MKS INSTRUMENTS

113314-P1
REV E, 11/95

PPT
Quadrupole
Residual Gas Analyzer

Operation Manual

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MKS INSTRUMENTS, INC.

WARRANTY

MKS Instruments, Inc. (MKS) warrants that the equipment described in the face of this warranty (the "equipment") manufactured by MKS shall be free from defects in materials and workmanship for a period of one year from date of shipment. For the period commencing with the date of shipment of this equipment and ending one year later, MKS will, at its option, either repair or replace any part which is defective in materials or workmanship without charge to the purchaser. The foregoing shall constitute the exclusive and sole remedy of the purchaser for any breach of MKS of this warranty.

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Operation Manual

PPT[1] QUADRUPOLE RESIDUAL GAS ANALYZER OPERATION MANUAL – 113314-P1, REV E, 10/95

PPT Host Software Version 4.30
PPT ECU Firmware Version 4.6

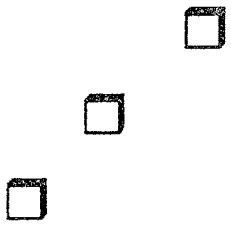
[1] U.S. Patent Number 5,302,827 issued to MKS Instruments, Inc.

Table of Contents

List of Figures

List of Tables

APPENDICES



Safety Messages

TEMPERATURE HAZARD

The PPT housing can become warm (up to 33°C).

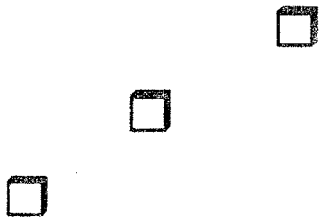
Definitions of CAUTION and NOTE messages used throughout the manual:

Caution 

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

Note 

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



Chapter One
General Information

Introduction

The Partial Pressure Transducer (PPT) utilizes Quadrupole Mass Analyzer technology to provide an instrument specifically designed for the production environment. It includes a self-contained Electronic Control Unit (ECU), an interactive software package, and a compact ion-source quadrupole sensor. Quadrupole Mass Spectrometry is a time-proven method of process gas analysis. The filtering action of the PPT's quadrupole sensor allows detection of distinct constituents in the gas environment. The ECU, interactive software, and quadrupole sensor combine to provide the speed, resolution and sensitivity required for partial pressure sensing.

The PPT system can be configured to operate with an RS-232 or BitBus™ communications link to an IBM® compatible PC. When utilizing BitBus™ communications, up to sixteen ECUs may be used simultaneously. With either communications protocol, spectral information in the molecular mass range of the sensor can be gathered and analyzed . A total system pressure reading is continuously available in the range of 1×10^{-4} to 2×10^{-9} Torr.

The PPT software package runs under DOS on an IBM AT™ and creates a display interface for the PPT. Information is gathered and presented in one of several different modes. The modes provide displays which are typical of many types of commercial Residual Gas Analyzer (RGA) instruments. These modes include an Analog display where the complete peak shape of the spectrum is available, a Bar-graph display where only peak amplitudes are indicated, and a Tabular Mode where up to twelve channels (spectral peaks) of numeric data are shown. A Pressure versus Time Mode provides an Amplitude versus Time plot for up to sixteen channels. Leak Mode is used to indicate (visually and audially) changes in the pressure of a selected gas. The Split Spectrum Mode simultaneously displays two spectral regions. Calibration and tuning adjustments can be made in Tune Mode and stored in non-volatile memory in the ECU. These changes can be entered manually and some calibration can also be performed automatically by the software.

How This Manual Is Organized

Once the PPT hardware is set-up and the custom software is installed on a computer, the remaining operator tasks primarily involve using the software. Understanding and operating the software is the main focus of this manual.

After the general information presented in this chapter, Chapter Two - *Installation and Set-up* covers hardware and software installation and set-up. Chapter Three - *Hardware Overview* provides an overview of the PPT and ECU. These are the hardware components of the PPT system.

An overview of the software is included in Chapter Four - *Software Overview*. This chapter provides a general understanding of how the software is structured, what functions and features are available, and the general guidelines for operation.

The major focus of the manual is covered in Chapter Five - *Overview of Modes*. Each mode is discussed in detail. This chapter provides the background needed to intelligently use the software to its fullest capacity. Once the purpose and features of the different modes are understood, it is easy to know which mode has the functionality required to best accomplish a specific task.

Product Specifications and File Descriptions are contained in the Appendices.

Customer Support

Standard maintenance services are available at all of our regional MKS Calibration and Service Centers in North America, Europe, and Asia. As an extended courtesy, MKS accepts pressure and flow instruments of other manufacturers for recalibration using the Primary and Transfer Standard calibration equipment located at all of our regional service centers. Please refer to the inside of the back cover of this manual for a list of MKS Calibration and Service Centers.

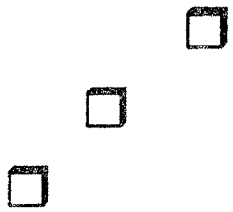
Should any difficulties arise in the use of your PPT system, or to obtain information about companion products MKS offers, contact any authorized MKS Calibration and Service Center. If it is necessary to return all or part of the PPT system to NGS, please obtain a Return Authorization Number *(RA Number)* from NGS and complete the *RA Form* before shipping. The RA Number expedites handling and assures proper servicing of your instrument. Call 1-800-282-1770 within the United States. Outside of the USA, contact your local agent or the MKS office in your area.

In the event of a PPT failure, the following procedure should be followed:

1. Call NGS Division and explain the problem.
2. Get an RA Number from NGS. We will FAX or mail you a Customer Repair Form with your RA Number.
3. Return the PPT with a completed Customer Repair Form.

NOTE  No work will be done without a completed Return Authorization Form!

Upon receipt of the defective PPT, NGS Division will swap the faulty p.c. board or analyzer section, and return the system to you. If the system is not under warranty, a subassembly swap charge will be assessed. This swap policy reduces the turn-around time to within 7 business days on repairs. All repairs are returned via U.P.S. Blue two-day service.



Chapter Two
Installation and Set-up

How To Unpack

1. Keep the sensor contained in its plastic shipping container until it is to be installed in the vacuum system.
2. Standard vacuum procedures should be used when handling the sensor.
3. The sensor is pre-cleaned and tested, so care must be taken to keep bare fingers or other contaminates from touching any portion of the sensor that will be exposed to the vacuum.

Product Location and Requirements

Hardware Requirements

1. Operating ambient temperature must be in the range of zero to 40° C.
2. Humidity must be kept between 5% and 80% relative, non-condensing.
3. The sensor may be placed in any orientation provided the following conditions are met:

A. A 2¾" CF™ nipple of at least 1.35" inside diameter is used to provide clearance for the sensor.

B. The sensor must be placed where it will be exposed to the typical environment to be analyzed.

C. Care should be taken to place the sensor away from gas inlets or pumps on the vacuum side, unless those are the areas of interest. Close proximity to evaporation sources may cause problems if the sensor is allowed to become coated.

D. The Sensor and ECU are sensitive to and must be kept away from strong RF and Magnetic Fields for proper operation.

E. Clearance must be allowed for the ECU, and its cables since the ECU is attached directly to the sensor.

4. The maximum operating pressure of the sensor is 1×10^{-4} Torr. At pressures above this value, a circuit automatically shuts off the sensor filament.
5. The ECU, requires a 24V +10%, -5% DC power source at 2.0 amps continuous current.

Software Requirements

Minimum System Requirements

1. An IBM AT ® or compatible, with the following configuration:
   A. A hard disk drive.
   B. 640K memory.
   C. EGA or VGA compatible display card and monitor.
   D. One serial Communications Port (for serial communications).
   E. A 1.44 megabyte, 3½-inch floppy drive.
2. DOS 3.1 or later.
3. See the *Software Compatibility* section of Chapter Two - *Installation and Set-up* for proper setup of CONFIG.SYS and AUTOEXEC.BAT

Note The 640K memory requirement assumes that only the PPT software and the operating system are utilizing RAM memory. Additional user-installed drivers, TSR programs, or network software may interfere with proper operation of the PPT software.

Optional System Requirements

1. Parallel Communications Port.
2. Epson® or IBM® compatible Printer.
3. BitBus™ Interface Card.
4. 16-Channel Pressure Trip Card.

Hardware Set-up

This section provides information on hardware installation. A basic understanding of standard vacuum procedures is required.

Sensor Installation

1. Determine placement of the sensor in the vacuum system according to the guidelines listed in the *Product Location and Requirements* section.
2. *CAREFULLY* remove the Sensor from its protective packaging.

Caution 

Do not touch with bare fingers or other contaminants, any part of the sensor that will be exposed to the vacuum

3. Position the copper gasket, and insert the sensor into the vacuum system.
4. Orient the sensor so that the small screw on the sensor connector is accessible.
5. Insert 6 bolts through the holes in the flanges, and secure them with the nuts provided. Tighten the bolts according to standard tightening procedures. That is, tighten one bolt slightly, skip a bolt and then slightly tighten the next one. Follow this pattern of partially tightening non-adjacent bolts until all of them are partially tightened. Repeat the procedure, tightening the bolts a little more. Repeat the procedure again to fully tighten the bolts.

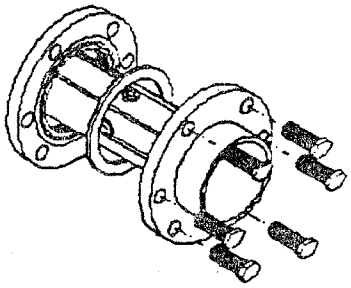


Figure 1: Bolting the Sensor into the Vacuum System

ECU Installation

The ECU attaches directly to the sensor and its alignment to the sensor is *very important.* Carefully follow the instructions below to insure proper alignment.

1. Notice that there is an alignment pin inserted into the sensor connector.
2. Rotate the caphead screws so that no threads protrude into the interior of the sensor connector.
3. Remove the black plastic cap from the ECU connector.
4. Observe that there is a groove in the exterior wall of the ECU connector.
5. Orient the ECU so that the alignment pin in the sensor connector lines up with the groove in the ECU connector.
6. Slide the ECU connector into the sensor connector so that the end of the alignment pin slides along the groove in the ECU connector.

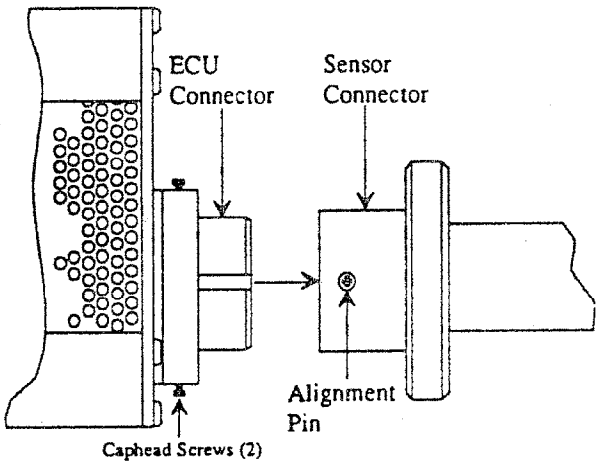


Figure 2: Connecting the ECU and the Sensor

7. Be sure the sensor connector completely covers the ECU connector to insure proper grounding of the ECU to the sensor.
8. Tighten the caphead screws in the sensor connector with the Allen key provided.

ECU Cable Connections

On one side of the ECU are four connectors, a bank of dipswitches, and a green LED which indicates when power to the ECU is on. Connecting the wrong cables to the ECU will not damage it, but it only operates when the proper cable connections are made. Cable Connections and Pinouts are listed in Appendix C on page C-1.

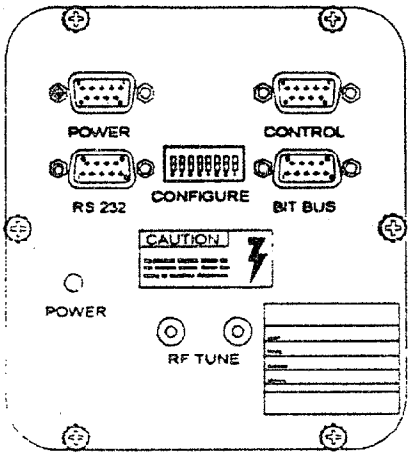


Figure 3: Connectors on the ECU

The hardware can be set up with both RS-232 and BitBus™ communications. The communication protocol (RS-232 or BitBus™) which gets used, however, is determined by the configuration file (PPTINSTL.EXE), which is loaded during installation of the software. The communication protocol can be changed by changing the configuration file.

1. If RS-232 communications are required between the ECU and the computer, use an RS-232 cable to connect them. The RS-232 port runs at 19.2 kBytes with 8 data bits, 1 stop bit and no parity.
   A. Insert the 9-pin Type D male cable connector into the ECU connector marked RS-232.
   B. Insert the 9-pin Type D female cable connector into the RS-232 port on the computer. An adapter is available from MKS Instruments if the computer has a 25-pin Type D connector (see Appendix D - *PPT Accessories*).

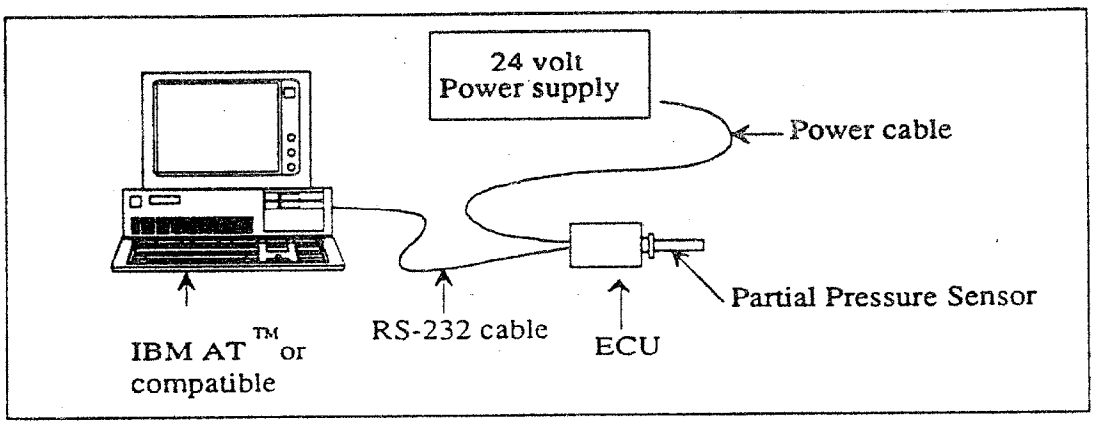


Figure 4: Single ECU, RS-232 Configuration
(see Appendix D - PPT Accessories for Part No.'s)

2. If BitBus™ communications are required between the ECU and the computer, a BitBus™ board must be installed in the computer, and an appropriate cable must be used.
   A. Insert the 9-pin Type D male cable connector into the ECU connector marked BIT BUS.
   B. Insert the 9-pin Type D female cable connector to the BitBus™ port on the computer.

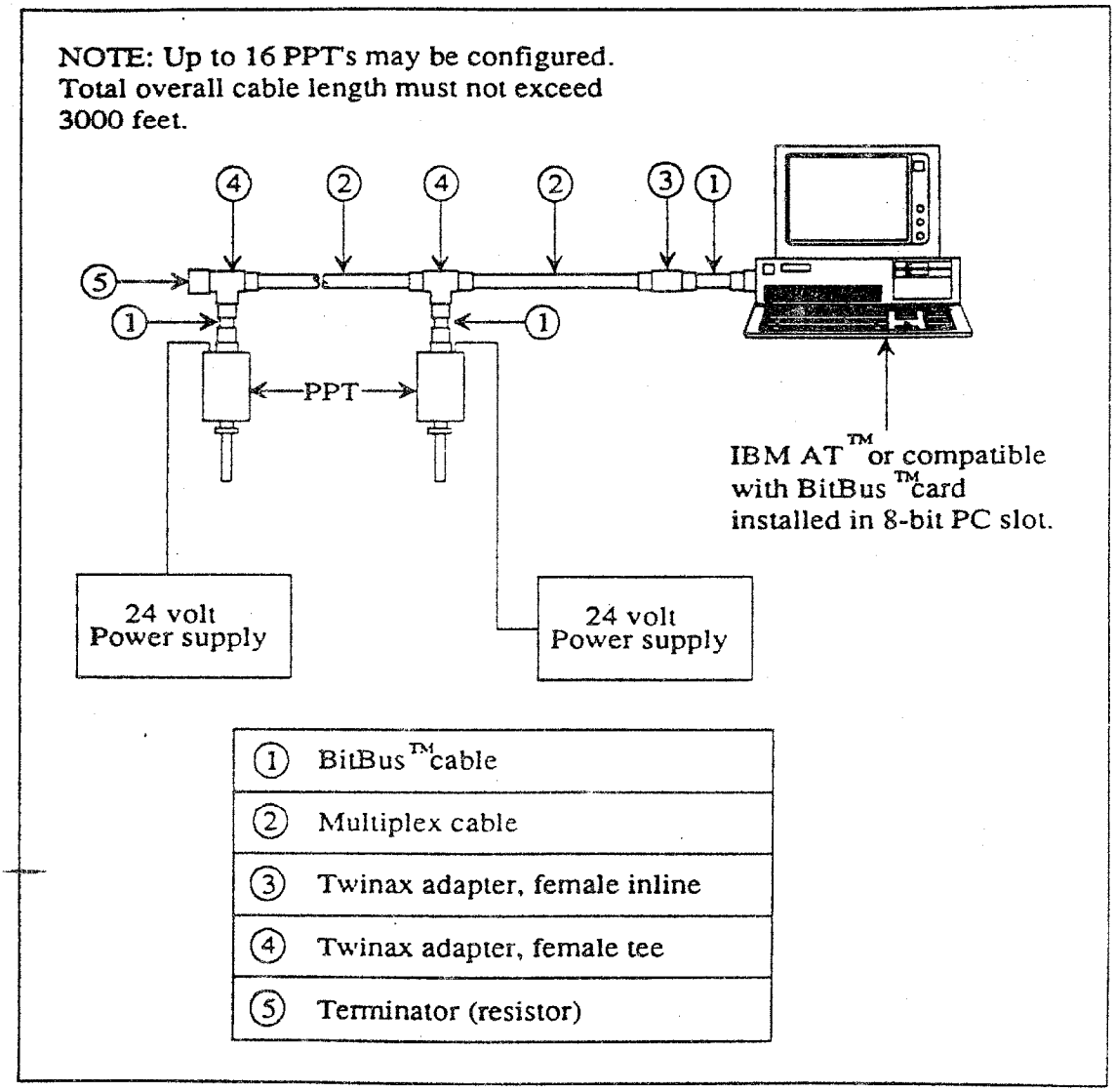


Figure 5: Multiple ECU, BitBus™ Configuration

(see Appendix D - PPT Accessories for Part No.'s)

3. The ECU must be powered with a 24V +10%, -5% DC power source at 2.0 amps. The power source must have a cable with a 9-pin Type D female connector on the free end.
   A. Insert the 9-pin Type D female cable connector into the ECU connector marked POWER.

When power is supplied to the ECU, the green LED on the ECU (labeled POWER), lights up.

ECU Dipswitch Settings — For BitBus™ Communications Only

The PPT operates with either a BitBus™ or RS-232 protocol (RS-232 is the default). The BitBus™ protocol communicates ASCII character information.

The dipswitch bank on the ECU contains eight dipswitches labeled 1 through 8. Dipswitches 1 through 4 are reserved for future use. Dipswitches 5 through 8 are used to set the BitBus™ communication node address for the ECU. Dipswitch 5 is the most significant bit, and switch 8 is the least significant bit.

To set a dipswitch in the ON position, push it in the direction of the arrow labeled ON. Refer to Table 1 for a list of BitBus™ addresses and dipswitch settings.

	Dipswitch Settings			
BitBus™ Addresses	Switch 5	Switch 6	Switch 7	Switch 8
0	off	off	off	off
1	off	off	off	ON
2	off	off	ON	off
3	off	off	ON	ON
4	off	ON	off	off
5	off	ON	off	ON
6	off	ON	ON	off
7	off	ON	ON	ON
8	ON	off	off	off
9	ON	off	off	ON
10	ON	off	ON	off
11	ON	off	ON	ON
12	ON	ON	off	off
13	ON	ON	off	ON
14	ON	ON	ON	off
15	ON	ON	ON	ON

Table 1: Dipswitch Settings

Software Installation

Making a Backup of the PPT software

Before installing the PPT software on your system, make a backup copy of the original distribution diskette in case something happens to it. To do this you need a high density, blank, formatted diskette.

If the system has two floppy disk drives:

1. Start up the computer.
2. Be sure the computer is at a DOS prompt.

   Most computers start up and display a DOS prompt. Some computers, however, have a DOS shell or other program which is automatically started after the computer is running. In these cases, exit out of the shell or other program to the DOS prompt.
3. Insert the PPT diskette in drive A: and close the door.
4. Place the blank formatted disk in drive B: and close the door.
5. Type **DISKCOPY A: B:** and press the **ENTER** key.

   The system responds by displaying the following message:

   Insert SOURCE diskette in drive A:

   Insert TARGET diskette in drive B:

   Press any key when ready . . .
6. Press any key.

   The system responds by copying everything from the source diskette (the PPT distribution diskette) onto the target diskette (the blank formatted diskette).

   When the copying is done, the system displays the following message:

   Copy another diskette (Y/N)?
7. Press the letter **N**

   The system responds by returning to the DOS prompt.
8. Store the original PPT diskette in a safe, dry place.

If the system only has one floppy disk drive:

1. Start up the computer.
2. Be sure the computer is at a DOS prompt.

   Most computers start up and display a DOS prompt. Some computers, however, have a DOS shell or other program which is automatically started after the computer is running. In these cases, exit out of the shell or other program to the DOS prompt.
3. Insert the PPT diskette in drive A: and close the door.
4. Type **DISKCOPY A: A:** and press the **ENTER** key.

   The system responds by displaying the following message:

   Insert SOURCE diskette in drive A:

   Press any key when ready . . .
5. Press any key.

   The system responds by displaying information about tracks/sectors which are being copied, and then displaying the following message:

   Insert TARGET diskette in drive A:

   Press any key when ready . . .
6. Remove the diskette from drive A:, replace it with the blank formatted diskette, and close the door.

Note

Steps 5 and 6 may need to be repeated several times before the backup process is complete. The system will prompt you for the correct diskette.

7. Press any key.

   The system responds by copying files to the diskette in drive A. When the copying is complete, the system displays the following message:

   Copy another diskette (Y/N)?
8. Press the letter **N**

   The system responds by returning to the DOS prompt.
9. Store the original PPT diskette in a safe, dry place.

Installing the PPT Software

1. Start up the computer.
2. Be sure the computer is at a DOS prompt.

   Most computers start up and display a DOS prompt. Some computers, however, have a DOS shell or other program which is automatically started after the computer is running. In these cases, exit out of the shell or other program to DOS.
3. Insert the PPT diskette in drive A: and close the drive door.
4. Type A: and press the ENTER key.

   The system responds by displaying the DOS prompt for drive A: (A>).
5. Type INSTALL and press the ENTER key.

   The system responds by displaying a series of menu driven screens. Each menu item has an explanation associated with it. Complete the sequence of menu items to install the software. If there is an error the install program will alert the user and cancel the install process.

Installation is now complete. The PPT software operates according to the defaults listed in Table 2. To start the program, type PPT and press the ENTER key.

PPT Installation Program Defaults	
Tune Menu Password Status	No Password
ECU Communications Protocol	RS-232
Port for ECU Communications	COM1
Port for Printer Communications	LPT1
Printer Driver	Standard Epson printer driver

Table 2: Configuration Defaults for PPT Software, Version 4.xx

Note 

To change any of the configuration parameters in Table 2, refer to the *Software Configuration Changes - **PPTINSTL*** section of Chapter Two - *Installation and Set-up*.

Software Configuration Changes—PPTINSTL

The PPT installation program loads several files onto the computer's hard drive. One of these files is called PPTINSTL.EXE. Use this file to:

Add/change/remove a Tune Menu password

Change the parallel port for printer communications

Change the ECU communication protocol (RS-232 or BitBus™)

Define the BitBus™ address if necessary

Change the serial Communications port for the ECU communications link.

Change the printer device driver.

To run PPTINSTL.EXE, begin at the DOS prompt where the PPT files are located.

1. Type PPTINSTL and press the ENTER key.

   The system responds by displaying the following message:

   PPTINSTL Version X.X xx/xx/xx

   Do you want to add/edit/delete a Tune Mode password or examine/edit the system configuration (Y/N)?

   The system will display the current configuration

2. Do you want to Edit the Current configuration (Y/N)?

   If you want to change the system configuration enter Y and proceed to step 3. If No go to step 17

3. Decide whether or not to have a password.

A. If no password is needed, type N , then proceed to step 6.

   The system responds by displaying the following question:

   What parallel port for line printer (1 or 2)?

B. If a password is needed, type Y , then proceed to step 4.

   The system responds by displaying the following message.

   Please enter Tune Menu Security Password

   >

4. Type a password and then press the ENTER key.

   The system responds by displaying the following confirmation message (where *password* represents the password you typed):

   Password is >*password*<.

   Is this correct (Y/N)?

5. Confirm the displayed password.

A. If the password is wrong, type **N** and try again.

B. If the password is correct, type **Y**

The system responds by displaying the following message:

Be sure to record or remember this.

