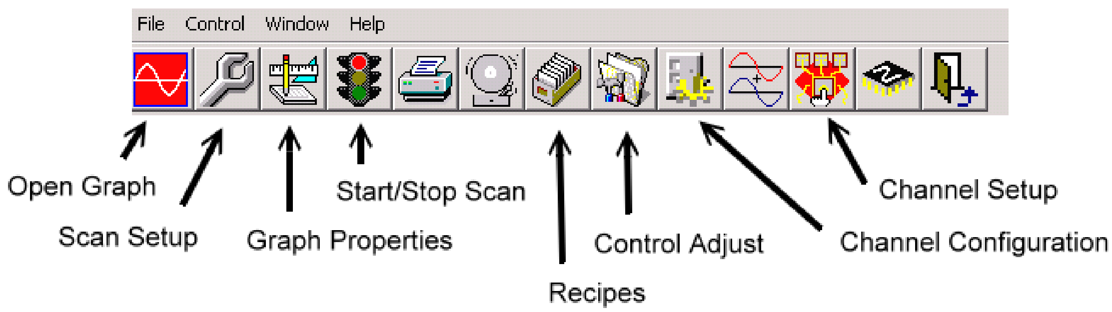


Figure 14: Toolbar Showing Menu Items Used With the VTS-1B and 2A

Click on the "Open Graph" button. This will open a view with a pressure vs time graph, as shown in Figure 15.

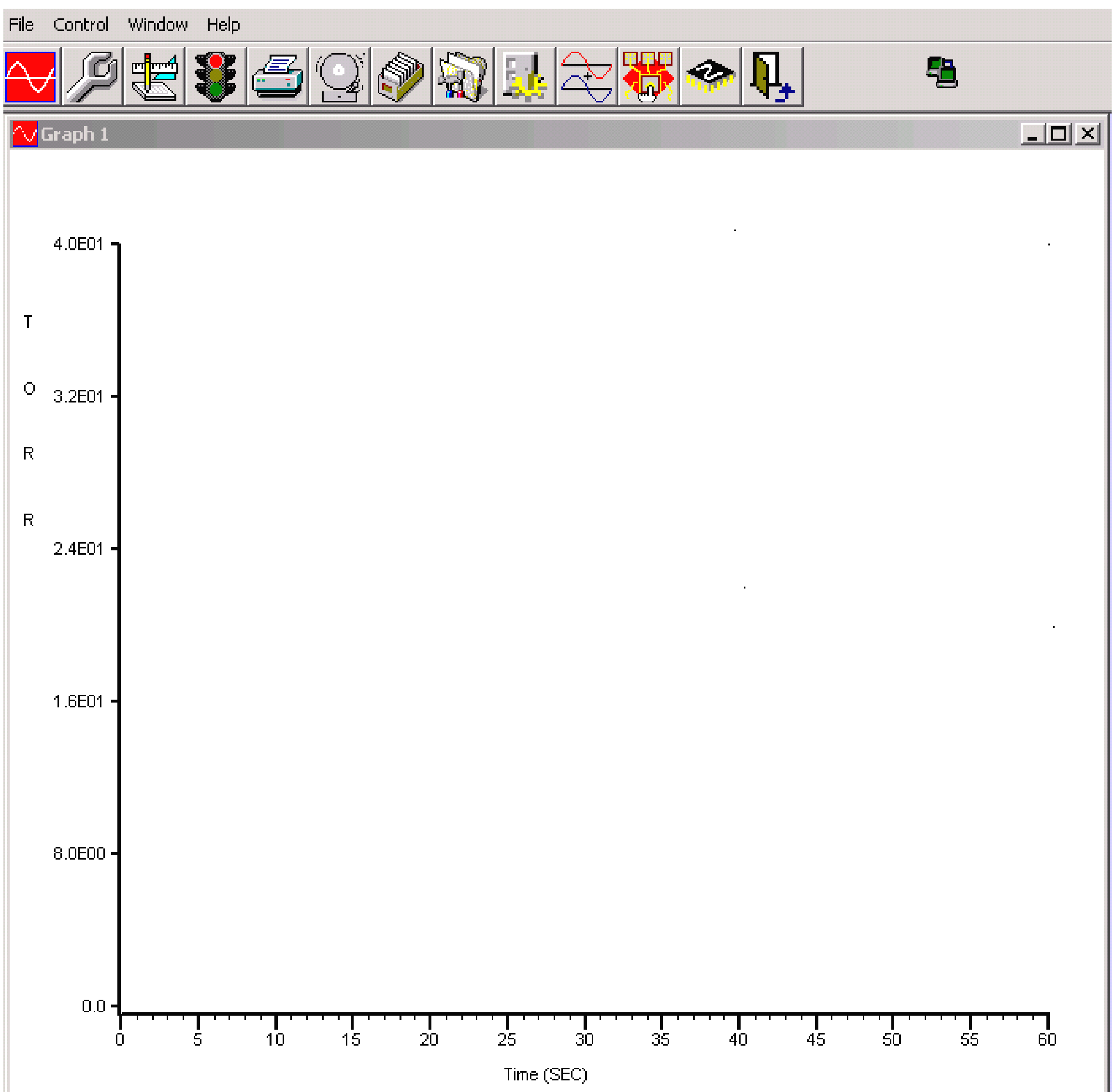


Figure 15: Pressure vs Time Plot

Click “Scan Setup.” The Scan Setup dialog box will appear, as shown in Figure 16.

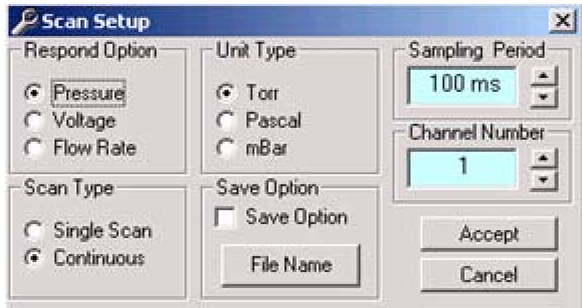


Figure 16: Scan Setup Dialog Box

The default settings are shown. Pressure units may be displayed in Torr (mmHg), Pascal, or milliBar. The sampling period should be faster than 100ms. The channel number selects which instrument is to be monitored and displayed on the graph:

Channel 1: Capacitance Manometer

Channel 2: Convection Pirani Gauge

Channel 3: Ion Gauge

Channel 4: Mass Flow Controller

For the exercises that are described in this manual, the selections will be limited to Channels 1-3.

Click “Save Option” if you want to save data in a format that can be imported to a spreadsheet program. Click the “File Name” button to assign a file name for the collected data. To generate an ASCII file, pick “all files” and save the file with the extension “.txt”.

Note The file will only be generated at the end of a scan. When scanning in continuous mode, a new file will be generated at the completion of each scan. The sequential files will have the assigned name with 001, 002, 003, etc. appended to the name.

Transducer output voltage can also be shown on the graph if desired. “Flow Rate” has nothing to do with the VTS-1B’s flow controller and this option is not used.

When “Graph Properties” is clicked, the Graph Properties dialog box will appear, as shown in Figure 17.

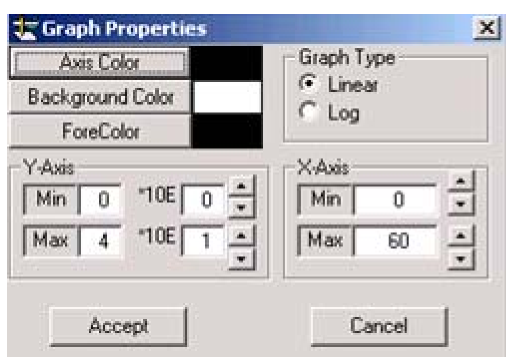


Figure 17: Graph Properties Dialog Box

Set the Y-Axis range to the pressure range of interest. Figure 17 shows a range of 0 to 40 Torr. The X-Axis time scale, for most exercises, will be in the range of 0 to 60 or 180 seconds. For most of the exercises, the linear Y-Axis will be the most useful. The log axis is of most benefit at low pressures (<1 Torr) using the Pirani or ion gauges.

"Channel Configuration" sets the ranges and attributes of each of the VTS-1B's instruments. For the most part, once set these can remain fixed. There is one dialog box for each instrument.

Referring to Figure 18, "Channel #1" sets the attributes for the capacitance manometer. The VTS-1B has a 1000 Torr full scale manometer with linear output and that should be reflected in the Range setting. "Resolution" should be 1 part in 10,000. In this case, that would be 0.1 Torr. Do not change the other settings. You may refer to the 146C manual for descriptions of the Auto Zero function.

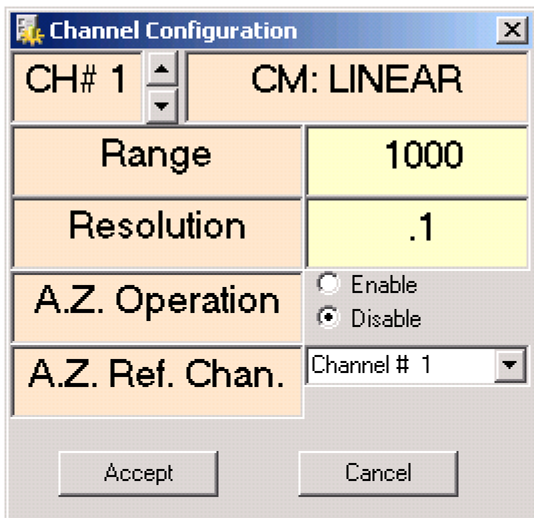


Figure 18: Channel #1 Configuration Settings

Referring to Figure 19, "Channel #2" sets the attributes for the convection Pirani gauge. The 146C instrument has built-in calibration curves for three gases: nitrogen (default), helium, and argon. For all of the exercises, the gas type will remain set to nitrogen. Do not enable the Auto Zero function.

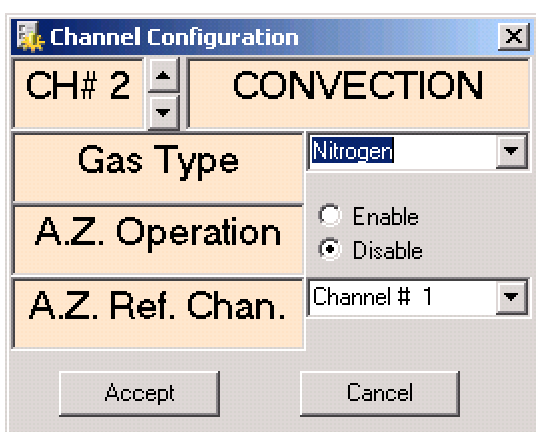


Figure 19: Channel #2 Configuration Settings

Referring to Figure 20, "Channel #3" sets the attributes for the hot cathode ion gauge. The "High Pressure Shutoff" is the pressure at which the ion gauge's filament will be shut off. This is to protect the filament against exposure to high pressures. The iridium filament that is incorporated in the VTS-1B's ion gauge is resistant to even atmospheric pressure exposure. The default for this parameter is 0.001 Torr, but it may be safely increased to 0.01 Torr if the ion gauge tends to turn off immediately after starting. The "Gauge Factor" is the calibration scaling and should be set for 10 unless and ion gauge with a different factor is used. All other parameters should remain set to the defaults shown.

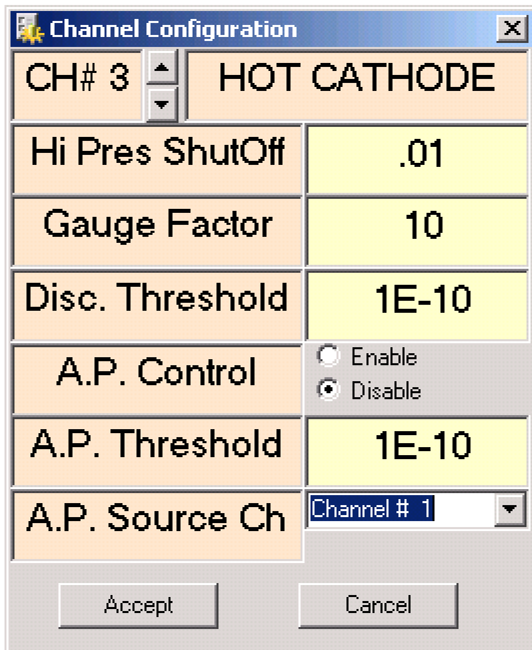


Figure 20: Channel #3 Configuration Settings

Referring to Figure 21, "Channel #4" sets the attributes for the mass flow controller. The range should be set to the full scale range of the included MFC. This is normally 100 sccm. "Mode" refers to the control mode for the MFC. Normally, this is set to "Setpoint" where the MFC delivers a specific flow rate of gas. This will be a value between zero and 100% of full scale. The 1179 MFC has a normal range of operation from 2% of full scale to 100%.

There are two other modes: "Ratio" and "Totaling." Ratio mode is used with upstream pressure control. That will be explained in the *Upstream Control* exercise. The Totaling mode is not used.

The other parameters should not be changed.

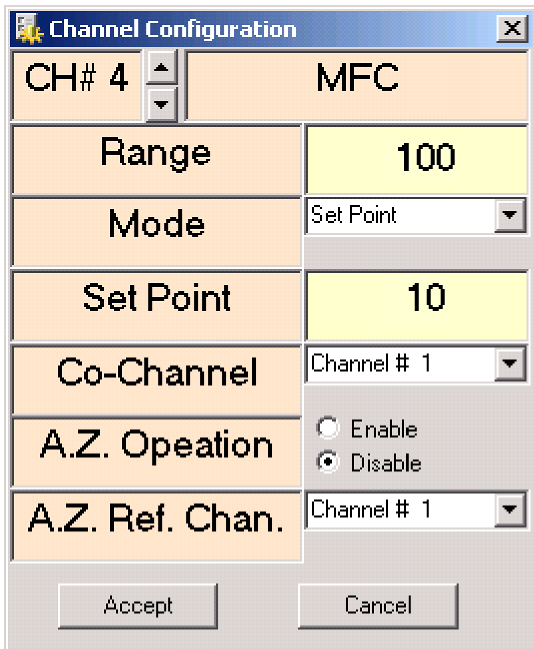


Figure 21: Channel #4 Configuration Settings

Channel Setup may be used to turn each of the channels on or off. When unplugging an instrument, it should be powered down. Turning channels on and off is often more efficiently done using the 146C instrument's keypad. Simply press, in sequence, "On" or "Off" followed by the Channel Number.

Channel Setup may also be used to span the convection Pirani gauge to atmospheric pressure. This is done to match the Pirani to the more accurate manometer reading. As shown in Figure 22, select "On" for "Span Channel" and click "Accept." The process takes a few seconds but when complete, Channel 2 should read the same as Channel 1.

Warning **Do not use the Zero feature. These should always be turned off.**

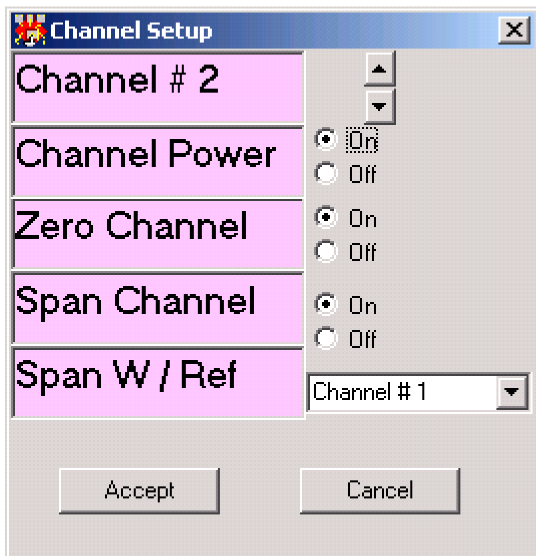


Figure 22: Channel #2 Setup
Establishing Recipes and PID Control Tuning Parameters

PID control may be implemented on the VTS by either downstream or upstream control. The first step is to establish the Set Point, Lead (derivative), and Gain (proportional) parameters using the Recipe item. See Figure 23.

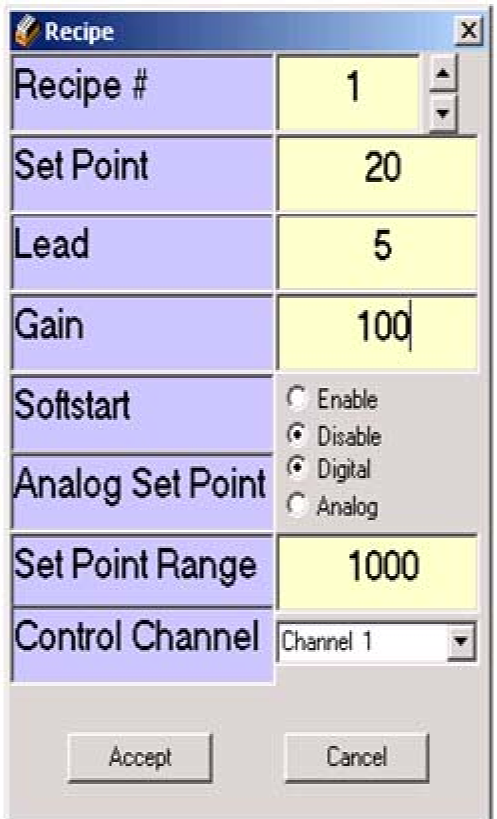


Figure 23: Recipe Dialog Box

Up to four recipes may be established. For the VTS exercises the Softstart, Analog Set Point, and Set Point Range items should be left with their default parameters.

Control Channel 1 will employ the capacitance manometer as the pressure input. For control at pressures under 1 Torr where the capacitance manometer is nearing its resolution limit, Channel 2 (convection Pirani gauge) may be used.

The lead and gain parameters shown in Figure 23 are good starting points for downstream control.

Once the recipe is established, you can proceed to the Control Adjust dialog box. This is shown in Figure 24.

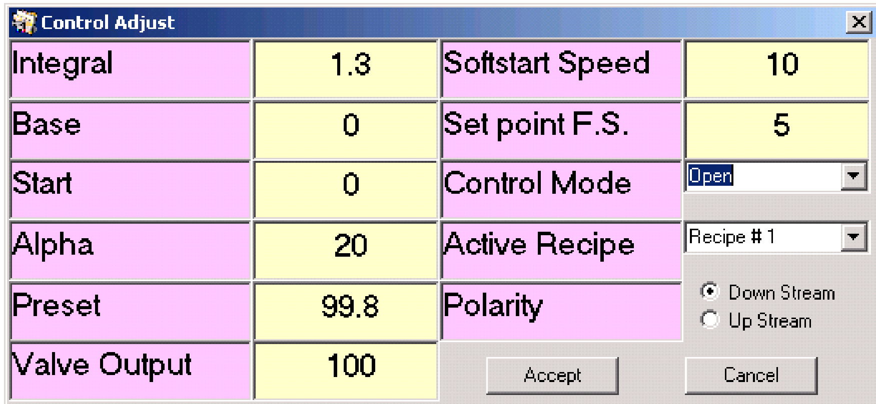


Figure 24: Control Adjust Dialog Box

The only parameters that are edited are the Control Mode, Active Recipe, and Polarity. All others should remain at their default values. The Control Mode has five options:

- Open: Control valve is forced fully open
- Close: Control valve is forced fully closed
- Hold: Holds the control valve in its current position
- Manual: Permits the valve to be opened by a manually inputted percentage
- Auto: Implements PID control as defined by the selected recipe

Except when running the system in upstream or downstream auto mode, the valve mode should be in the Open mode. The Close mode is most useful when controlling with the MFC (upstream control) where it may be beneficial to close the valve to reach base pressure.

It should be noted that in the 146 unit's manual and keypad instructions, the term "direct polarity" refers to downstream control and "reverse polarity" refers to upstream control. In downstream control mode, the 153 Throttle Valve will control the pressure. In upstream control mode, the MFC's control valve will control the pressure. In upstream mode the 146 unit will be sending control signals to both the 153 Throttle Valve and to the MFC. In this situation the 153 Throttle Valve must be held in the open position using the toggle switch at the rear of the valve.

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Chapter Four: Operating and Using the System: Exercises and Demonstrations

Introduction

The following pages offer a series of exercises and demonstrations that can be performed with the Vacuum Training System. These are designed to cover many of the key concepts of importance in vacuum-based process systems. They by no means represent the total capability of the VTS-1 and VTS-2 systems as training tools.

These exercises and demonstration are designed to accompany the three vacuum system training courses that have been developed by MKS Instruments, Inc. The courses (MKS part numbers for the course books are in parentheses) are:

Introduction to the Creation and Control of the Vacuum Process Environment (119839-P1)

Introduction to Vacuum Gauging Techniques (119840-P1)

Introduction to Mass Flow Controllers (119841-P1)

The exercises and demonstrations covered in this chapter are as follows:

- Getting Started: Zeroing the Instruments and Leak Checking
- System Time Constant
- Dynamic Response Characteristics of the Convection Pirani Gauge
- Adiabatic Cooling
- Q=PS Exercise
- Manual Pressure Control - Downstream
- Auto Pressure Control - Downstream
- Auto Pressure Control - Upstream
- Gauge Calibration - Gas Sensitivity with Indirect Gauges
- Simple Method for Supplying an Alternative Gas
- Using the Hot Cathode Ion Gauge
- Mass Flow Controller Flow Verification Using the Pressure Rate-of-Rise Technique
    - Volume Determination
    - Flow Determination
    - Determining a Gas Correction Factor
- Sizing Leaks
- MFC Troubleshooting with a Breakout Connector
- MFC Troubleshooting - Flow Constriction
- Locating Leaks
- Outgassing and Permeation
- Glow Discharge, Cold Cathode Electron Gun

Getting Started: Zeroing the Instruments and Leak Checking

Once the instrument has been set up we need to ensure that the pressure and flow devices are properly adjusted and that the system is leak free.

As with any precision instrumentation, the capacitance manometer and the MFC require zeroing when the VTS is set up. Additionally, the range (span) of the convection Pirani must be adjusted. Students should learn these procedures, performing them whenever the instrument is used for a new set of exercises. Only perform these procedures after the system is fully warmed up (30 minutes).

Bringing the System to Base Pressure, Zeroing the Baratron, Running an Up Leak Check, and Spanning the Pirani

Configure the VTS as follows:

- Throttle and butterfly valves open
- MFC set point at 0
- Line from the MFC pinched closed
- Vent closed and bypass closed

Pump the system to a pressure of 0.05 Torr or below as measured by the Pirani gauge. With the capacitance manometer's output displayed on the 146 instrument's main display, locate the Baratron transducer's zero adjust pot and, with a small screwdriver, adjust the zero pot to give a reading of 0.0 Torr. The Baratron gauge is now zeroed.

To leak check the system perform a simple "up leak" check. This is done by closing the butterfly valve to isolate the VTS from the pump, and observing the pressure rise. With the parameters of the Channel Mode Screen set up as is shown in Figure 25, you should observe a slow, linear (at least initially) rise of pressure. The Leak Rate parameter gives the slope of the curve in Torr/sec. If the system is reasonably tight and the system has been recently exposed to atmospheric pressure, this rate-of-rise should be about 0.001 Torr/sec.

Most of the pressure rise is due to virtual leaks: outgassing of water vapor from the system plumbing and elastomer outgassing. If the pressure rise is observed over a long period of time (hours), it should slow as the source of internally generated gases is dissipated.

Continued pumping also serves to reduce the gas sources that contribute to virtual leaks. Pumping the system for a couple of hours after exposure to atmospheric air reduces the up leak rate by a factor of two or more.

If the leak rate is significantly more than what is indicated above, you should inspect each fitting and connection for looseness, contamination, missing or defective O-rings, etc.

Leak rates are normally specified in terms of standard condition volumetric flow, for example standard (or atmosphere) cubic centimeters per second (Atm. cc/sec). A later exercise deals with the relationship between pressure rate of rise, volume, and standard condition flow rate. From that it is possible to calculate the leak rates due to intentionally induced real leaks.

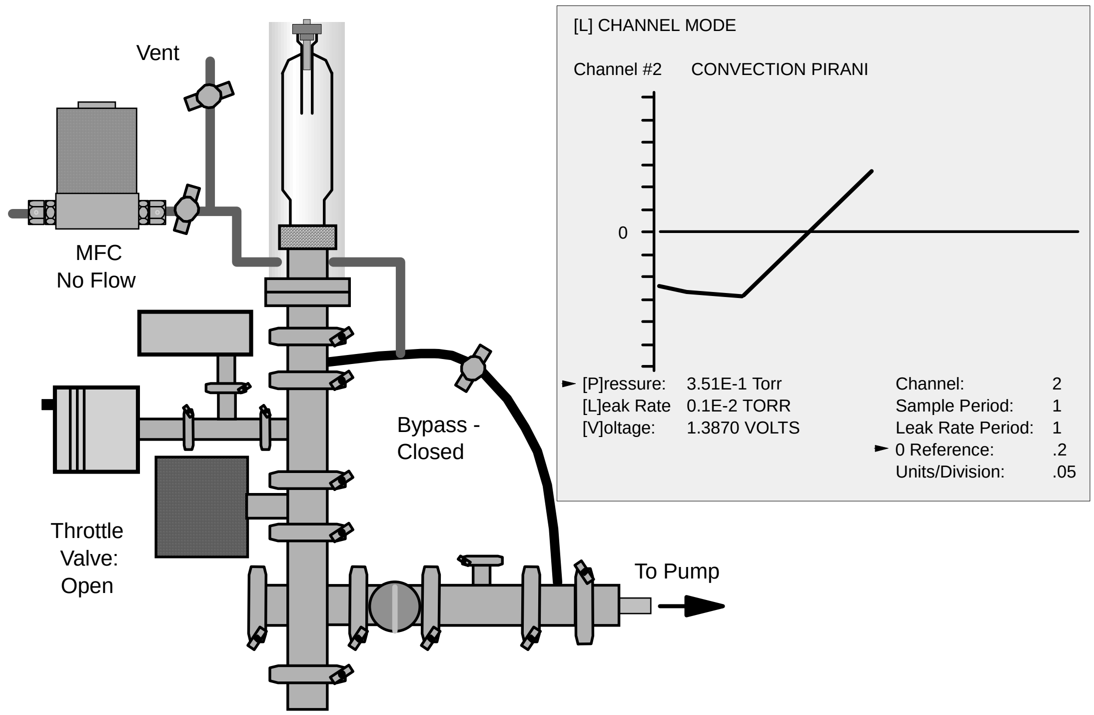


Figure 25: Up Leak Check

At this point the system can be returned to atmospheric pressure. Read all the steps before performing this sequence, since the timing is very important.

18. Make sure that the butterfly valve is open.
19. Turn the pump off.
20. Immediately after stopping the pump, open the vent valve (tubing clamp).

    Failure to vent the system quickly (within about 5 seconds) will result in oil from the mechanical pump backing up through the foreline into the manifold. This is not damaging, but it necessitates the disassembly and cleaning of the lower (horizontal) portion of the manifold.

If the pump is equipped with an inlet isolation valve, modify the above procedure by closing the isolation valve (leaving the pump running), then venting the system. When the system has returned to atmosphere (no need to hurry in this case), turn the pump off, then open the isolation valve.

Automatic protection against oil backup can be afforded by equipping the system with an MKS VACUUM SENTRY® solenoid valve.

When the system has returned to atmospheric pressure, the Pirani gauge and Baratron pressure readings probably differ substantially. This indicates that the Pirani must be *spanned*. This is done by adjusting the scale of the Pirani gauge so that the reading agrees with a reference. In the VTS-1A, the Baratron is the reference.

To span the Pirani gauge:

21. Return to the main menu.
22. Press [E] SPAN CHANNEL.
    The screen prompts you to enter the channel to span.
23. Enter 2 for the Pirani.
    The screen prompts you to enter the reference channel.
24. Enter 1 for the Baratron.
    The Pirani reading now matches that of the Baratron.

Zeroing the Mass Flow Controller

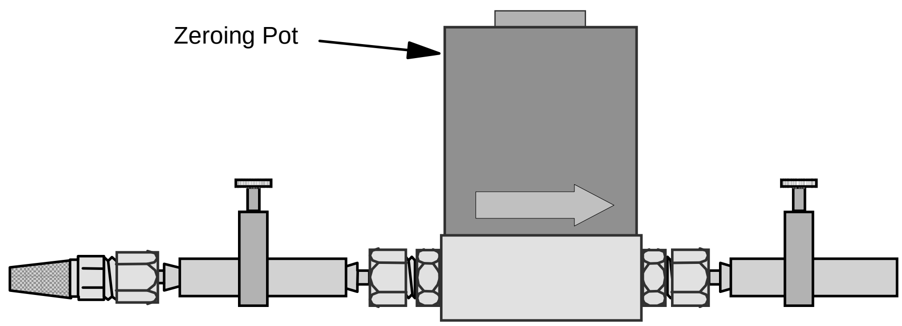


Figure 26: Zeroing the MFC

To zero the Mass Flow Controller, first ensure that there is no flow through the device. The proper way to zero an MFC is to close off the inlet and outlet with valves. In the Vacuum Training System this is accomplished by placing pinch clamps close to the MFC on the inlet and outlet tubes. This is shown in Figure 26.

With the clamps tightened and with the 146 instrument showing channel 4 (the MFC flow indication) in the main display window, turn the zeroing pot until the reading is as close as possible to 0.000.

Attitude changes and air currents directed toward the open inlet of the MFC affect the zero setting. This can be observed on the display of the 146 instrument. It can also be shown graphically on the Channel Mode [L] screen of the RTI. To do this, set the channel for the MFC (4) and adjust the other settings for adequate time and flow resolution.

System Time Constant

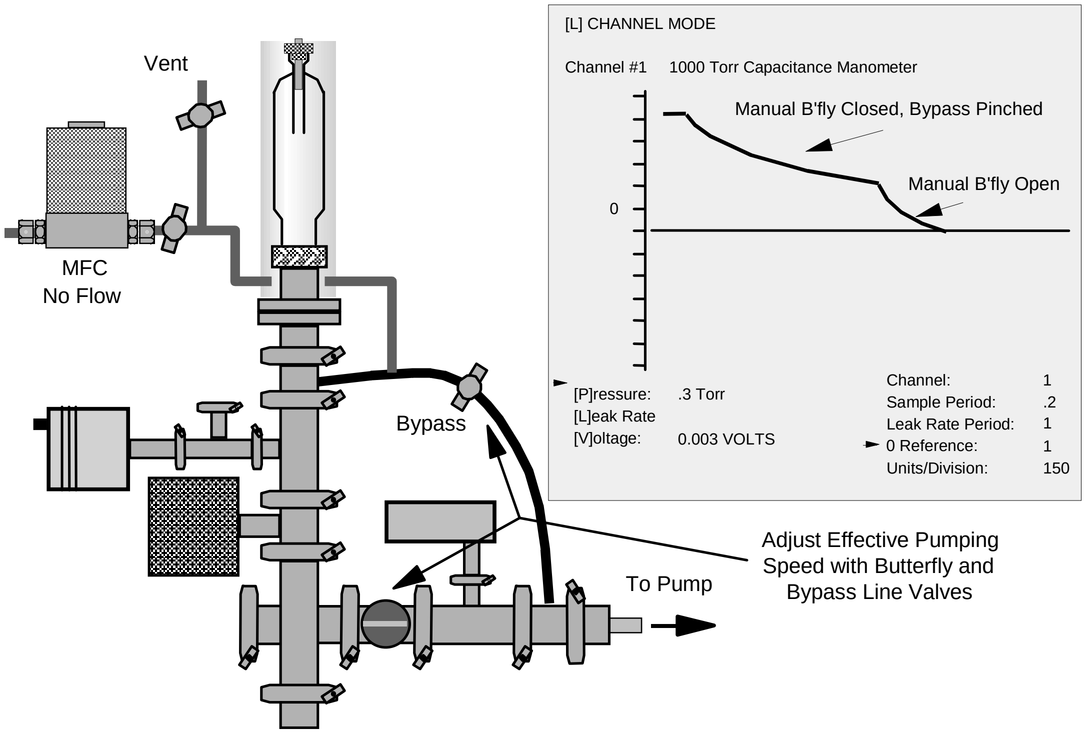


Figure 27: System Time Constant Exercise

The time constant of a vacuum system is analogous to the time constant of an RC circuit. The volume of the chamber is like the capacitor, the effective pumping speed through the connecting lines is like the resistor. In a vacuum apparatus, the time constant, τ, (in seconds) is equal to the chamber volume (usually in liters) divided by the effective pumping speed (usually in liters/sec). The characteristic pump down curve is therefore a declining exponential.

Figure 27 shows the setup for displaying the pump down curve. The time constant can be altered by closing the butterfly valve and achieving a finely adjustable, lower flow through the bypass line using the pinch clamp.

The time constant can be used to gauge the "health" or performance of a system. With a couple of different conductance conditions, determine the system time constants. The time constant can also be modified by partially closing the pump's isolation valve, if so equipped, or by inserting a longer length of hose between the pump and the system.

There is always a pressure drop across a conductance element when there is gas flow. This effect can be shown by moving the Pirani gauge to the lower port. The pressure difference between the capacitance manometer and the Pirani is most noticeable when the butterfly valve is closed and the bypass is partially constricted.

Low conductance bypasses are often used in vacuum process systems to reduce adverse effects of turbulence and adiabatic cooling. The main valve is opened when the pressure is low enough for these effects to be absent. We look at these in the next two exercises.

Dynamic Response Characteristics of the Convection Pirani Gauge

In the previous exercise we used a direct measuring gauge to measure the pressure in the system during pumpdown from atmospheric pressure. In this exercise we use the convection Pirani gauge, an indirect gauge, to perform the same task. This serves to illustrate how the system environment can interact with a measurement instrument to produce a response that may appear at odds with what is really happening. Knowing how any gauge operates is important in accurately interpreting what the gauge is indicating.

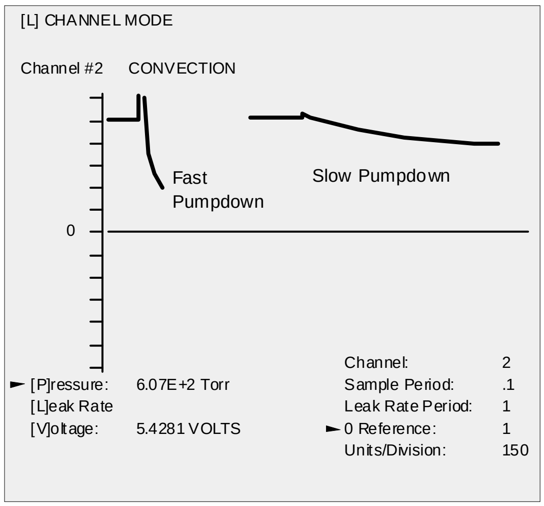


Figure 28: Convection Pirani Response

The reading of a Pirani gauge is based on the rate at which heat is removed from a hot wire element (the filament). At lower pressures (below a few tens of Torr), the indication is based on the rate at which molecular collisions transfer heat from the filament. At higher pressures, heat removal is dominated by convection currents that circulate around the filament. At these pressures, the gauge is in the viscous flow regime. The higher the pressure, the greater the amount of convection cooling, hence a higher pressure indication. By exploiting these two heat removal modes, the convection Pirani can measure pressures from a few milliTorr to 1000 Torr.

Fast pumping of a chamber from atmospheric pressure causes turbulence in the chamber. This is a concern in many industrial processing applications, because the turbulence redistributes any small particles in the system, possibly leading to product contamination. Minimization of turbulence is therefore an important consideration in the design and setup of many vacuum systems. Turbulence is minimized by throttling the exhaust line during the initial phase of evacuation. Rapid pumping also alters heat flow from the Pirani filament. The gauge interprets increased heat flux due to turbulence and other factors as a higher pressure.

The procedure is the same as that for the exercise on page 47 except that the convection Pirani channel (Channel 2) is monitored. As shown in Figure 28, a fast pumpdown results in a sharp initial spike in the pressure trace, unlike the capacitance manometer, which showed no such spike. Slowing the pumpdown by using the bypass leads to a reduction in this spike. To show this, increase the time constant in several increments. Does the effect ever totally go away? Considering how the gauge operates, what effects other than turbulence might be having an influence on the indication? What is the gauge saying or not saying about turbulence in the rest of the system?

As noted above, convection effects lose dominance somewhere below 100 Torr. Evaluate this by pumping to increasingly lower pressures (400, 300, 200, 100, 75, etc.), holding at each of those pressures for a few seconds by closing the butterfly valve, then resuming fast pumping by quickly opening the valve. Note the amount of spike at the commencement of pumping and note where this effect becomes negligible. Discuss under what conditions this gauge would be a reliable indicator or control device.

Adiabatic Cooling

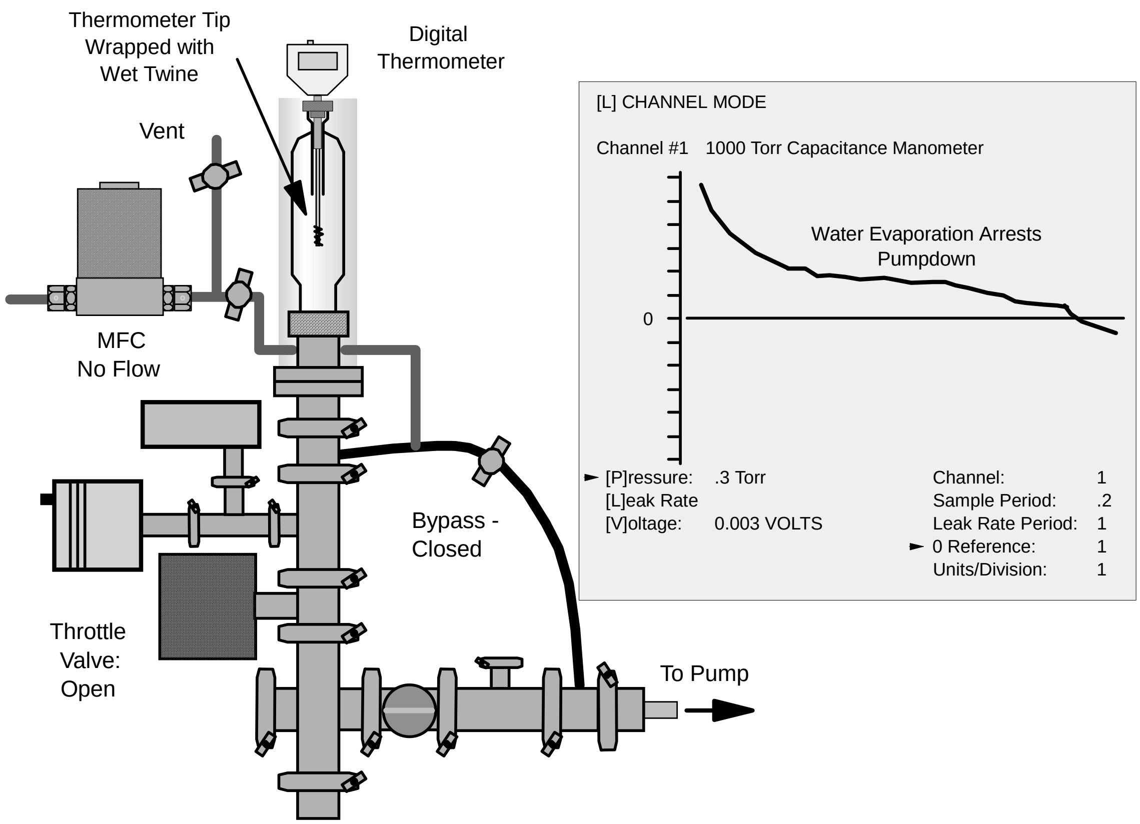


Figure 29: Adiabatic Cooling Exercise

This exercise shows the adiabatic cooling effect due to rapid evaporation of condensed moisture. The effect is seen in systems that contain moist air (for example loadlocks that may have drawn in some room air when the loadlock door was opened). Here we exaggerate the effect so that a measurable effect is seen on a wet-bulb thermometer whose probe is inserted into the vacuum chamber. (See Figure 4, page 23.)

Wrap a short length of fine cotton twine around the tip of the thermometer probe several times and secure it with a knot. Moisten the twine with water. If the pump has a gas ballast, operate the pump with the gas ballast valve open to minimize water condensation in the pump oil.

Immediately begin pumpdown with all downstream valves open. Note the drop in temperature as shown by the readout. Done properly, the temperature should go to about -20 °C, possibly lower. If the pressure versus time profile is displayed as shown in Figure 29, notice that the pumpdown becomes arrested and erratic at about 1 Torr. This is due to the rapid evaporation of water. During the process the water will probably freeze and the vapor will sublime from ice. When the water has dissipated, the pumpdown will continue normally to the system's base pressure and the temperature will rise. At this point, vent the system. The thermometer can be removed to show that it is quite cold.

Liquid crystal thermometers, though not usually available in low temperature reading ranges, are sensitive and show the effect with no added water. The type used on home aquariums work well.

Q=PS Exercise

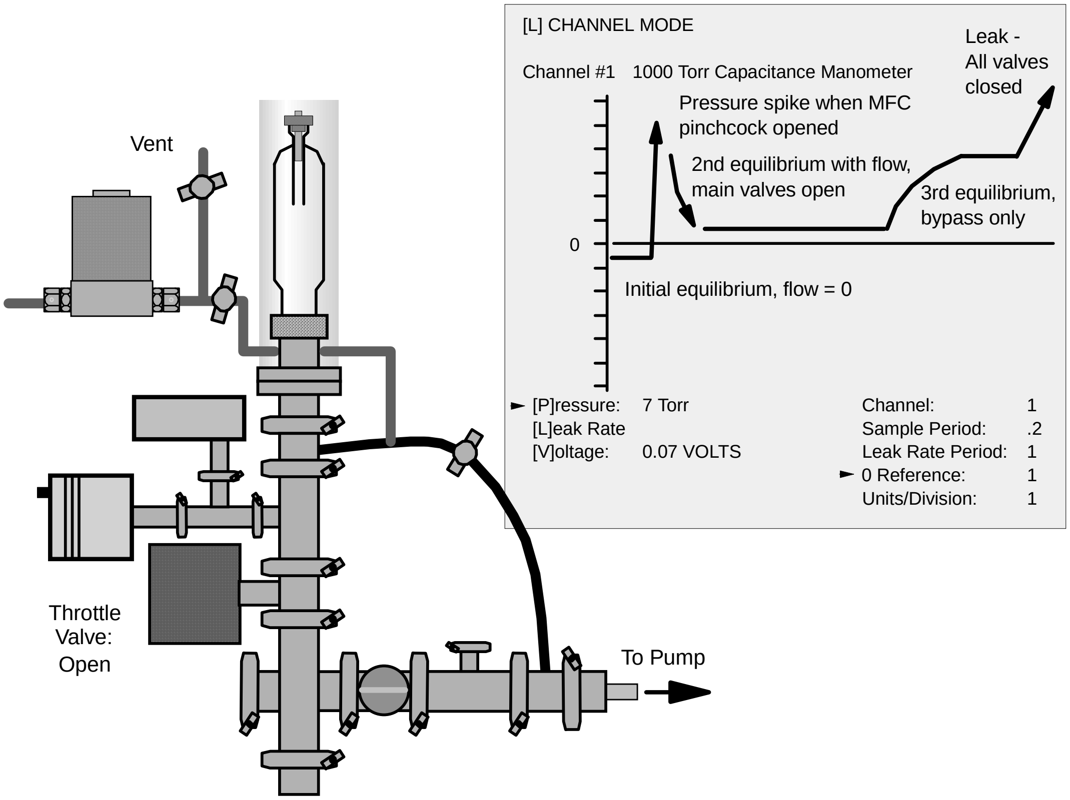


Figure 30: Q=PS Exercise

In this exercise we look at how the pressure in a system varies as controlled amounts of gas are introduced to the system. Using the relationship between throughput (Q) in Torr-liters/sec, pressure (in Torr) and pumping speed (in liters/sec), we can determine the effective pumping speed at the manifold.