Press any key to go on.

6. Press any key.

The system responds by displaying the following question:

What parallel port for line printer (1 or 2)?

7. Type **1** for LPT1, or **2** for LPT2.

The system responds by displaying the following question:

Will PPT ECUs be linked with BitBus (Y/N)?

8. Decide if ECU communications will be BitBus™ or RS-232.

A. If BitBus™ communications are needed, go to step 11.

B. If RS-232 communications are needed, go to step 8.

9. Type **N**

The system responds with the following message:

What serial port for ECU comm. link (1 or 2)?

10. Type **1** for Communications port 1, or type **2** for Communications port 2. Go to step 17.

11. Type **Y**

The system responds with the following question:

Do you wish a default address of 208 hex, 520 decimal
as an I/O base address for the BitBus interface. (Y/N)?

A. To change the base address, type **N** and then enter the correct address when prompted.

B. To keep the default address, type **Y**

The system responds by accepting the base address and displaying the following:

You have selected BitBus, which supports multiple ECUs on a network. Each ECU has an address value (0 to 15) selectable on the ECU by way of a dip switch. The PPT program can refer to these ECUs with a name which is assigned to the ECU by this install program. When asked for an ECU address, enter 0 through 15 to define an ECU which will be placed

on the network. When asked for the ECU name enter an alphanumeric name (30-character maximum). When all have been entered use 99 or some other illegal ECU address to terminate the naming session. Be careful not to rename a ECU more than once, as this is allowed should the same ECU selection address be entered more than once. Entering the ! punctuation character in a name field will cause a line break when the name is displayed in a multiline box format and will print as a space when on a single line display. Do not use the # character as this is a comment prefix and all following letters will be ignored.

Enter station ID 0 . . 15, other to exit. > . . <

12. To exit this parameter sequence, go to step 15, otherwise proceed to step 12.
13. Enter a number between zero and 15.

    The system responds by displaying the following message:

    Enter station name, just return to erase name and ECU from active list.

14. Enter a station name (maximum length is 30 alphanumeric characters), to add or change an ECU station name, OR press the RETURN key (also called the ENTER key), to delete the name and station ID number of the ECU selected in the above step.

    The system responds by displaying the following message:

    Enter station ID 0 . . 15, other to exit. > . . <

15. Return to step 11 and enter another numeric value.
16. Enter a number above 15.

    The system responds with a beep, and displays the following message:

    Invalid ECU ID. Do you wish to exit (Y or N)?

    A. To continue with this parameter sequence, type N and go to step 12.

    B. To exit this parameter sequence, type Y

    The system responds by displaying the following message (where *number* is an ECU number, and *ECU name* is an ECU name you entered):

    Writing out list of names you have defined.

    ECU ADDRS *number* = '*ECU name*'

17. Do you want to change printer assignment(Y/N)?

    If NO the system returns to the DOS prompt.

If YES the system responds by displaying the Printer Install Program screen.

18. Use the cursor keys to scroll through the printer list until the correct printer is highlighted.

    The system responds by scrolling through the printer list.

19. Press the Spacebar to select the highlighted printer.

    The system responds by copying the selected printer's name to the column on the right.

20. Press the F10 key (NOTE: If more than one printer is selected, an error message is displayed, and the additional printer selections are ignored).

    The system responds by installing the driver for the selected printer, and displaying the following message:

    ****

    Printer Description file PPT.PDT must be in working directory

    of the PPT runtime system for printer support.

    Press any key to complete.

    ****

    Strike a key when ready . . .

21. The system responds by displaying the following message and returning to the DOS prompt:

    Installation complete. File PPT_DEV.CFG created

    with user options. This file must exist in the runtime PPT directory.

Configuration changes are now complete.

Press any key.

The system responds by returning to the DOS prompt.

The printer driver installation is complete.

Note For complete security, the PPTINSTL file should be removed from the hard drive to prevent someone from eliminating the Tune Mode password.

Checking Available System Memory

To determine if there is enough free executable program memory on your system:

1. Go to the directory where the PPT files are located.
2. At the DOS prompt, type "MEMCHK" and press <ENTER>.
3. If the *MEMCHK* utility reports there is NOT enough free executable program memory on your system, you must either disable concurrently running programs or move them to high memory using the MS-DOS utility *MEMMAKER* or similar utility.

Starting the Program

To start the PPT software, begin at the DOS prompt where the PPT files are located.

1. Type **PPT** and press the **ENTER** key.

   The system responds by starting the program and displaying the System Menu.

2. There are option codes that may be typed after PPT that will allow the system to change a default parameter. The option codes are as follows:

   a. NOALARM This command disables the beeper sound which normally occurs during a communication failure. To use the NOALARM option, type the following command when starting the program

      PPT NOALARM (notice that there is a space between PPT and NOALARM)

      The System responds by starting up the PPT program and disabling the beeper sound normally associated with a communication failure. This command has no affect on any other beeper sound produced by the PPT program.

      If there is a communication failure upon start-up or during operation of the program, the only response from the system is a display of COMMUN. FAILURE error message. The beeper sound for a communication failure only operates again after quitting the PPT program and re-entering without the NOALARM command.

   b. TUNEPRT This command causes a pRint menu item to be displayed and enabled in the Tune Mode menu. To use the TUNEPRT option, type the following command when starting up the PPT program:

      PPT TUNEPRT (notice that there is a space between PPT and TUNEPRT)

      The system responds by starting up the PPT program and enabling the pRint function in Tune Mode.

   c. NOBREAK This command disables the supervisor BREAK feature, which defaults to enabled. When enabled, loss of communication with the ECU causes the Host to shut down (ECU keeps operating even without communications). When disabled, loss of communications has no effect on Host or ECU.

Software Compatibility

Keyboard Interface Contention

When the PPT is Scanning, communications between the Host PC and the ECU is continuous. An interrupt from the keyboard sometimes causes disruption in the display due to the operation of certain memory managers. Communications between the PC and the ECU are enhanced when the Interrupt Service Routine (ISR) for the keyboard is shadowed (copied into RAM from the ROM-based BIOS). This is done by selecting shadowing from the set-up routine (entered immediately after re-booting or from power up). However, some computers (not just laptops) do not give the user the option of shadowing. For these users, NGS will configure the computer to minimize the problems encountered when the ISR affects ECU/PC communications. Examples of AUTOEXEC.BAT and CONFIG.SYS files that NGS uses to configure PC systems are shown on the following pages. NGS always configures PC systems prior to shipment from the factory. Figure 6 is a sample set-up screen (advanced CMOS) showing shadowing of ROM BIOS routines.

```
                BIOS SETUP PROGRAM - ADVANCED CMOS SETUP
          (c)1990 American Megatrends Inc., All Rights Reserved

Typematic Rate Programming : Disabled   Adaptor ROM Shadow D400,16K: Enabled
Typematic Rate Delay (msec): 500        Adaptor ROM Shadow D800,16K: Enabled
Typematic Rate (Chars/Sec) : 10         Adaptor ROM Shadow DC00,16K: Enabled
Above 1 MB Memory Test     : Enabled    Adaptor ROM Shadow E000,16K: Enabled
Memory Test Tick Sound     : Enabled    Adaptor ROM Shadow E400,16K: Enabled
Hard Disk Type 47 RAM Area : 0:300      Adaptor ROM Shadow E800,16K: Enabled
Wait For <F1> If Any Error : Enabled    Adaptor ROM Shadow EC00,16K: Enabled
Floppy Drive Seek At Boot  : Disabled   System  ROM Shadow F000,64K: Enabled
System Boot Up Sequence    : A:, C:
System Boot Up CPU Speed   : High
External Cache Memory      : Enabled
Internal Cache Memory      : Enabled
Password Checking Option   : Disabled
Video   ROM Shadow C000,16K: Enabled
Video   ROM Shadow C400,16K: Enabled
Adaptor ROM Shadow C800,16K: Enabled
Adaptor ROM Shadow CC00,16K: Enabled
Adaptor ROM Shadow D000,16K: Enabled

   ESC:Exit  Sel  (Ctrl)Pu/Pd:Modify  F1:Help  F2/F3:Color
   F5:Old Values  F6:BIOS Setup Defaults  F7:Power-On Defaults
```

Figure 6: Sample Set-up Screen of ROM BIOS Routine Shadowing

The following pages offer examples of what could be entered for CONFIG.SYS and AUTOEXEC.BAT. These listings, entered as a pair of files, permit the user to pick one of three types of configurations. The "PPT" configuration should be selected when the PPT software is to be run. NGS does not assume responsibility for any adverse affects caused by improper loading of these files.

Note

NGS always configures computer systems at the factory for best operation. In the case of a user supplying their own computer system, NGS recommends using one of these files or a subset of them. If you have any questions, please call for assistance.

CONFIG.SYS for Laptops

[MENU]

MENUITEM= MIN, BOOT WITH PCMCIA DRIVERS INSTALLED (REDUCES AVAILABLE RAM)

MENUITEM= MAX, BOOT WITHOUT PCMCIA DRIVERS INSTALLED (MAXIMIZES AVAILABLE RAM)

MENUITEM= PPT, BOOT WITHOUT EMM386 DRIVER (REQUIRED FOR PROPER PPT COMMUNICATIONS)

[MIN]

DEVICE=C:\DOS\HIMEM.SYS

DEVICE=C:\DOS\EMM386.EXE NOEMS x=D000-DFFF x=CB00-CBFF

BUFFERS=15,0

FILES=30

DOS=UMB

LASTDRIVE=Z

FCBS=4,0

DEVICE=C:\WINDOWS\IFSHLP.SYS

DOS=HIGH

STACKS=9,256

REM CARDSOFT

DEVICEHIGH /L:0;1,8112 /S =C:\DOS\POWER.EXE ADV:MAX

DEVICEHIGH=C:\CARDSOFT\SSCIRRUS.EXE

DEVICEHIGH=C:\CARDSOFT\CS.EXE

DEVICEHIGH=C:\CARDSOFT\CSALLOC.EXE

DEVICEHIGH=C:\CARDSOFT\ATADRV.EXE

DEVICEHIGH=C:\CARDSOFT\MTSRAM.EXE

DEVICEHIGH=C:\CARDSOFT\MTDDRV.EXE

DEVICEHIGH=C:\CARDSOFT\CARDID.EXE

[MAX]

DEVICE=C:\DOS\HIMEM.SYS

DEVICE=C:\DOS\EMM386.EXE NOEMS

BUFFERS=15,0

FILES=8
DOS=UMB
LASTDRIVE=E
FCBS=4,0
DEVICEHIGH /L:1,12048 =C:\DOS\SETVER.EXE
DOS=HIGH
DEVICEHIGH /L:1,4560 =C:\WINDOWS\IFSHLP.SYS
STACKS=9,256

[PPT]
DEVICE=C:\DOS\HIMEM.SYS
BUFFERS=15,0
FILES=8
DOS=UMB
LASTDRIVE=E
FCBS=4,0
DEVICEHIGH /L:1,12048 =C:\DOS\SETVER.EXE
DOS=HIGH
STACKS=9,256

AUTOEXEC.BAT for Laptops

```
GOTO %CONFIG%

:MIN
@ECHO OFF
C:\WINDOWS\SMARTDRV.EXE /X
PROMPT $p$g
PATH C:\WINDOWS;C:\DOS;C:\MOUSE;C:\CARDSOFT;C:\CARDVIEW;C:\VGA;
SET TEMP=C:\DOS
MTB
GOTO END

:MAX
LH /L:0;1,45456 /S C:\WINDOWS\SMARTDRV.EXE /X
@ECHO OFF
PROMPT $p$g
PATH C:\WINDOWS;C:\DOS;C:\MOUSE;C:\VGA;
SET TEMP=C:\DOS
LH /L:1,29136 MTB
GOTO END

:PPT
@ECHO OFF
PROMPT $p$g
PATH C:\WINDOWS;C:\DOS;C:\MOUSE;C:\VGA;
SET TEMP=C:\DOS
MTB
GOTO END

:END
```

CONFIG.SYS for Generic PCs

[MENU]

MENUITEM= PPT, BOOT WITHOUT EMM386 DRIVER (REQUIRED FOR PROPER PPT COMMUNICATIONS)

MENUITEM= MAX, BOOT WITH NORMAL CONFIGURATION

[MAX]

DEVICE=C:\DOS\HIMEM.SYS

DEVICE=C:\DOS\EMM386.EXE NOEMS

BUFFERS=15,0

FILES=8

DOS=UMB

LASTDRIVE=E

FCBS=4,0

DEVICEHIGH /L:1,12048 =C:\DOS\SETVER.EXE

DOS=HIGH

DEVICEHIGH /L:1,4560 =C:\WINDOWS\IFSHLP.SYS

STACKS=9,256

[PPT]

DEVICE=C:\DOS\HIMEM.SYS

BUFFERS=15,0

FILES=8

DOS=UMB

LASTDRIVE=E

FCBS=4,0

DEVICEHIGH /L:1,12048 =C:\DOS\SETVER.EXE

DOS=HIGH

STACKS=9,256

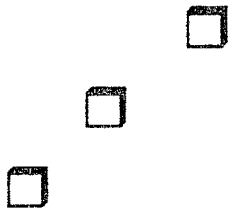
AUTOEXEC.BAT for Generic PCs

```
GOTO %CONFIG%

:MAX
LH /L:0;1,45456 /S C:\WINDOWS\SMARTDRV.EXE /X
@ECHO OFF
PROMPT $p$g
PATH C:\WINDOWS;C:\DOS;C:\MOUSE;
SET TEMP=C:\DOS
GOTO END

:PPT
@ECHO OFF
PROMPT $p$g
PATH C:\WINDOWS;C:\DOS;C:\MOUSE;
SET TEMP=C:\DOS
GOTO END

:END
```



Chapter Three
Hardware Overview

The PPT consists of two hardware components and a software package. The hardware components are a partial pressure quadrupole sensor and an ECU. The software package presents scanned data in several forms, is used to calibrate the PPT, and defines display parameters.

The Partial Pressure Sensor

The PPT's sensor contains an electron bombardment type ion source, quadrupole filter rods, and a Faraday Cup and/or continuous dynode Electron Multiplier detector. It is mounted with a standard 2 ¾ inch CF™ flange. The sensor is designed to operate in the pressure range of 10^{-4} to 10^{-9} Torr (10^{-4} to 10^{-12} Torr with Electron Multiplier detector) *directly* and up to atmosphere with a properly designed pressure reduction inlet system. The sensor has an electron bombardment type degas capability, and is designed to be able to withstand an external bakeout to 250°C.

When the PPT's sensor is properly placed inside a vacuum system, it provides an external connector for direct connection to an ECU.

The Electronic Control Unit

The ECU is a control and data gathering device with a built-in microprocessor. It connects directly to a partial pressure sensor and also to a PC. Using different hardware configurations, up to sixteen ECU's, connected to sixteen sensors, can all be connected to a single computer.

The ECU can be hardwired to interface with a PC with both RS-232 and BitBus™ communications. The communication protocol (RS-232 or BitBus™) is determined by the configuration file PPTINSTL.EXE. The communication protocol can be changed by editing the configuration file. Refer to the *Software Configuration Changes - PPTINSTL* section in Chapter Two - *Installation and Set-up* for information on changing the configuration file.

The ECU monitors the operating environment and automatically turns the sensor filament off if an overpressure condition, sensor power supply failure, or other improper operating condition arises.

How It All Fits Together

The PPT's sensor is installed inside a vacuum system. The ECU connects to the electrical feed through flange of the sensor. The ECU interfaces with a PC via RS-232 or BitBus™ communications. Data sent from the ECU is displayed on the PC in various formats (analog graphs, bar graphs, and tabular form). Also included in the PC software is the ability to calibrate the PPT by editing calibration parameters.

A pressure reduction system is required if the vacuum chamber pressure exceeds 10^{-4} Torr (see Appendix D).

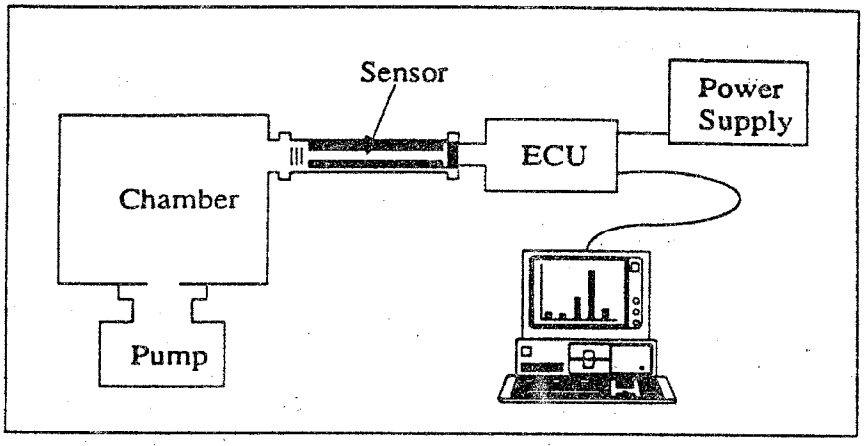


Figure 7: Generic System Set-up When Operating at Pressures Below 10^{-4} Torr.

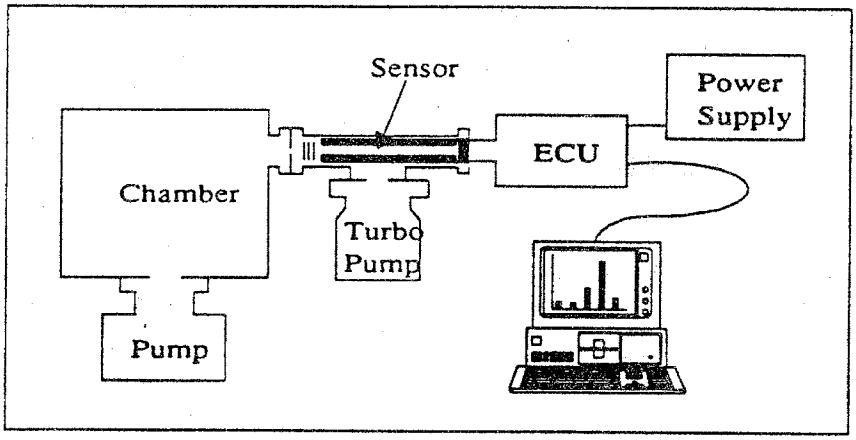


Figure 8: Generic System Set-up When Operating at Pressures Above 10^{-4} Torr.

External Control

In addition to the pre-existing two channels of analog monitoring, two opto-isolated input signals provide external control of Emission and Scanning. These signals work in parallel with the function keys F1 and F2 on the Host computer; however, the intention is that the user will use one or the other set of inputs (external control or keyboard control). A cable is available for connection to an external controller (PLC or computer).

The input signals for external control of Emission and Scanning are optically isolated. The signals are applied to the ECU by connecting a source of DC voltage in the range from +5 volts to +24 volts (nominal) to pin 1 of the connector on the rear panel of the ECU, marked 'CONTROL'. The signals are active low and connected to pins 2 and 3 of that connector (see Table 3).

The analog monitor signals appear on pins 4 and 5 of the connector on the rear panel of the ECU, marked 'CONTROL'. The ground reference pin for the analog monitor outputs is pin 6.

The cable assembly N401169-G1 (ordered separately) makes these connections. Connect the cable to the 'CONTROL' connector and connect the leads (already stripped) to the PLC or to another switching apparatus.

FUNCTION	J5 PIN #	COLOR
Source of DC voltage	1	Blue
External Control of Emission	2	Green
External Control of Scanning	3	Red
Analog Monitor Channel 1	4	Black
Analog Monitor Channel 2	5	Orange
Analog Monitor Ground	6	White

Table 3: External Control Cable Assembly N401169-G1 Pin Assignments

The PPT, Sensor and computer are installed in the normal way. Refer to Chapter Two - *Installation and Set-up* for detailed instructions. Connect the External Control cable assembly to the external control circuits (PLC, computer, etc.). Do not connect the External Control cable assembly to the ECU yet. Wait until after the familiarization with normal operation time.

Read the instructions in Chapter Four - *Software Overview* referring to software operation, in particular the control of Emission and Scanning using the function keys, F1 and F2. Note that the function keys have 'toggling' effects. That is, each time the key is pressed, the Emission (or Scanning) toggles between on and off.

When using the function keys for the first time (that is, during familiarization time with the PPT and its normal operation), the signal leads for external control of Emission and Scanning should not be connected to the ground side of the source of DC voltage. This will make it easier to learn how the function keys turn Emission and Scanning on and off. To do this, merely disconnect the External Control cable from the rear panel connector.

After the familiarization time, press function key F1 to turn Emission off. The external controls can be connected to external control circuits (connect the External Control cable).

With the External Control cable connected, make sure the function keys have toggled both Emission and Scanning to off. Then, using the PLC or another switching device, connect the external control of Emission signal lead to ground (the ground side of the source of DC voltage). The 'EMISSION' icon on the computer screen will turn on, just as if the function key had been pressed. Disconnect the external control of Emission from ground. The 'EMISSION' icon will turn off. Turn it on again. After a suitable time to allow the Emission Control Circuit in the ECU to stabilize, connect the external control of Scanning signal lead to ground. The 'SCAN' icon on the computer screen will turn on.

Now release the external control of Scanning; the 'SCAN' icon will turn off. Note that this operation is not toggling: when the signal lead is grounded, the transition turns the function on

and when the signal lead is ungrounded, the transition turns the function off. This is the normal operation with external controls.

The function keys can override the external controls; the opposite is also true. For example, if the external control for Emission is grounded, the 'EMISSION' icon will turn on. If then the F1 function key is pressed, the icon will turn off. Pressing it again turns Emission back on, even though the external control has been 'on' all this time. Then if the external control input is ungrounded, Emission will turn off again. The software looks for a transition on the external input. Thus, it detects the transition from on to off and from off to on. This interaction is true for Scanning as well.

A common situation which might need explanation is when the PLC turns Emission on and the user turns it off with the F1 key. Emission cannot be turned on by the PLC until it turns it off and then on again.

Chapter Four
Software Overview

General

The PPT software allows scanned data to be displayed on an IBM AT™ in a variety of formats. For example, an Analog graph is used in Analog Mode, a Bar graph is used in Bar Mode, and a tabular format is used in Table Mode. Most screen displays contain a menu box containing a list of menu items. To perform a function or switch modes, it is only necessary to select the function or mode from the list of available menu items. At the bottom of each screen display are instructions pertinent to the display. Occasionally, instructions are replaced with an error message.

Some functions edit display or Scanning parameters, and some are involved in calibration of the PPT. The configuration of a display is saved when exiting most modes. As a result, when those modes are re-entered the previous parameters and setup (the configuration), are operative.

The PPT has the ability to operate so that analog output continues to be periodically updated even when communication to the Host computer is lost. That is, the Host computer update queries are no longer required for automatic analog output updating. This means if the PPT analog output is required in process control, it is available even when the Host computer is disconnected or not responding on the RS-232 communications line.

Screen Format

There are common elements to all the screen displays presented in the PPT software. The table below summarizes the common elements, and Figure 9 shows their location.

Screen Element	Description
Status Area	This area is the uppermost line of text in the display. Starting on the left, the software name, Host software version number, and ECU firmware version number are shown. If the system is configured for BitBus™ communications and multiple ECU's are used, the system displays the number and name of the primary ECU. Still further to the right is the date and time (from the internal clock of the PC). All the way to the right are the words TOTAL PRESSURE and immediately under them is the total pressure reading of the system as seen by the primary ECU. Within the quadrupole sensor, there is a separate measurement made of the total ion current in the ion source. This provides an approximate indication of the total pressure at the sensor. This is the reading used by the ECU to determine when to shut off the filament due to overpressure. The total pressure display will change to "<5e-7" whenever the total pressure value falls below this threshold.

Caution

If the Total Pressure value is edited (in Tune Mode), the resultant Total Pressure value may be incorrect. This erroneous value could lead to a false safe reading being sent to the ECU during a time of overpressure. As a result, filament degradation may be accelerated.

Menu List	The menu list consists of modes/functions which are currently available. Each menu item has a capitalized, bolded letter. The item can be selected by pressing its capitalized letter, or by using the **cursor movement keys** to scroll the highlight bar to the menu item and then pressing the **ENTER** key.
Instruction Area	This area contains short instructions or, if appropriate, error messages.
Graphics Area	This is the area which contains the graphical or text display of scanned data. The displayed data can be from an ongoing scan, or data retrieved from a previous scan.
Function Keys	A Function Key is a programmed key. When a function key is toggled on, the display of that key and its function description turn white.