With butterfly valves open, the bypass pinch clamp closed, the MFC flow set to about 40 sccm and the pinchcock on the MFC line to the chamber closed, pump the system to base pressure and note this initial equilibrium pressure. Make sure that the pressure has stabilized.

Release the pinch clamp and note the burst as the atmospheric pressure air between the MFC and the pinch cock enters the system. Such bursts can be detrimental to processes, as they push contaminants and particulate matter that may be in the lines into the process environment.

Once the system has stabilized again, note this second equilibrium pressure. Knowing the pressure rise (ΔP) and the Q from the MFC, calculate the effective pumping speed. You must convert from sccm to Torr-liters/sec. This effective speed represents the pumping speed at the point in the manifold to which the capacitance manometer is ported. Compare this to the speed rating of the pump from the manufacturer's data.

Now that we know the effective pumping speed, it is possible to calculate the gas load that resulted in the initial equilibrium pressure. The pressure rate-of-rise up leak technique (see page 44) can also be employed to determine if the gas load is from real leaks, virtual leaks, or a combination.

Next, close the butterfly valve and open the bypass pinch clamp slightly and note a third equilibrium pressure. Again calculate the effective pumping speed.

Finally, close both valves and note the linear pressure rise rate. This is characteristic of a constant mass flow (Q) into the system. The slope of the curve is used in the MFC mass flow verification exercises beginning on page 62.

Manual Pressure Control – Downstream

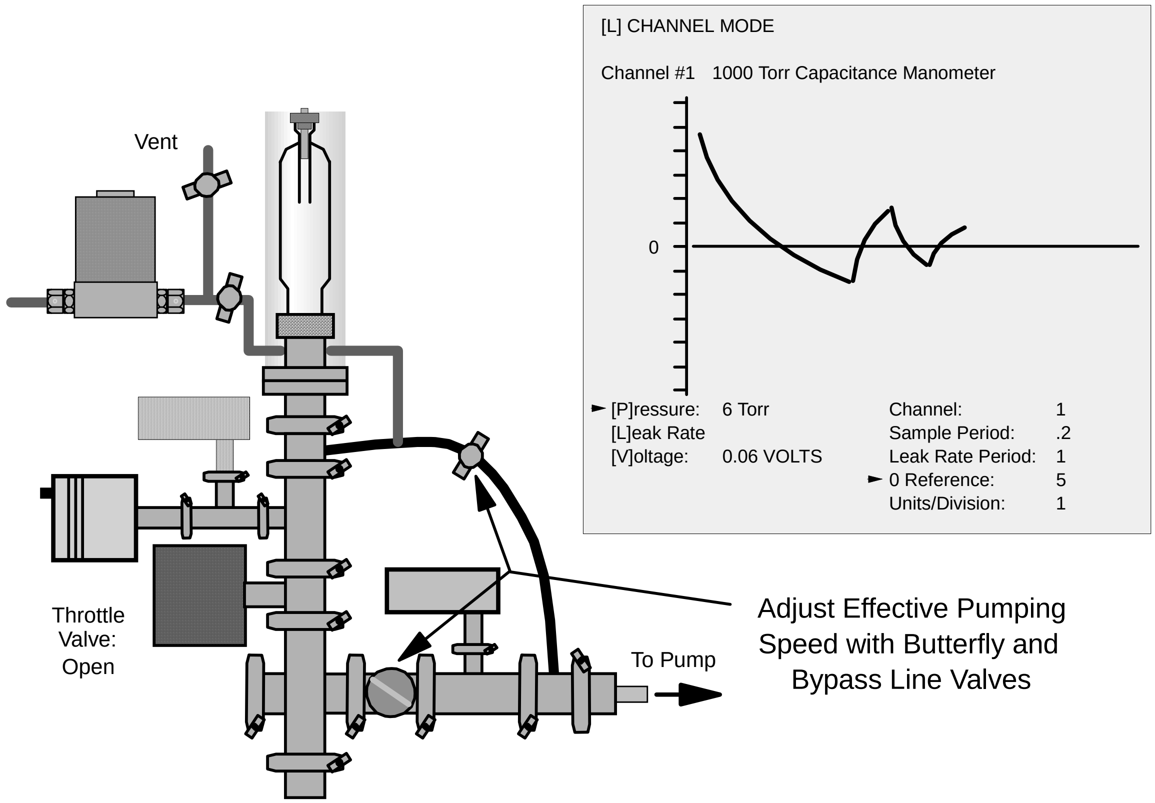


Figure 31: Downstream Manual Pressure Control

The purpose of this exercise is to manually acquire and maintain a set point pressure (for example 5 Torr) with manual downstream control. The configuration of the Vacuum Training System is shown in Figure 31. Set the MFC to flow 20 to 50 sccm. Display the [L] channel mode screen of the RTI as shown with the 0 reference set to the intended set point pressure. Begin with the bypass pinch clamp closed.

With these parameters, acquiring and maintaining the pressure with the butterfly is difficult, as the valve has to operate near its closed position. This illustrates the importance of properly sizing the control valves in a system. Next, use the bypass pinch clamp as the control element, with the manual butterfly closed. Under the given conditions of flow and set point, it is much easier to hold a steady pressure with the fine adjustment and lower conductance of the bypass/pinch clamp arrangement.

Note that the capacitance manometer, readout, valve operator, and valves form a simple closed-loop pressure control system.

Once the set point has been achieved and held for a while, stop adjusting the valves. Observe what happens to the pressure over a period of a few minutes.

If the Pirani gauge is moved to the lower port as shown, it is possible to read the downstream pressure and compare that to the pressure being controlled upstream of the control element. Note the pressure drop across the control valves.

Auto Pressure Control – Downstream

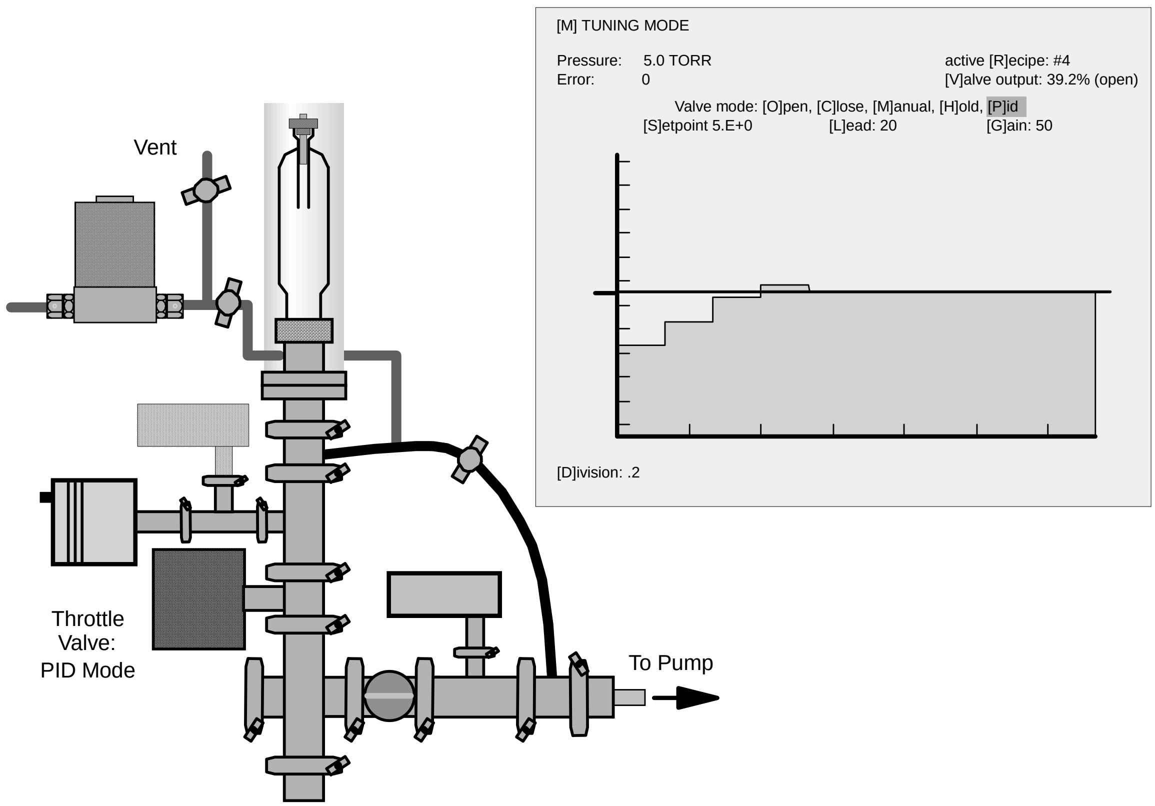


Figure 32: Downstream Auto Pressure Control

The system can be run in its closed-loop PID mode from the [M] Tuning Mode screen as shown in Figure 32. The flow controller should be set to at least 20 sccm. Pressure on the downstream side of the 153 valve can be monitored by placing the Pirani as shown. Start by pumping the system to base pressure with the Valve Mode set to [O]pen. Ensure that the bypass line is closed so all flow is through the throttle valve.

Command a pressure set point of 5 Torr and place the system in PID mode by entering [P]id. The system moves toward the set point pressure. The quickness, amount of overshoot (if any) and presence of oscillation depend on a number of factors, most notably the Lead and Gain settings. Try several other set points and tuning parameters, and observe the effects. Start with Lead and Gain settings of about 5 and 100 respectively. Pushing the gain to 500 should result in oscillation about the set point pressure.

Observe the valve output reading, which indicates % open. Nearly closing the manual butterfly, thereby reducing the effective pumping speed, results in the 153 valve opening more to achieve a given pressure. This makes the system more sensitive to oscillation at high gain settings.

With the system stabilized at a moderately high set point (e.g. 30 Torr), it is instructive to switch to the [L] Channel Mode screen and monitor the Pirani. This is at a lower pressure (by a few Torr), and if the pressure scale is at a high resolution (0.1 Torr/division), pressure fluctuations are seen.

Auto Pressure Control – Upstream

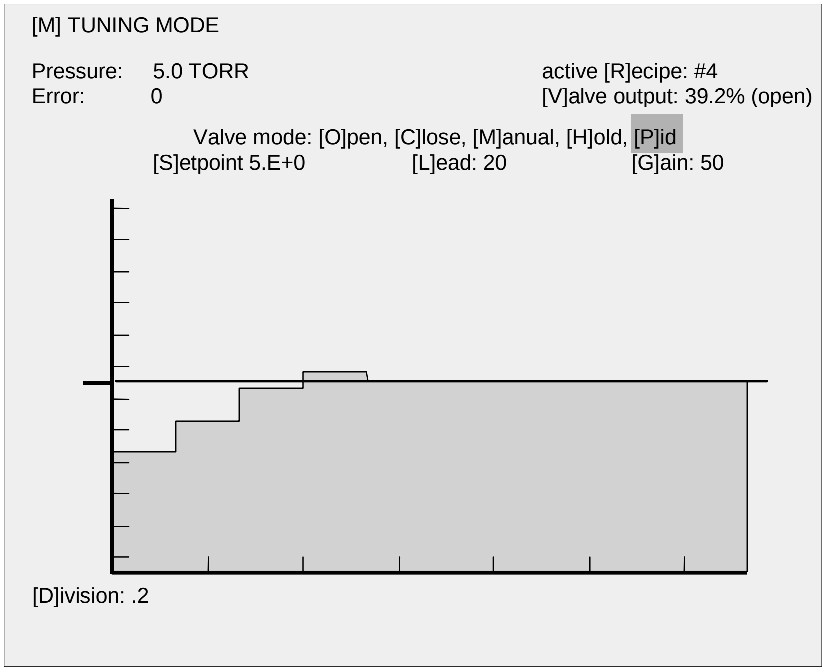


Figure 33: Upstream Auto Pressure Control

The system can be run in the upstream control mode using the proportioning valve in the MFC as the control element. Since the throttle valve is not used, disable it in the fully open position by setting the position switch on the valve to the "HOLD" position while the valve is open. If this is not done, the control signal will be sent to the MFC's valve and to the throttle valve.

To set up this mode:

25. On the [K] Setup Mode screen, change the MFC mode from SETPOINT to RATIO and the set point to "100."

    This takes the MFC out of its set point mode and places its valve in a pressure control function. The MFC's sensor now monitors flow but is not part of the control loop.

26. On the [M] Tuning Mode screen #2, change the polarity from DIRECT (downstream control) toREVERSE (upstream control).

Screen 1 of the [M] Tuning Mode is shown in Figure 33. Parameters can be adjusted as with downstream control, except that the valve output is the relative opening of the MFC's valve.

If the [L] Channel Mode screen is displayed with the channel set to 4 (MFC), the output of the flowmeter is plotted. Thus it is possible to see how the valve changes flow to maintain a constant pressure if, for example, the effective pumping speed is altered by partially closing the butterfly valve or by pumping through the bypass line. Various parameters such as tuning can be adjusted as per the downstream control exercise. (See page 54.)

Gauge Calibration - Gas Sensitivity with Indirect Gauges

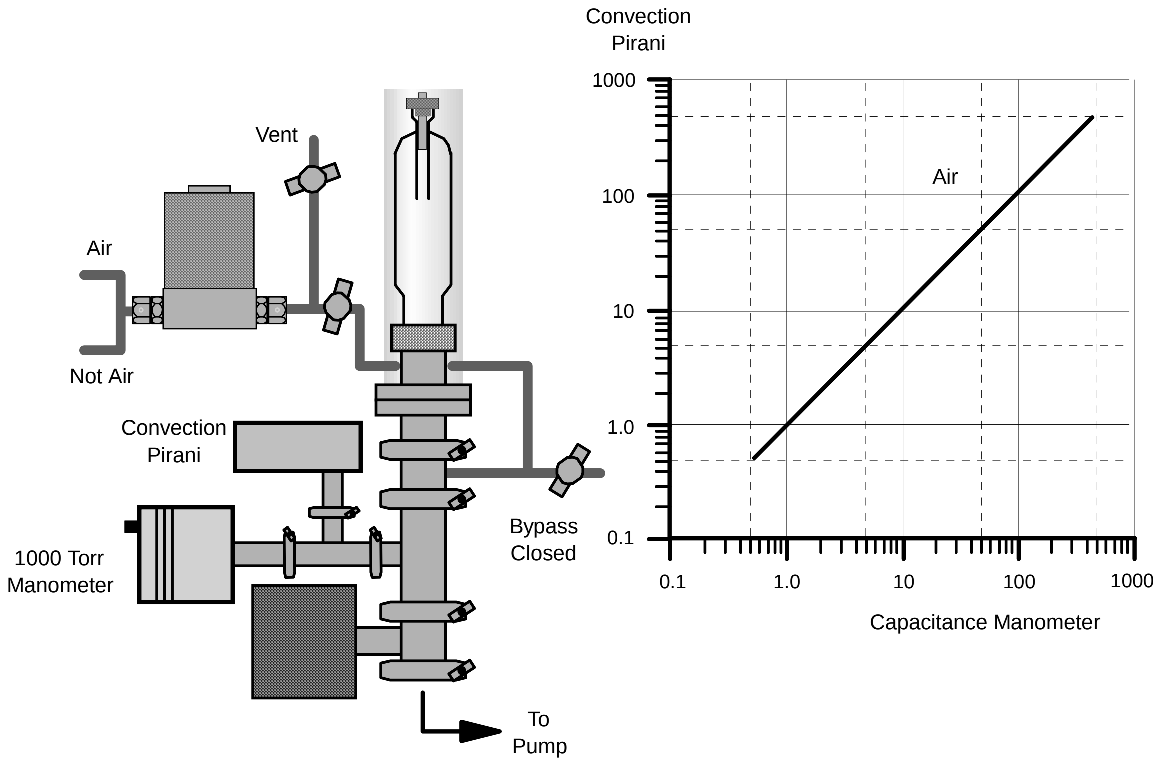


Figure 34: Gas Sensitivity Exercise

The objective is to compare an indirect reading gauge (in this case, the convection Pirani) to a direct reading capacitance manometer using air and with a gas dissimilar to air. The system is set to control pressure automatically using the capacitance manometer as the pressure measurement element of the control system. Either downstream or upstream control can be used, and each has its own characteristics over the pressure range that should be covered by this exercise (from about 0.1 to 500 Torr).

The first part of the exercise is to develop a capacitance manometer versus Pirani gauge calibration curve with air being fed through the MFC. Before starting, zero the capacitance manometer and span the Pirani to the capacitance manometer. (See page 44.)

Take data points at several pressures from 0.1 Torr to at least 500 Torr. Also record the transducer output voltage for each gauge. (You need to access the Channel Mode [L] screen of the RTI.) A plot similar to the one shown in Figure 34 will be developed. The worksheet on page 58 can be used for producing this plot. There will be some deviations from a straight-line 1:1 plot. The significance of these should be discussed.

Note how the capacitance manometer and Pirani gauge are mounted with respect to each other and to the system manifold. Is this positioning appropriate?

With another gas source connected (see page 58), repeat the exercise. Discuss under what initial conditions the system is best purged of air. Repeat the above procedure to develop the new curve.

A few additional items may be discussed:

- Did the curves cross over at any point? Remember that the convection Pirani has two distinct modes of operation (see page 48).
- How could an unsafe condition arise if one believed the Pirani gauge?
- What would be the general form of the curve for a light gas such as helium?
- How could the Pirani gauge be used to detect the ingress of a gas dissimilar tonitrogen/air?
- How did the pressure rate-of-rise with the alternative gas compare with that of air? (Note that the MFC is also an indirect instrument.)
- Develop a voltage versus pressure plot for each of the gauges. (Use a log-log scale for the capacitance manometer, semi-log for the Pirani gauge.) Is there a direct correspondence between pressure and output voltage for either or both of the gauges? From its plot, can you identify the two operating modes of the Pirani gauge (the molecular conduction mode and the convection mode)?
- In the convection mode the Pirani gauge is position sensitive. For proper operation, the gauge tube must be mounted with its reference line horizontal, otherwise the convection currents will not form properly. This can be demonstrated by removing the gauge from the system while at atmospheric pressure and changing its attitude. If the gauge is intentionally mounted in a non-horizontal attitude (done by rotating the connecting tee), can it be spanned properly?If it can be spanned, what happens to its accuracy across its reading range (as determined by comparison with the capacitance manometer)?
- The Type 722 capacitance manometer has an accuracy of 0.5% of reading. Discuss the effect of thison readings taken across the instrument's range.
- The capacitance manometer's zero is position sensitive as gravity exerts differing forces on the diaphragm depending on the instrument's attitude. This can be examined by removing theBaratron transducer from the tee and rotating it by hand. Note that position does not affect the calibration of a capacitance manometer (in terms of span and linearity), as long as it has been properly zeroed.

Warning **Under no circumstances should the Vacuum Training System be used with a toxic or hazardous gas.**

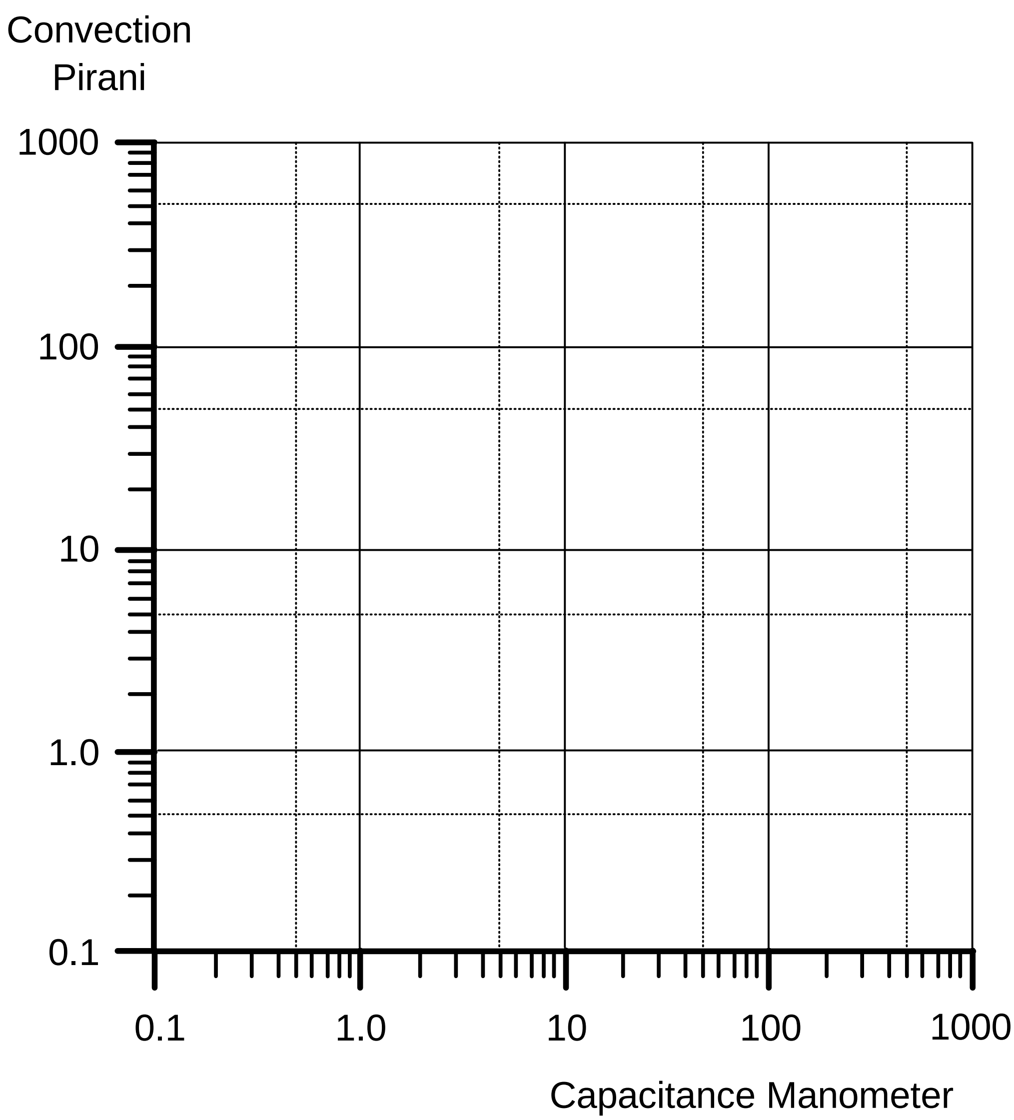


Figure 35: Worksheet for Gas Sensitivity Exercise

Simple Method for Supplying an Alternative Gas

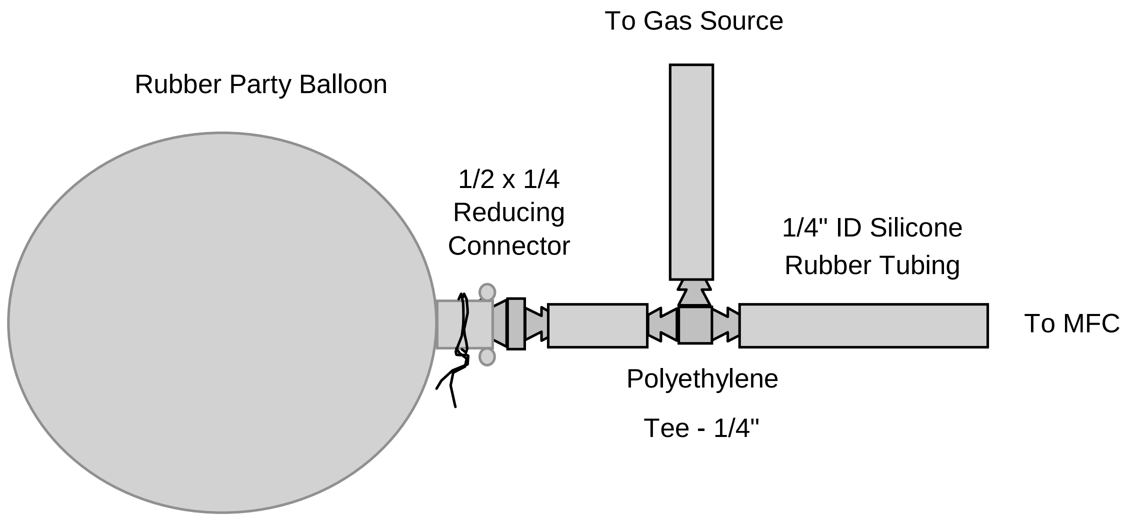


Figure 36: Alternative Gas Source

An alternative gas (other than air) can be supplied to the MFC using this simple scheme. This is convenient in terms of ease of setup and is quite satisfactory, given that the flow rates through the MFC are rather low.

Two “standard” gases that can be used in this setup include helium and argon. Simply bleed enough gas to partially inflate the balloon. Add more gas whenever the balloon begins to collapse.

A satisfactory and easy to use gas is the type of environmentally safe gas supplied in pressurized cans for removing dust from components and keyboards. One such material is 1,1,1,2 tetrafluoroethane, which Radio Shack sells under the name “Dust Remover Spray.” Radio Shack also has a valve/wand attachment that couples well to $^{1}/_{4}$-inch tubing. The Radio Shack part numbers are 64-4325 and 64-4343 respectively.

After attaching to the hardware shown in Figure 36 to the MFC, allow the gas to flow for about two minutes with the system under vacuum to purge the lines.

Using the Hot Cathode Ion Gauge

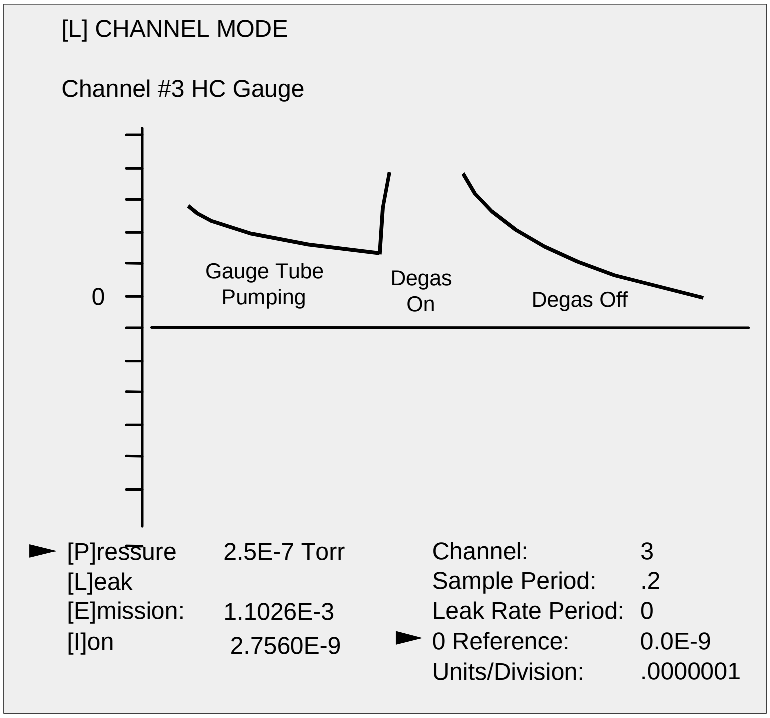


Figure 37: Hot Cathode Ion Gauge Channel

This exercise can only be performed with the VTS-1 system. The VTS-2 does not include the evacuated and sealed ion gauge tube.

The evacuated and sealed-off hot cathode ion gauge can be used to show general ion gauge operation, gauge sensitivities to attitude (relative positional shifting of the elements), gauge tube pumping, pressure rise due to degas, etc. In fact, the evacuated ion gauge is a small vacuum system unto itself with a pump (ion gauges pump at a speed of about 0.1 of a liter/sec), a contained quantity of adsorbed gas, and a means of measuring pressure.

To use the ion gauge, connect the supplied cable to the 146 instrument. The other end of the cable fastens to the gauge. The separate wire with clip connector is attached to the collector terminal at the top of the gauge.

Warning

The ion gauge is made of glass and is under vacuum. Handle it with care and wear safety glasses. Place the tube behind a clear plastic safety shield or mount the tube in a small enclosure with a plastic window for viewing the operation of the gauge.

When the gauge is activated the pressure should be in the range of the low to mid 10^{-6} Torr range. With use, the pressure will fall into the low 10^{-7} Torr range. Initiating the degas cycle will raise the pressure to the 10^{-5} Torr range. The pressure/time profile can be viewed on the [L] Channel Mode screen, shown in Figure 37. The parameters may vary from the settings shown in the illustration.

To avoid disrupting the RTI's display, the gauge can be operated from the front panel of the 146 instrument:

With the 146 instrument in Normal mode, turn on the gauge by pressing ON then "3".

To turn the gauge off, press OFF then "3".

To initiate the degas cycle:

27. Place the 146 instrument in Leakage Mode
28. Press DEGAS
29. Press ON
30. Press "3".

Stop degas by:

31. Press DEGAS
32. Press OFF
33. Press "3".

Caution **Do not degas the gauge for longer than 2 minutes, as it may overheat.**

Mass Flow Controller Flow Verification Using the Pressure Rate-of-Rise Technique

The pressure rate-of-rise technique is a proven method for calibrating mass flow instruments and verifying flow controller settings. The technique uses the relationship between throughput and the rate of rise of pressure as gas flows into a known, fixed volume.

Properly designed rate-of-rise calibration systems can achieve accuracies of 0.2% to 1.0%. Devices using the rate-of-rise technique include stand-alone calibration systems and dedicated instruments incorporated in a process tool's gas box.

In some process tools, a rate-of-rise system can be improvised by using the tool's pumps, process manometer and isolation valving. Owing to a number of factors such as volume and temperature variations, this is usually more of a consistency check as opposed to a precise calibration method.

This exercise is divided into three sections:

Section 1: Since the volume of the Vacuum Training System is unknown, we determine its volume by flowing gas at a known throughput into the manifold and observing the pressure change over a known period of time.

Section 2: With the flow controller set at an unknown rate, we determine that mass flow rate by observing the pressure rate-of-rise into the (now) known volume of the manifold.

Section 3: We determine the real flow of another gas, dissimilar to air/nitrogen, with a known nitrogen equivalent flow, then determine the gas correction factor (GCF) for that particular gas.

Since temperature deviations from standard conditions (0 °C) affect the results, we will monitor the prevailing temperature and compensate for the difference in the computations.

Volume Determination

$$V\text{ (liters)} = \frac{Q\text{ (sccm)}}{79}\left[\frac{273 + T}{273}\right]\left[\frac{t}{\Delta P}\right]$$

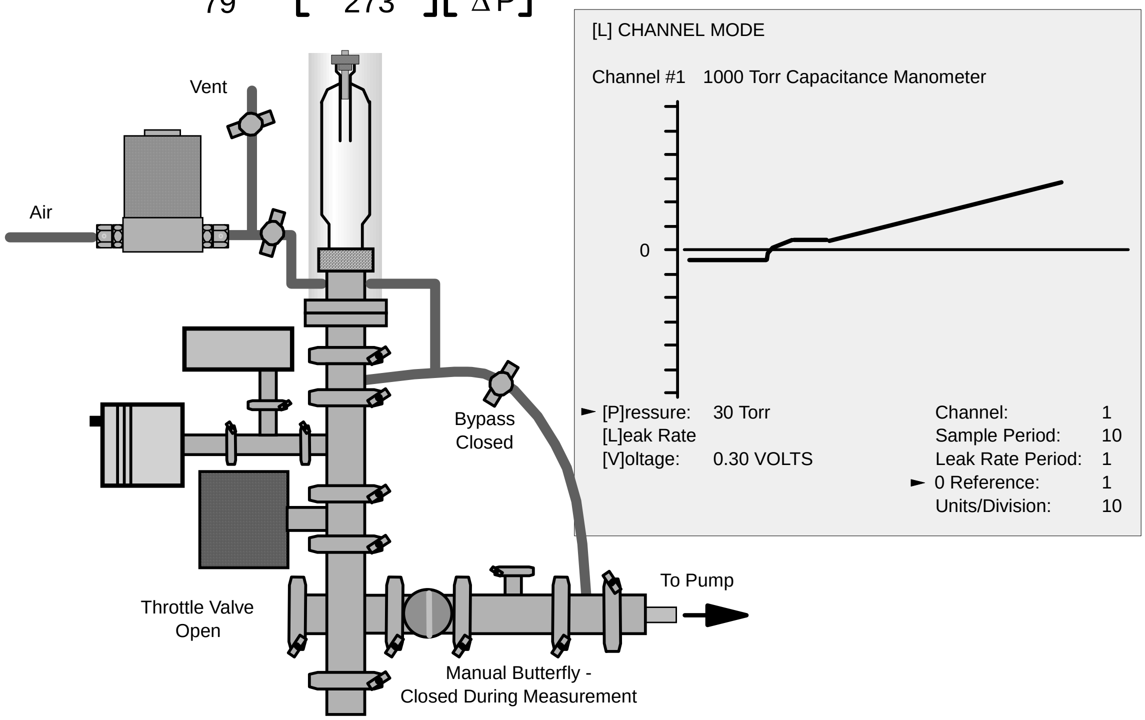


Figure 38: Volume Determination Exercise

In this first section we determine the volume of the chamber and that of the plumbing above the manual butterfly valve and back to the MFC. The result depends on the accuracy of the MFC. Discuss what other methodologies might be employed to ensure the accuracy of the volume measurement.

The equation used to calculate the volume is shown in Figure 38. Note that the equation is derived from the throughput relationship (Q=PS) with the added factors of temperature compensation and the conversion from sccm to T-l/sec.

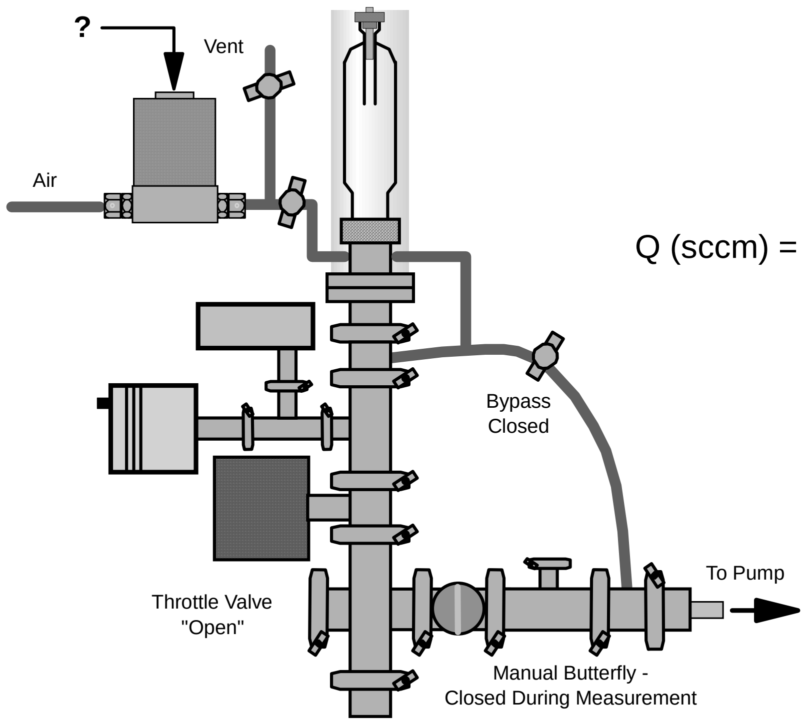
The system is run in manual mode with the 153 throttle valve open. Have the thermometer either near the chamber or, preferably, inserted into the chamber. Display the Channel Mode [L] screen to show the pressure rise characteristic. Perform the following steps:

34. Set the MFC to some flow at or above 50% of full scale and pump the system to its base pressure with the line from the MFC to the chamber closed.
35. When the system reaches its base pressure, close the butterfly valve and do an up leak check. (See page 44.) If the system has a negligible upleak, open the line from the MFC and allow the system to stabilize at the new base pressure.
36. Begin the measurement by closing the manual butterfly valve fully and observing the pressure rise curve. At some predetermined point, say at 5 or 10 Torr, note the pressure and begin timing.

37. After two to three minutes, record the final pressure and the elapsed time in seconds. Record the ambient temperature and perform the calculation. Does the calculated volume seem reasonable?

If the calculated volume is significantly different from previous calculations, check the computation or re-run the experiment. If the number is still different, the MFC may require servicing. Since this calculation affects the exercises in the next two sections, a previously calculated “correct” volume can be substituted. That serves to show the error associated with the MFC.

Flow Determination



$$Q\ (\text{sccm}) = 79 \left[\frac{273}{273 + T}\right]\left[V \frac{\Delta P}{t}\right]$$

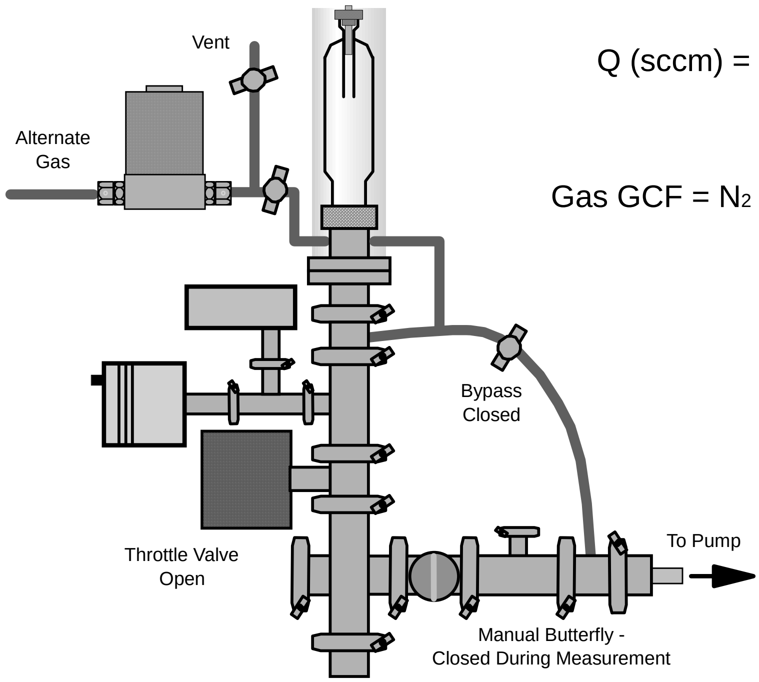
Figure 39: Flow Determination Exercise

Now that we know the volume, the next step is to figure out the flow rate with the MFC set to an unknown flow rate.

38. Set this flow to a value in the upper 50% of the MFC’s range.
39. Using the same procedure as described on page 63, compute the “unknown” flow in sccm using the equation shown above.

If the MFC is still in calibration, the number should come out to within about 1% of the set value. If the volume determination is a known error, substitute the correct value to get the true flow.

Determining a Gas Correction Factor



$$Q\ (sccm) = 79 \left[\frac{273}{273 + T}\right]\left[V \frac{\Delta P}{t}\right]$$

$$\text{Gas GCF} = N_2\ \text{GCF}\ (1.000) \times \frac{\text{Actual Flow}}{\text{Set Flow}}$$

Figure 40: Gas Correction Exercise

In this section, we look at the effect on the MFC when a gas other than air or nitrogen is used with the MFC. The result is an experimentally determined gas correction factor (GCF). The gas correction factor is the number that the set flow would be multiplied by, to get the true flow for a gas other than the gas used to calibrate the MFC (in this case, N_2).

With the Vacuum Training System configured as shown in Figure 40.

40. Connect an alternative gas source to the MFC (see page 59) and set the MFC to a known flow set point, preferably toward the upper end of the MFC's range. To ensure that the gas has reached the MFC's sensor, flow the gas for about 2 minutes before beginning the test.
41. Conduct the rate-of-rise test as was done in the prior section (page 64). Calculate the true flow and compute the gas correction factor (GCF) using the equation in Figure 40.

Discuss what characteristics of the MFC cause the gas to flow at a different rate from air or nitrogen.

Sizing Leaks

The usual units for leaks rates are Atm. cc/sec. This is essentially the same as the Std. cc/min (sccm) terminology used with the MFC except for the time unit (seconds versus minutes).

Previously we looked at the upleak rate as an indication of system leaks. The units provided by the 146 instrument are in Torr/sec. By knowing the volume of the system and by using the rate of rise equation from page 64, we can calculate system leak rates in terms of standard condition volumetric flow.

This exercise is done in several parts according to the following sequence:

42. Pump the system to base pressure with all downstream valves open and with no gas flowing through the MFC.
43. When the system has stabilized at its base pressure, close the manual butterfly valve, making sure that the bypass line is pinched closed.
44. Observe the rate of rise and calculate the leak rate in the range between base pressure (about 50 milliTorr) and a couple hundred milliTorr. Use the equation on page 64.
45. Let the system pressure continue to rise and perform a measurement in the range of two to three hundred milliTorr. Is the rate faster or slower than what was measured at the lower pressure?
46. If the pressure is still observed to rise, perform another measurement in the vicinity of 1 Torr.The leak rate should decrease at higher pressures, as most of the gas entering the system should be from outgassing of the elastomeric components, an effect most noticeable below 1 Torr.
47. Real leaks (leaks that are channels leading through the vacuum system wall from the outside world) can be simulated by laying a piece of fine wire, solid fiber (for example monofilamentfishing line) or even dental floss across one of the KF fitting O-rings. (Do not use wires of hard materials such as steel that could damage the fittings.) For this size system, pieces of wire or fiber 0.005 to 0.010 inch in diameter yield pressure rates-of-rise in the range of about 0.1 to 1.5 Torr per second. A piece of hair results in a pressure rate-of-rise of about 0.02 Torr per second. With a variety of such leak sources in place, determine the leak rates in Atm. cc/sec.