Table 4: Summary of Common Screen Elements

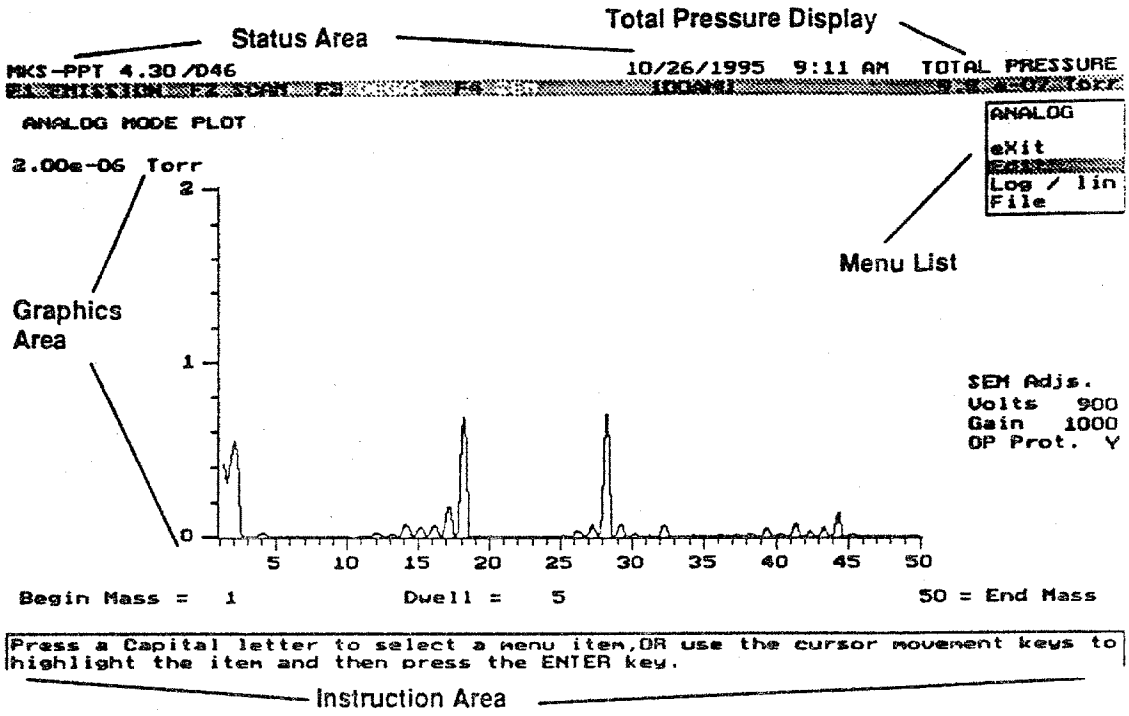


Figure 9: Screen Format

Keys

The PPT software utilizes Function Keys (F1 through F4), Cursor Movement Keys, and the normal Typing Keys (including TAB and ENTER).

Function Keys	
F1 - Emission	Toggles filament and ionizer power supplies on and off. When **Emission** is on, the word EMISSION is white.

Caution **Do not turn F1 Emission on until the system pressure is *less than* 10^{-4} Torr.**

F2 - Scan	Toggles Scanning On and Off. When Scanning is on, the PPT gathers data and the PC displays it. Scanning can only be turned on if **Emission** is already on. When Scanning starts, the word SCAN is temporarily replaced with the word ZERO. This means the ECU is recording the zero level (background noise). This can take several seconds if the **Dwell** is large. When zeroing is finished, the word SCAN is displayed in white.
F3 - Degas	Toggles the automatic sensor degas cycle on and off. When **Degas** is on, **Emission** becomes turned on even if it was not already on. The **Degas** function increases the emission current and the energy of the electrons being emitted by the filament. Degas times out in 5 minutes. The purpose of the **Degas** function is to remove contaminants from the ion source. If there is a high level of water vapor when the emission process is started, **Degas** can help eliminate the vapor. When **Degas** is on, the words EMISSION and DEGAS are white.
F4 - SEM	Turns on the Secondary Electron Multiplier Voltage to the value set. When the **SEM** is on, the word SEM will be white. Note: if the total pressure reading is above 10^{-6} Torr and Overpressure Protection is ON, this Function Key will be inoperative.

Caution **Using the Degas function decreases the life expectancy of the sensor filament. For best results only turn on Degas when the system pressure is below 10^{-6} Torr.**

Cursor Movement Keys	
Home, End, PgUp, PgDn, and the Arrow keys	These keys move the highlight/cursor. The **Arrow keys** move the highlight/cursor in the directions of the arrows. The **Home key** moves the highlight/cursor to the top of a list or to the first editable parameter on display. **End** moves the highlight/cursor to the end of a list or to the last editable parameter on display. **PgUp** and **PgDn** move the highlight/cursor to the top or bottom (respectively) of the part of a list which is currently displayed.
Typing Keys	
Tab	When appropriate, this key displays a list of filenames. If part of a filename has been entered in a Filename field, the **Tab** key lists all filenames which match the partial filename typed in. For example, if A is typed in, the **Tab** key displays all files which begin with the letter A.
ENTER (also called Return, Carriage Return, and CR)	This key confirms a command or field entry, and sends the command or entry to the CPU (central processing unit) inside the PC. For example, when retrieving a file, a filename may first be highlighted in a list of filenames. The ENTER key causes the highlighted file to be retrieved.
Alphanumeric keys	Letters and numbers are used to enter data. Additionally, when a letter is capitalized and bolded in a menu, pressing the bolded letter selects the menu item and executes its function. For example, almost all PPT menus include the menu item **eXit**. The letter **X** selects this menu item and causes the system to exit from its current display and return to the previous display.

Table 5: Keys and Their Functions

Functions

Just as there are display elements common to all modes, there are functions common to all or several modes. Table 6 indicates which functions are contained within each mode. The **eXit** and **Edit** functions are common to every mode. Although **Edit** is available in each mode and performs the same task (editing), the *exact* editing task depends upon which is the current mode. This is because the parameters which can be edited are different in different modes.

Other functions, such as **Log/lin** and **File**, are available in several but not all modes. **Log/lin** appears in the modes which have a graph with a linear or logarithmic Vertical Axis. **File** is available in all but Tune Mode. Still other functions, such as **liBrary** and **Auto tune**, appear in only one mode.

All functions are displayed in the menu box when they are available. When some functions (such as **Edit**) are selected, the menu box turns gray indicating that the other displayed functions are temporarily unavailable. To enable the menu box functions again, press **ESC** . This causes the system to escape from its current task (Editing in our example), enable the menu box functions, and return the menu box it to its previous colors.

How To Select a Function/Mode

The procedure for selecting a mode or function is exactly the same throughout the program. All available modes and functions are displayed in the menu box at the upper right area of the display. Each mode or function has one capitalized, bolded letter. There are two ways to select a mode/function:

1. Press the capitalized, bolded letter.

   For example, a common menu item is eXit. Notice the **X** in eXit is capitalized and bolded. To select eXit , it is only necessary to press the letter **X**.

2. Alternately, use the **cursor movement keys** to highlight the item and then press the **ENTER** key.

   For example, if the highlight bar happens to be near the bottom of the menu item list, the **Home** key, **PgUp** key, or repeated presses of the **Up arrow** key, move the highlight bar to the eXit menu item. When the highlight bar is on the word **eXit**, pressing the **ENTER** key selects the **EXIT** function.

	Analog	Bar	Table	P vs Time	Leak	Split	Tune
eXit	*	*	*	*	*	*	*
Edit	*	*	*	*	*	*	*
Log/lin	*	*		*	*	*	*
File	*	*	*	*	*	*	
liBrary		*					
New base		*	*				
View base		*	*				
Clear				*			
Beeper					*		
Pick left							*
pIck right							*
Auto tune							*
Save tune							*
Old tunes							*
Trip prog							*
loGger		*		*			

Table 6: The Functions Contained Within Each Mode

As shown in Table 6, there are several functions (for example, **eXit** and **File**), which are common across more than one mode. Each of these common functions is discussed below. The functions which are unique to a mode (for example, **liBrary** and **Beeper**), are explained in detail in the appropriate mode description in Chapter Five - *Overview of Modes*.

eXit

The **eXit** function is available in almost all menus throughout the program. This function returns the system to its previous display.

Edit

The **Edit** function is for modifying parameters. Each mode has its own editable parameters, and **Edit** allows them to be modified. The editable parameters within each mode are described in Chapter Five - *Overview of Modes*.

When **Edit** is selected, the current menu box turns gray (indicating its menu items are currently unavailable), and a highlight box appears. The instructions on the bottom of the screen change to:

Enter data, use arrow keys, ESC to menu

The parameter inside the highlight box is available for editing. To modify a parameter, type the desired new parameter value and press the ENTER key. To select another parameter for editing, use the cursor movement keys to move the highlight box around the screen.

If the new value typed in is out of range or inappropriate, the system responds with the following error message:

Entry error, use ESC.

Press the ESC to delete the new data and try again.

At all other times, the ESC enables the currently displayed (but unavailable) menu items. If a valid new value is typed in but the ENTER key has not yet been pressed, then ESC enables the currently displayed menu items without saving the new value.

Log/lin

Log/lin switches the vertical axis through five logarithmic formats and one linear format. The log formats display two, three, four, five, or six decades. Scanned data in the PPT is stored in floating point form which eliminates the need to re-scan the mass range when switching the vertical axis scale. Data is redrawn with each new scaling format.

The vertical axis can be switched through these six formats by repeatedly pressing the letter L which repeatedly selects **Log/lin**. Alternately, these six formats can be scrolled through by using the cursor movement keys to highlight the **Log/lin** function and then repeatedly pressing the ENTER key.

File

The **File** function is used to print, save, and retrieve scanned data. When **File** is selected, a menu appears with the following menu items: eXit, pRint, Save cfgr, Get cfgr, sAve data, and gEt data.

A. The **eXit** function returns to the previous menu.

B. Selecting **pRint** causes the current screen display to print. The data/graph, status information, and instructions are printed. The Function Key strip which appears in the screen display is not printed.

C. The **Save cfgr** function is used to save the current configuration settings to a file. Additionally, the displayed data is saved as a baseline.

When **Save cfgr** is selected, the instructions are replaced with the following message:

Tab/Filename:

ESC returns to the previous menu.

To save the configuration in a *new* file, enter an unused filename (eight characters maximum).

To save the configuration to a *previously saved* file, enter the file's filename or use the **TAB** key. The **TAB** key recalls all saved configuration files for the current mode. To retrieve only a partial list of currently saved files, type one or more characters of the filename(s) you want to retrieve, and then press the **TAB** key. The system responds by displaying all files which begin with the character(s) typed in.

For example, if the letters **MKS** are typed in and then the **TAB** key is pressed, only those filenames which begin with the three letters **M K S** are displayed.

Once a list of files is displayed, the **cursor movement keys** can be used to highlight the file you want to update with the current configuration. When the **ENTER** key is pressed, the following message appears:

File exists, are you sure? [y/n]

Press the letter **Y** and the system saves the current configuration to the highlighted filename.

D. The **Get cfgr** function is used to recall a previously saved configuration file. After the configuration is retrieved, all parameters can be edited and a new scan can commence.

When **Get cfgr** is selected, the instructions are replaced with the following message:

Tab/Filename:

ESC returns to the previous menu.

To recall a saved file, enter the filename of a saved file *or* use the **TAB** key. The **TAB** key recalls a list of saved configuration files for the current mode. To retrieve only a partial list of currently saved files, type one or more characters of the filename(s) you want to retrieve, and then press the **TAB** key. The system responds by displaying all files which begin with the character(s) typed in.

E. The **sAve data** function is similar to the **Save cfgr** function. The only difference is what gets saved. With **sAve data**, the currently displayed configuration *and scanned data* get saved. When **sAve data** is selected, the instructions are replaced with the following message:

Tab/Filename:

ESC returns to the previous menu.

To save the configuration and data to a *new* file, enter a filename (eight characters maximum).

To save the configuration and data to a *previously saved* file, enter a filename or use the TAB key. The TAB key recalls all saved configuration/data files for the current mode. To retrieve only a partial list of saved files, type one or more characters of the filename(s) you want to retrieve, and then press the TAB key. The system responds by displaying all files which begin with the character(s) typed in.

For example, if the letters MKS are typed in and then the TAB key is pressed, only those filenames which begin with the three letters M K S are displayed.

Once a list of files is displayed, the cursor movement keys can be used to highlight the file name you want to update with the current configuration and data. When the ENTER key is pressed, the following message appears:

File exists, are you sure? [y/n]

Press the letter Y and the system saves the current configuration and data to the highlighted filename.

In Analog, Bar, and P vs Time Modes, data is saved in binary format. To convert these data files to an ASCII format, use the provided file conversion utilities. See Appendix G - *File Conversion Utilities*, for detailed information regarding the use of these utilities.

F. The **gEt data** function is used to recall a previously saved configuration/data file. This function is similar to Get cfgr except that with **gEt data**, a file containing a configuration *and data* gets retrieved. Another difference is that the only editable parameter is the Vertical Axis, and this is only available in some modes (all parameters can be edited when just the configuration is retrieved). When the **gEt data** function is used, a new scan cannot commence (a new scan is possible when just the configuration is retrieved).

When **gEt data** is selected, the menu changes and the instructions are replaced with the following message:

Use arrow keys, or capital letters.

The menu is now labeled as the GET DATA menu and includes the following functions: eXit, Edit, Log/lin, Print, and Get data. The **eXit** function returns to the previous menu. The only other function which is enabled at this point is **Get data.**

When **Get data** is selected, the instructions are replaced with the following message:

Tab/Filename:

ESC returns to the previous menu.

To get a file containing data and a configuration, enter a filename or press the TAB key. The TAB key recalls all configuration/data files for the current mode. To retrieve only a partial list of files, type one or more characters of the filename(s) you want to retrieve, and then press the TAB key. The system responds by displaying all files

which begin with the character(s) typed in. Use the **cursor movement keys** to scroll through the list. and then press ENTER to select a file.

Once the data and configuration are retrieved, the display can be printed by selecting **Print** from the menu. The **Log/lin** function is operable in those modes which list it in their menu. The **Edit** function allows the Vertical Axis scale to be edited, but does not allow other parameters to be changed.

New Base

Two modes (Bar and Table), contain the **New base** function. The purpose of this function is to establish a baseline of data from currently displayed spectrum information. Once the baseline is established, any deviation from that baseline (positive or negative) can be observed. To observe deviation from the baseline, a parameter called the *Subtraction Switch* must be enabled. When the Subtraction Switch is enabled, the system subtracts the baseline values from the current data, and displays the difference.

To establish a baseline, simply select the **New base** menu item. The system responds by capturing all the currently displayed data and saving it in a file. Only one baseline can be stored per mode. To view the stored baseline, use the **View base** function.

Note 

Although only one baseline can be stored with the **New base** function, additional baselines can be stored with the **Save cfgr** function. When a configuration is saved, the displayed data is saved as a baseline.

View base

Bar and Table Modes contain the View base function. This function displays the stored baseline for the current mode. Only one baseline is stored per mode.

To view the baseline for the current mode, simply select the **View base** menu item. The system responds by displaying the spectral data contained in the baseline file.

loGger

The **loGger** function is used to set up the Store function key parameters. Use the Edit function to enter the edit screen and toggle storage enable to Y to allow storage of ASCII data. When **loGger** is selected, the user is given a screen with datalogging options. These options are the path and filename of the datalogged file and the log interval. The log interval is in tenths of minutes and cannot be zero.

To activate Bar Mode continuous data storage, use the edit function and scroll to the DataLog Switch. When the DataLog Switch is set to 'Y', continuous data is stored to an ASCII file that is user defined. When the switch is set to 'N' the data is not saved to the file. By selecting the **loGger** option, the user is able to specify the path and filename for the logfile as well as the log

interval. The log interval is in tenths of minutes and cannot be zero. The fastest log interval available is 0.1 minutes (6 seconds). A .BAR extension will be assigned to the file.

To activate the P vs Time Mode continuous data storage, use the edit function and scroll to the DataLog Switch. When the DataLog Switch is set to 'Y', continuous data is stored to an ASCII file that is user defined. When the switch is set to 'N' the data is not saved to the file. By selecting the loGger option, the user is able to specify the path and filename for the logfile as well as the log interval. The log interval is in tenths of minutes and cannot be zero. The fastest log interval available is 0.1 minutes (6 seconds). A .PVT extension will be assigned to the file.

Data logging does not begin until a new sweep has begun. Therefore, to initiate data logging after the DataLog Switch is set to 'Y', press the ESCAPE key and select the Clear option. This clears the screen, initiating a new sweep. Once the DataLog Switch is set to 'N', the file will be closed at the end of the sweep. By selecting the Clear option the user can force the sweep to end and the file to be closed.

Modes

There are several modes in the PPT software. Each mode manipulates or presents data in a significantly unique way. All modes are always available from the System Menu. A summary of the modes and their functions is presented in Table 7.

Mode	Function
Analog	Displays a user-defined portion of the mass spectrum in a line graph format. Data is displayed as peak shapes corresponding to the partial pressures of the scanned amu's.
Bar	Displays a user-defined portion of the mass spectrum in a bar graph. The function of this mode is identical to Analog Mode, but the information gathered is displayed differently. Discrete amu values appear as bar chart partial pressures instead of peak shapes as in Analog Mode.
Table	The data gathered for up to twelve masses is displayed in tabular form. This mode shows values for discrete points in the spectrum, not for a range of the mass spectrum as in the two previous modes.
P vs Time	The partial pressures for up to sixteen discrete amu values are plotted in a Pressure versus Time graph. The time period for the graph ranges from 6 minutes (.1 hours), to 100 hours (about 4 days). This mode is useful for observing trend analysis of various gases.
Leak	A user selected amu value is continuously scanned with a display refresh period of 0.1 minutes to 10 minutes. This mode is useful for detecting leaks in a vacuum system by using a trace gas (such as helium), and selectively increasing the concentration of the gas around suspected areas of the vacuum system.
Split	This mode displays the data in a fashion similar to what is shown in Analog Mode. The difference is that in Split Mode two graphs of spectral data are displayed simultaneously (as opposed to just one graph as in Analog Mode). Each graph can cover a different mass range, and have different Vertical Axis scaling and Dwell values.
Tune	Calibration and resolution of the PPT is performed in this mode. This calibration can be used to accommodate different gases (the sensor is calibrated with nitrogen).

Table 7: Summary of Modes

The System Menu

The System Menu is the first display in the PPT software. All modes are listed in the System Menu. In addition, the System Menu has Quit and Reset ecu functions. If the system is configured for BitBus™ communications the Device # function are added to the System Menu.

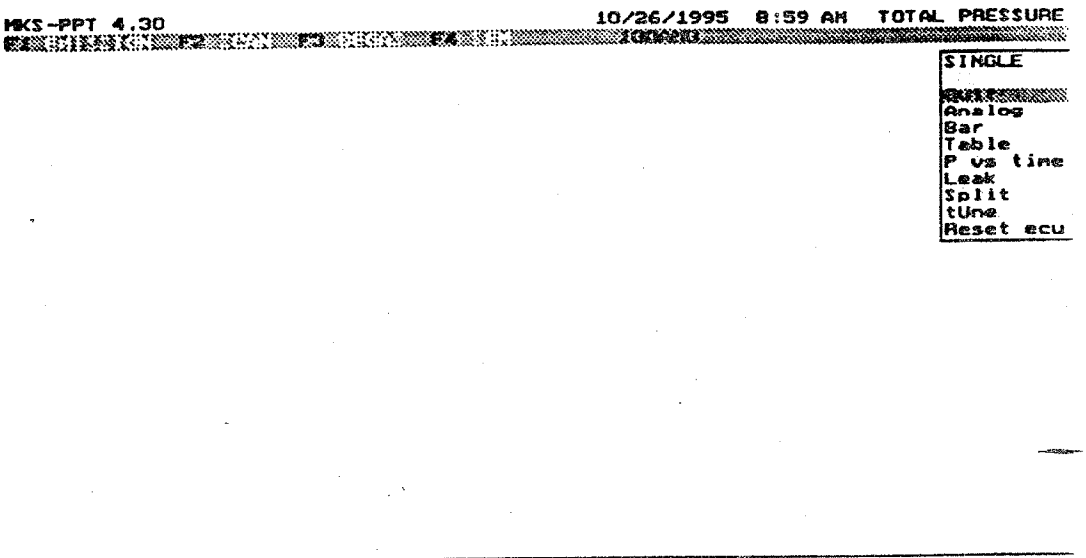


Figure 10: The System Menu Display When Configured For RS-232 Communications.

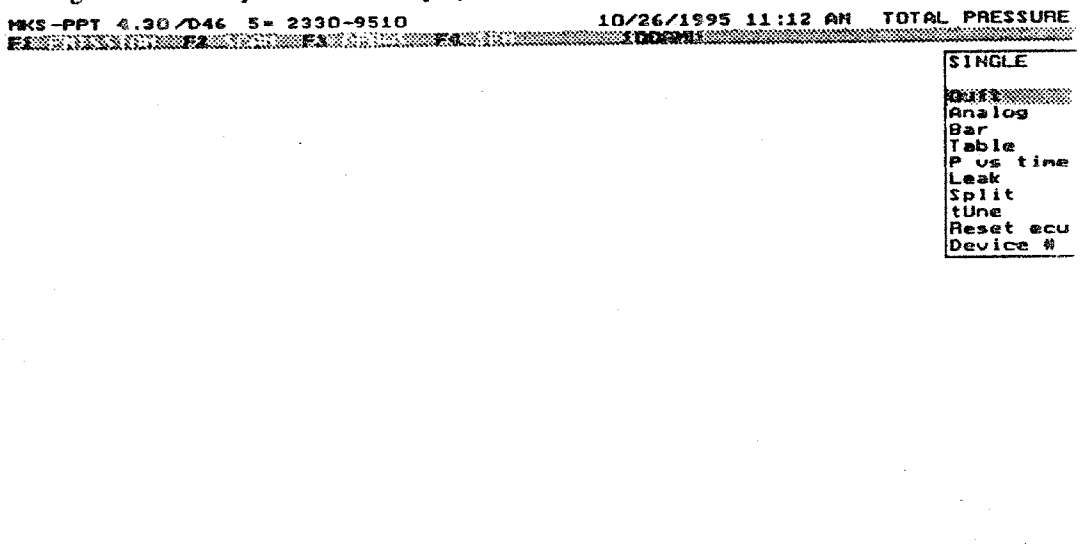


Figure 11: The System Menu Display When Configured For BitBus™ Communications

1. The **Quit** function exits the program. If **Emission** is still on when the **Quit** function is evoked, the system responds by displaying the following message:

   User Exited With Emission Off

   The software will turn **Emission** off before exiting.

2. If a mode is selected from the System Menu, the system responds by switching to the mode selected. If **Emission** is on, Scanning begins immediately.

3. To reset the ECU select the **Reset ecu** menu item.

The system responds by displaying the following message:

RESETTING THE ECU, PLEASE WAIT . .

When the ECU has been reset, the instructions return to the normal System Menu message (Use arrow keys, or capital letters).

4. If the system is configured for BitBus™ communications, the **Device #** menu item becomes available.

   The Device number menu item refers to the ID numbers of the ECU's configured in the system. Each ECU must be given an ID number and station name during the installation process when the system is configured for BitBus™ communications (see the *Software Configuration Changes - PPTINSTL* section in Chapter 2 - *Installation and Set-up* to change system configuration).

   Since BitBus™ operation allows more than one ECU to be configured in the system, it becomes necessary to select which one is to be used in all modes to obtain scanned data, and which one is also to be used in all modes to determine the Total Pressure reading.

   When **Device #** is selected, the System Menu box and its contents are subdued (they turn gray), and a list of the currently configured ECU ID numbers and their station names is displayed in a box in the graphics area of the screen (refer to Figure 12). After each station name, the emission status (EMIS ON, or EMIS OFF) is displayed. Only one ECU in the listing is highlighted. The instructions change to the following:

   Use arrows, ESC, CR to select

   ESC exits out of the Device # display, and enables the System Menu again (the menu box is no longer subdued).

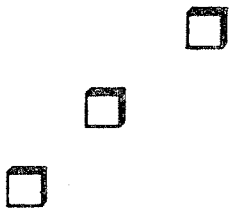
1 = Etching Chamber	EMIS ON
2 = CVD Chamber	EMIS ON
3 = Etching Chamber 2	EMIS OFF

Figure 12: An Example of the Device # List

   A. To change the Emission status of an ECU, use the **cursor movement keys** to highlight the ECU, then press the **F1 EMISSION** key to toggle the Emission status between On and OFF.

   B. To select an ECU as the primary ECU (the one which is used by all other modes and is used to determine Total Pressure), use the **cursor movement keys** to highlight the ECU, then press the **ENTER** key.

The system responds by configuring the selected ECU as the primary ECU and displaying the ECU number and station name on the Status Line (see Figure 9 for the location of the Status Line).