MFC Troubleshooting with a Breakout Connector

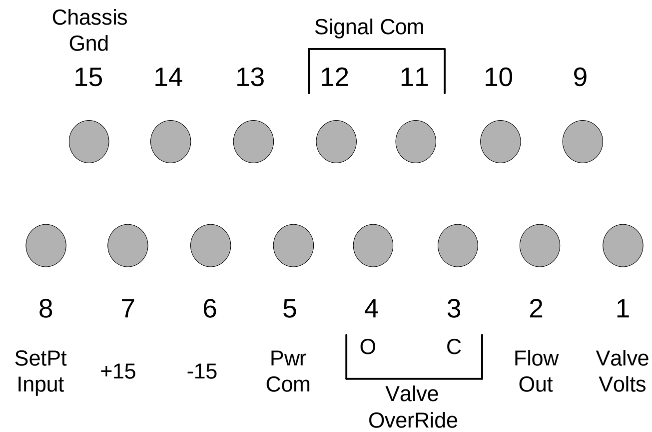


Figure 41: Breakout Connector Pinout

The purpose of this exercise is to become familiar with the use of a breakout connector and a voltmeter to perform simple diagnostics on a mass flow controller.

Figure 41 shows the pinout for the 1179 MFC supplied with the Vacuum Training System. Perform the following in sequence:

48. Check power supply voltages against the manufacturer's specification.
49. Zero the MFC with inlet and outlet tubes clamped. (See page 46)
50. With vacuum applied to the downstream side of the MFC, check the following voltages at 0, 25, 50, 75, 100 sccm as set points: set point input voltage, flow meter output voltage, valve voltage. Discuss the meaning and importance of each parameter.

Next, introduce a problem. The class should repeat the above characterization and, using the troubleshooting guide provided with the MFC manual, discuss the problem.

One problem that can be introduced is a slight leak through the MFC with the device set for zero flow. This can be accomplished by backing off the valve preload adjustment (see the 1179 manual for details). Partial clogging can be simulated by introducing a flow constrictor before the MFC. A simple arrangement is detailed on page 68.

MFC Troubleshooting - Flow Constriction

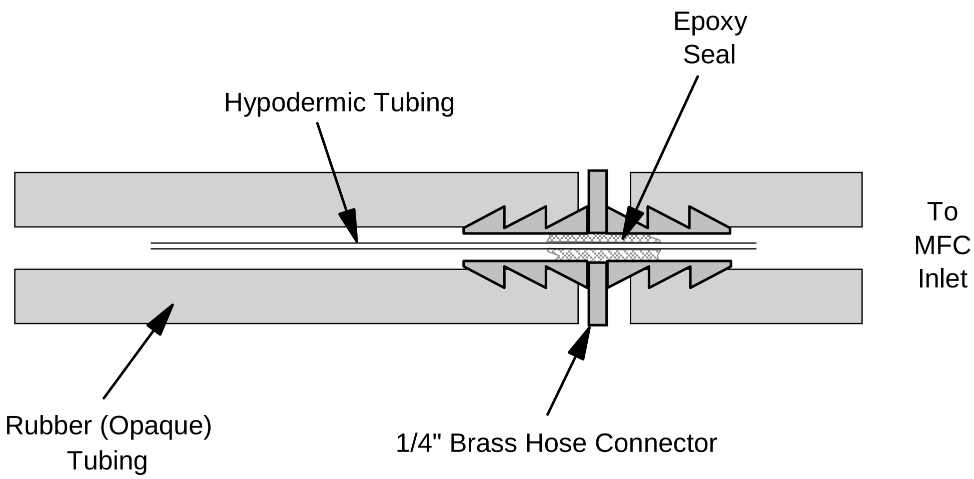


Figure 42: Flow Constriction Device

Here we introduce an abnormality in the form of an upstream flow constriction. Real examples of this could include a partially clogged inline filter or a barely open upstream isolation valve. Similar effects are seen when the internal passageways of an MFC become partially clogged.

The constrictor is a modified barbed hose connector placed in the inlet line. In the connector there is inserted a piece of 27 gauge (0.008" inside diameter) hypodermic tubing*.

With the constrictor in place notice that the MFC performs properly at the lower flow settings. However, as 50 sccm is approached, the valve has to open wider to permit more flow. Over 50 sccm, the valve moves to the full open position (indicated by a valve voltage near 0) and the flow meter reading indicates that higher set points are not achievable. It may be necessary to shorten the tube so that the flow begins to limit somewhat above 50 sccm.

Once the voltage measurements have been made, discuss what the symptoms might indicate.

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* Suitable tubes may be obtained from Small Parts Inc., 13980 N.W. 58th Court, Miami Lakes, FL 33014, 1-800-220-4242. A stock 6" length (catalog number E-HTX-27-6) will limit the flow to about 50 sccm.

Locating Leaks

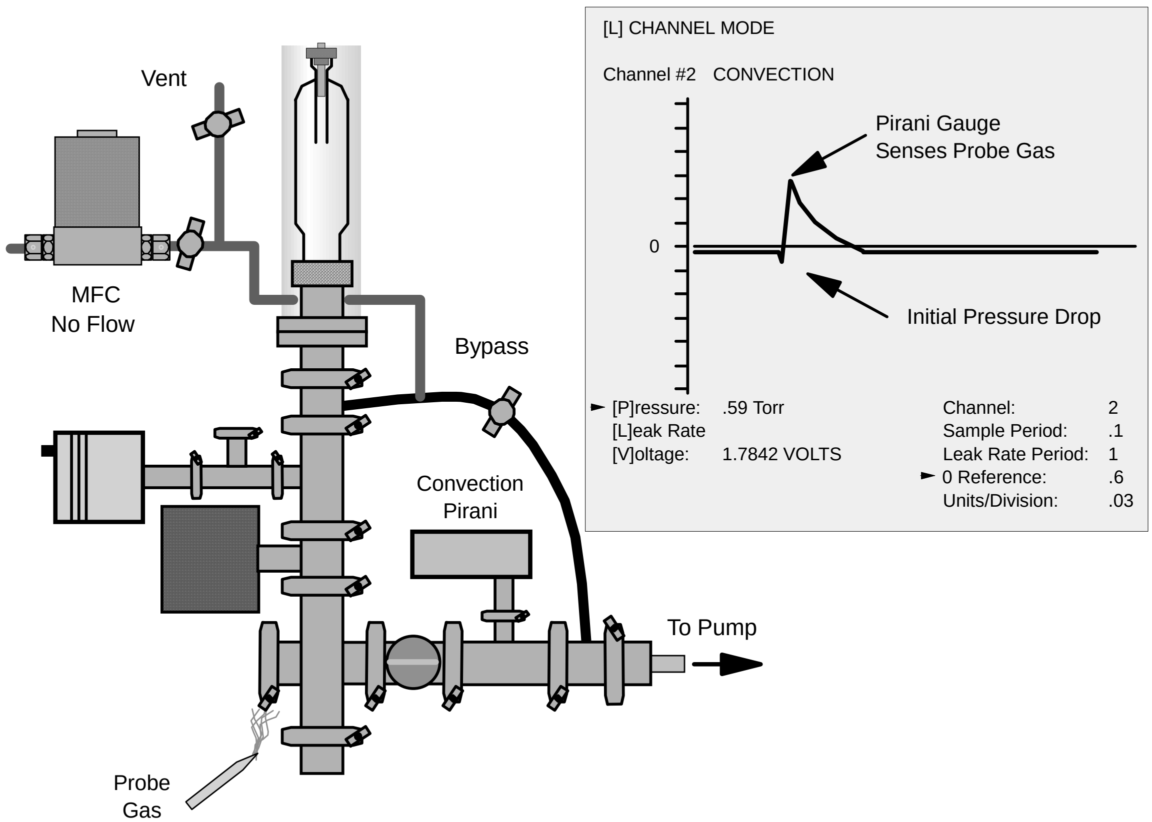

Figure 43: Leak Detection Using the Pirani gauge

From the exercise *Sizing Leaks*, page 66, we learned that the rate-of-rise technique could be used to assess the total amount of leakage. However, this method does not locate the leak. To find the leak, a common procedure is to spray each likely leak source with a probe gas such as helium. With a detector sensitive to the probe gas located downstream of the area where the leak might be, an indication is given when the leaked probe gas reaches the detector. The standard method for detecting very fine leaks is to use a helium mass spectrometer leak detector (MSLD). In our system we can exploit the gas sensitivity of the Pirani gauge to perform the same function. While the Pirani gauge cannot detect very fine leaks (its limit is in the range of $1x10^{-4}$ Atm. cc/sec), it is a useful and convenient procedure, given that many systems incorporate Pirani gauges and a substantial fraction of leaks encountered fall within the range that the Pirani can detect.

For this exercise, locate the Pirani gauge on the lower KF16 port as shown in Figure 43. One or two leaks can be introduced into the system by placing fine copper wires (5 to 10 mil diameter) across a similar number of O-rings as explained on page 66. While helium can be the probe gas, it may be more convenient to use the “Dust Remover Spray” as described on page 58.

Once the system has reached its base pressure, assess the presence of a real leak by performing a rate-of-rise test as detailed on page 44. Referring to page 66, the size of the leak can also be assessed.

After competing the rate of rise test, return the system to its base pressure by opening the butterfly valve. Monitor the Pirani using the Channel Mode screen as shown in Figure 43. Set the Reference value to the steady state pressure reading of the Pirani and increase the sensitivity to about 0.03 Torr per division.

Begin the leak detection process by placing the applicator nozzle close to a fitting and *gently* puffing some gas into the area of the clamp opening. Observe the pressure display while doing this. Move from connector to connector noting any seals where a pressure deviation is indicated.

The order that the seals are tested is important. In general, proceed from the area farthest from the pump and sensor, moving downstream one connector at a time. Since the dust remover gas is heavier than air, be careful that the gas sprayed on one connector doesn't just sink to a lower connector where the leak might be. When leak detecting on a vertical assembly, if the gas is heavier than air, start at the bottom and move up. With helium, which is lighter than air, the normal procedure is to go from top to bottom.

With the dust remover spray, a leak shows a positive deviation, provided that the base pressure of the system is below a few Torr. (Refer to the calibration table generated during the *Gas Sensitivity Exercise* on page 56.) A slightly negative initial deviation might also occur. This is due to the large size of the 1,1,1,2 tetrafluoroethane molecules as compared with air molecules. When the gas is introduced, it reduces the leak rate thereby causing the real system pressure to drop. When the gas infiltrates the Pirani sensor shortly after its first introduction, the positive response of the Pirani swamps the slight pressure drop. This real drop can be verified by monitoring the pressure with the capacitance manometer.

When all leaks have been located, vent the system, disassemble the offending connections, remove the wires, reassemble and recheck.

Outgassing and Permeation

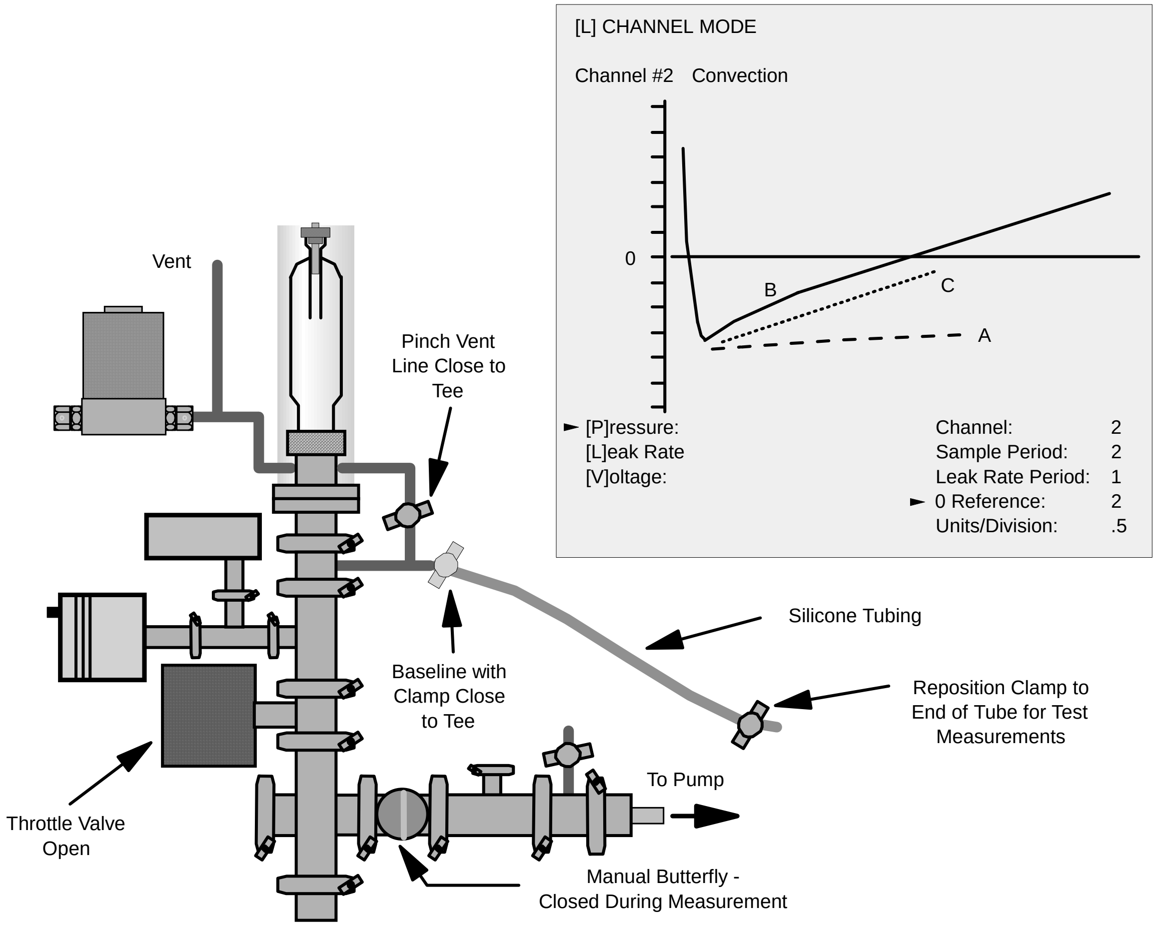

Figure 44: Observing Outgassing and Permeation

Now we examine two properties of elastomeric materials that limit their usefulness in vacuum systems. The first property is the propensity of the material to evolve gases contained on the surface or in the bulk of the elastomer. This is termed outgassing. The second characteristic is the degree to which gases can be transmitted through the bulk of the elastomer. This is termed permeation. While all materials exhibit permeation and outgassing, polymeric materials are particularly prone to these effects. Furthermore, different polymers show differing characteristics with regard to these effects.

In this exercise we look at the outgassing and permeation of gases from and through a piece of tubing connected to the system. These behave like leaks, in that they add gas to the system. A simple pressure rate-of-rise test can be used to observe both phenomena.

Set up the apparatus as shown in Figure 44. In place of the bypass line, attach a 2-foot piece of silicone tubing. This piece of tubing should have been exposed to atmosphere (inside and out) for at least one hour before running the experiment.

First, we establish a baseline. For this, pinch the tubing as close as possible to the connecting tee.

Use the Pirani gauge as opposed to the 1000 Torr capacitance manometer to monitor the pressure. This provides better resolution at the lower pressures. Set up the [L] Channel Mode screen as shown in Figure 44, on page 71.

To perform the baseline test, pump the system to its base pressure. When the pressure starts to level off (after about 1 minute), close the butterfly valve and observe the pressure rise. You should see a trace similar to that of (A) in Figure 44. Record and plot the data for a period of about 10 minutes. Return the system to atmosphere.

Now move the pinch clamp to the other end of the silicone tubing. This demonstrates the rate-of-rise change due to the added length of tubing. Pump the system down, closing the butterfly valve as soon as the pressure starts to level off. Record and plot the data for another period of 10 minutes; it should create a trace similar to that of (B) in Figure 44.

Notice that the trace has two components: an initial fast rise followed by a slower, fairly linear ramp. The initial fast rise is due mostly to outgassing. The linear region is predominantly due to permeation of external air through the tube. This occurs at a constant rate.

The outgassing can be minimized by repumping the system and holding it at base pressure for at least 15 minutes. If we now close the butterfly valve and observe the rate-of-rise, a trace like that of (C) of Figure 44 is seen. The initial fast rise (outgassing) is no longer present (to the same degree) but the slow, linear signature of permeation is still evident. When the outgassing effect disappears, the slopes of the curves (B) and (C) should also be similar, indicating that permeation is not affected by degassing under vacuum.

Different elastomers have widely varying characteristics with regards to outgassing and permeation. Silicone is an example of a poor material from this standpoint. (However, it also has a number of good chemical and physical characteristics that make tradeoffs necessary under some circumstances.)

This test can be repeated using other elastomers. The Norprene tubing supplied with the system and clear PVC tubing (obtainable from local hardware stores) are useful candidates.

Glow Discharge, Cold Cathode Electron Gun

This section describes a set of accessories that can be put together to make a simple cold cathode electron gun and plasma source that can be used to illustrate the appearance of the glow discharge at various pressures, the formation of electron beams at low pressures, and the changing color of the plasma with changes in the composition of the residual gas in the system.

The "gun" is the 3/8" diameter aluminum rod supplied with the system. A hole at one end accepts a standard banana plug.

The next section describes how to construct a phosphor screen assembly that detects the electron beam. The remaining sections cover use of the apparatus in a number of demonstrations.

Assembly

Obtain the following components (refer to Figure 45):

- Steel shaft collar - 7/8" inside diameter x 1½" outside diameter
- ⅛" diameter brass rod - 7½" long
- Brass Sheet – ¾" wide x 2½" long x 0.015" thick (approx.)
- Short length of #14 gauge bare copper wire
- Soft solder (2% silver-tin recommended)
- Phosphor screen material

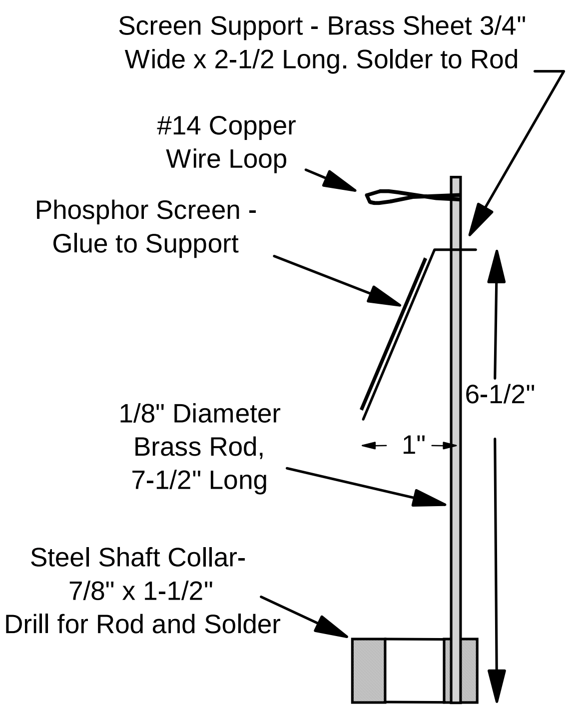

Figure 45: Screen Assembly

The phosphor screen can be obtained in 5 x 7 inch sheets from MCI Optonix Inc., P.O. Box 1, Cedar Knolls, NJ 07927, (800) 678-6649. The particular material (Type PFG) is a high output, green emitting cadmium sulfide (CdS) screen normally used in x-ray fluoroscopes. The phosphor is encapsulated in the plastic sheet and is therefore easy to handle. However, since the phosphor is cadmium-based, the manufacturer recommends cutting only in a well ventilated area and washing your hands after handling.

Fabrication and assembly steps are as follows:

51. Drill the collar to accept the brass rod. Locate the holes as close as possible to the center hole. Be sure that the holes do not interfere with the set screw. Solder the rod in place.
52. Drill a ⅛" hole in the brass sheet, centered approximately ¾" from one end. With the brass rod supported in a horizontal position, insert the rod into the hole. Position the sheet

6½" from the collar-end of the rod and align the sheet with the collar. Solder the sheet in place and bend as shown in Figure 45.

53. Cut a piece of phosphor screen approximately ¾" x 2" and fasten it to the brass sheet using contact cement or a similar adhesive.
54. Fashion a narrow loop from a piece of #14 bare copper wire and solder to the end of the brass rod as shown.
55. Remove any solder flux residue with a suitable solvent and mount the completed assembly in the chamber as shown in Figure 46. The set screw can be reversed and used to hold the collar in position just below the lower end of the glass chamber.

The power source must be a current limited induction coil that can produce a negative high voltage pulsed output. A suitable unit is the ID 200ST from Electro-Technic Products, Inc. (4644 N. Ravenswood Ave., Chicago, IL 60640, (312) 561-2349). On this unit the output voltage is adjustable and the polarities of the two output terminals can be switched with a toggle switch. These are made specifically for school use and are sold through school science equipment suppliers such as Frey Scientific.

Connect the negative high voltage lead to the aluminum electrode using a short length of well insulated wire (automotive ignition coil wire is satisfactory). The positive terminal must be grounded and that wire must also be attached between the coil and the CF flange as shown in Figure 46.

The next sections describe the various experiments that can be performed with this set up.