Chapter Five
Overview of Modes

Analog

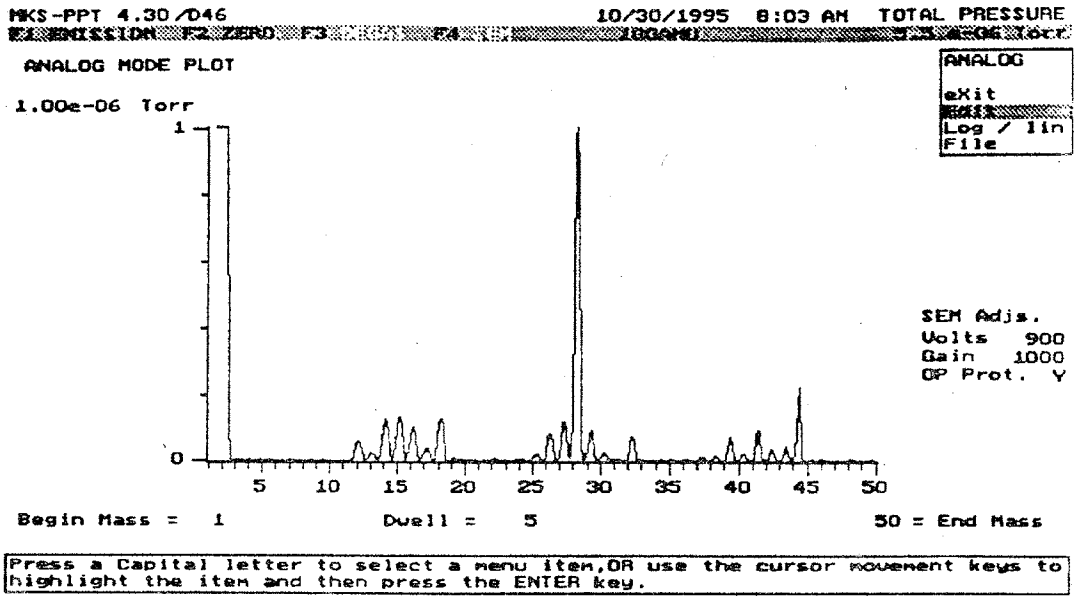


Figure 13: Analog Mode Display

The Analog Mode allows examination of a portion of the mass spectrum in one graph. It is often useful to scan the entire AMU range to find peaks of interest. These peaks can then be displayed in more detail in Analog Mode or another mode.

Edit Parameters	Description of Analog Mode Editable Parameters
Vertical Axis Scaling	This is the full scale pressure value used for viewing the spectrum. This parameter is edited separately for each graph. The range is from 1 x 10^{-3} Torr to 1 x 10^{-10} Torr in Faraday Mode and 1 x 10^{-3} Torr to 1 x 10^{-14} Torr with the SEM on. This parameter is typed as ***n*e-*x*** where ***n*** is an integer between 1 and 10 inclusive, and where ***x*** is an integer between 3 and 10 inclusive.
Begin Mass	This is the amu value where scanning begins. The **Begin Mass** range is 1 to 100 amu.
Dwell	**Dwell** represents the desired rate of filtering needed for making each measurement. If the **Dwell** is increased, Scan Time increases but noise is reduced. The **Dwell** range is 1 to 1000. Scan Time = (**Dwell** * 10 ms) per data point. Number of Data Points = 401/(**End Mass** - **Begin Mass** + 1)
End Mass	This is the amu value where scanning ends. The **End Mass** range is the AMU range of the RGA. To make a meaningful graph, the **End Mass** value should be greater than the **Begin Mass** value.
Volts	This value adjusts the SEM voltage. The **Volts** range is 0 to 3000.
Gain	The gain is the amplification scalar applied to the SEM signal. The typical **Gain** value is 1000. The **Gain** value range is 1 to 30000.
OP Prot.	When set to 'Y', the Overpressure Protection keeps the SEM from turning on if the total pressure is greater than 10^{-6}. When set to 'N', Overpressure Protection is disabled, allowing the SEM to turn on regardless of the total pressure. Overpressure Protection defaults to 'Y'.

Table 8: Editable Parameters in Analog Mode

Caution 

The PPT sensor Electron Multiplier may be damaged if exposed to total pressures above 10^{-4} Torr. Do not disable Overpressure Protection if using the PPT above 10^{-4} Torr.

Note 

It is possible to set the **Begin Mass** and **End Mass** to the same amu value. A straight line scan will result.

It is also possible to enter an **End Mass** value which is greater than the **Begin Mass** value. In this case, the system automatically swaps the two values so that the **Begin Mass** is less than the **End Mass**.

Bar

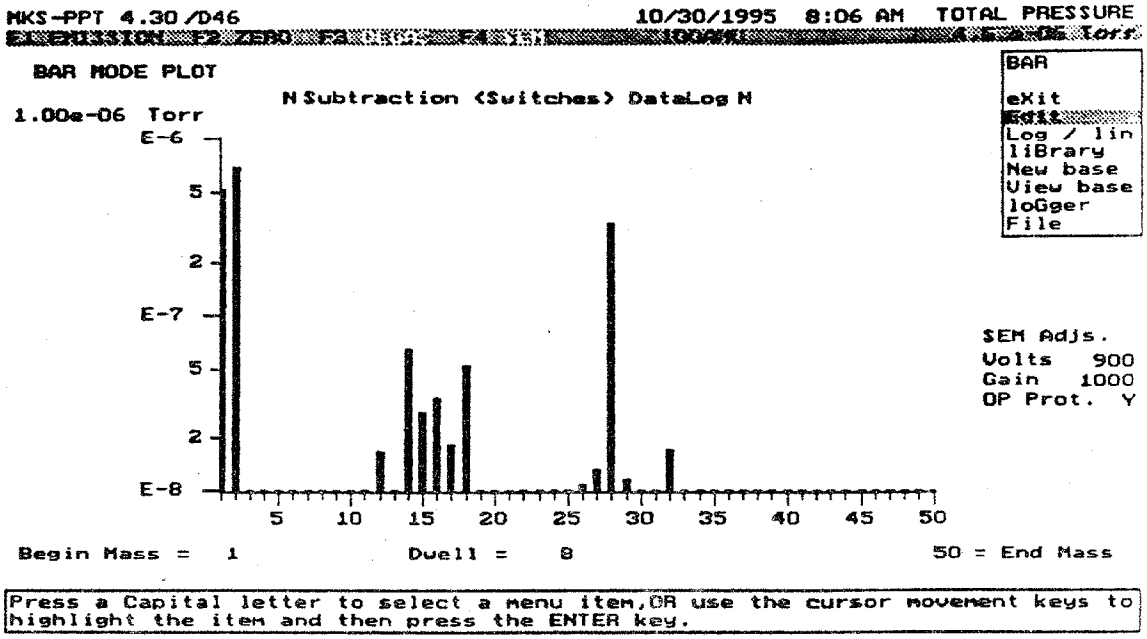


Figure 14: Bar Mode Display

Bar Mode allows examination of a user-defined portion of the mass spectrum in one graph. The scanned data is displayed differently however, from the display in Analog Mode. Discrete amu values appear as bar chart partial pressures instead of peak shapes as in Analog Mode.

Bar Mode has a unique liBrary function and the ability to store continuous ASCIIdata. In addition, it has the ability to create a baseline from displayed scanned data (not displayed liBrary information),and use the baseline for comparison with other scanned data.

Edit Parameters	Description of Bar Mode Editable Parameters
Subtraction Switch	The Subtraction Switch uses a previously saved spectrum baseline as the basis for a new display. As scanning proceeds, the display shows any deviation (positive or negative), from the baseline data. This parameter is not available when using Bar Mode's **liBrary** function. The Subtraction Switch can be used to display the effect of a new gas introduced into the system. It is also useful in determining if leakage is occurring.
DataLog Switch	When enabled, the DataLog feature stores continuous ASCII data to a file that is user defined. See Appendix F for the data format. Continuous data will be appended to this file until the switch is disabled or the file is erased.
Vertical Axis Scaling	This is the full scale pressure value used for viewing the spectrum. This parameter is edited separately for each graph. The range is from 1 x 10^{-3} Torr to 1 x 10^{-10} Torr in Faraday Mode and 1 x 10^{-3} Torr to 1 x 10^{-14} Torr with the SEM on. This parameter is typed as ***n*e-*x*** where ***n*** is an integer between 1 and 10 inclusive, and where ***x*** is an integer between 3 and 10 inclusive.
Begin Mass	This is the amu value where scanning begins. Its range is the AMU range of the RGA.
Dwell	Dwell represents the desired rate of filtering needed for making each measurement. If the Dwell is increased, Scan Time increases but noise is reduced. The Dwell range is 1 to 1000. Scan Time = (Dwell * 10 ms) per amu.
End Mass	This is the amu value where scanning ends. Its range is 1 to 100 amu. To make a meaningful graph, the End Mass value should be greater than the Begin Mass value.
Volts	This value adjusts the SEM voltage. The Volts range is 0 to 3000.
Gain	The gain is the amplification scalar applied to the SEM signal. The typical Gain value is 1000. The Gain value range is 1 to 30000.
OP Prot.	When set to 'Y', the Overpressure Protection keeps the SEM from turning on if the total pressure is greater than 10^{-6}. When set to 'N', Overpressure Protection is disabled, allowing the SEM to turn on regardless of the total pressure. Overpressure Protection defaults to 'Y'.

Table 9: Editable Parameters in Bar Mode

Caution 

The PPT sensor Electron Multiplier may be damaged if exposed to total pressures above 10^{-6} Torr. Do not disable Overpressure Protection if using the PPT above 10^{-6} Torr.

Note

It is possible to set the **Begin Mass** and **End Mass** to the same amu value. A straight line scan will result.

It is also possible to enter an **End Mass** value which is greater than the **Begin Mass** value. In this case, the system automatically swaps the two values so that the **Begin Mass** is less than the **End Mass**.

The **liBrary** function is unique to Bar Mode. The **liBrary** is a collection of standard spectra. In each **liBrary** entry, the largest peak is at full scale. When **liBrary** is selected, a menu appears with the following items: eXit, Edit, Log/lin, Previous, Next, Catalog, and File.

The **liBrary** feature causes the screen to divide into two graph areas. The upper graph displays currently scanned data and the lower graph is for the **liBrary** spectrum. Each gas has a standard cracking pattern of potentially many peaks. The **liBrary** cracking pattern however, displays only the six largest peaks (if there are that many significant peaks), in the cracking pattern. For example, the cracking pattern stored in the liBrary function for water is H, H_2, O, OH, and H_2O (only five peaks).

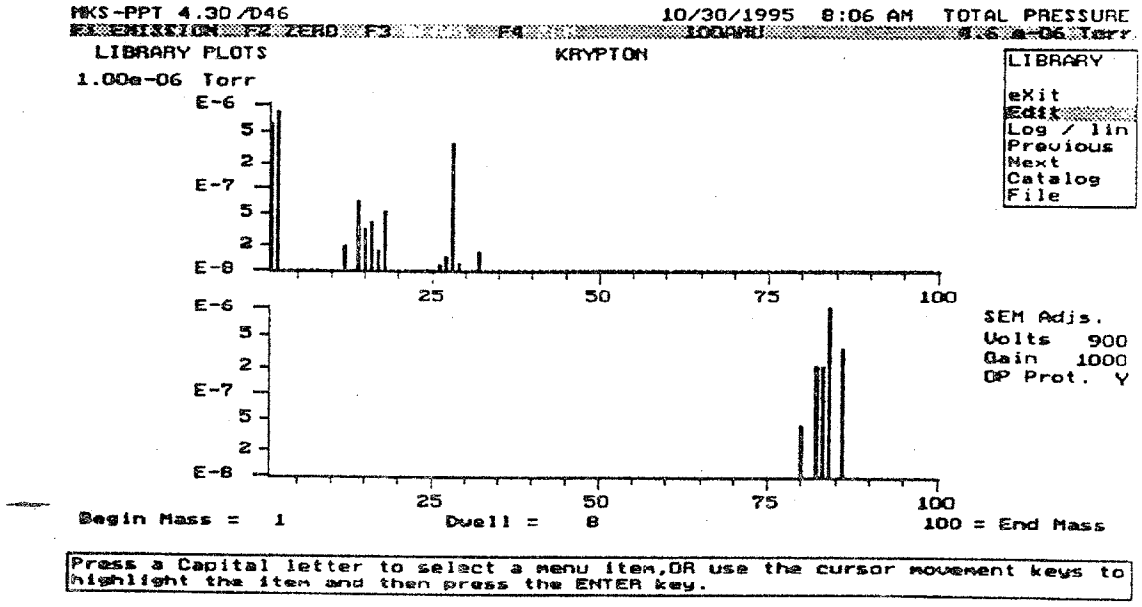


Figure 15: The liBrary Display in Bar Mode

The name of the gas type currently displayed in the **liBrary** graph is shown at the top of the graphics area on the screen. In the above example, nitrogen is the gas type displayed in the **liBrary** graph.

Note

1. The **liBrary** is an ASCII file and can be edited in DOS.
2. It is a good idea to maximize the highest peak in the upper graph without exceeding full scale. This makes it easier to compare the scanned spectrum against a **liBrary** spectrum.

A. The **eXit** function returns to the previous menu.

B. The **Edit** function allows editing of the following parameters: Vertical axis scale, Begin Mass, Dwell, and End Mass. These parameters are edited simultaneously for both graphs in the display.

C. The **Log/lin** function switches the vertical axis on both graphs through three logarithmic formats and one linear format (recall that the *scale* for the vertical axis is edited with the **Edit** function). The logarithmic formats cover two, three, or four decades.

D. Selecting **Previous** causes the system to display the previous spectrum in the **liBrary**'s list of spectra.

E. Selecting **Next** causes the system to display the next spectrum in the **liBrary**'s list of spectra.

F. When **Catalog** is chosen, a window replaces the **liBrary** graph. Inside the window is an alphabetical list of available **liBrary** spectra with a highlight bar over one of the entries. To the left of each entry's name is the mass value of the maximum peak for that entry.

Use the cursor movement keys to move the highlight bar through the entire list of spectra in the **liBrary**. The ENTER causes the window to be replaced with a **liBrary** spectrum for the highlighted gas.

G. The liBrary **File** function is used to Print, Save and Get configuration files, and sAve and gEt data/configuration files.

The **eXit** function returns to the previous menu. The **Print** function prints whatever is currently displayed on the screen. The data/graph, status information, and instructions are printed. The Function Key strip which appears in the screen display is not printed. **Save cfgr** saves the current configuration settings to a file. The configuration settings include the vertical axis full scale value, the vertical axis scaling format (logarithmic or linear), Begin Mass, Dwell, and End Mass for both the currently scanned data and the **liBrary** graph. **Get cfgr** gets a configuration which was previously stored as a file. A specific filename may be typed in and is retrieved when the **ENTER** key is pressed, or a list of stored filenames can be retrieved by pressing the **TAB** key. The **sAve data** function saves the current configuration *and scanned data* to a file. The **gEt data** function allows for retrieval of previously saved configuration/data files.

More About The liBrary Spectra File—PPT_SPEC.CFG

The PPT installation program loads several files onto the computer's hard drive. One of these files is called PPT_SPEC.CFG. This ASCII file contains cracking pattern information for all the gas types in the liBrary.

The list of information in the PPT_SPEC.CFG file is presented as follows:

Listed on the left is the name for each gas type in the liBrary.

To the right of each gas type are several sets of cracking pattern values. The first number in each set is the percent of peak height, and the second number is an amu value. If there are six cracking pattern masses, then there are six sets of cracking pattern values.

For example, one gas type listed in the liBrary is WATER. The cracking pattern information for water is presented as follows:

WATER, 100,18, 25,17, 6,1, 2,16, 2,2

This information means that a peak at 100% scale is available for mass 18 (H_2O), a peak at 25% scale is available for mass 17 (OH), a peak at 6% scale is available for mass 1 (H), and a peak at 2% scale is available for mass 16 (O) and for mass 2 (H_2).

Additional gas types and their cracking pattern information can be added to the PPT_SPEC.CFG file with an editor. Existing information can also be edited. For example, when at the DOS level, the DOS editor *edlin* or *edit* can be used to modify the PPT_SPEC.CFG file.

Note

After editing the PPT_SPEC.CFG file, some text editors leave a <CNTL>–Z character at the end of the file. This character must be removed for proper operation of the PPT software. Place the cursor at the start of the line below the last entry in the file. Delete this line and the two lines that follow it. DO NOT delete the last entry in the file.

Table

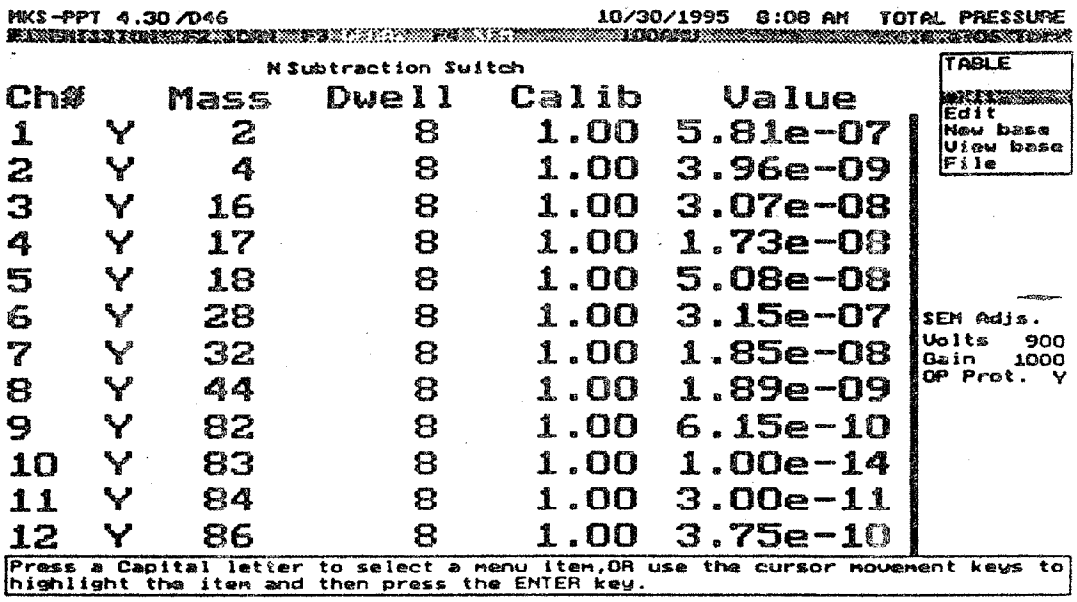


Figure 16: Table Mode Display

In Table Mode, data gathered for up to twelve different masses are displayed in tabular form. This mode shows values for discrete amu values in the spectrum, not for a range of the mass spectrum as in Analog and Bar Modes.

Edit Parameters	Description of Table Mode Editable Parameters
Subtraction Switch	The Subtraction Switch uses a previously saved spectrum baseline as the basis for a new display. As scanning proceeds, the display shows any deviation (positive or negative), from the baseline data. The Subtraction Switch can be used to display the effect of a new gas introduced into the system. It is also useful in determining if leakage is occurring. NOTE: If the Edit function is used (e.g., to change a mass) the baseline does not reflect the edited parameter.
Channel Activation	*Channel* refers to a method of labeling rows in the display. Each channel (row) contains information for one scanned peak. A channel can be activated or deactivated (toggled on or off). Only channels that are turned on (activated) are scanned and they are displayed in white. Channels that are turned off are displayed in subdued gray. A channel is turned on (activated), by using the cursor movement keys to highlight the gray dash in the channel, typing the letter Y and pressing the ENTER key. The system responds by placing a check mark where the dash used to be, and displaying the channel information in bright text. A channel is turned off (deactivated), by using the cursor movement keys to highlight the bright check mark in the channel, typing the letter N and pressing the ENTER key. The system responds by placing a dash where the check mark used to be, and displaying the channel information in subdued gray.
Mass	This is one of the twelve possible amu values to be scanned. The value must be within the AMU range of the RGA.
Dwell	Dwell represents the desired rate of filtering needed for making each measurement. If the Dwell is increased, Scan Time increases but noise is reduced. The Dwell range is 1 to 1000. Scan Time = (Dwell * 20 ms) + 10 ms per channel.
Value	Although Value is not an editable parameter, it is included here because it appears in the same table as the editable parameters. Value is the scanned partial pressure value for the peak (amu) of interest. This number can be indirectly edited by changing the Calib (Calibration Factor) to a number other than one. NOTE: If a baseline is created (with New base) and the Edit function is used (e.g., to change a mass), the baseline is not updated with the edited parameter. The original Value numbers are still stored in the baseline for each channel and will be used if the Subtraction switch is turned on.

Calib	The **Calibration Factor** is a display multiplier. The scanned value is multiplied by this calibration factor, and the result is displayed in the column labeled *Value*. For example, if the calibration factor is two, the scanned value is doubled and the result is displayed in the *Value* column. The Calibration Factor range is 0.01 to 10.00. The Calibration Factor can be used to more accurately assess the level of different gases in the system due to the variation of ionization probabilities of different diameter molecules (the sensor was calibrated with nitrogen).
Volts	This value adjusts the SEM voltage. The **Volts** range is 0 to 3000.
Gain	The gain is the amplification scalar applied to the SEM signal. The typical **Gain** value is 1000. The **Gain** value range is 1 to 30000.
OP Prot.	When set to 'Y', the Overpressure Protection keeps the SEM from turning on if the total pressure is greater than 10^{-6}. When set to 'N', Overpressure Protection is disabled, allowing the SEM to turn on regardless of the total pressure. Overpressure Protection defaults to 'Y'.

Table 10: Editable Parameters in Table Mode

Caution 

The PPT sensor Electron Multiplier may be damaged if exposed to total pressures above 10^{-4} Torr. Do not disable Overpressure Protection if using the PPT above 10^{-4} Torr.

Note 

It is a good idea to turn off (deactivate), all channels not needed for observation. Only activated channels are scanned, so the scanning process is quicker if fewer channels are activated.

Pressure vs Time

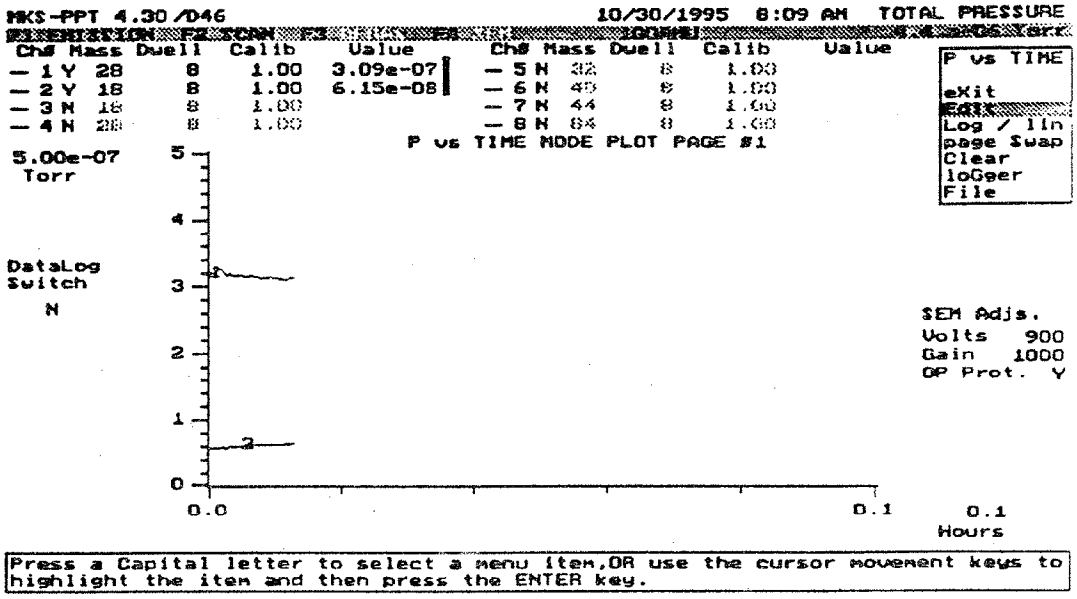


Figure 17: P vs Time Mode Display

The P(ressure) vs Time Mode is useful for observing trend analysis of various gases. Up to sixteen (eight per page) user-selected gases are scanned and the gathered data is displayed in two different formats. One format plots the sixteen (eight per page) discrete spectrum points in a Pressure versus Time graph. The other format displays the data in tabular form. The table has the same parameters as those found in Table Mode (Channel activation, Mass, Dwell, and Calib values, and a Value column). Each row of information has a colored line next to it which serves as a key for the graph portion of the display.

Edit Parameters	Description of P vs Time Mode Editable Parameters
Channel Activation	*Channel* refers to a method of labeling rows in the tabular display. Each channel (row) contains information for one scanned peak. A channel can be activated or deactivated (toggled on or off). Only channels that are turned on (activated) are scanned and they are displayed in white. Channels that are turned off are displayed in subdued gray. A channel is turned on by using the **cursor movement keys** to highlight the gray dash in the channel, typing the letter **Y** and pressing the **ENTER** key. The system responds by placing a check mark where the dash used to be, and displaying the channel information in bright text. A channel is turned off by using the **cursor movement keys** to highlight the bright check mark in the channel, typing the letter **N** and pressing the **ENTER** key. The system responds by placing a dash where the check mark used to be, and displaying the channel information in subdued gray.
DataLog Switch	When enabled, the DataLog feature stores continuous ASCII data to a file that is user defined. See Appendix F for the data format. Continuous data will be appended to this file until the switch is disabled or the file is erased.
Mass	This is one of the four possible amu values to be scanned. The value must be within the AMU range of the RGA.
Dwell	**Dwell** represents the desired rate of filtering needed for making each measurement. If the **Dwell** is increased, Scan Time increases but noise is reduced. The **Dwell** range is 1 to 1000. Scan Time = (**Dwell** * 20 ms) + 10 ms per channel.
Calib	The **Calibration Factor** is a display multiplier. The scanned value is multiplied by this calibration factor, and the result is displayed in the column labeled *Value*. For example, if the calibration factor is two, the scanned value is doubled and the result is displayed in the *Value* column. The Calibration Factor range is 0.01 to 10.00. The Calibration Factor can be used to more accurately assess the level of different gases in the system due to the variation of ionization probabilities of different diameter molecules (the sensor was calibrated with nitrogen).
Value	Although **Value** is not an editable parameter, it is included here because it appears in the same table as the editable parameters. **Value** is the scanned partial pressure value for the peak (amu) of interest. This number can be indirectly edited by changing the **Calib** (Calibration Factor) to a number other than one.

Vertical Axis Scaling	This is the full scale pressure value used for viewing the spectrum. This parameter is edited separately for each graph. The range is from 1 x 10^{-3} Torr to 1 x 10^{-10} Torr in Faraday Mode and 1 x 10^{-3} Torr to 1 x 10^{-14} Torr with the SEM on. This parameter is typed as ***n*e-*x*** where ***n*** is an integer between 1 and 10 inclusive, and where ***x*** is an integer between 3 and 10 inclusive.
Scan time	Scanning time is plotted on the horizontal axis. The range is 0.1 hours (6 minutes) to 100 hours (4 days). When a completed P vs Time plot is created, scanning stops. To resume the scanning, press the **F2** key. This clears all previously displayed data.
Volts	This value adjusts the SEM voltage. The **Volts** range is 0 to 3000.
Gain	The gain is the amplification scalar applied to the SEM signal. The typical **Gain** value is 1000. The **Gain** value range is 1 to 30000.
OP Prot.	When set to 'Y', the Overpressure Protection keeps the SEM from turning on if the total pressure is greater than 10^{-6}. When set to 'N', Overpressure Protection is disabled, allowing the SEM to turn on regardless of the total pressure. Overpressure Protection defaults to 'Y'.

Table 11: Editable Parameters in P vs Time Mode

Caution 

The PPT sensor Electron Multiplier may be damaged if exposed to total pressures above 10^{-6} Torr. Do not disable Overpressure Protection if using the PPT above 10^{-5} Torr.

The **Clear** function is used to clear the P vs Time plot. If the **Clear** function is used *during* a scan, the plot area is cleared and scanning continues but the plotting begins again at time zero.

Leak

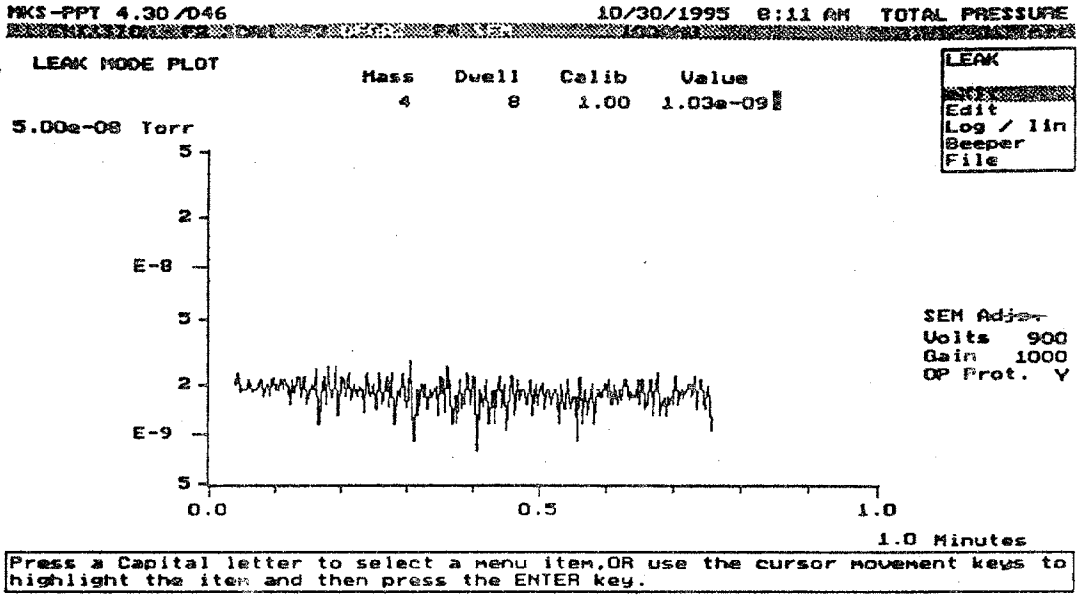


Figure 18: Leak Mode Display

This mode is useful for detecting leaks in a vacuum system by using a trace gas (such as helium), and selectively increasing the concentration of the gas around suspected areas of the vacuum system.

Data is displayed in two different formats. One format plots the partial pressure data in a Pressure versus Time graph; the other format displays the data in tabular form. The table has most of the same parameters as those found in Table Mode (Mass, Dwell, Calib values, and a Value column).

Edit Parameters	Description of Leak Mode Editable Parameters
Mass	This is the amu value to be scanned. The value must be within the AMU range of the RGA.
Dwell	**Dwell** represents the desired rate of filtering needed for making each measurement. If the **Dwell** is increased, Scan Time increases but noise is reduced. The **Dwell** range is 1 to 1000. Scan Time = (Dwell * 20 ms) + 10 ms.
Calib	The **Calibration Factor** is a display multiplier. The scanned value is multiplied by this calibration factor, and the result is displayed in the column labeled *Value*. For example, if the calibration factor is two, the scanned value is doubled and the result is displayed in the *Value* column. The Calibration Factor range is 0.01 to 10.00. The Calibration Factor can be used to more accurately assess the level of different gases in the system due to the variation of ionization probabilities of different diameter molecules (the sensor was calibrated with nitrogen).
Value	Although **Value** is not an editable parameter, it is included here because it appears in the same table as the above editable parameters. **Value** is the scanned partial pressure value for the peak (amu) of interest. This number can be indirectly edited by changing the **Calib** (Calibration Factor) to a number other than one.
Vertical Axis Scaling	This is the full scale pressure value used for viewing the spectrum. This parameter is edited separately for each graph. The range is from 1 x 10^{-3} Torr to 1 x 10^{-10} Torr in Faraday Mode and 1 x 10^{-3} Torr to 1 x 10^{-14} Torr with the SEM on. This parameter is typed as *n*e-*x* where *n* is an integer between 1 and 10 inclusive, and where *x* is an integer between 3 and 10 inclusive.
Scan time	Scanning time is plotted on the horizontal axis. The range is 1 to 10 minutes.
Volts	This value adjusts the SEM voltage. The **Volts** range is 0 to 3000.
Gain	The gain is the amplification scalar applied to the SEM signal. The typical **Gain** value is 1000. The **Gain** value range is 1 to 30000.
OP Prot.	When set to 'Y', the Overpressure Protection keeps the SEM from turning on if the total pressure is greater than 10^{-6}. When set to 'N', Overpressure Protection is disabled, allowing the SEM to turn on regardless of the total pressure. Overpressure Protection defaults to 'Y'.

Table 12: Editable Parameters in Leak Mode

Caution 

The PPT sensor Electron Multiplier may be damaged if exposed to total pressures above 10^{-4} Torr. Do not disable Overpressure Protection if using the PPT above 10^{-4} Torr.

The Beeper is used to audibly indicate a leak in the system. The **Beeper** function toggles the Beeper on and off.

When the system is scanning, a change in pressure is indicated by a change in the plot and a change in pitch (frequency), of the beeper sound. The volume of the beeper sound does not change, just the pitch. A leak can be detected by looking for a substantial change in the plot. Alternately, the leak can be detected by listening for a sharp and substantial increase in the pitch of the beeper sound.

Split

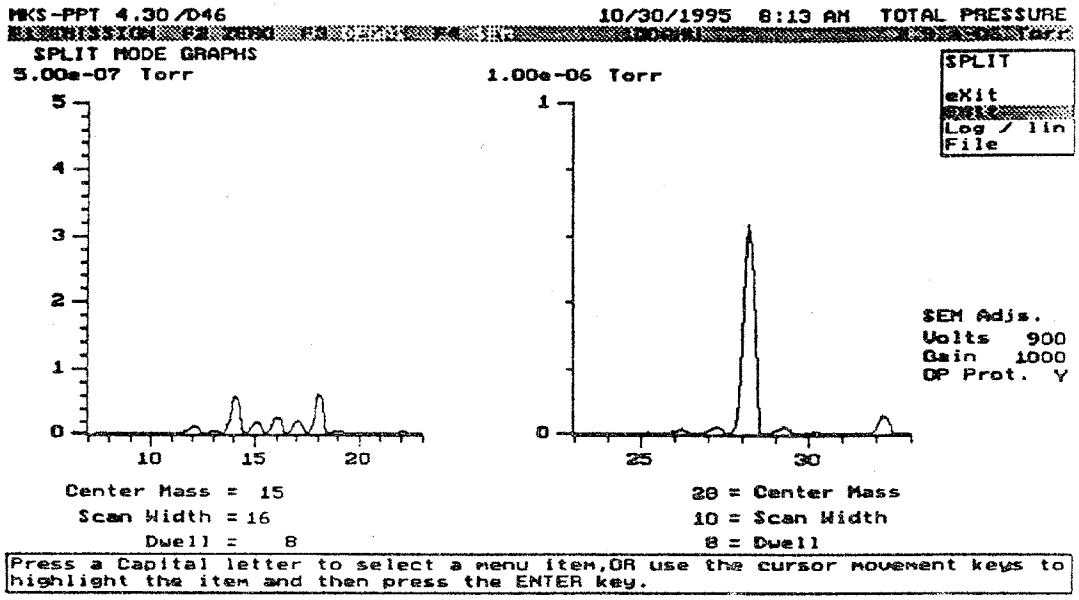


Figure 19: Split Mode Display

This mode displays data in a similar fashion to what is shown in Analog Mode. The difference is that in Split Mode two graphs of spectral data are displayed simultaneously (as opposed to just one graph as in Analog Mode). Each graph can cover a different mass range, and have different full scale values and Dwells.

It might be useful to scan the entire AMU range in Analog Mode to find ranges of interest. Two of these ranges can then be displayed in more detail in Split Mode.

Edit Parameters	Description of Split Mode Editable Parameters
Vertical Axis Scaling	This is the full scale pressure value used for viewing the spectrum. This parameter is edited separately for each graph. The range is from 1 x 10^{-3} Torr to 1 x 10^{-10} Torr in Faraday Mode and 1 x 10^{-3} Torr to 1 x 10^{-14} Torr with the SEM on. This parameter is typed as ***n*e-*x*** where ***n*** is an integer between 1 and 10 inclusive, and where ***x*** is an integer between 3 and 10 inclusive.
Center Mass	This is the amu value which is centered on the horizontal axis. This value should be the mass for peak of interest.
Scan Width	This parameter, along with the **Center Mass** value, defines the Begin and End Mass values for a graph. The scan width is the total number of mass units spanned on the horizontal axis. Its range is from 1 to 50 amu.
Dwell	**Dwell** represents the desired rate of filtering needed for making each measurement. If the **Dwell** is increased, Scan Time increases but noise is reduced. The **Dwell** range is 1 to 1000. Scan Time = (**Dwell** * 10 ms) per data point. Number of Data Points = 401/(**End Mass - Begin Mass** + 1)
Volts	This value adjusts the SEM voltage. The **Volts** range is 0 to 3000.
Gain	The gain is the amplification scalar applied to the SEM signal. The typical **Gain** value is 1000. The **Gain** value range is 1 to 30000.
OP Prot.	When set to 'Y', the Overpressure Protection keeps the SEM from turning on if the total pressure is greater than 10^{-6}. When set to 'N', Overpressure Protection is disabled, allowing the SEM to turn on regardless of the total pressure. Overpressure Protection defaults to 'Y'.

Table 13: Editable Parameters For Each Graph in Split Mode

Caution 

The PPT sensor Electron Multiplier may be damaged if exposed to total pressures above 10^{-4} Torr. Do not disable Overpressure Protection if using the PPT above 10^{-4} Torr.

Tune

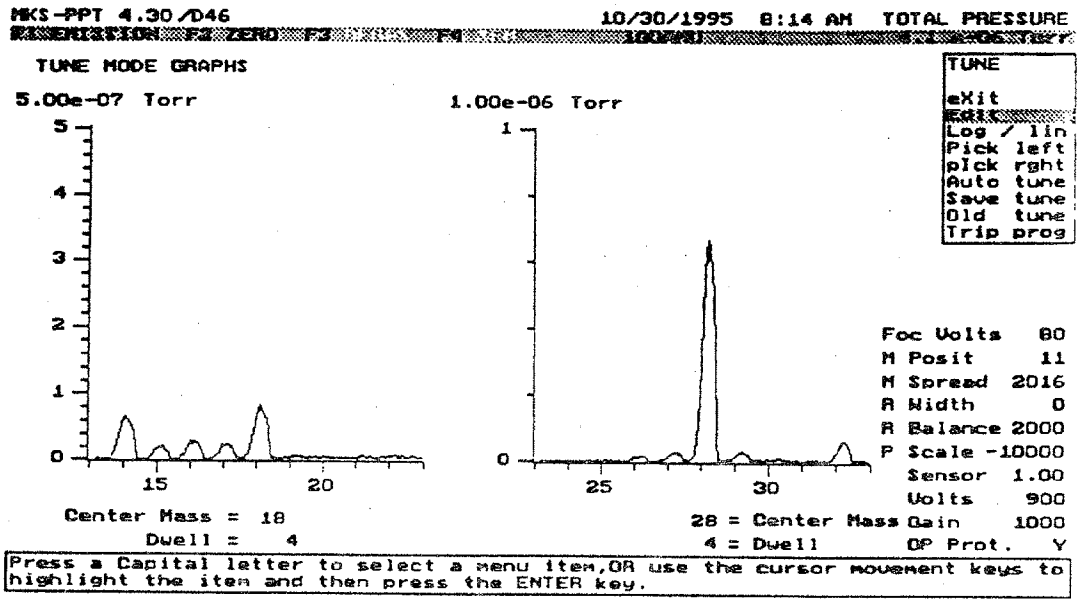


Figure 20: Tune Mode Display

Calibration of the PPT is performed in this mode. Calibration includes adjustment of peak position, peak resolution, total pressure calibration, and sensitivity. The display in Tune Mode is similar to the display in Split Mode. The major differences are that in Tune Mode there are editable calibration parameters (located on the right side of the display), and the Scan Width is fixed at 10 amu (it is adjustable in Split Mode).

During the installation of the PPT software, there is an opportunity to assign a password to Tune Mode. If this is the case, when Tune Mode is entered, the instructions at the bottom of the screen change to the following prompt:

Enter password:

If the password is unknown, access to Tune parameters is denied. If the password is entered incorrectly, the system responds by temporarily displaying the following message, and then returning to the System Menu:

Invalid password, entry denied

If the system is configured with no Tune password, all parameters are accessible. To change the system configuration to include or eliminate a password, refer to the *Software Configuration Changes - PPTINSTL* section in Chapter Two - *Installation and Set-up.*

Note For complete security, the PPTINSTL file should be removed from the hard drive to prevent someone from eliminating the password.

Tune Mode provides two methods to calibrate peak position. To determine if the PPT requires peak position calibration, set the left spectrum window to a center mass of a known low amu peak value which is present in the vacuum being monitored. Set the right spectrum window to a center mass of a known high amu value. After the system has scanned both peaks and displayed their data, examine the graphs. If the peak locations are incorrect, the system needs peak position calibration.

M Posit (Mass Position), and **M Spread** (Mass Spread), can be used to manually adjust peak position. Alternately, the Tune menu items **Pick left**, **pIck right**, and **Auto tune** can be used to have the computer perform the same adjustments. Details on how to use all the calibration parameters are provided in the discussion of the Edit function. Tune parameters are stored in non-volatile memory in the ECU.

Edit Parameters	Description of Tune Mode Editable Parameters
Vertical Axis Scaling	This is the full scale pressure value used for viewing a spectrum. This parameter is edited separately for each graph. The range is from 1 x 10^{-3} Torr to 1 x 10^{-10} Torr in Faraday Mode, and from 1 x 10^{-3} Torr to 1 x 10^{-14} Torr with SEM on . This parameter is typed as ***ne-x*** where ***n*** is an integer between 1 and 10 inclusive, and where ***x*** is an integer between 3 and 10 inclusive.
Center Mass	This is the discrete amu value which is centered on the horizontal axis. This value should be the mass for the peak of interest. This parameter is edited separately for each graph.
Dwell	Dwell represents the desired rate of filtering needed for making each measurement. If the **Dwell** is increased, Scan Time increases but noise is reduced. The **Dwell** range is 1 to 1000. Scan Time = (**Dwell** * 10 ms) per data point. Number of Data Points = 400
Foc Volts	The **Focus Voltage** parameter corresponds to a potential on the focus plate in the sensor ion source. It should be set to a value such that peak height is maximized for a given resolution. **Foc Volts** is usually optimized in the range of 40 to 100 volts. The entry range is 20 to 200 volts.
M Posit	**Mass Position** shifts peaks to the left or right on the horizontal axis. **M Posit** is used to position a peak on its actual amu value after **M Spread** is adjusted. The value entered for this parameter is interpreted by the Host computer and used to shift peaks. The entry range is -1000 to +1000. As the value moves in the negative direction, the spectrum is shifted to the right on the display.
M Spread	**Mass Spread** begins at the **Begin Mass** of a graph and is used to set the spread *between* peaks. As a result, changes in **Mass Spread** have a greater impact at higher amu values than on lower amu values. The entry range is 0 to 4000. Decreasing the number increases the spread between peaks in the spectrum.
R Width	**R Width** affects the width of peaks in the entire spectrum. **R Width** should be used after **R Balance** (see below). Good resolution is achieved when at a height equal to 10% of the total peak height, the full width of an isolated peak is 1 amu. The entry range is -1000 to +1000. As the **R Width** value moves in the positive direction, peak width increases (resolution decreases).

R Balance	**R Balance** is used to balance the width of the peaks at opposite ends of the spectrum. adjusting **R Balance** affects peak width to a greater extent at the higher end of the spectrum than at the lower end. The entry range is 0 to 4000. Increasing this number causes peak widths to decrease.
P Scale	Changes in the **P Scale** value affect the displayed **Total Pressure** value. Changes in the **P Scale** value should be made *after* all other adjustments are made. The **P Scale** value should be adjusted so that the resultant **Total Pressure** value agrees with that of the system ion gauge (if such a gauge is present). This should be done at a total pressure of approximately 3×10^{-7} Torr. The **P Scale** number is used internally by the computer and translated into a pressure value. A typical value is -10,000 and the entry range is -32,000 to 0. The more negative the **P Scale** value gets, the larger the displayed **Total Pressure** value becomes.

Caution 

Miscalibration of the P Scale value may result in instrument damage, or improper operation. Adjusting P Scale changes the Total Pressure value. The Total Pressure value is referenced by the ECU to provide overpressure protection for the sensor. If the Total Pressure value is incorrect, the ECU may fail to turn off the sensor when an overpressure condition arises. Alternately, the ECU may shut off the sensor due to an overpressure condition which is in reality a miscalibration.

Sensor	This parameter is a scaling factor used to adjust sensitivity of the PPT readings. The sensor is typically calibrated by sampling a pure nitrogen spectrum with the PPT and also with a reference gauge such as an MKS Spinning Rotor Gauge. The **Sensor** value is adjusted until the displayed partial pressure of nitrogen at 28 amu equals the MKS Spinning Rotor Gauge reading. The entry range is 0.05 to 9.99. A change in the **Sensor** value takes effect immediately in the plot.
Volts	This value adjusts the SEM voltage. The Volts range is [illegible] to 3000.
Gain	The gain is the amplification scalar applied to the SEM signal. The typical **Gain** value is 1000. The **Gain** value range is 1 to 30000.
OP Prot.	When set to 'Y', the Overpressure Protection keeps the SEM from turning on if the total pressure is greater than 10^{-6}. When set to 'N', Overpressure Protection is disabled, allowing the SEM to turn on regardless of the total pressure. Overpressure Protection defaults to 'Y'.

Electron Energy	This value adjusts the **Electron Energy** voltage. The **Electron Energy** voltage range is 10 to 100 volts in 1 volt increments. The default value is 75 volts.
Electron Emission	This value adjusts the **Electron Emission** current. The **Electron Emission** current range is 100 to 1000 uA in 10 uA incrementes. The default value is 1000 uA.

Table 14: Editable Parameters in Tune Mode

Caution 

The PPT sensor Electron Multiplier may be damaged if exposed to total pressures above 10^{-4} Torr. Do not disable Overpressure Protection if using the PPT above 10^{-4} Torr.

The Pick left , pIck right, and Auto tune functions are discussed together because they must be used together.

The display should be set up to have a *known* low amu peak value selected as the **Center Mass** of the left graph and a *known* high amu peak value selected as the **Center Mass** for the right graph. Both **Center Mass** gases must be present in the vacuum system in sufficient quantity to allow the PPT to make a good scan. Allow the PPT to make a full scan. If the two known peaks are at least 20% of full scale, then the **Auto tune** feature can be used.

A. Select **Pick left** from the menu.

   The system responds by selecting from the left graph the leftmost peak which is at least 20% of full scale. A vertical line appears in the selected peak. The line should be within the center two thirds of the peak.

B. If the peak selected is not the peak you chose for the Center Mass value, use the right arrow key to move the vertical line to the peak which corresponds to the Center Mass value.

   Now that the vertical line is on the correct peak, notice that there is also a horizontal line crossing the vertical line. The horizontal line is placed at 10% of the peak's height. Descending from the horizontal line are two small vertical lines. These small lines mark 1 amu on the horizontal axis. If the peak position and width are well calibrated, an isolated peak is centered on its known amu value, and when at a height equal to 10% of the total peak height, the full width of the peak is 1 amu.

C. Select **pIck right** from the menu.

   The system responds by selecting from the right graph the leftmost peak which is at least 20% of full scale. A vertical line appears in the selected peak. The line should be within the center two thirds of the peak.

D. If the peak selected is not the peak you chose for the Center Mass value, use the right arrow key to move the vertical line to the peak which corresponds to the Center Mass value.

The system also displays the same horizontal line and small, descending vertical lines as in the left graph. These lines indicate the same values as the analogous lines in the left graph.

E. Select **Auto tune** from the menu.

The system responds by determining the proper **M Posit** (peak position), and **M Spread** (peak width) parameters to use. After implementing the new parameters, the system resumes scanning.

The **Save tune** function is used to save tuning parameter values.

Select the **Save tune** function after a desired spectrum response is achieved. If the user selects the **to ECU** option, the system responds by storing all tuning parameter values in non-volatile memory in the ECU. If the user selects the **to Disk** option, the user is then prompted to enter a filename. The tune values will then be stored to disk as this file. Tuning parameter values are used in all other modes to properly display scanned data.

Tun Mode parameters are automatically saved when exiting Tune Mode. However, it is still advisable to use the **Save tune** function to insure that parameters values are saved, in case of hardware or software failure.

The **Old tune** function recalls and implements the previously saved tuning parameter values. If the user selects the **from ECU** option, the tune parameters are read from the ECU's non-volatile memory. If the user selects the **from Disk** option, the user is then prompted for a filename. Through the use of the **TAB** key, the user can select a file from which the tune parameters will be read.

These include: Vertical axis scale, Vertical axis mode (logarithmic/linear), the Center Mass and Dwell values for both graphs, and the values for Foc Volts, M Posit, M Spread, R Width, R Balance, P Scale, and Sensor.

The **Trip prog** allows the system to monitor sixteen separate channels and use these channels to control a signal based on the high and low setpoints of the pressure trips that have been set.. Use edit to enter data into the data screen. Cursor to the parameter that needs to be set and enter the value required as follows:

I/O Card Base Address Is the address at which the Pressure Trip Card is installed in the PC. If there is a conflict with other cards in the PC this address must be changed to an unused address. Otherwise, use the default.

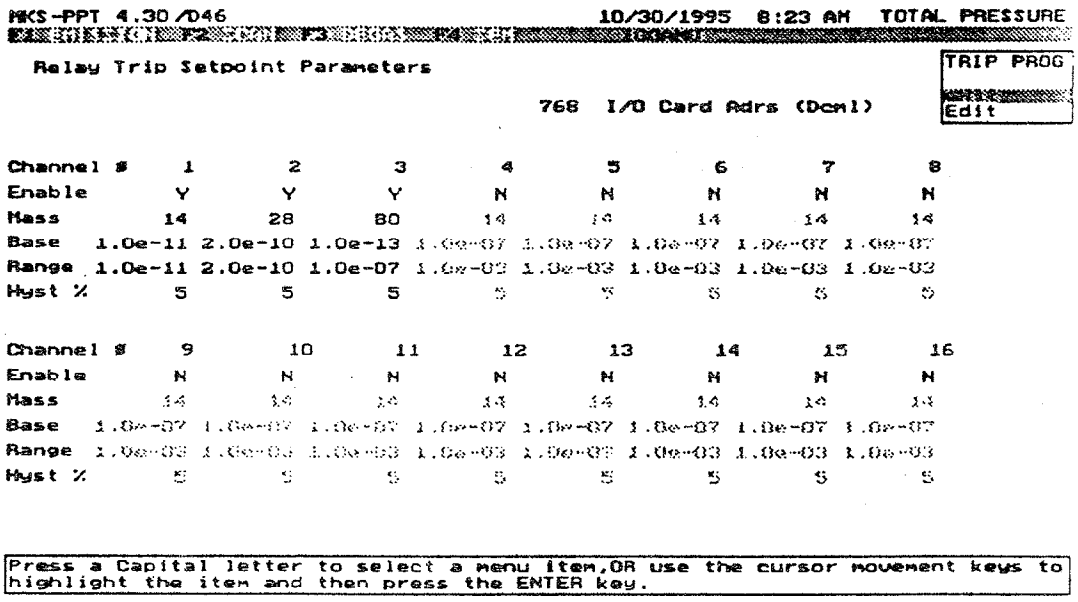


Figure 21: Trip Mode Display

Channel # is the number assigned to the trip channel.