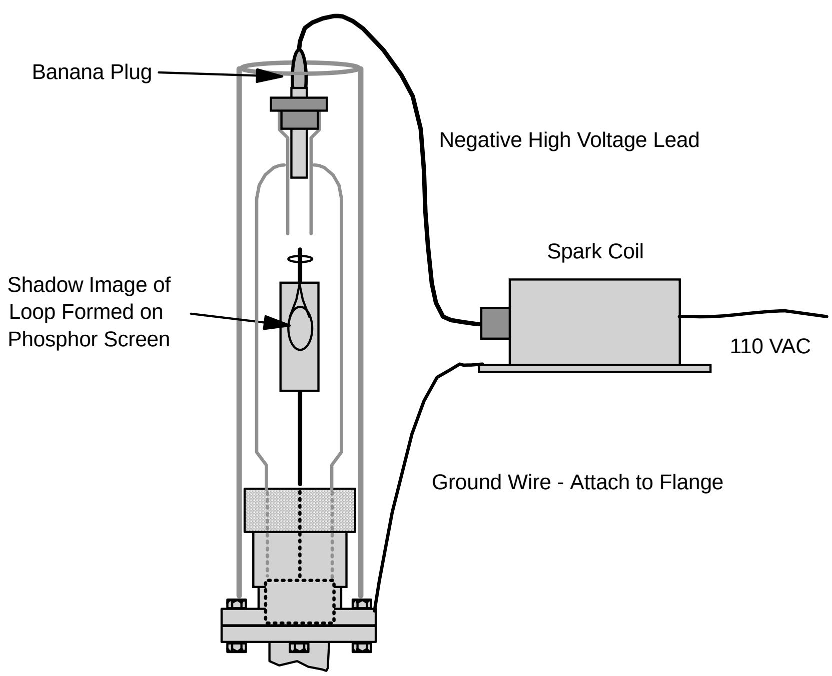

Figure 46: Cold Cathode Electron Tube Assembly

The Glow Discharge at Varying Pressure, Effects of Increasing Mean Free Path

In this exercise we look at the formation and appearance of a glow discharge plasma at varying pressures and the effects of increasing mean free path as pressures decline. This exercise is best done in a partially darkened room.

Set up the chamber as shown in Figure 46 on page 74. The Vacuum Training System should initially be operated in manual mode with no flow through the MFC. Since we will be looking at visual effects as the pressure in the chamber decreases, it is also best to slow pump the chamber by closing the manual butterfly valve and pumping through the partially constricted bypass line. The 146 unit should be set to show Channel 2 (Pirani gauge) in the main display. This provides the best resolution in the pressure range from 50 Torr down to the system base pressure.

Once the system has been set up, turn on the spark coil, then start the pump. At first, as the pressure begins to decline, the chamber remains dark. However, as the pressure begins to approach about 40 Torr, a series of streamers should appear, passing between the cathode rod and the top of the phosphor screen support. Note how the discharge is confined to the shortest path between electrodes. At this point the mean free path is long enough to permit sufficient electron-molecule interactions to produce the plasma, but not long enough to provide enough mobility for the electrons and ions to move from this direct path.

As the pressure falls below about 10 Torr, the discharge should become more diffuse, filling the volume of the small glass tube in the chamber. At this point the discharge is still fairly bright and remains generally confined to the space between electrodes.

As the pressure dips below about 1 Torr, the discharge becomes dimmer and starts to fill the entire volume of the chamber. At this point the phosphor screen should begin to glow a greenish color. This indicates that the mean free path has increased sufficiently for the accelerated electrons to move past the upper end of the screen support structure and impinge on the screen. Also note the various brighter and dimmer regions in the discharge column. These striations (bright disk-like areas associated with the positive region of the discharge) and the dimmer spaces near the cathode are associated with the glow discharge at low pressures. The appearance, especially the width of the “dark” region near the cathode, is a rough indicator of pressure and has been used as a primitive pressure gauge.

Finally, as the pressure gets to about 0.3 to 0.5 Torr, an image of the wire loop emerges on the phosphor screen. Now, not only are the electrons impinging on the screen, but the mean free path has increased so there is a well collimated beam of electrons that can form a clear shadow image. This illustrates why long mean free paths (hence low pressures) are required to produce well focused, crisp beams in such devices as cathode ray tubes, electron microscopes and particle accelerators.

As the pressure further declines, the sound of the spark coil mayget louder. This corresponds to the voltage across the electrodes increasing. This is because, at lower pressures, there are fewer electron-molecule interactions, hence a less dense and more electrically resistive plasma is formed. If the system is clean and well sealed, the discharge becomes erratic and very faint as the base pressure is approached.

Effect of a Magnetic Field

Note the pressure where the image of the wire loop on the phosphor is well defined and bright. Turn off the spark coil and return the system to atmospheric pressure. Now change the system's operating mode to closed-loop pressure control (see page 54). Ensure that the bypass line is fully closed and the manual butterfly is fully opened. Since we are controlling the pressure in the range of 0.4 to 0.6 Torr, the MFC's set point should be fairly low, just a few sccm at most. The pressure can be controlled using either the Pirani gauge or the capacitance manometer.

Start the pump and turn on the spark coil when the pressure has stabilized at the set point. Bring a small magnet near the chamber, in proximity to the phosphor screen. Note that the magnetic field moves the electron beam and, therefore, the shadow image of the wire loop. Since electrons are moving charged particles, they are influenced by magnetic fields. (Electrons are also influenced by electrostatic fields, an effect not demonstrated in this exercise. The same applies to the positive ions. However their motions are not detectable with the phosphor.)

The predictable effect magnetic and electric fields have on the trajectories of moving electrons and ions is key to the operation of cathode ray tubes, ion implanters, electron microscopes, particle accelerators, and residual gas analyzers, for example.

Coloration of the Discharge

The "color" of the glow discharge is caused by the activation of the gases in the chamber. The red-purple seen in this example is due to nitrogen, the dominant gas in the system. At very low pressures, it might be noted that the discharge turns more whitish. This is due to the prevalence of water vapor as the residual gas in the system. This effect can be amplified by deliberately placing a couple drops of water on the chamber wall before pumping.

If a source of one or more inert gases is available (such as helium or argon), add these gases, one at a time, to the system to observe the different colors. Just as the appearance of the glow discharge has been used as a semi-quantitative indicator of pressure, so can the discharge color be used as an indicator of what gases are dominant in the system. "Neon" signs are simple discharge tubes and one type of sign acquires its distinctive color from the types of gas contained in the sign tubes. The other variety of neon sign uses a phosphor coating on the inside of the sign tube that glows when bombarded by ultraviolet energy. The ultraviolet radiation is produced by the glow discharge when the tube contains a small amount of mercury vapor. As we have seen, the cadmium sulfide phosphor glows green when bombarded by electrons. The same happens with exposure to ultraviolet radiation.

Chapter Five: Installing the High Vacuum and RGA Upgrades

Introduction

The capabilities of the basic Vacuum Training System can be expanded by adding the High Vacuum Modification Package (MKS p/n 121344-G1 for the VTS-1, MKS p/n 121344-G2 for the VTS-2). These component kits include all of the necessary fittings, isolation and roughing valves, and gauging to permit incorporation of a small turbomolecular pump in the MKS Vacuum Training System.

The greatest benefit of high vacuum capability is realized by adding a quadrupole residual gas analyzer (RGA) to the system. This chapter details the installation of the High Vacuum Modification Package and the recommended RGA, an MKS Partial Pressure Transducer (PPT). Also covered are issues related to the selection of the high vacuum pump and procedures for operating the system with and without the RGA.

Mechanical Assembly

This section describes how to assemble the high vacuum system and RGA add-on options and integrate them with the Vacuum Training System. Since the options can be mounted and assembled in several ways, it is important to read the *entire* chapter before starting the installation.

High Vacuum Manifold

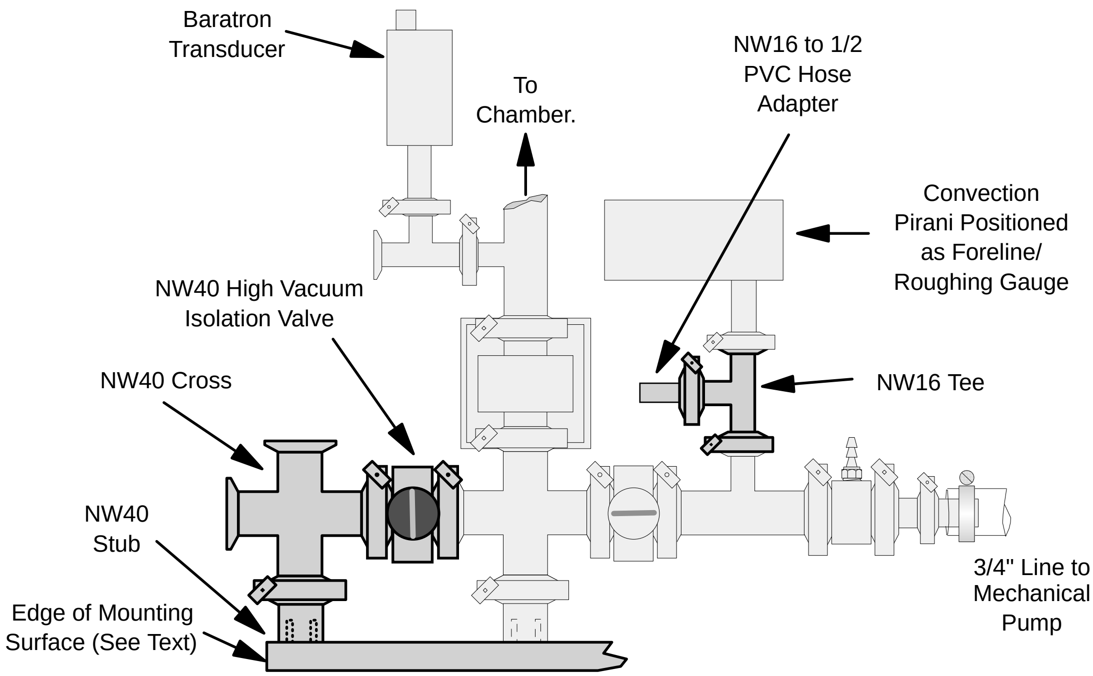

Figure 47: Beginning the Assembly of the High Vacuum Manifold

Assemble the components shown in Figure 47. You also need one center ring and wing nut clamp for each connection. Existing VTS-1 or VTS-2 system components are shown in light gray.

The NW40 stub is attached to the mounting surface using 1/4-20 hardware. The distance from the existing stub is set by the high vacuum butterfly valve and the NW40 cross. Figure 47 shows the stub near the edge of the mounting surface. This position is required if the high vacuum pump is located below the level of the mounting surface, for example if the pump only operates in a vertical attitude. If other attitudes are possible, all of the components can be located above the mounting surface. The instructions that follow assume a vertical attitude for the pump. However, alternatives are suggested.

Note that the Baratron and Pirani gauges have been repositioned on the system. The Pirani is used for monitoring the high vacuum pump's foreline pressure. The NW16 tee with the hose adapter, below the Pirani, is used to connect this part of the manifold to the high vacuum pump outlet.

Now assemble the manual high vacuum vent valve and filter as shown in Figure 48 on page 79. Seal the 1/4-inch pipe threads with epoxy as described on page 20. The in-line filter contains a sintered brass element that limits the entry of small particles. To operate the vent, loosen the O-ring sealed cap a couple of turns. This permits a slow entry of air into the system. There is no need to remove the cap. Closing the vent is accomplished by tightening the cap, finger-tight only. This manual vent is optional if your high vacuum pump is equipped with a mid-stage vent valve (a highly desirable feature).

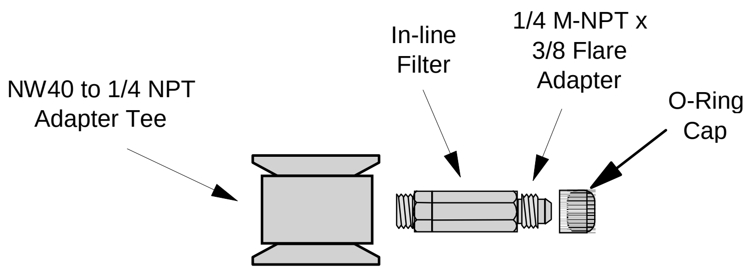

Figure 48: Assembly of the Manual Vent

Adding the High Vacuum Components

Now we add another NW40 cross, high vacuum ion gauge, turbo pump and RGA. Referring to Figure 49, the manual vent and another NW40 cross is added to the left of the previously installed components. This cross is the coupling point for the pump, gauge and RGA. The figure shows the components mounted in a vertical attitude. If this is inconvenient and if the pump can be mounted horizontally, an acceptable alternative would be to turn the cross 90 degrees, and swap the positions of the pump and ion gauge. The RGA is now parallel to the mounting surface.

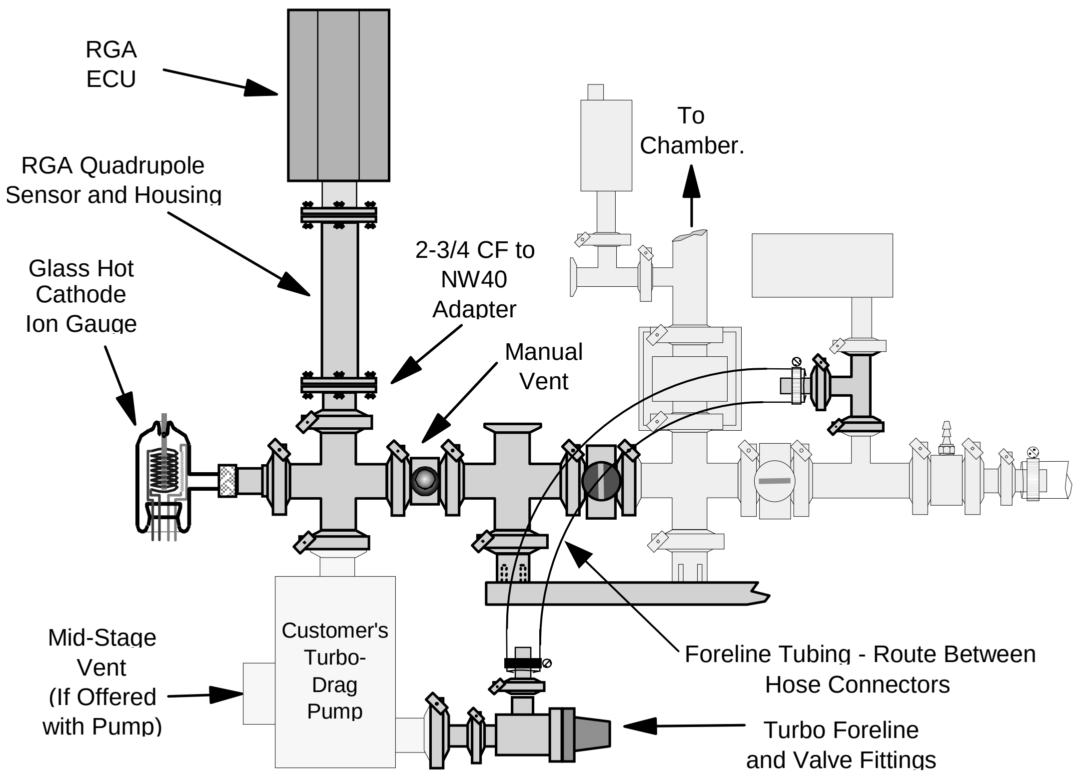

Figure 49: Adding the High Vacuum Components

The glass ion gauge is connected to its port with a ¾-inch compression adapter. The CE compliant nude ion gauge is attached directly to the cross with itsNW40 flange. Your turbo pump may have an NW40 inlet fitting. If not, an adapter with associated hardware may be necessary to couple the pump to the manifold. Contact MKS Instruments for an appropriate adapter.

If the pump is available with an integral mid-stage vent, the separate manual vent can be omitted. Mid-stage vents are usually manual O-ring sealed valves. A very convenient option is an automatic vent that derives its control signal from the pump's power converter. These valves provide a soft vent timed to open only when the pump's motor drops below a given speed.

Fittings provided for the pump's outlet include NW16 hardware (butterfly valve, 90 degree angle and adapter for ½-inch PVC hose). This fits most small turbo pumps. An NW25 to NW16 adapter is provided if the pump has an NW25 connection.

Mount the turbo pump to the desired port and in an attitude that provides a reasonably direct path from the turbo foreline port to the NW16 tee by the Pirani gauge. Then connect the ½-inch PVC hose fittings with a length of ½-inch wire reinforced hose. In the configuration shown (Figure 49 on page 79), the NW16 tee can be rotated rearward so the hose passes just behind the manifold, under the 153 throttle valve.

Installing the RGA Sensor and Sampling System

The RGA's sensor is supplied in a protective package. Follow the instructions in the RGA's manual to unpack the sensor and install it in the vacuum housing. The vacuum housing has 2¾-inch CF fittings. Use an NW40 adapter as shown to attach the sensor to the NW40 cross.

If the system is used without the RGA, place blank flanges on the open ports (two NW40 ports and the NW16 adjacent to the Baratron). If an RGA is used, add the sampling port.

The sampling port is used with the system in a differential pumping configuration. The "process" side of the system (the basic VTS-1 or VTS-2 system) is operated at medium vacuum conditions while the high vacuum side of the instrument is operated under the conditions necessary for proper operation of the RGA, (a pressure under 1×10^{-4} Torr). The sampling system consists of a 100 micron diameter orifice (MKS p/n 401574-P1) placed between the two sides of the system. Gases from the higher pressure side of the system are drawn into the high vacuum side where they can be analyzed with the RGA. The orifice is sized so there is a sufficient flow of gases to permit a usable level of sensitivity but a low enough flow so the pressure does not rise over the 1×10^{-4} Torr operational limit of the RGA.

The sampling system is shown in Figure 50 on page 81. First, install the hose adapters in the NW16 fittings. Use epoxy cement to seal the threads as described on page 20. The orifice is made from a blank Swagelok 4-VCR® gasket. Center the orifice on the face of one VCR fitting, and thread the other into it. Tighten finger tight, then apply wrenches to each nut and tighten an eighth of a turn. Cut a piece of eighth-inch clear plastic tubing about six inches long, and slip a plastic tube clamp over it. Push each end of the tubing over a hose connector. Install the completed assembly on the system with clamps and center rings.

At this point, the system should look like Figure 51, on page 81.

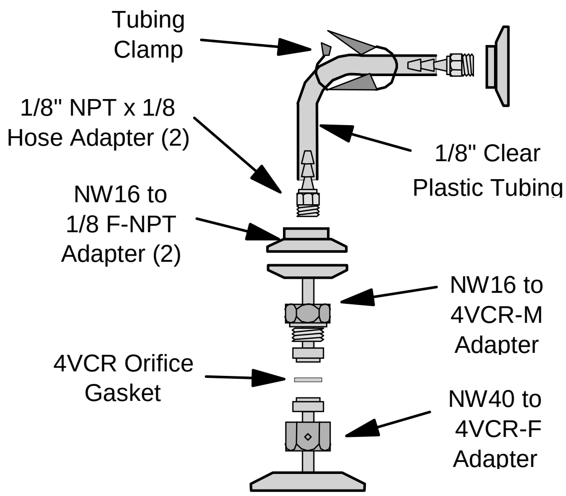

Figure 50: Sampling System

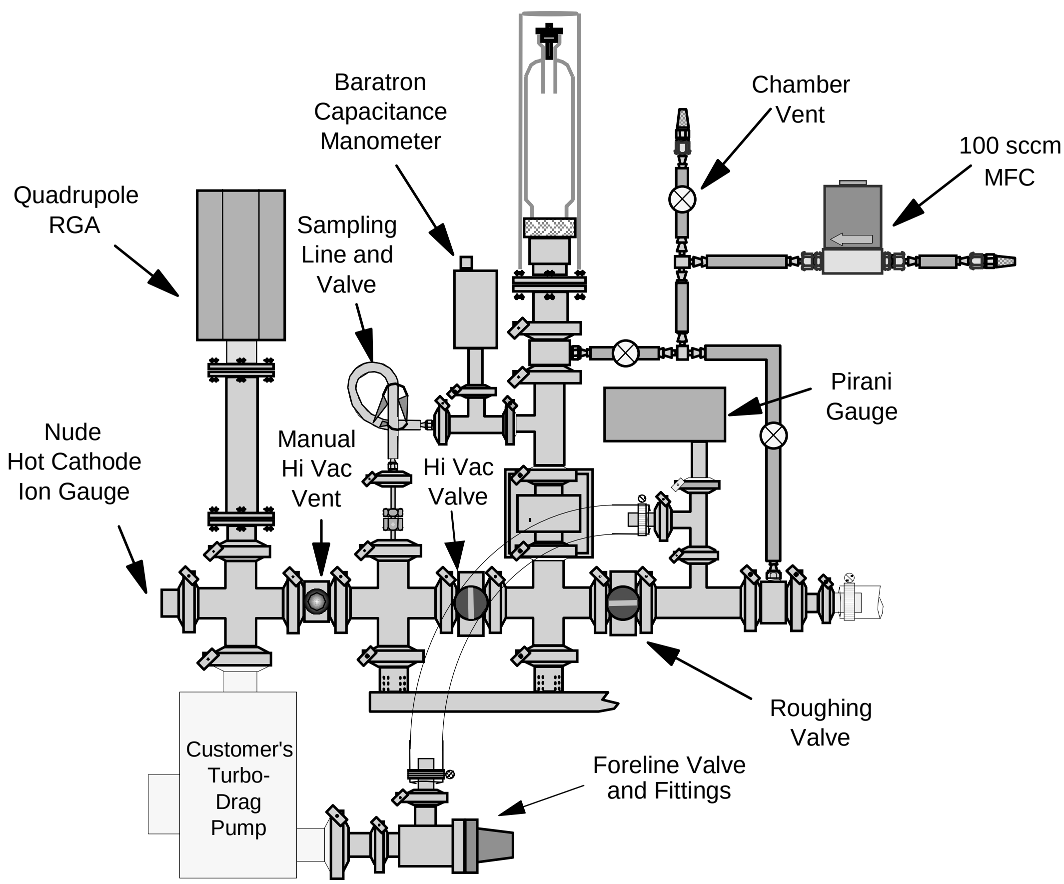

Figure 51: Fully Assembled System (CE Compliant Version)

A Note on Selecting a High Vacuum Pump

The primary factors that drive pump selection (other than cost) are pump speed, inlet pressure range and outlet (foreline) pressure tolerance.

With regard to speed, there is no need to use a pump of high capacity: the design of the manifold above the inlet of the pump limits the conductance to approximately ten to twenty liters/second.

With regard to the latter issues, to take full advantage of the Vacuum Training System's differential pumping capability along with moderate flows of gas into the system through the MFC, the pump should be able to tolerate moderately high inlet and foreline pressures. For example, with only 2 sccm flowing into the chamber, the turbo inlet is at about 1 milliTorr and the foreline is somewhere above 100 milliTorr. These conditions are at the upper limit for most "pure" turbomolecular pumps.

To provide a greater degree of operational flexibility and reliability, use a combined turbomolecular/ drag, or hybrid, pump. The pumps used on our in-house systems are the TMH 065 model manufactured by Pfeiffer Vacuum Technology, Inc. (24 Trafalgar Square, Nashua, NH 03063, 603-578-6500). This pump is rated at 30 liters/sec (N_2), can tolerate a foreline pressure of up to 13.5 Torr and maintains a useful pumping speed up to an inlet pressure of about 100 mTorr. The pump has a midstage vent and can be equipped with an automatic vent valve. The pump is available with an ISO-KF40 inlet flange.

Similar pumps are made by other manufacturers.

Many pumps have a standby mode that considerably reduces rotor speed. This lowers the compression ratio and, hence, the pumping performance. However, it reduces the pump's susceptibility to damage from bumping, improper venting, etc. You may find that the standby mode represents a good trade-off between reliability and performance in a classroom setting.

General Operating Procedures for Pumpdown and Venting

This section describes the system operating procedures. Refer to Figure 51, on page 81 for valve nomenclature and locations.

A typical VTS-1 or VTS-2 system in classroom use should achieve a pressure below the mid 10^{-5} Torr range after about 15 minutes of pumping. Closing the pinch valve closest to the chamber limits the amount of exposed elastomer, which helps attain a good base pressure. With the high vacuum valve closed, pressure should quickly fall below 1×10^{-5} Torr. Additional pumping will get the high vacuum section to about 1×10^{-6} Torr.

Be sure to familiarize yourself with your high vacuum pump by reading its instruction manual before running the system.

Initial Pumping of the Entire System

Follow this procedure for initial pumpdown with all parts of the system at atmospheric pressure. The chamber is roughed through the turbo pump.

56. Close the roughing valve and open the foreline and high vacuum valves. Ensure that the vent valves are closed.
57. Start the mechanical pump. Monitor the pressure as indicated on the Pirani gauge. If the pressure is dropping satisfactorily, start the turbo pump.
58. Continue to monitor the Pirani gauge, ensuring that the pressure drops below the recommended maximum forepressure for the high vacuum pump.
59. When the pump has come up to speed (usually indicated by a green light on the pump's controller), turn on the ion gauge to monitor the pressure on the high vacuum side of the system.

Vent with High Vacuum Pump Running

The chamber can be brought back to atmosphere without stopping the turbo pump. The area to the left of the high vacuum valve will remain under high vacuum conditions.

60. Close the high vacuum valve. Ensure that the sampling line pinch clamp is closed.
61. Close the roughing valve. The mechanical pump is now isolated from the chamber.
62. Vent the chamber using its vent pinch valve.

Repump the Chamber to High Vacuum

To return the chamber to high vacuum when the turbo pump is still running and isolated from the chamber area:

63. Close the chamber vent valve.
64. Close the foreline valve. This keeps the outlet of the high vacuum pump at a low enough pressure for the pump to continue working while the chamber is roughed.
65. Open the roughing valve. When the pressure drops below the maximum forepressure rating of the turbo pump, close the roughing valve and open the foreline valve.
66. Turn off the ion gauge.
67. Open the high vacuum valve to pump the entire system.
68. Turn on the ion gauge.

Using Pressure Control

The pressure in the chamber can be controlled using downstream or upstream control while pumping with the high vacuum pump. This is useful when the chamber pressure must be brought lower than the range attainable using just the mechanical pump. Only a low flow of gas through the MFC is required (or tolerable) when controlling in the range of about 10 milliTorr to 1 Torr. A flow of 2 to 10 sccm is appropriate for the downstream control mode.

Since the capacitance manometer has a resolution of 0.1 Torr, attempting to control below or near the resolution limit is difficult. There are two alternatives: swap the capacitance manometer and Pirani gauge and control with the Pirani (remember it is gas sensitive). Or, acquire a lower range capacitance manometer and use it. A 10 Torr full scale device would be a good choice.

The following procedure assumes that the turbo inlet is at high vacuum:

69. Open the high vacuum valve and close the roughing valve. The foreline valve is open.
70. Turn the ion gauge off as the pressure in this region of the system will rise above one milliTorronce gas has begun to flow.
71. Follow the procedure on page 54 for downstream control or the procedure on page 55 for upstream pressure control.

Differential Pumping (Sampling)

The differential pumping mode permits use of the RGA to analyze the residual gases in the chamber when the chamber is running at or above the foreline pressure. This occurs when the chamber is operated independently of the high vacuum pump, usually when gas is flowing though the MFC and the chamber is being operated in a closed-loop pressure control mode. In this mode, the high vacuum side is connected to the chamber through the 100 micron sampling orifice. With this orifice, the chamber pressure can be brought to over one Torr while maintaining a proper high vacuum environment at the RGA’s sensor. The following assumes that the turbo inlet is at high vacuum:

72. Close the high vacuum valve (if open). The foreline and roughing valves are open.
73. Open the pinch clamp on the sampling line. Monitor the ion gauge to ensure that the high vacuum section stays under 1×10^{-4} Torr.
74. Gases can be introduced with the MFC at this point and chamber pressure can be controlled by downstream (see page 54) or upstream (see page 55) control. Monitor the Pirani gauge to ensure that the maximum forepressure of the high vacuum pump is not exceeded.

Pressure Control: Setting Parameters from the 146 Unit's Front Panel

When controlling the chamber pressure in closed-loop mode, your computer is probably dedicated to the task of running the RGA, and is unavailable to operate the 146 unit. In this case, the 146 unit can be operated from its front panel. Assuming operation in downstream control mode, use the following procedures to set the MFC flow rate, and recipe values for pressure set point and tuning parameters:

75. Change MFC Flow Set Point:
    A. Repeatedly press the [DISPLAY MODE] key until the 146 is in Setup Mode.
    B. Use the arrow keys to scroll to the CODE legend.
    C. Enter the number 174 (assuming the MFC is on channel 4) and press the [ENTER] key.
    D. Enter the flow rate (probably in the range of 2 to 10 sccm) and press the [ENTER] key.
76. Edit Recipe (Lead, Gain, Set Point):
    A. Repeatedly press the [DISPLAY MODE] key until the 146 unit is in Tuning Mode.
    B. Enter the number of the recipe to be created or edited (1-4).
    C. Press the [OFF/GAIN] key and enter a value for Gain (0.001 to 10,000). Press [ENTER].
    D. Press the [ON/LEAD] key and enter a value for Lead (0.001 to 1000 seconds). Press [ENTER].
    E. Press the [DEGAS/SET POINT] key and enter a value for the set point. Press [ENTER].
77. Return the 146 unit to Normal Mode by repeatedly pressing the [DISPLAY MODE] key. When the display does not show a mode label, you are in Normal Mode (it does not show **TUNING**, **LEAKAGE** or **SETUP**).

Vent and Shut Down

Follow this procedure to vent the system from high vacuum and shut the system down.

The primary situations to avoid are a sudden inrush of air while the turbo pump is running at full speed and oil backup from the mechanical pump. With regard to the former, some turbo pumps are more susceptible than others to catastrophic failure due to repeated venting during operation. It is good practice to vent slowly while the pump is slowing down. Consult the pump manufacturer's operating manual for any special procedures or cautions. Concerning the latter, while oil backup in the manifold is only an inconvenience, entry of oil into the turbo requires disassembly and cleaning of the pump. The design of the manifold makes the possibility of oil getting into the turbo quite small; oil is usually confined to the connecting tubing from the mechanical pump and the first cross. For further details, review the information on page 45.

78. Close the high vacuum valve (if open) and close the foreline valve. The roughing valve is be open.
79. Turn the ion gauge off.
80. Turn off the turbo pump. Keep the mechanical pump running.
81. Open the manual high vacuum vent valve just enough for air to slowly bleed into the system. If the turbo is equipped with an automatic midstage vent valve, the controller takes care of the high vacuum vent process. In this case the manual high vacuum vent should be left closed.
82. Close the mechanical pump's isolation valve, if provided, and vent the chamber side of the system by opening the chamber vent. Turn off the mechanical pump and open its isolation valve. If the mechanical pump does not have an isolation valve, turn off the pump and immediately vent the chamber.
83. Keep the foreline and high vacuum valves closed until the system is used again.

Chapter Six: Exercises Using the RGA

Introduction

The MKS Partial Pressure Transducer (PPT) utilizes Quadrupole Mass Analyzer technology to provide an instrument compatible with semiconductor production environments. The MKS PPT RGA can display data in numerous formats including analog, bar graph and pressure versus time. The exercises in this chapter introduce the student to each of these formats. While the examples assume the use of a 100 amu (atomic mass unit) PPT with MKS' PPT for DOS software, they generally apply to other RGAs that could be coupled to the Vacuum Training System.

The mass scans shown in this chapter are derived from actual scans taken in the same situations as described in the text. These scans should be representative of what the student observes in a classroom situation.

Initial Set Up

Detailed set up procedures are found in the manual for the PPT and are not repeated here except in the brief overview that follows.

To start the RGA unit, first ensure that the power to the Electronic Control Unit (ECU) is on, the proper RS-232 cable is attached between the ECU and the computer's RS-232 communication port, and that the appropriate level of vacuum ($<1 \times 10^{-4}$ Torr) has been obtained around the PPT sensor assembly as measured by the ion gauge.

The PPT is controlled with a DOS program, currently at revision level 4.30. This software should be stored on your computer's hard drive in a subdirectory. To start the software, switch to the subdirectory, type PPT at the prompt and press [enter]. This activates the PPT software. If the RS-232 port on the computer is properly connected to the ECU, the software should start. If you hear three beeps and see a "Communication Fail" message in the upper right hand section of the software screen, the ECU is not communicating with the computer. If communication is not established, the first areas to test are the communication cable connection and configuration. If no problems are found there, check the communication port configuration on the computer and in the PPT configuration software. Refer to the PPT Operation Manual for more information on the PPT software configuration specifications.

Once the software is running, the PPT's filament can be started by pressing the F1 function key. After a slight delay a Total Pressure reading is displayed in the upper right corner of the display screen. If a Total Pressure reading is not observed, check to ensure that the PPT sensor's environment does not exceed the maximum pressure and that the PPT's filament is intact. The PPT Operation Manual contains detailed information on how to test the PPT's filament assembly.

With the PPT operating, we proceed to the exercises.

The Mass Scan in Analog Mode

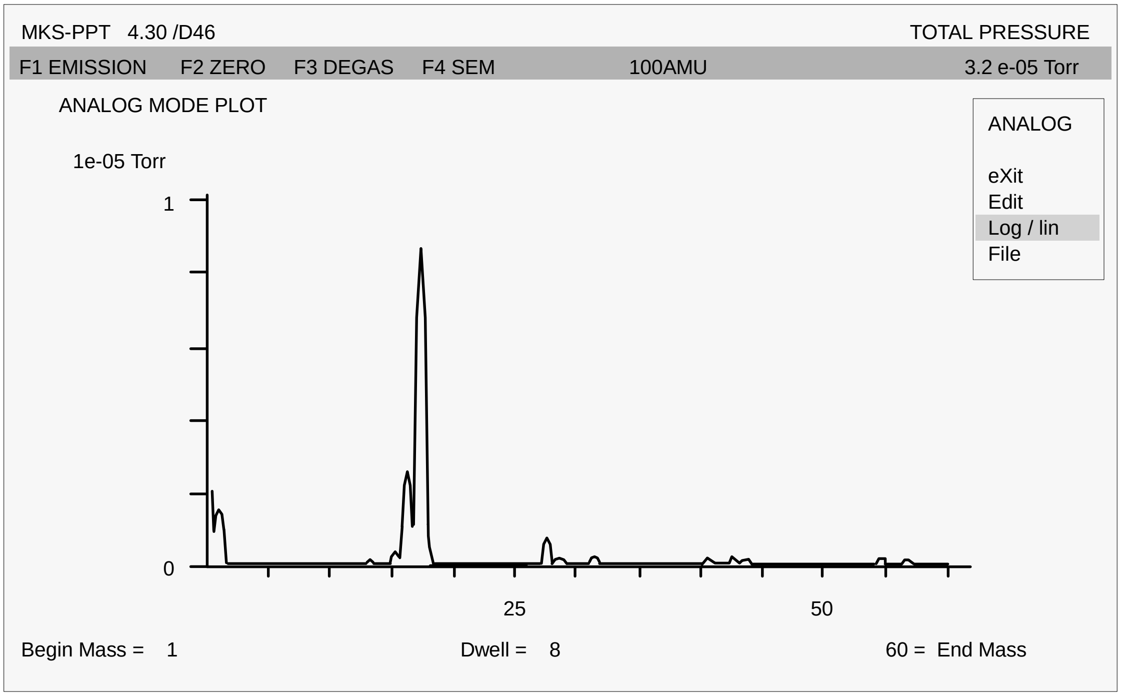

Figure 52: Analog Mode Mass Scan with Linear Pressure Scale

This exercise is best done soon after pumping the system from atmosphere. When pumping, configure the VTS-1 system so the entire system, including chamber, is under high vacuum (see page 83, *Initial Pumping of the Entire System*). The roughing valve should be closed and the high vacuum valve should be open. Ensure that no gas is flowing through the MFC.

With the system below 1 x 10^{-4} Torr and with the PPT's filament turned on, activate the Analog Mode by using the cursor keys to highlight the Analog option on the main menu. When Analog is highlighted, press the [enter] key. This brings up the Analog plot. Now press the F2 function key to start the mass scan. The data begins displaying on the screen. The vertical axis scaling can be changed by selecting the Log/lin menu option and pressing the [enter] key. Repeating this results in cycling through several levels of y-axis logarithmic displays before returning to a linear display format.

Select the Analog Mode with a linear pressure scale. You should observe a scan similar to that of Figure 52. In the figure, the mass range has been edited to scan from 1 to 60 amu. The most significant peaks include mass values of 2 (H_2^+), 16 (O^+), 17 (OH^+), 18 (H_2O^+), 28 (N_2^+) and 32 (O_2^+). You can edit the scan range by entering new Begin Mass and End Mass values. This lets you to view the PPT's entire mass range (1-100 amu) or view any given segment of the spectrum.

The analog data display format is useful for ensuring that the RGA is operating properly. This format typically displays the raw data from the sensor. The standard analog data peaks should be almost Gaussian in shape with a smooth round top. The peak width should be such that adjacent mass peaks (peaks 1 amu apart) can be resolved. The analog peak tops should also align with the mass scale markings for any given amu value.

Now return to the menu and toggle again on the Log/lin item to bring up a logarithmic pressure plot. The display should look like Figure 53. Pressing [enter] again displays a pressure range one decade lower. Pressing the key again results in another decade lower range. Notice how the display gets increasingly "busy", indicating a wide variety of very low pressure residuals. Some of the species that should be observable include an isotopic form of nitrogen at mass 29, CO_2^+ at mass 44, and hydrocarbon fractions at mass values of 39, 42, 55, 57 and higher.

If a printer is attached to the computer, copies of the screens can be printed by selecting the File menu option and pressing [enter]. In this menu, highlight the pRint menu option and press [enter]. The screen prints. When done printing, select the Exit MENU option press the [ENTER] key to return to the Analog menu.

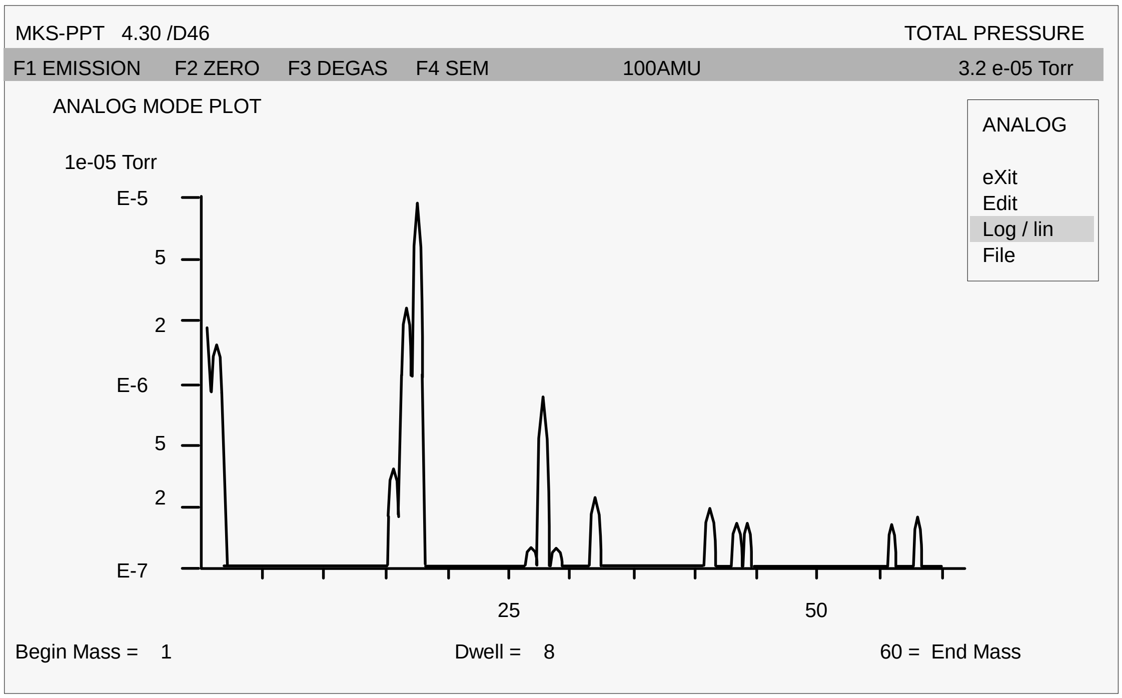

Figure 53: Analog Mode Mass Scan with Logarithmic Pressure Scale

The Mass Scan in Bar Mode

The Bar Mode displays the same information contained in the Analog Mode except that it represents the data as a single data point for each scanned amu. In contrast, the Analog Mode collects 10 data points for each amu. Thus, the PPT in Bar Mode scans at a faster rate than it does in the Analog Mode.

If still in the Analog mode, select the eXit menu option to return to the main menu. Select Bar Mode by highlighting that menu option. Press the [enter] key to activate this mode. If the filament is still activated (F1 Filament area is highlighted) then the F2 Scan automatically starts collecting data. If the F1 area is not highlighted, press the F1 function key once. Next, press the F2 function key to start a data scan. This sweeps the data over the Begin Mass through the End Mass data range. The default values are Begin Mass = 1 and End Mass = 100, the entire range of the PPT. As with the Analog Mode, the y-axis data ranges can be changed by highlighting the Log/lin menu option and pressing [Enter] three times.

Figure 54 shows a scan in the Bar Mode. This scan was taken immediately after pumping down from atmosphere. The 17 and 18 amu peaks of water are over-scale.

Because it has a “cleaner” appearance, you may find the Bar Mode scan is easier to read than the analog scan. Also, it is possible for the software to analyze and manipulate the data when shown in the bar format. We do this in several exercises later in this chapter.

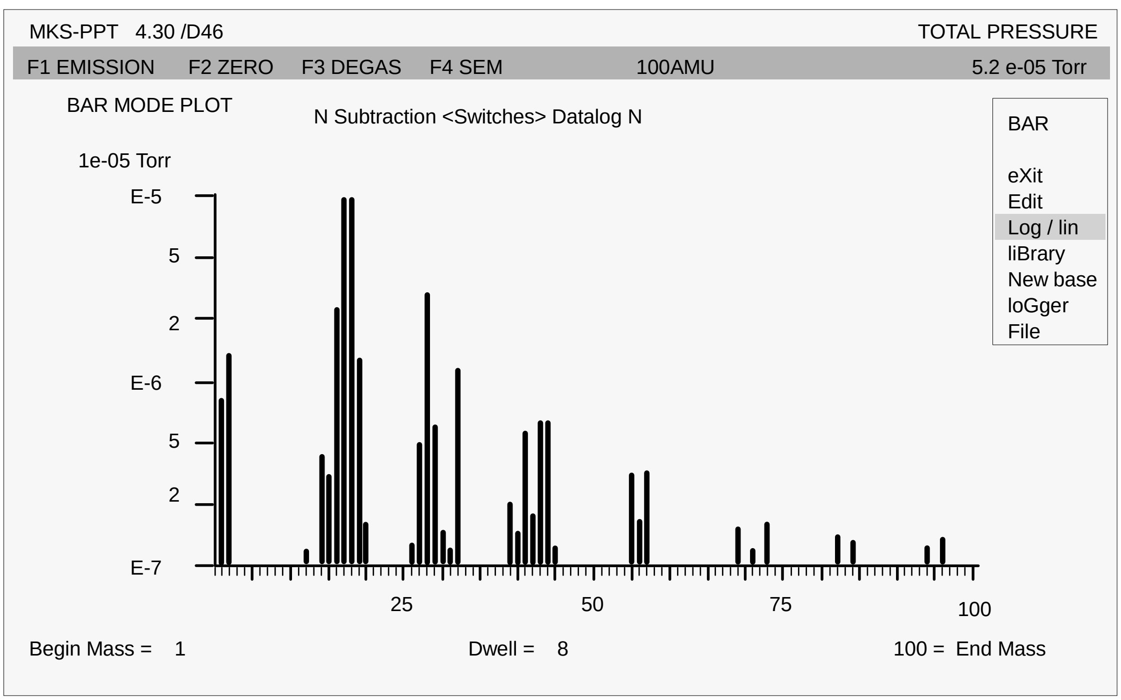

Figure 54: Bar Mode Mass Scan with Logarithmic Pressure Scale

Up to this point we have been looking at the residuals in the entire system. We can clean the system up quite a bit by simply closing the high vacuum valve. (Refer to Figure 51 on page 81 for the location of this valve.) Figure 55 depicts a scan taken several minutes after the scan of Figure 53 on page 89. The high vacuum valve was closed just after taking that scan.