Enable selects a channel to be displayed or not displayed.

Mass is the AMU to be tracked.

Base is the lower limit of the pressure trip.

Range is the range the trip will be inactive above the Base of the trip.

Hysteresis (%) is the amount of deviation allowed before setting the trip.

Displaying Trip Status

The PPT has available to it sixteen trip points. Setup of these points is covered in the Tune Mode section of the PPT Operation Manual. However, the F7 function key will

toggle a window that displays the mass and active status of all trip points in any Display Mode.

Striking the F7 function key once activates the Trip Identification Window:

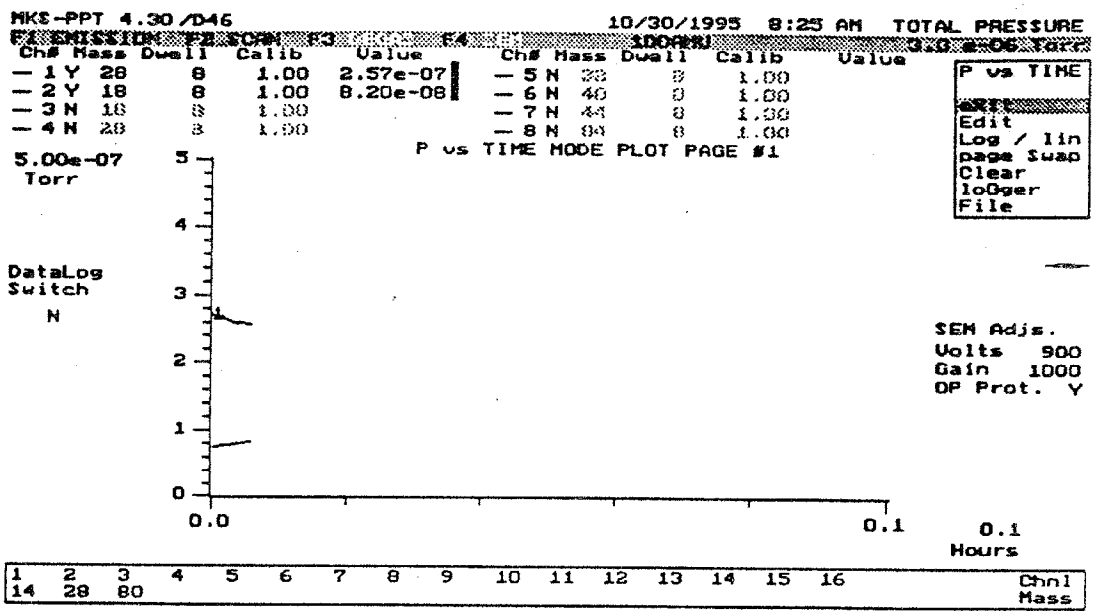


Figure 22: The Trip Identification Window

The sixteen channel numbers are displayed across the first line of the window. The AMU number associated with the channel is located just below the channel number.

Striking the F7 function key a second time changes the window to Trip Status.

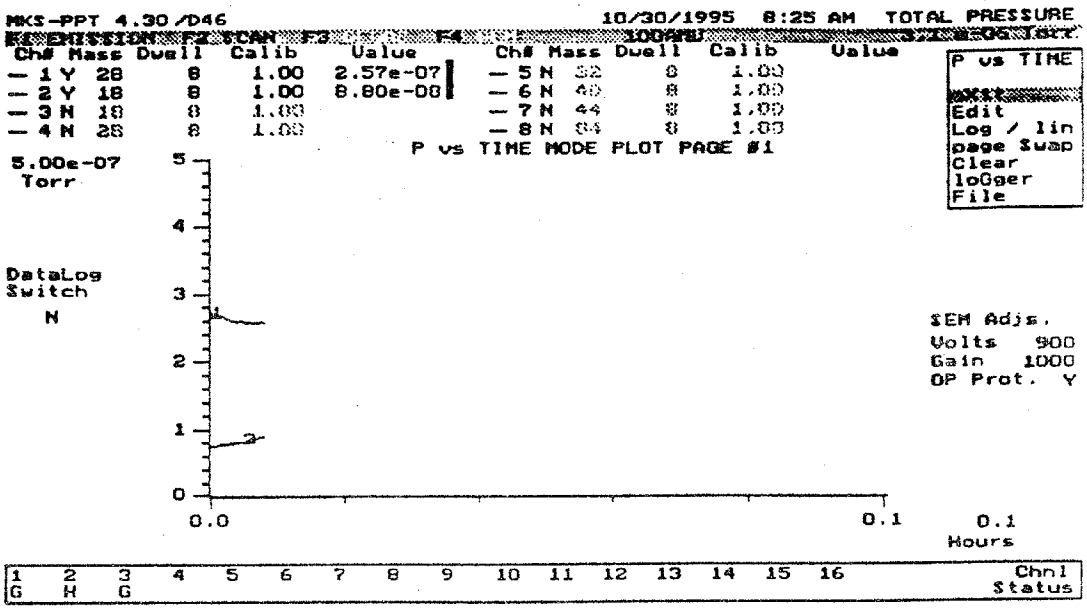
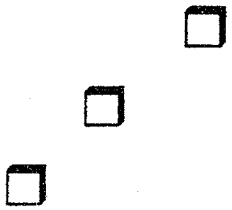


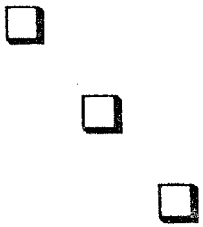
Figure 23: The Trip Status Window

The sixteen channel numbers are displayed across the first line of the window. The active status of the trip is located directly below the channel number. The 'G' indicates that the level of the gas is greater than the trip level that was set in the Tune Menu. The 'L' indicates that the level of the gas is less than the trip level that was set in the Tune Menu.

Striking the F7 function key a third time deactivates the Trip Status Window.



APPENDICES



Appendix A
Product Specifications

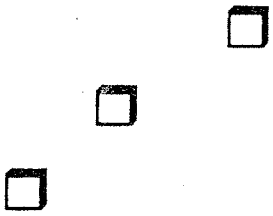
Sensor Specifications	
Sensor Type	Quadrupole
Type of Detector	Faraday Cup, Electron Multiplier
Mass Range	1 to 50, 100, 200, 300 amu
Resolution (10% Valley)	Peak width < 1 amu @ 10% of peak height throughout mass range
Sensitivity (nitrogen)	2×10^{-4} Amp/Torr @ 28 amu with resolution set as above
RF Drive Voltage	$400V_{P-P}$, $800\ V_{P-P}$
RF Drive Frequency	1.6 to 3.0 MHz
Rod Diameter	0.250 inches
Rod Length	3.5 inches, 5.5 inches
Mounting Flange	2 ¾ " OD CF™
Protrusion inside vacuum	100FC=6.24", 200FC=8.24" 100EM=8.39", 200EM=10.39"
Vacuum Leakage	$< 10^{-9}$ scc/sec He
Maximum Operating Temperature	40° C
Bakeout Temperature	250° C (Sensor only, non-operating)
Filament Type	Oxide Coated Iridium
Filament Voltage	8 Volts max.
Filament Current	4 Amps max.
Analyzer Axis Potential	+175 Volts
Anode Potential	+180 Volts
Cathode Potential	100 Volts (Variable Emission option: 80-170 Volts)
Focus Potential	20 to 200 Volts
Ion Energy	5 Volts
Emission Current	1 mA max (Variable Emission option: 10-1000 uA).
Degas Power	10 Watts
Maximum Direct Operating Pressure	1×10^{-4} Torr, 1×10^{-6} Torr

Electronic Control Unit	
Emission Regulator:	
Type	Constant current, closed-loop
Value	1 mA
Electron Energy	75 eV
Filament Power	20 W max., 8 V max., 4 Amps max.
Faraday Cup Amplifier:	
Type	bipolar charge amplifier
Noise Floor	1×10^{-14} Amps
Max. Current	1×10^{-7} Amps
Dynamic Range	120 dB
Total Pressure Amplifier:	
Noise Floor	1×10^{-12} Amps
Max. Current	1×10^{-7} Amps
Dynamic Range	100 dB
RF Generator:	
Range	1.6 to 3.0 MHz, 800 V_{p-p} balanced
Control	closed-loop
Amplitude Detection	full wave
Resolution	15 bit
DC Generator:	
Range	1/6 RF voltage
Control	closed-loop
Resolution	15 bit
Input Power:	24 VDC +10%, -5% @ 2.0 Amps
Communications:	
RS-232 Connector	9-pin, D-type, Female
BitBus™ Connector	9-pin, D-type, Female
Size	7.25 x 4.5 x 5 inches
Weight	3.5 lbs
Temperature:	
Operating	Zero to 40° C
Storage	- 40° C to 65° C
Power Connector	9-pin, D-type, Male

Appendix B
Significant Files

The following is a list of the significant files created during the installation process.

FILE NAME	FILE FUNCTION
BDRV.PDT	Contains the complete list of all supported printers.
EGAVGA.BGI	Graphics driver.
INSTALLP.EXE	Installs the user-selected printer. This file is called up by PICK_PRN.BAT.
PPT.CFG	Contains the most current parameter settings.
PPT.EXE	Runs the operating software.
PPTINSTL.EXE	An editable configuration file for communication protocol, password, port definition, etc.
PPT_SPEC.CFG	Contains spectra liBrary data in ASCII format.
INSTALL.EXE	Automatic installation program.
CONFIG.BAT	Configures the Host PC ports.
PRINTER.BAT	Selects a printer from a menu.
README.43X	File explaining the use of conversion software to ASCII format.
CVAND.BAT	Converts .AND files to ASCII format.
CVBAD.BAT	Converts .BAD files to ASCII format.
CVPVD.BAT	Converts .PVD files to ASCII format.



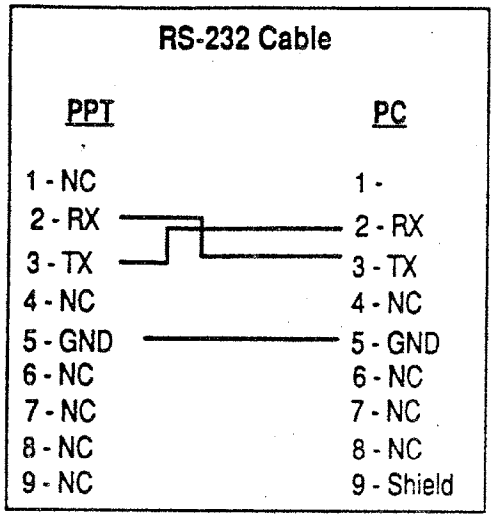
Appendix C
Pinouts at Rear Panel

Control (9-pin, D-type, Female)	
Signal	Pin
Ext. Control + DC	1
Ext. Control /Emission	2
Ext. Control /Scan	3
CHANNEL 1 DC OUTPUT (PvT)	4
CHANNEL 2 DC OUTPUT (PvT)	5
GND	6
GND	7
GND	8
GND	9

RS-232 (9-pin, D-type, Female)	
Signal	Pin
NC	1
RX	2
TX	3
TO2	4
GND	5
NC	6
NC	7
NC	8
GND	9

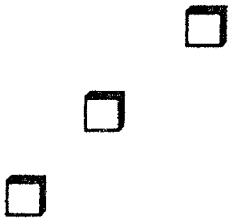
Power (9-Pin, D-type, Male)	
Signal	Pin
+24 VDC	1
+24 VDC	2
NC	3
GND	4
GND	5
+24 VDC	6
NC	7
NC	8
GND	9

BitBus™ (9-pin, D-type, Female)	
Signal	Pin
NC	1
GND	2
DATA 1	3
NC	4
NC	5
NC	6
GND	7
DATA 2	8
NC	9


RS-232 Cable
PPT
PC
1 - NC
2 - RX
3 - TX
4 - NC
5 - GND
6 - NC
7 - NC
8 - NC
9 - NC
1 -
2 - RX
3 - TX
4 - NC
5 - GND
6 - NC
7 - NC
8 - NC
9 - Shield

Appendix D
PPT Accessories

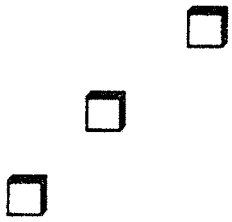
ITEM	PART NUMBER
24 VDC Power Supply Cable With Cable	PPT-PS1
Extension Cable for PPT-PS1	CBPS1-X
RS-232 Cable (DB9 Male/DB9 Female)	CB600N-4-X
BitBus™ Cable	CB600N-5-X
Multiplex Cable	CB600N-6-X
Twinax Adapter, female inline	113-N8290
Twinax Adapter, female tee	113-N8291
Twinax Terminator	113-N8292
16-Channel Pressure Trip Card	PSP-1
100 amu Faraday Cup Quadrupole Sensor	S100FC
200 amu Faraday Cup Quadrupole Sensor	S200FC
100 amu Electron Multiplier Quadrupole Sensor	S100EM
200 amu Electron Multiplier Quadrupole Sensor	S200EM
PPT 100FC Vacuum Housing	VH06-NN
PPT 200FC Vacuum Housing	VH08-NN
PPT 100EM Vacuum Housing	VH08-NN
PPT 200EM Vacuum Housing	VH10-NN
Oxide Coated Filament Assembly	N1129471
External Control I/O Cable Assembly	N401169-G1



Appendix E
Error Messages

ECU Message	Explanation
Commun. Fail	There is a fault with the communications between the PPT and the computer. Check RS-232 cable, BitBus™ Cable, or BitBus™ card for proper installation.
Ovr Pres	If the T-Press value rises above 2 x 10^{-4} Torr, then the filament will be automatically turned off and this error message displayed. The T-press value should be calibrated in Tune Mode against an ion gauge.
24V Fail	The 24 Volt power supply is less than 18 Volts.
Reset ECU	Power has been restored to the ECU, but the state machine has not been initialized.
Supervisory Break	There has been an unrecoverable communications error. The PPT must be reset before continuing operation.
Emission Fail	The ECU was unable to sustain Emission. This is most likely caused by a problem with the sensor filament.

DOS Message	Explanation
HEAP EMPTY Exiting Now	Not enough conventional memory was available on the PC running the PPT Host software. Run a memory manager program to free more conventional memory. Run the utility memchk provided on the PPT Host software install diskette to determine how much conventional memory is required. The memchk utility is located in the PPT4xx subdirectory where the "xx" is the Host software version installed.



Appendix F

Archiving Test Data with the Data Logger Switch

The data logger feature is used in both the Bar and P vs Time Modes to continuously store spectral data.

Bar Mode Data Logger:

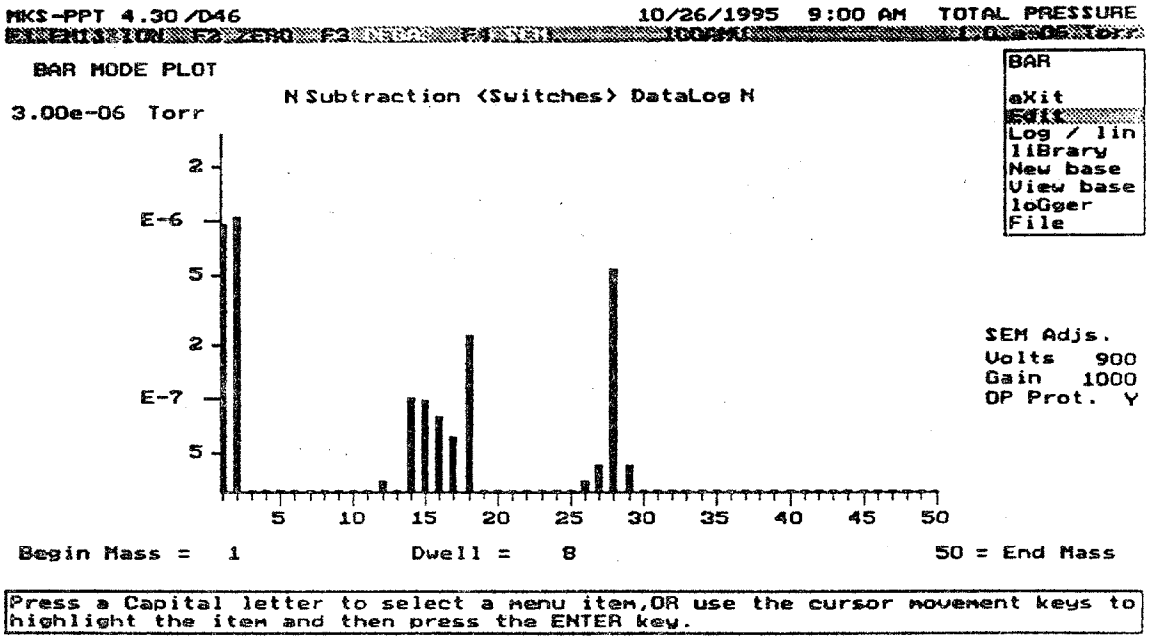


Figure 24: The Data Logger in Bar Mode

To activate Bar Mode continuous data storage, use the edit function and scroll to the DataLog Switch.

When the DataLog Switch is set to 'Y', continuous data is stored to an ASCII file that is user defined. When the switch is set to 'N' the data is not saved to the file. By selecting the loGger option, the user is able to specify the path and filename for the logfile as well as the log interval. The log interval is in tenths of minutes and cannot be zero. The fastest log interval available is 0.1 minutes (6 seconds). A .BAR extension will be assigned to the file (see Figure 25).

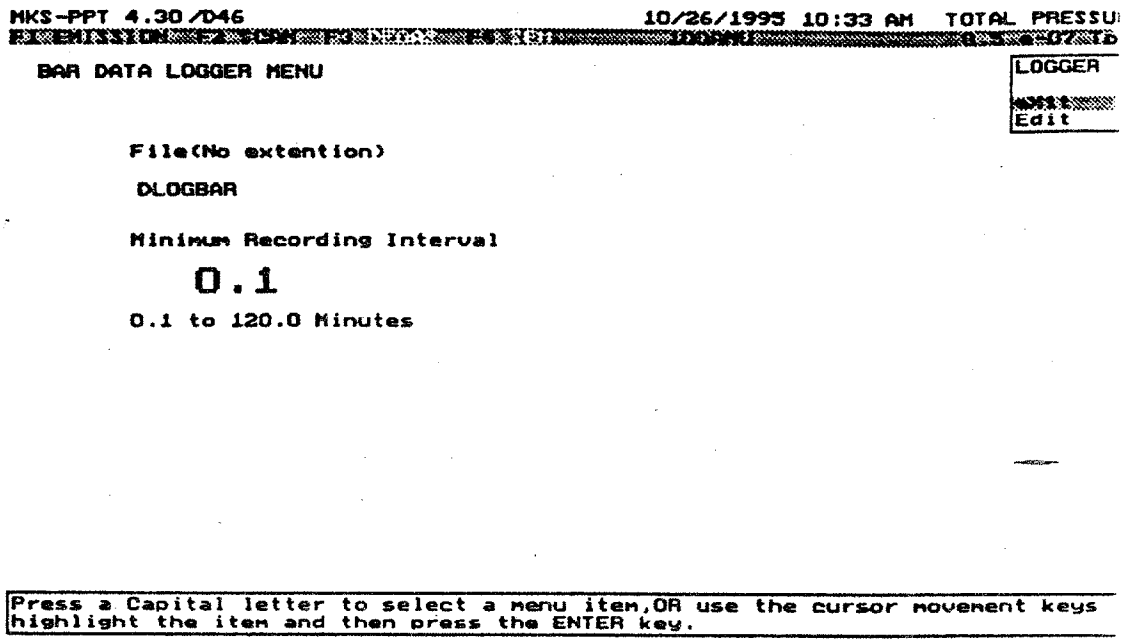


Figure 25: The Logger Menu in Bar Mode

The format of the Bar Mode continuous data is:

"LOGIN at",11:24:00,02/03/1994	*Time That Bar Mode was Entered*
,8	*Dwell Time for all Scans*
**********	
Time,11:25:00,02/03/1994	*Start Time of Continuous Data*
Mass,Intensity	*Data Headings*
1, 9.78E-08	
2, 6.01E-08	
3, 1.00E-14	
4, 2.26E-08	
5, 1.00E-14	
6, 2.02E-10	
7, 9.17E-10	
8, 1.00E-14	
9, 1.00E-14	
10, 1.00E-14	
11, 3.33E-10	
12, 2.50E-09	
13, 2.24E-09	
14, 5.74E-07	
15, 1.25E-08	
16, 2.51E-08	*Data*
17, 1.12E-07	
18, 4.02E-07	
19, 1.73E-09	
20, 1.13E-07	
21, 5.17E-10	
22, 7.82E-10	
23, 1.00E-14	
24, 1.22E-10	
25, 1.02E-09	
26, 4.80E-09	
27, 1.21E-08	
28, 4.29E-06	
29, 5.38E-08	
30, 3.78E-09	
31, 1.52E-09	
32, 7.78E-08	
33, 1.00E-14	
34, 4.13E-10	
35, 2.02E-10	
36, 2.31E-09	
37, 6.51E-10	
38, 9.39E-10	
39, 3.75E-09	
40, 2.55E-07	
"LOGOUT at",11:25:00,02/03/1994	*Time That Bar Mode was Exited*

P vs. Time Data Logger:

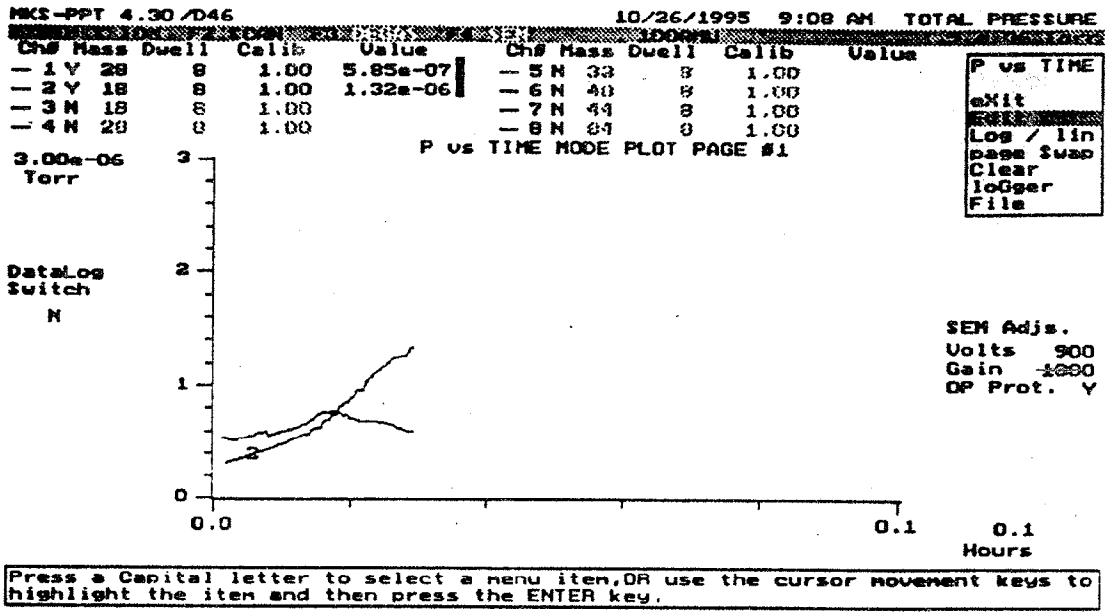


Figure 26: The Data Logger in P vs Time Mode

To activate the P vs Time Mode continuous data storage, use the edit function and scroll to the DataLog Switch.

When the DataLog Switch is set to 'Y', continuous data is stored to an ASCII file that is user defined. When the switch is set to 'N' the data is not saved to the file. By selecting the loGger option, the user is able to specify the path and filename for the logfile as well as the log interval. The log interval is in tenths of minutes and cannot be zero. The fastest log interval available is 0.1 minutes (6 seconds). A .PVT extension will be assigned to the file (see Figure 27).

Data logging does not begin until a new sweep has begun. Therefore, to initiate data logging after the DataLog Switch is set to 'Y', press the ESCAPE key and select the Clear option. This clears the screen, initiating a new sweep. Once the DataLog Switch is set to 'N', the file will be closed at the end of the sweep. By selecting the Clear option the user can force the sweep to end and the file to be closed.

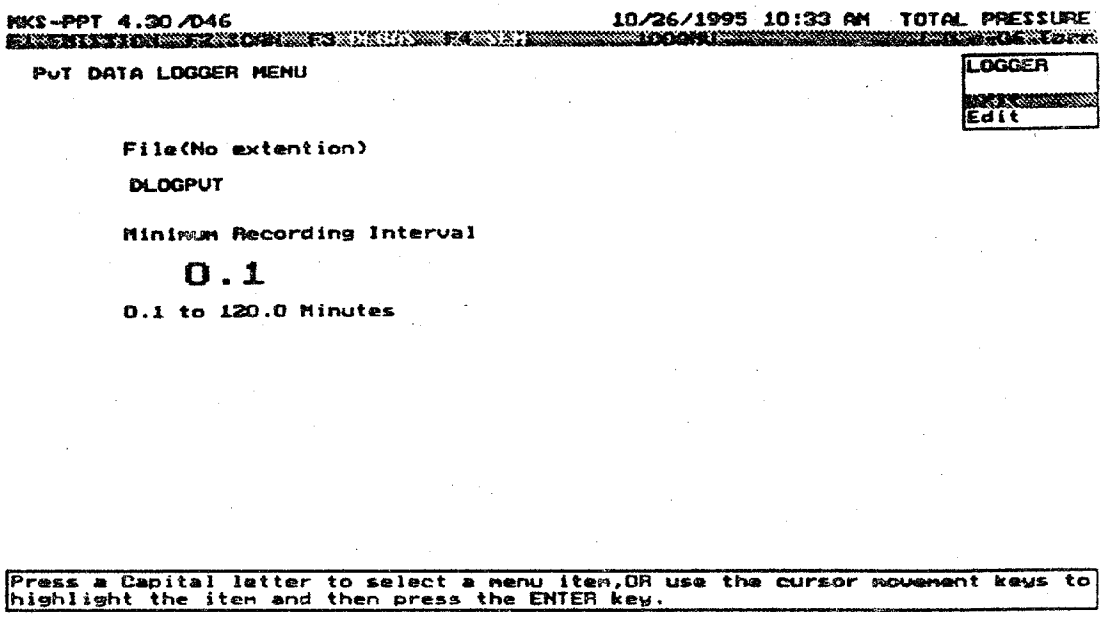


Figure 27: The Logger Menu in P vs Time Mode

The format of the P vs. Time continuous data is:

"LOGIN at",11:35:00,02/03/1994 *Time That PvT Mode was Entered*
"Chnl1 Dwell","Chnl2 Dwell","Chnl3 Dwell","Chnl4 Dwell","Chnl5 Dwell","Chnl6 Dwell","Chnl7 Dwell","Chnl8 Dwell" *Dwell Data Headings*
8,8,8,8,8,8,8,8 *Dwell Time Data*
****
Time,11:35:00,02/03/1994 *Start Time of Continuous Data*
"Chnl1 AMU", "Intensity","Chnl2 AMU", "Intensity","Chnl3 AMU", "Intensity","Chnl4 AMU", "Intensity","Chnl5 AMU", "Intensity","Chnl6 AMU", "Intensity","Chnl7 AMU", "Intensity","Chnl8 AMU", "Intensity" *Partial Pressure Data Headings*
28, 3.35E-06,18, 4.37E-07,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,28, 3.35E-06,18, 4.37E-07,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,11:35:30,02/03/1994
28, 3.35E-06,18, 4.37E-07,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,28, 4.47E-06,18, 4.65E-07,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,11:36:00,02/03/1994
28, 4.47E-06,18, 4.65E-07,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,28, 4.49E-06,18, 4.64E-07,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,11:36:30,02/03/1994
28, 4.47E-06,18, 4.64E-07,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,28, 4.47E-06,18, 4.65E-07,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,11:37:00,02/03/1994
28, 4.47E-06,18, 4.64E-07,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,28, 4.49E-06,18, 4.65E-07,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,11:37:30,02/03/1994
28, 4.50E-06,18, 4.65E-07,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,28, 4.50E-06,18, 4.64E-07,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,0, 0.00E+00,11:38:00,02/03/1994
"LOGOUT at",11:39:00,02/03/1994 *Time That PvT Mode was Exited*

CVPVD.BAT

Batch file which imports PPT .PVD data files and translates them to .CSV files of the same root name. The .PVD file must be located in the same subdirectory that contains the files NG42PV.H, NG43PV.H, and NG45PV.H. These header files are used by the utility in the conversion process. The resultant .CSV file contains the ASCII spreadsheet form of the report data. In addition to the .CSV file, the file CONVPVD.LOG will be generated and contains the information regarding the attempted conversion process. This file will contain the pertinent error information should the conversion process be unsuccessful. NOTE: the .PVD extension of the filename(s) to be translated must be included.

Format:
cvpvd [switches] {filename(s)} {Host Version}

filename(s):	Files to be converted (wildcards acceptable).	
Host Version:	PPT Host Version (e.g. 4.30).	
switches:	-h,?	On line help.

Example Usage:
cvpvd *.pvd 4.30

This example converts all .PVD files and assumes that the files were saved from PPT Host Version 4.30.

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Appendix H

Recommended Practice for the Calibration of Mass Spectrometers for Partial Pressure Analysis

Reprint from

The Journal of Vacuum Science Technology

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American Vacuum Society Recommended Practice

Recommended Practice for the Calibration of Mass Spectrometers for Partial Pressure Analysis

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(Received 1 October 1991; accepted 9 January 1993)

This Recommended Practice addresses issues involved in the use of partial pressure analyzers (PPAs) for quantitative analysis and describes recommended apparatus and procedures for determining resolution and sensitivity of a PPA so that the instrument can be used quantitatively for partial pressure, partial flow and gas composition analysis. This updates previous material in the AVS Standard 2.3—1972 (tentative) by including reference to current pressure transfer standards and computer controlled PPAs. This document presents an introduction to PPAs and how they work, definitions pertinent to the use of PPAs, equipment needed for calibration, instrument setup prior to calibration and the measurement of sensitivity and linearity by various methods. Four methods of calibration of a PPA are described as follows: (1) the direct comparison of the PPA output with a transfer standard pressure gauge, (2) the indirect comparison of PPA readings with readings of a transfer standard pressure gauge separated by a flow restriction (pressure divider method), (3) comparison of the PPA output with the calculated pressure generated in an orifice-flow system, and (4) calibration of the PPA response to known gas flow rates. The first three methods may be carried out on a test stand of suitable design or *in situ*. The fourth method requires that the pumping speed during calibration be the same as the pumping speed during use, and normally implies that the PPA is calibrated *in situ*. Discussion on gas interactions, sources of nonlinearity, stability of sensitivity and quality assurance methods is given.

CONTENTS

American Vacuum Society Recommended Practice

Recommended Practice for the Calibration of Mass Spectrometers for Partial Pressure Analysis

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CONTENTS

I. INTRODUCTION

A. Forward

This publication recommends procedures for preparation and calibration of partial pressure analyzers (PPAs) by establishing the correspondence, between the change in ion signal and the corresponding change in partial pressure of the gas from which the ion is produced. This updates previous material in the AVS Standard 2.3—1972 (tentative) by including reference to current pressure transfer standards and computer controlled PPAs.

The text was developed by a subcommittee of the AVS Recommended Practices Committee. Subcommittee members are the authors. This material is presented to encourage comment from a wider audience before the text is submitted for AVS Board approval by the Recommended Practices Committee.

B. Disclaimer

This Recommended Practice is based on sources and information believed to be reliable, but the American Vacuum Society and the authors disclaim any warranty or liability based on or relating to the contents of this Recommended Practice.

The American Vacuum Society does not endorse products, processes, manufacturers, and suppliers. Nothing in this publication should be interpreted as implying such endorsement.

C. Scope

This Recommended Practice has two purposes. First, to familiarize users of PPAs with the issues involved in the use of these instruments for quantitative analysis. Second, to describe recommended apparatus and procedures for determining resolution and sensitivity of a PPA so that the instrument can be used quantitatively for partial pressure, partial flow and gas composition analysis.

This document is divided into five sections. An introduction to PPAs and how they work is given in the present section. Section II contains definitions pertinent to the use of PPAs. Equipment needed for calibration is described in Sec. III. Section IV deals with instrument setup prior to calibration. Measurement of sensitivity and linearity by several methods is described in Sec. V.

D. Background

A mass spectrometer is an analytical instrument which separates and detects ions according to their mass-to-charge ratio. A PPA is a mass spectrometer in which the ionizer is immersed in the gas to be analyzed, and the ionizer is characterized by an open construction in which the gas may enter and leave in all directions. It is assumed that the gas is homogeneous and that changes in the gas density with time occur slowly enough that the instrument is always in equilibrium with the gas. Analysis of molecular beams or fast transient events are beyond the scope of this document. A PPA can be used to identify the kinds of molecules present in the gas and, when calibrated, can be used to determine their concentrations or absolute partial pressures. Except where noted otherwise, this recommended practice applies to all types of PPAs, although PPAs based upon the electric quadrupole filter or the magnetic sector filter are by far the most common. General accounts of PPAs may be found in the literature.[1–3]

A partial pressure analyzer is composed of three basic parts: the ionizer, the mass-to-charge ratio filter, and the detector. These three parts are mounted as an assembly on a vacuum flange, which connects to a mating flange on a vacuum vessel containing the gas to be analyzed. In this document, this assembly will be referred to as the measuring head of the PPA. The associated electronic units supply power to the measuring head via cables and electrical feedthroughs on the flange of the measuring head.

The function of the ionizer is to ionize some of the gas atoms or molecules. Commercial instruments usually employ an electron-impact type of ionizer, in which electrons from a hot filament are accelerated through a potential difference of, typically, 70 V. Some gas atoms and molecules will ionize by interaction with the fast electrons. Generally such ionizing collisions will yield positive ions (one or more electrons removed from the target atom or molecule). At very low electron energies (below the threshold for positive ion formation) negative ions can be formed by the process of electron attachment. For each type (species) of gas atom or molecule and depending on the electron energy, electron impact excitation will yield the parent atom or molecule ionized with a charge of plus one or more, and (in the case of molecules) molecular fragment ions with a charge of plus one or more. This characteristic set of positive ions is called the cracking pattern and is often useful in the identification of species and analysis of gas mixtures. The AVS monograph on PPAs and partial pressure analysis has a more detailed discussion of this subject.[1]

The mass filter determines which ions reach the detector at any given time. In the magnetic sector instrument, the ions of different mass-to-charge ratio are separated spatially because of the different trajectories they follow in a magnetic field. In the electric quadrupole filter, which is the type most commonly employed in commercial PPAs, the filtering action is based upon a mass-to-charge ratio dependent orbit stability of the ions as they travel through the transverse rf and dc fields of the filter. Comprehensive accounts of quadrupole theory and applications may be found in the literature.[4–6] Both the magnetic sector instruments and the quadrupole-based instruments allow continuous measurement of a specified group of ions. The time-of-flight based instruments on the other hand do not operate continuously. Bunches of ions of equal kinetic energy are injected into a field-free flight tube. The ions are distinguished according to their mass-to-charge ratio by differences in arrival time at the detector.

The detector produces an output signal dependent on the flux of the selected ions. The simplest detector employs an electrometer to directly measure the ion flux or charge reaching the Faraday cup or plate collector. To increase the size of the measured current and to reduce measuring

time, secondary electron multipliers are often used in place of the Faraday collector. Where stability as well as speed is of importance, pulse counting is used in conjunction with secondary electron multiplication.

If the PPA is to be used only to detect the presence of a particular species, it may be sufficient to calibrate only the mass-to-charge ratio scale of the instrument and to use published cracking pattern data for identification of the species. On the other hand, if one wishes to measure partial pressures or concentrations, a calibration of the instrument's response to the species of interest is necessary.[7–12] This is true even if one is only interested in the ratio of pressures of two or more gases in a mixture, because the response of a PPA is species dependent. An underlying, but often unstated, assumption in using a PPA is that there is a linear relation between the partial pressure and the corresponding PPA signal. Calibration also serves to make clear the pressure range over which such a linear relationship holds.

II. DEFINITIONS

The definitions, symbols, and descriptive terminology given below are intended to facilitate discussion of calibration and analytical procedures and to aid in comparing the performance of partial pressure analyzers.

(1) *Atomic mass unit (amu).* A unit of mass equal to one twelfth the mass of a neutral carbon atom having six protons and six neutrons (^{12}C); equivalent to $1.660\,540 \times 10^{-27}$ kg.

(2) *Mass number, M.* The mass number M is the sum of the number of protons and the number of neutrons in an atom and, by extension, the number of protons and neutrons in a molecule. As defined here, the mass number is a very convenient and, for most applications a very accurate, approximation to the mass of an ion in atomic mass units (amu).

(3) *Charge, Q.* The electron charge of an ion. Ion charge occurs in integer multiples of the electron charge e and, in this recommended practice, Q shall be expressed in units of electron charge ($e = 1.602\,177\,3 \times 10^{-19}$ C). For example, $Q(Ar^{2+}) = +2$.

(4) *Mass-to-charge ratio, M/Q.* The ratio of the mass number M of an ion to its charge Q, measured in units of the electron charge e. For example, doubly charged ions of argon isotope 40 ($^{40}Ar^{2+}$) have a nominal $M/Q = 40/2 = 20$.

(5) *Partial pressure analyzer, PPA.* A partial pressure analyzer, also called a residual gas analyzer (RGA), is a gas analysis system composed of three main parts: (i) an ionizer, which produces ions from the gas to be analyzed and directs these ions to (ii) an analyzer or filter, which separates the ions on the basis of mass-to-charge ratio and directs the ions into (iii) a detector, which yields an output signal dependent on the flux of ions reaching it from the analyzer. Supporting these three main parts are the power supplies, control electronics, electrometer, and cables required for operation.

(6) *Mass range.* The range of mass numbers defined by the mass numbers of the lightest and the heaviest singly charged ions which can be detected by a particular mass spectrometer. It can also specify a range of M/Q values in a scan for reference in discussion of the spectrum.

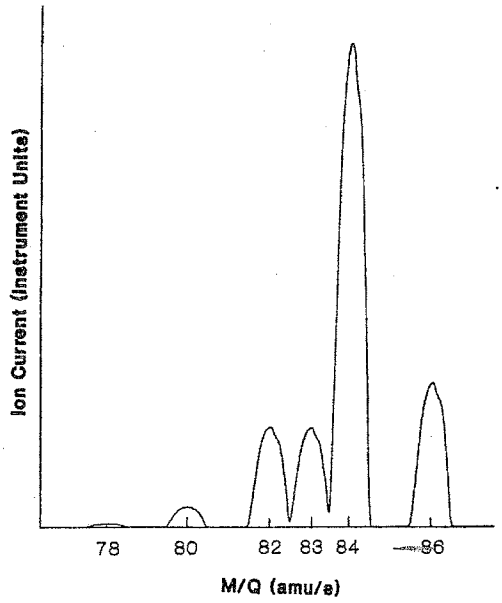

FIG. 1. A mass scan of krypton showing isotopic masses $M/Q = 78$–86.

(7) *Scan parameter, X.* In a partial pressure analyzer, an instrumental parameter such as voltage, frequency, magnetic field strength, or time delay which is varied so as to vary the mass-to-charge ratio of the ions which reach the detector. This term may also be used interchangeably with some output quantity derived from the scan parameter, such as oscilloscope x-axis drive voltage or a digital display number.

(8) *Scan.* (i) Any kind of display, analog or digital, generated by the PPA which shows the signals of ions developed as a function of the scanning parameter. Synonyms are mass scan or mass spectrum. Figure 1 shows a scan of the singly charged isotopes of krypton. (ii) The act or process of varying the scanning parameter(s) over all or part of the mass range of the partial pressure analyzer.

(9) *Cracking pattern or fragmentation factor.* (a) Cracking pattern: The characteristic species of ions which are produced by and unique to the ionization process. For example, electron impact excitation of N_2 produces N_2^+, N_2^{+2}, N^+, and N^{+2} ions. This definition is also intended to include the case of multiple ionization of an atomic gas; e.g., the Ar^+ and Ar^{+2} ions from Ar. (b) Fragmentation factor, f: The relative signal strengths of detected ions which are produced from a given chemical species in a partial pressure analyzer under specified conditions of pressure, gas composition and instrument operating parameters. For example, electron impact excitation of CO can produce CO^+, C^+, C^{+2}, O^+ and O^{+2} ions. If the ion signal peak heights are $H[CO^+]$, $H[C^+]$, $H[C^{+2}]$, $H[O^+]$, and $H[O^{+2}]$ and the sum of these peak heights is H*, then the corresponding fragmentation

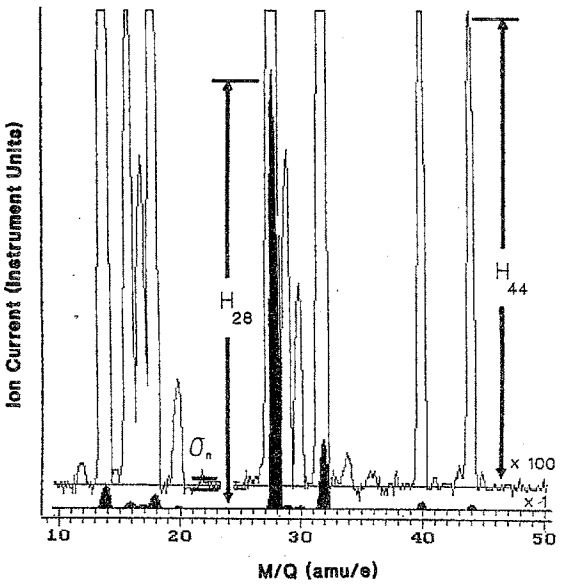

FIG. 2. A mass scan of an air sample from a computer-controlled PPA. Major components are shown with area under the curve shaded. Minor components are shown with ion current multiplied by 100. Baseline noise is indicated as σ_n and peak heights H_i are shown referenced to the appropriate baseline.

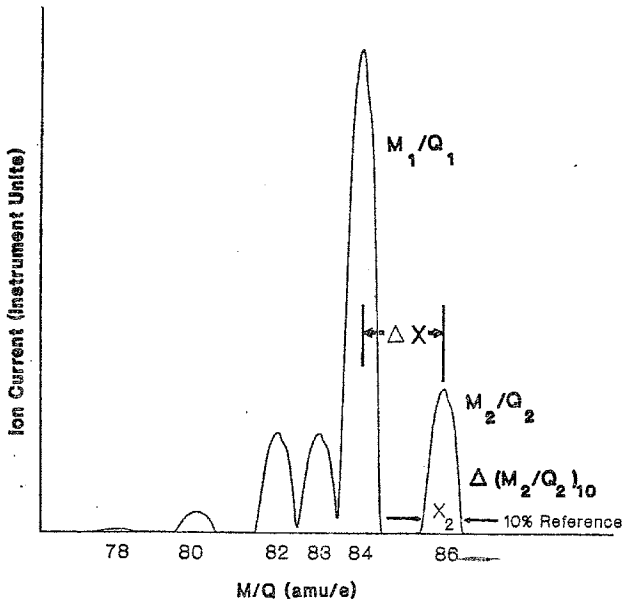

FIG. 3. Peak width $\Delta(M_2/Q_2)_{10}$ defined at 10% peak height and the associated scan parameter width X_2 and distance ΔX between the $M/Q = 84$ and 86 (2 amu/e).

factors would be $f[CO^+] = H[CO^+]/H^*$, $f[C^+] = H[C^+]/H^*$, etc. Fragmentation factors are not unique, since they depend on the instrument's properties as well as on the cracking pattern. This is the reason why published "cracking pattern" data is so variable. It is in fact fragmentation factor data, and therefore, instrument dependent.

(10) *M/Q peak or mass peak.* The complete record or profile, not just the maximum value, of the output signal measured relative to the baseline versus the scan parameter developed from ions of mass-to-charge ratio M/Q. The term "mass peak" refers to the signal developed from singly charged ions (see Fig. 2). The signal developed from singly charged ions with mass-to-charge ratio 28 for instance, is referred to as the "mass 28 peak."

(11) *Baseline.* The output signal from the gas analyzer when no ions are arriving at the detector. This is the reference level from which peak height [definition (14)] is measured. The baseline is frequently approximated by tuning the instrument to an M/Q value for which the ion signal is negligibly small.

(12) *Background signal, H_0.* Output signal, measured with respect to baseline, which is obtained before the introduction of any sample or calibration gas. This term may refer to the output signal at a particular M/Q value. When referred to a scan , the term background scan is used.

(13) *Background pressure, P_0.* Total pressure before introduction of the calibration or the sample gas. Usually, background pressure is the lowest pressure achieved in the apparatus in which the partial pressure analyzer operates. However this definition does not restrict background pressure to low values.

(14) *Peak height, H.* For a given M/Q peak, the maximum ion signal developed in the partial pressure analyzer (labeled as H in Fig. 2). Peak height is measured with respect to the baseline. Use of arbitrary units for H requires consistency throughout calibration and use.

(15) *Peak width, $\Delta(M/Q)_v$ or ΔM_v.* For a given peak, the difference in units of M/Q between the M/Q values on either side of the peak at which the signal has dropped to $v\%$ of the peak height H. V is frequently taken as 10. If the mass peak is such that the signal does not drop to $v\%$ or less of peak height, this indicates overlapping of adjacent peaks. This peak should not be used for determination of peak width. For the peak labeled M_2/Q in Fig. 3, the arrows denote the 10% of peak height points. Note that other definitions of peak width exist.

(16) *Tailing contribution, $t_\pm$.* The ion signal at the position $(M/Q) \pm 1$, resulting from the nonzero width of the peak at M/Q. Evidence of tailing can be seen in Fig. 2 at $M/Q = 27$ due to $M/Q = 28$. Tailing contribution can be expressed as a percent of the peak height at M/Q. Since peaks are not, in general, perfectly symmetrical, the $+$ and $-$ subscripts are to distinguish values of t obtained at $(M/Q) + 1$ and $(M/Q) - 1$ respectively. Examples of this asymmetry can be seen by careful examination of M/Q 40 and 44 in Fig. 2. As a way to characterize a peak shape, this definition is an alternative to that given in definition (15). Tailing contribution is also referred to as "contribution to neighboring peak." Tailing contribution is inversely related to the old term "abundance sensitivity."

(17) *Peak separation, ΔX.* The difference between the values of the scan parameter [definition (7)] corresponding to the peak heights of two known peaks (see Fig. 3). The peak separation establishes an M/Q scale [definition (18)]

which may be used for determining peak width.

(18) *M/Q scale.* The correspondence between the value of the scan parameter and the M/Q value to which the instrument is tuned. This correspondence is established by scanning over peaks of known M/Q value. For certain types of instruments such as the magnetic sector (with either ion energy scanning or magnetic field scanning), the scan parameter–M/Q relation is inherently nonlinear. For others such as the quadrupole, a nearly linear relation is obtained. The peak separation ΔX [definition (17)] between two known peaks can be used to establish a linear approximation to the M/Q scale in the interval between the two known peaks.

(19) *Resolving power, R.* A measure of the ability of a partial pressure analyzer to separate ions according to their mass-to-charge ratio. The width $\Delta(M/Q)_{10}$ of a peak is one measure of this ability. In keeping with long established and widespread usage, the value of R at a particular M/Q is defined in this recommended practice as the dimensionless ratio of M/Q to the peak width $\Delta(M/Q)_{10}$ at that M/Q

$$R = (M/Q)/\Delta(M/Q)_{10}.$$

(20) *Number density, n.* The number of gas particles per unit volume.

(21) *Mole fraction, f_i.* In a mixture, mole fraction of the gas species i is the ratio of the number density n_i of the species i to the total number density Σn_i of the mixture.

(22) *Partial pressure.* In a mixture of gases, the partial pressure of a component is defined as the product of the total pressure of the mixture and the mole fraction of the component. For the range of total pressures in which partial pressure analyzers are useful, a gas mixture behaves as a perfect gas mixture, in which the partial pressure P_i of the ith component is independent of the other components of the mixture. The partial pressure of the ith component of the mixture is the same as the pressure exerted by the ith component acting alone. The partial pressure P_i and the number density n_i are related as $P_i = n_i kT$, where $k = 1.38\times10^{-23}$ J/K is Boltzmann's constant, and T is the absolute gas temperature (K). This independence of partial pressures of gas components is the basis for using a PPA, calibrated with pure, single-component gases to analyze mixtures in terms of the partial pressure of each component. An additional assumption is that the PPAs response to a given component of the gas mixture depends only on the number density, n_i of that component (see Sec. VI).

(23) *Calibration.* The correspondence, or the act of establishing the correspondence, between the change in ion signal and the corresponding change in partial pressure of the gas from which the ion is produced. This correspondence may be presented graphically as in the graph shown in Fig. 4, or as a table of values of change in ion signal versus change in partial pressure. These changes of signal with partial pressure are computed with reference to background values.

(24) *Sensitivity, S.* The sensitivity to a particular gas species is defined as the ratio of the change $(H - H_0)$ in peak height to the corresponding change $(P - P_0)$ in total pressure due to a change in partial pressure of a particular gas species. H_0 and P_0 are background values [see definitions (12) and (13)]

$$S(P,P_0) = (H - H_0)/(P - P_0).$$

The units for sensitivity are ion current per unit pressure (A/Torr, for example). The sensitivity is obtained from the basic calibration data [see definition (23)].