It is quite evident that water remains the major residual in the system. As pumping continues, the water peaks decrease. We can observe this change with time by going to a third mode that displays pressure versus time.

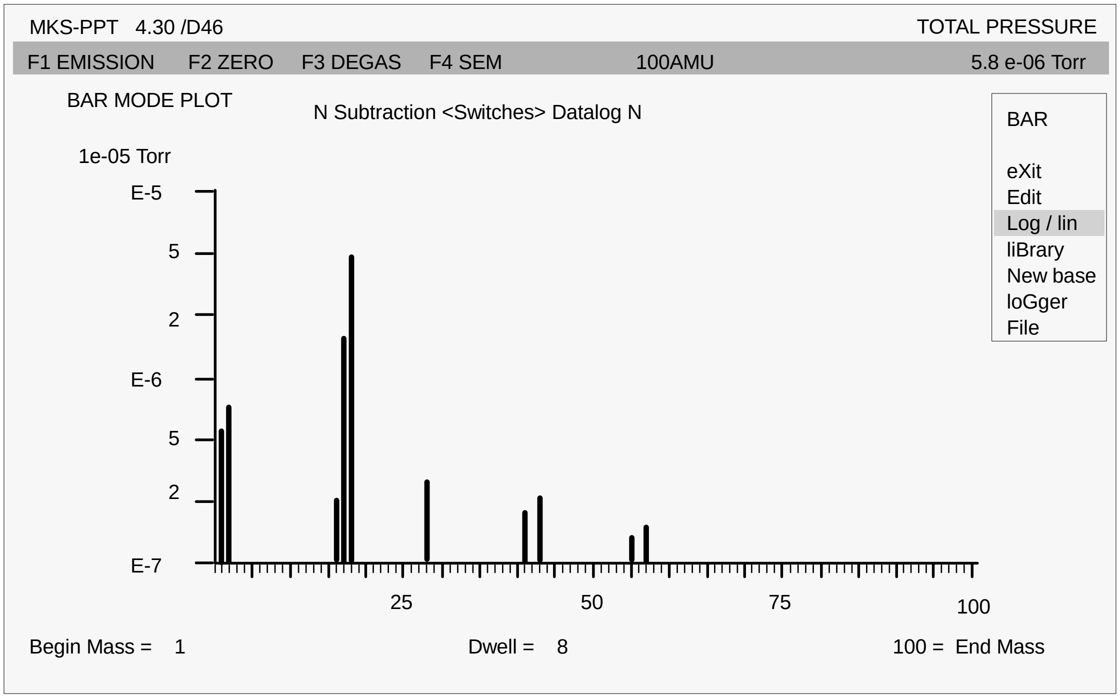

Figure 55: Bar Mode Mass Scan After Closing High Vacuum Valve

Pressure versus Time Mode

The Pressure vs Time Mode is useful for gathering trend information about your vacuum system or process. With regard to the latter, the mode can be used to detect transient gas bursts or other forms of contamination in the process. Reaction by-products can also be monitored.

In this mode, the PPT software permits the selection of up to 16 discrete amu values for monitoring, eight on each of two screens. As shown in Figure 56, a number of masses have been entered in the table. The table can be edited by selecting the Edit option from the menu and then using the cursor keys to move through the table. In this example only mass 18, the major peak of water, has been selected. This was done by entering Y in the Channel # column for Channel 2. For the activated channels, the table shows the current partial pressure for the selected amu value.

The plot shows the decline in water content as the system is pumped continuously.

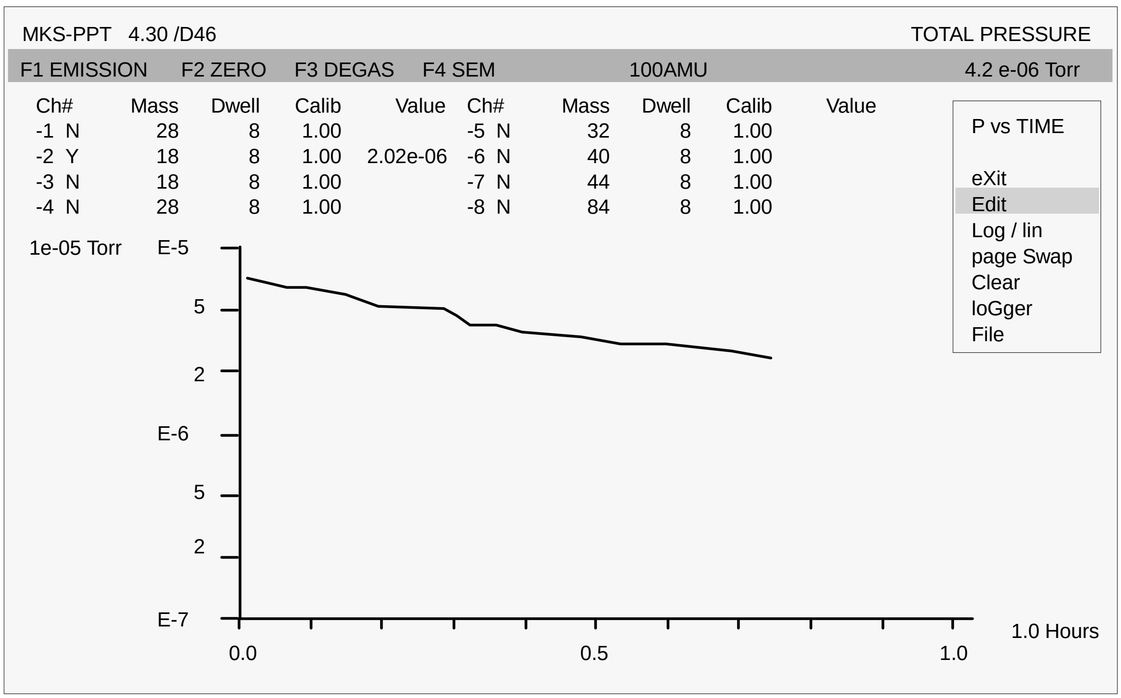

Figure 56: Pressure vs Time Mode Plot for Mass 18

The Library Function

Identifying the various gases that comprise the mass spectrum can be a complex task. On one hand, some gases, such as helium (single peak at mass 4), are simple and unambiguous. At the other extreme, the more complex molecules fragment into a bewildering array of peaks. Tables exist that describe the spectra associated with a wide variety of materials and these can be used for analyses. Such tables are also included with the PPT's software in the Library Catalog.

In this exercise we use the Library Function to identify the species that exist in the system after pumping from atmosphere as was done in the exercise on page 90.

From the Bar menu, select the liBrary item. This produces a screen like that of Figure 56. From the Library menu select the Catalog item. This brings up a list of various materials. When a material is selected, the spectrum for that material is shown in a separate plot, below the current scan. The library also has spectra for some typical situations such as "unbaked vacuum."

The library spectra are normalized. This means that the largest peak in each library spectrum has been set to 100%; the remaining peaks are a percentage of the 100% peak. The library shows up to six peaks for each spectrum.

Using the spectra in the catalog, try to identify as many of the residuals as possible. Start by calling up the spectra of the most probable constituents (water, air, oils, etc.).

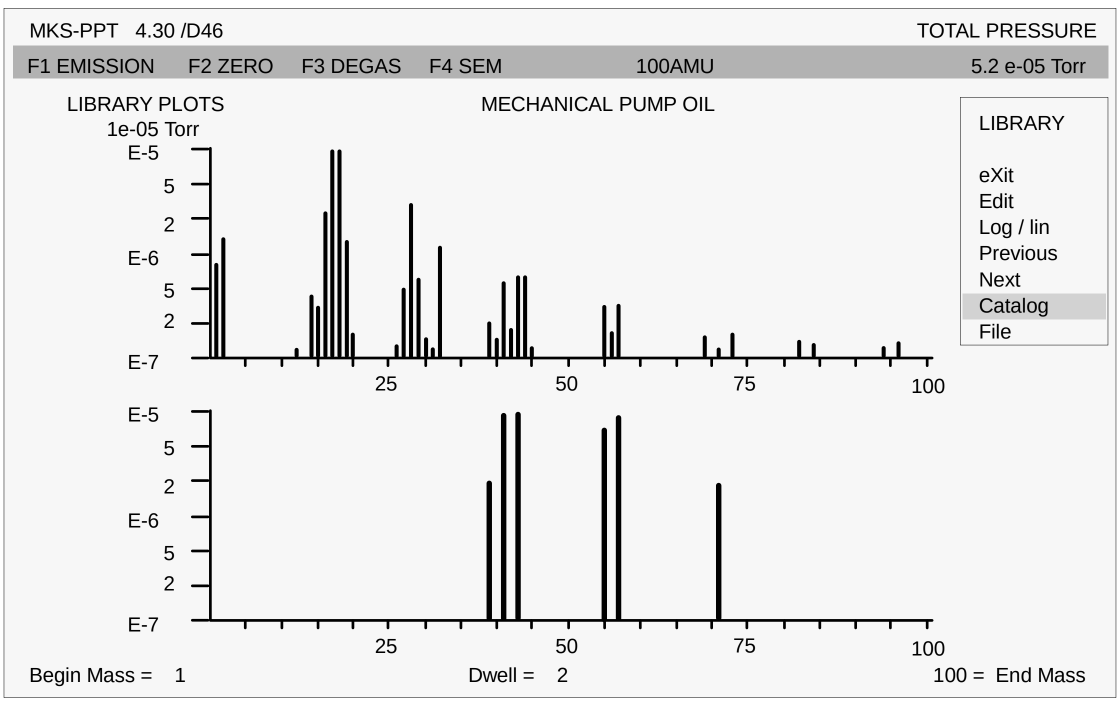

Figure 57: Library Plot
Showing Current Data (Top) and Library Spectrum for Mechanical Pump (Bottom)

The Real World - Working from a Baseline

Most process applications involve reducing the unwanted residuals to a very low level, relative to the environment created when the process gases are introduced. In a typical process monitoring application, what is of interest are the gases introduced into the chamber, the by-product gases that may result from the process, and contaminants. The background residuals, as long as they are at low enough levels, are usually not of interest.

In the exercises done thus far, the RGA has revealed all of the gases that it is able to detect. If we are concerned with changes in the process environment, we can use the Subtraction feature to establish a baseline. After establishing the baseline, the RGA spectrum only shows changes to that baseline.

In this exercise we use the Subtraction feature to establish two baselines. The first is for just the immediate environment of the RGA's sensor with the sampling line closed. After establishing this baseline we look at deviations from the baseline when the sampling line to the chamber is opened. This then forms the second baseline. Finally, with the chamber baselined, we introduce a "process" gas to the system.

With the PPT in Bar Mode, close the high vacuum valve and sampling line pinch clamp to isolate the RGA from the rest of the vacuum system. A scan like that of Figure 55 on page 91 should be seen.

Select the "New base" menu option and press the [enter] key. This stores the present data in a baseline buffer. Next, select the Edit menu option and press the [enter] key. This highlights the [N] letter in front of the Subtraction parameter. Press the [Y] key to change this parameter. Notice that the graph changes to display a dashed line in the center of the Y-axis. This line represents the baseline starting location for the current New Base data set. The values displayed above the line represent data (partial pressures) larger than the presently stored New Base values. Those below represent partial pressures lower than those stored in the New Base data set.

The current scan should look like Figure 58, on page 95. In addition, the plot shows small peaks above and below the center line. This indicates that the current data and the New Base are equivalent.

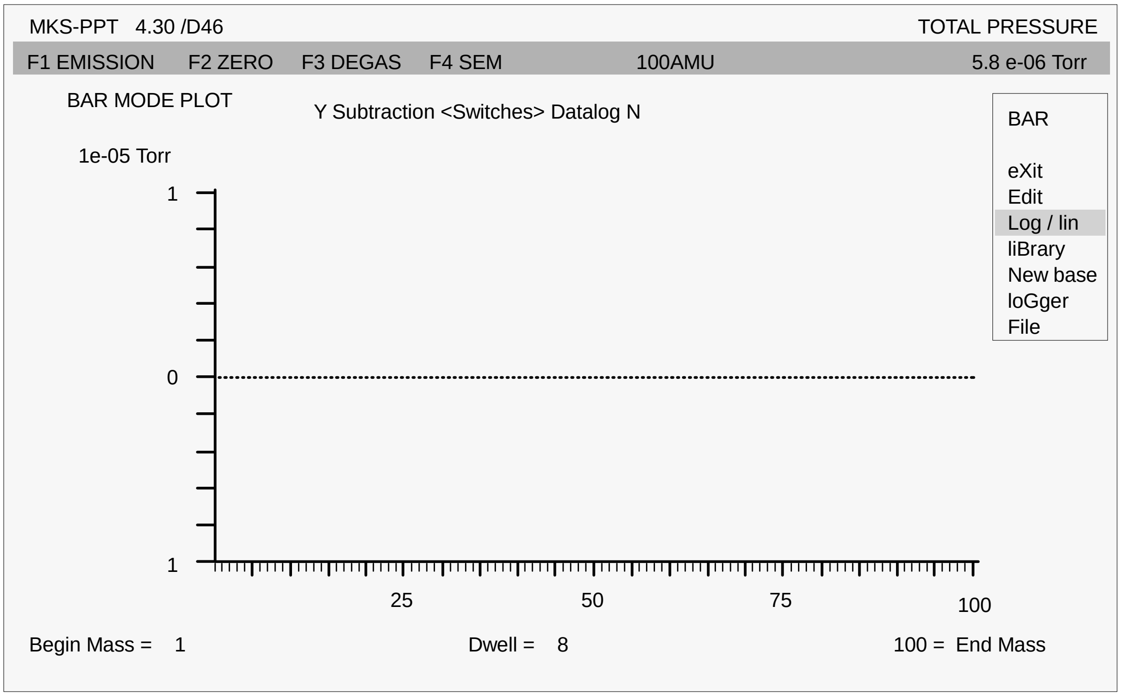

Figure 58: Baseline Using the Subtraction Parameter

Make sure that the MFC is not flowing any gas, then open the pinch clamp on the sampling line. You should see a series of peaks that indicate the presence of new residuals and residuals at differing partial pressures. You should be looking at a plot that is essentially the difference between the data of Figure 54 (see page 90) and Figure 55 (see page 91). Now establish another baseline, this time for the process chamber.

If a spark coil is available to produce a plasma in the chamber (refer to the exercise *Glow Discharge, Cold Cathode Electron Gun*, page 73), observe the scan when a plasma is struck. You should see an increase in water (mass peaks at 16, 17 and 18 amu) due to ion bombardment degassing. You should also see an increase in hydrogen (mass 2) caused by the fragmentation of the water molecule.

Next, we introduce gases to the process chamber.

Allow the MFC to flow about 10 sccm of room air and observe any changes to the spectrum.

With the MFC continuing to flow air, connect a source of another gas to the inlet of the MFC. Observe changes to the spectrum as the air is displaced by the new gas. (Remembered that the RGA does not show what is happening in the chamber instantaneously. The sampling system of the PPT introduces its own time constant resulting in an additional delay. In actual process tools where process pressures are fixed, the sampling systems are optimized to minimize this lag.)

If the alternate gas is 1,1,1,2 tetrafluoroethane, CF_3CH_2F (refer to page 59 for details on how to introduce this gas into the system), you should see a spectrum similar to that of Figure 59. (The peaks shown are taken from the NIST data base for this material. Peaks occur at 21, 29, 31, 33, 34, 44, 51, 59, 63, 69, and 83. The major peak is at 33.) Try to identify the fragments associated with each peak.

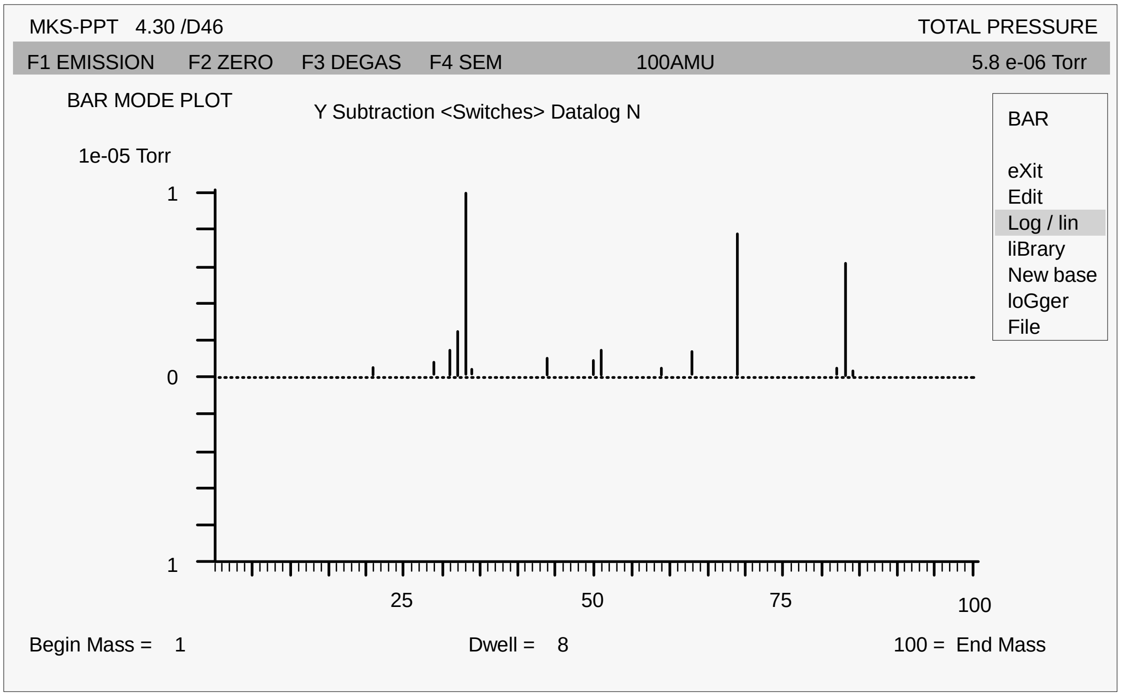

Figure 59: Normalized Spectrum of 1,1,1,2 Tetrafluoroethane (NIST Data)

Leak Detection

An RGA can be used as a leak detector by setting the RGA to Pressure vs Time Mode and monitoring the peak of the probe gas used for leak detection. (There is also a dedicated Leak Mode on the system and that can be used, as well.) Since helium permeates a system rapidly, is not seen in the normal spectrum and since its location at mass 4 is unambiguous, it is often the gas of choice for leak detection. Dedicated leak detectors are usually designed to work only with helium. However, an RGA can be programmed to use any convenient tracer gas.

For this exercise, configure the chamber side of the system with a small leak (refer to the exercise *Locating Leaks*, page 69). Configure the high vacuum side of the system with the RGA in the sampling mode: high vacuum valve closed and the pinch clamp on the sampling line open. In Pressure vs Time Mode, set the parameters to monitor the major peak of the probe gas. Select mass 4 for helium or mass 33 for 1,1,1,2 tetrafluoroethane.

Follow the procedure outlined on page 69 to identify the leaking connection.

Outgassing and Permeation

In the exercise *Outgassing and Permeation*, page 71, we looked at the pressure rate-of-rise of a sealed system with a gassy and permeable material (a length of silicone tubing) appended to the manifold. We can use the RGA to determine what gases are evolved from, and permeate through, the appended tubing.

Set up the chamber side of the system as described on page 71. Configure the high vacuum side of the system with the RGA in the sampling mode: high vacuum valve closed and the pinch clamp on the sampling line open.

With the silicone tubing pinched off close to the connecting tee (minimal surface area exposure), establish the residual gas baseline (see page 94) for the RGA. Next, *slowly* open the pinch clamp to evacuate and expose the remaining length of tubing. Monitor the Pirani gauge to be sure you do not exceed the forepressure limit of the high vacuum pump. Observe the spectrum over a period of at least 15 minutes and note any changes. In the latter part of this period, most of the gas evolved is from permeation.

As a final step, coil up the tubing and insert it into a plastic food storage bag. Close the opening of the bag as much as possible around the tubing. Now, direct some helium into the bag, maintaining a low, steady flow of gas. Observe how long it takes the helium to permeate through the tubing and reach the RGA's sensor. Next, remove the bag and observe the rate at which the helium is purged from the tubing. (The Pressure vs Time Mode is very useful for this part of the exercise.) Repeat with different types of tubing (such as Norprene and PVC) and gases (argon, 1,1,1,2 tetrafluoroethane).

Discuss the ramifications of He leak detection on systems with O-ring seals. For example, how would one approach leak detection on a system with silicone seals, and what would be some of the pitfalls?

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