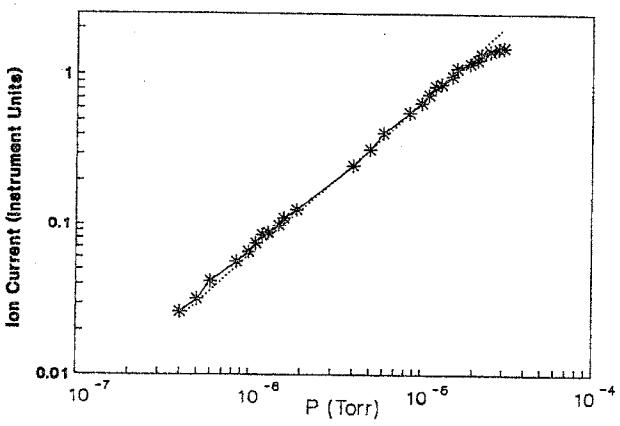

FIG. 4. PPA response (ion current) vs ion source pressure. A linear response is indicated by the dotted line

(25) *Incremental sensitivity, I.* The incremental sensitivity is defined as the rate of change of ion signal with the partial pressure at specific total pressure and gas composition. It is expressed in the same units as sensitivity and is the slope dH/dP_i of the tangent line at a particular point (H_i,P_i) on the curve of ion signal H_i versus partial pressure P_i. The essential distinction between sensitivity and incremental sensitivity is that for sensitivity [definition (24)], pressure and ion current are referenced to the background values (H_0,P_0) whereas for the incremental sensitivity, these changes are referenced to an operating point (H_i,P_i) where the instrument is being used. In the linear response region of a PPA, the sensitivity and incremental sensitivity are equal. Incremental sensitivity is an alternate representation of the basic calibration data [see definition (24)]. Incremental sensitivity is *only* useful in interpreting small changes ΔH_i in ion signal in terms of small changes ΔP_i in partial pressure.

(26) *Mass discrimination.* The variation of ion transmission through the mass filter and the detection efficiency as a function of mass-to-charge ratio is called mass discrimination. Because the sensitivity of a given instrument depends on factors such as ionization cross section, ionizer parameters, gas pressure, gas composition, cracking pattern, as well as mass discrimination, it is necessary to calibrate each instrument for each chemical species to be analyzed. In isotope analysis it is essential to know the instrument's mass discrimination. Methods for determining mass discrimination are outside the scope of this document. References to such methods can be found in Sec. VI of this document.

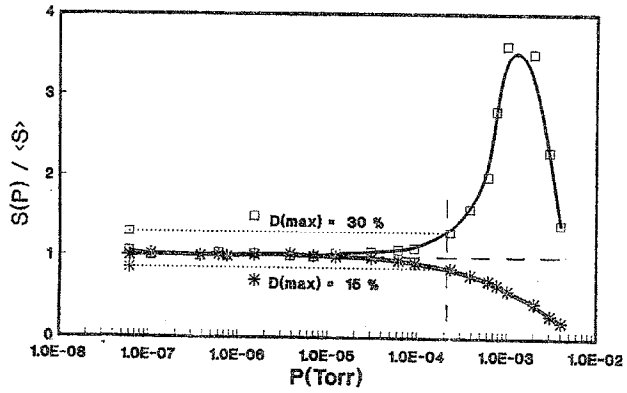

FIG. 5. Relative sensitivity vs ion source pressure for a PPA exhibiting different nonlinear response depending on ion energy (Ref. 11). Linearity for ion energy of 3 eV (□) is 30% and for 8 eV (*) it is 15% for pressures less than 2×10^{-4} Torr (3×10^{-2} Pa).

(27) *Linearity.* The extent to which the change in output signal is proportional to the corresponding change in partial pressure. A measure of an instrument's linearity is the largest (±) deviation (%) of sensitivity from the average sensitivity over a specified interval of total pressure. An example of a linearity statement is in Figs. 5 and 6.

(28) *Linear response range.* An instrument is said to be in its linear response range when the change in output signal is directly proportional to the corresponding change in partial pressure, i.e., the sensitivity is independent of pressure. The user must define the deviation from linear response that can be tolerated for the accuracy requirement of a particular application.

(29) *Noise.* Noise is the random fluctuation in the output signal unrelated to a change in the partial pressure of the gas from which the signal is derived. The appropriate measure of noise is the standard deviation σ_N of N independent determinations of the average output signal obtained at constant partial pressure

$$\sigma_N = [\Sigma(A_i - \langle A\rangle)/(N-1)]^{1/2},$$

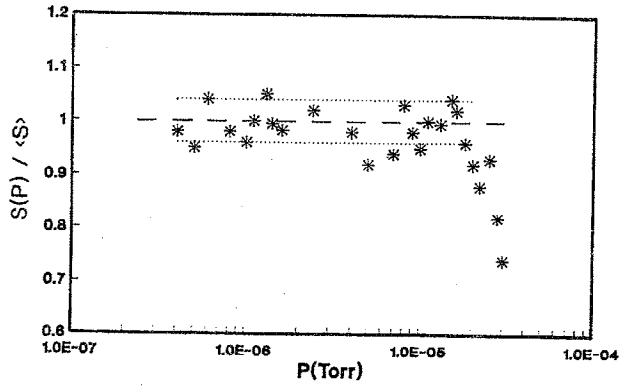

FIG. 6. Relative sensitivity vs ion source pressure corresponding to data in Fig. 4. Linearity in this example is 8% for pressures less than 2×10^{-5} Torr and shows a random error in sensitivity measurements of 4% standard deviation from the mean.

where A_i is the value of the ith determination of output signal and $\langle A\rangle$ is the average of A_i. The time interval over which the average value the A_i is determined should be the same for each determination, and the same as that to be employed during measurement of an unknown partial pressure. Noise is dependent upon the signal integration time of the instrument used to measure it. For example, a chart recorder does not respond to high frequencies (Fig. 1) so it gives lower noise levels than high speed data acquisition displays using a computer (Fig. 2). An example of $\pm\sigma_N$ for a computer scanned mass spectrum is shown in the baseline of Fig. 2 near $M/Q = 23$. In many computer controlled PPAs, the number of samplings of ion current at a given point on the mass scale are related to the scan speed; fast scans are noisy and slower scans have less noise.

(30) *Drift.* A change with time in the average output signal at constant partial pressure. Drift is specific to a particular instrument and its operating conditions. Its components are changes with time in baseline and sensitivity.

(31) *Minimum detectable partial pressure change,* ΔP_{min}. The partial pressure change corresponding to the smallest signal change which can be distinguished from noise. As a very general prescription,

$$\Delta P_{\min} \approx \sigma/S,$$

where σ is the noise associated with the reference level with respect to which the change is measured, and S is the instrument's sensitivity for the gas and ion species of interest. The noise value can depend upon the total pressure as well as on the background partial pressure, drift, and tailing contributions. To obtain a value of $\Delta P_{\min}$ which is characteristic of the instrument alone, with minimum environmental influence, the total pressure should be as low as possible. Minimum detectable partial pressure change is a derived quantity which depends on the definition of a "just detectable" change in signal, as well as on sensitivity and noise level. For this reason, no exact expression for $\Delta P_{\min}$ is given here, because different users have different criteria for deciding when a change in signal is distinguished from noise. When specifying a value for $\Delta P_{\min}$, all instrument parameters which significantly influence that value should also be stated. This will include some or all of the following: Electron emission current, electron energy, ion energy, peak width, and secondary electron multiplier gain, as well as the ion source pressure and the particular ion species from which the signal is derived.

III. APPARATUS

A. Partial pressure analyzers and their operation

A PPA is a type of mass spectrometer that has its ion source immersed in gas to be analyzed. To accomplish this, its design is usually optimized for high sensitivity, low mass range, and low resolution.

The complexity of mass spectrometers requires that many adjustments be made. However, the range of adjustments permitted to the operator varies widely. In many of the instruments designed for routine or semiquantitative

applications, most of these adjustments are set at the factory while more stringent applications may require field alignment. Operator tuning of scan speed, electrometer damping, peak location, resolution, rf tuning [in the case of a quadrupole mass spectrometer (QMS)], and the ion source voltages and emission current are included in instruments meant for higher precision analyses. These adjustments by a knowledgeable user permit optimized instrument performance. Adjustment of these parameters affects the quantitative output of the instrument and they must be set to suitable values long enough before calibration is commenced that thermal and electronic stability is reached. In a properly operating instrument, the magnitude of the output will be independent of the mode of scanning and consistent in all forms of display. Any such data that are proven to be consistent and repeatable are acceptable for calibration, provided that the operating conditions are *identical* for calibration and sampling procedures.

Many electronics units are computer operated and feature a variety of scanning modes and forms of data presentation in addition to a simple spectral scan. Many instruments can do bar graphs and single- or multiple-ion monitoring. Output may be digital rather than analog and displays may be numerical rather than graphical. Some instruments also apply a variety of correction factors and some even include spectrum analysis programs using matrix inversion techniques. The user should be aware that some data reduction can give erroneous results if, e.g., library sensitivities and cracking patterns are not updated by the most recent calibration of the instrument.

B. Precautions to observe before calibration

(1) The sensing head must be clean and in good condition. Inspect the ion source for heavy accumulations of dark material, although some discoloration or distortion of the filament is normal. Mild contamination can be removed by vacuum baking according to the manufacturers instruction. Do not attempt to calibrate an instrument if the sensing head is obviously contaminated. Removal and disassembly for cleaning are required for very contaminated ionizers. Glow discharge cleaning (GDC) has been shown effective for *in situ* reduction of hydrocarbons and water vapor[13,14] when normal bakeout[15] is not sufficient. Coating ion source electrodes with Cr followed by baking and GDC offers further reduction hydrocarbons and water released.[16]

(2) The instrument must be properly installed and grounded. Verify that excessive instrument noise is not present at the anticipated operating level, due to faulty connections, electrical interference or mechanical vibration. Ground loops, a frequent cause of power line noise, can sometimes be reduced by assuring that the vacuum system and electronics have a common ground.

(3) Verify that peak shapes are suitable for measurement. Instruments that produce an irregular or jagged peak shape at the top where peak height will be measured should be adjusted, or the sensing head should be serviced to provide ion current signals which vary smoothly with mass. With a QMS, ion energy and focus controls have the greatest effect on peak shape. Contamination in the head is a frequent cause of irregular peak top structure.

(4) Verify that ion current signals are stable. Signal amplitudes should be repeatable from one to five percent for a given scan rate. If peak heights measured by continuous monitoring of a single peak are greater than those measured by scanning the same peak, fault probably lies in use of too fast a scan speed and/or too long an electrometer time constant (damping) for that electrometer range. The faster the scan rate the smaller the peak amplitude due to the effect of time constant of the electrometer. Scan speeds in Faraday cup mode are typically slower than those when a secondary electron multiplier (SEM) is used. SEM gain instabilities will sometimes give different peak heights between scanning and monitoring modes. It is important that peak heights measured for sensitivity calibration be measured in the same manner as application measurements are made. Unstable Faraday cup or SEM signals are usually due to contaminated sensing heads or defective electronics. Sometimes baking the sensing head under vacuum will correct contamination problems.

(5) The instrument should be warmed up (filament and electronics) to a stable operating condition. The degree of stabilization required depends on the accuracy required and on the inherent stability of the specific instrument. However, as several hours are required for a sensing head to warm up from an off condition to normal operating temperature, PPAs should be left on unless use is not anticipated for extended periods. Likewise, cooldown from a bakeout at 350 or 400 °C takes as long as 6 h.

(6) Make any necessary tuning adjustments following the manufacturer's recommended adjustment sequence. It should not be assumed that an instrument will operate well over the entire range of parameter values achievable. Unless there are reasons to the contrary, instruments which are designed to permit the user to adjust operating parameters of the ionizer and the analyzer should be operated at the manufacturer's specified values. The values specified for one instrument are usually not suitable for another model. Quadrupole instruments in which the rf drive must be tuned to resonance should be tuned before calibration. Adjustments which affect resolution of quadrupole PPAs should be changed prior to calibration. For quadrupole instruments, the position of peaks in the mass scale is adjustable by varying the rf amplitude and the resolution is adjustable by varying the ratio of rf to dc voltage applied to the analyzer rods. A 10% valley between adjacent peaks, as shown in Fig. 3, is frequently recommended. The procedure for determining the resolving power is given in Sec. IV B. Other adjustments, including ionizer settings, scan speed, and damping, once selected must not be changed after calibration. Subsequent changes in resolution and other QMS parameters will require a new calibration. In nearly all instruments, adjustments are made at two points in the mass scale; suitable test gases are required to get mass peaks in the right mass ranges. A final check should be made to verify that all adjustment requirements have been met.

C. Systems for calibration

Four methods of calibration of a PPA are described: (1) the direct comparison of the PPA output with a transfer standard pressure gauge, (2) the indirect comparison of PPA readings with readings of a transfer standard pressure gauge separated by a flow restriction (pressure divider method), (3) comparison of the PPA output with the calculated pressure generated in an orifice-flow system, and (4) calibration of the PPA response to known gas flow rates. The first three methods may be carried out on a test stand of suitable design as described below. The fourth method requires that the pumping speed during calibration be the same as the pumping speed during use, and normally implies that the PPA is calibrated *in situ*.

The vacuum chamber for test stand calibrations has the function of presenting a known pressure of test gas to the ionizer of the PPA. To accomplish this, the chamber geometry, gas entry point and pumping port must have a symmetry that produces points of equivalent pressure in the measuring region. Background gases due to outgassing and other sources should be minimized. The following are recommended practices to meet these requirements.

The test chamber should be a right circular cylinder having a length-to-diameter ratio between 0.5 and 2.0. A spherical test chamber is also acceptable. The test chamber is continously pumped through an orifice located at the center of one end of the chamber. The orifice diameter should not be greater than 0.1 times the chamber diameter or length, whichever is less. The conductance of the orifice should not be less than 10 L/s for nitrogen at room temperature. If it is not convenient to use a single orifice, a set of orifices having the same total area as the single orifice described above and located symmetrically around the axis at a radius not exceeding 0.1 of the diameter of the chamber is acceptable. The ports for the PPA sensing head and reference gauge (if used) should be located in the cylinder wall at a distance of at least 5 orifice diameters from the pumping orifice. Where more than one port is used, it is very important that the interaction of measurement devices be prevented. Often locating the ports at right angles to each other will be sufficient but it may be necessary to install electrically grounded baffles or screen. It is good practice to have the axes of the ports in the same plane perpendicular to the axis of the cylinder, but this arrangement is not a requirement if the pumping aperture is small.

An economical realization of a calibration chamber with good pressure uniformity can be achieved by using a standard UHV fitting such as a four or six-way cross. The PPA and reference pressure gauges are mounted symmetrically on the arms of the cross. The gas inlet would be on top and the pump at the bottom. A pump orifice can be part of the gasket joining the lower chamber and pump.

The test chamber should be constructed of metal, preferably stainless steel with welded joints. Demountable seals should be metal to minimize local outgassing. Provisions for bakeout of the chamber to lower background pressure is not required for all applications but is frequently useful. If bakeout is used, the chamber and instruments to be used in calibration should be uniformly heated to avoid localized outgassing sources. The temperature and duration of the bakeout depend on the base pressure required and are not specified in this recommended practice. However it is essential that the apparatus be stabilized at an equilibrium operating temperature with the instruments running before calibration measurements are undertaken.

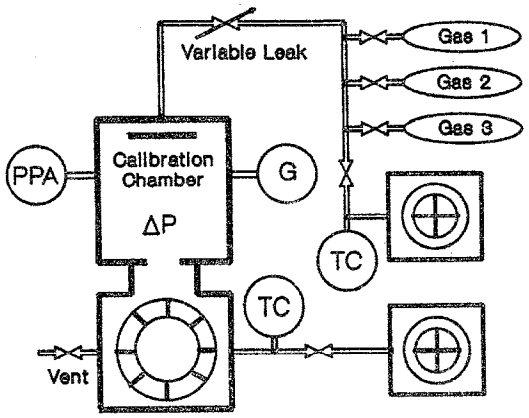

FIG. 7. System for calibration of PPAs by direct comparison of the PPA ion signal with a pressure reading on a calibrated MDG or IG.

The test gas input to the chamber should be directed along the axis. Since the gas flow pattern emitted by a long tube is concentrated into a relatively narrow beam, some means of scattering the gas molecules at the entry point should be employed. A baffle placed in front of the gas entry as shown in Fig. 7 induces scattering of gas molecules with the walls to randomize motion. For a comparison system, the gas stream can be directed into the pump orifice, using the backscattered molecules as the input to the test chamber. This method is not acceptable in the pressure generator where pumping speed must be calculated.

The pump used to evacuate the test chamber should have a pumping speed at least 10 times as large as the orifice conductance for all gases used in calibration. Users are cautioned to remember that orifice conductance for each gas species varies inversely with the square root of molecular weight of the gas. Systems used for calibration with relatively light gases such as hydrogen and helium must be supplied with relatively large pumping capacities. In addition to the capacity, the pumping system must be capable of evacuating the test chamber to a base pressure at least one decade lower than the lowest test pressure to be used. The pumping system should also be of a type which does not introduce contaminants harmful to the instruments into the vacuum environment. A turbomolecular pump of adequate capacity is often a good choice for the primary pump but other types can be successfully used.

Four different calibration system designs are described below. The first three are for calibration stands on which the PPA is to be calibrated before transfer to the process system. The fourth discusses issues involved in PPA calibration while on the process system.

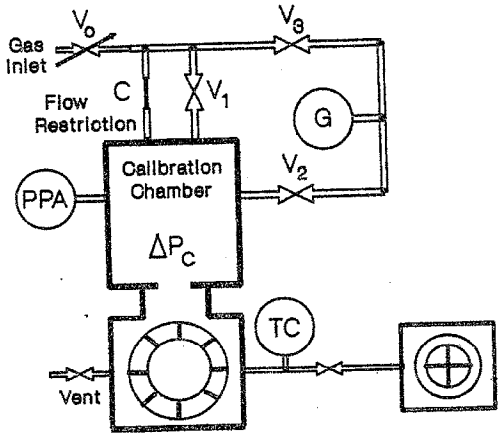

FIG. 8. Pressure-divider calibration system. Pressure gauge G is a MDG or CM transfer standard gauge.

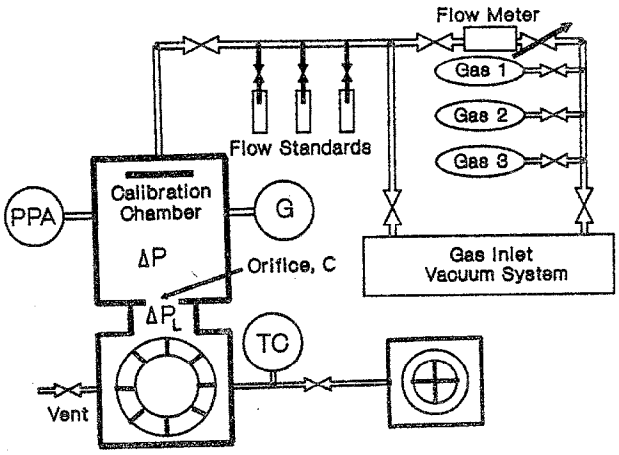

FIG. 9. Direct-flow calibration test stand for determining the sensitivity of a PPA in reference to ion source pressure calculated from $P = F/C$ where C is the conductance of the test chamber.

1. Direct pressure comparison system

The direct pressure comparison system is shown in Fig. 7. It uses a gas inlet system with a valve to control flow. Known gas flow rates are not required for this technique. The calibration system contains the PPA sensor and a calibrated pressure gauge. Two recommended transfer standard gauges are the molecular drag gauge (MDG) and calibrated ion gauge (IG). The operating pressure ranges of the MDG and PPAs have limited, but sufficient overlap, allowing this to be the preferred method. Because both transfer standards are total pressure gauges and both have species-dependent sensitivities, only those pure gases for which calibrations have been performed can be used. The PPA and the pressure transfer standard should be mounted in a manner that ensures the same pressure at the two gauges. See the appropriate AVS Recommended Practices for proper use of these gauges.

2. Pressure divider calibration system

The pressure divider system[11,17] is shown in Fig. 8. The gas inlet system uses the valve V_0 to control flow of gas to the chamber. Known gas flow rates are not required for this technique. This system requires a pressure transfer standard gauge, such as a capacitance manometer or a molecular drag gauge. A calibrated ion gauge, however, is not recommended for use with this technique because of the ion gauge's nonlinearity for pressures above 10^{-4} Torr. See the appropriate AVS Recommended Practices for proper use of these gauges.

In parallel between the gas inlet and the calibration system are valve V1 and a restricted bypass. V1 is open for initial outgassing only. To maintain the transfer standard within its operating pressure range and allow PPA calibration over much lower pressures, valves V2 and V3 are used to allow the pressure transfer standard to be valved into the chamber or into the gas inlet system, respectively. Calibrations are performed with constant gas flow rates. With V1 and V3 closed and V2 open, direct comparison of PPA and the calibrated gauge readings are performed. Lower calibration pressures are achieved by performing a pressure measurement with V1 and V2 closed and V3 open. The ratio of the pressure, P_h, on the higher pressure side of the flow restricting element to the pressure, P_l, on the lower pressure side of the element is called the pressure ratio, R_p, is as follows:

$$R_p = P_h/P_l\,.$$

R_p is approximately equal to $1 + S_{\text{eff}}/C_{\text{res}}$ where S_{eff} is the effective speed with which the calibration chamber is pumped and C_{res} is the conductance of the flow restricting element. It is not necessary to know the actual pumping speed and conductance because R_p can be determined directly by measuring pressures above and below the restriction, using the calibrated reference gauge. To insure a constant pressure ratio R_p, the pressure P_h on the higher pressure side of the flow restriction must be kept low enough that the mean free path of the gas present is much larger than the characteristic dimension of the flow restriction. For example, for a flow restriction element with flow channel dimensions as large as 1 mm, the pressure P_h should be kept below about 10^{-3} Torr for N_2 at room temperature.

3. Orifice flow calibration system

In the orifice-flow system shown in Fig. 9, the value of the calibration pressure ΔP that the PPA experiences is calculated from a measured value of gas flow F through a known conductance C,

$$\Delta P = [R/(R-1)](F/C),$$

where R is the ratio $\Delta P/\Delta P_l$ of corresponding pressure changes ΔP and ΔP_l on the high and low pressure sides of the orifice, respectively. The pressure ratio may also be expressed in terms of the conductance of the orifice and the pumping speed S of the pump as $R = [1 + S/C]$. The flow-restricting element in this system is a circular orifice of area

A, fabricated in such a way that its molecular flow conductance can be calculated with small uncertainty. In the first approximation,

$$C \approx C_0 = 3.64(T/M)^{1/2}A \ (\ell/\text{s}),$$

where T is the gas temperature (K), M is the gas molecular weight, and A is the orifice area (cm^2). The exact value of the conductance may be expressed as

$$C = KC_0,$$

where K is a correction factor.[18–22] A thin circular orifice 1 cm in diameter will have a molecular conductance of about 9.4 ℓ/s for N_2 at room temperature. Compared with the pressure comparator or pressure divider systems described previously, the orifice-flow system is more demanding in its construction and operation because of the requirement to know the conductance and to measure the flow. More details on the orifice flow system can be found in Refs. 18–22.

4. Calibration of PPAs in situ

To assure the best performance of the PPA installed in a process vacuum system, the analyzer must be located at a process point that samples the composition of interest but also does not exceed the pressure range for linear response of the analyzer. Where possible, the ion source should be immersed in the UHV chamber to avoid confusing wall outgassing with the main atmosphere. Often the PPA is connected as an appendage unit to the main vacuum chamber to keep it out of the way of the process. This can have the beneficial effect of shielding the PPA from electrons, ions, and fields produced by the process. Isolation is assured by having a grounded, conductive screen attached in front of the pumping duct of the PPA or an elbow. If attached on an appendage, the conductance of the PPA appendage should be high enough that the gas at the ionizer reflects changes in the process chamber with a short time constant (volume/conductance), typically less than 0.05 s. This assures that the gas being analyzed is representative of that in the system and is not a local atmosphere in which components created in the appendage appear in the mass spectrum. If more rapid sampling of process changes is desired, then a higher conductance is needed to reduce the time constant. For measurements in UHV systems, a PPA with an open ion source should be used and the conductance to the appendage should be very high. For higher pressure processes, up to 10 Torr, a selected orifice for sampling from the process together with a separate pump for the analyzer can be used to reduce the pressure of the process to obtain linear analyzer response. For pressures up to one atmosphere, sampling systems with differential pumping are commercially available.

If an ionization gauge or a molecular drag gauge is used as the reference pressure sensor for calibration, it should be located at an equivalent pressure point with a high conductance to the chamber so that it and the PPA are exposed to the same pressure. If such a location is not possible, the gauge should be located near enough to the PPA that its reading has a fixed relation to the pressure at the PPA by the pumping system geometry. The reference pressure sensor for calibrating the partial pressure response of the PPA can also be a capacitance manometer located on the high-pressure side of an orifice leak.[9,14]

The preferred method for introducing calibration gases is through the same line that process gases enter the PPA region so that the calibration gas flow duplicates the gas flow of normal process gases. Ideally the process sampling point is downstream from the gas introduction point so that sampling is by back diffusion rather than by a directed molecular beam. Three ways to introduce gases for *in situ* calibration are as follows.

(1) Introduction of pure gases or a standard mixture through a fixed or controlled leak with composition similar to that of the process gas. An alternate to a leak is pulsed gas injection with a steady pulse rate.[23]

(2) Introduction of low pressure selected gases via a molecular leak; pressures are measured by a capacitance manometer.[9,14]

(3) A single or combination of flow standards with a gas supply.

D. Gas supply and introduction

Vacuum systems designed for PPA calibration will have attached to them one or more gas sources. For considerations of system geometry, see Sec. III C. Sources of calibration gases fall into two categories: (1) controlled but unknown flow rates to produce a measured pressure and (2) calibrated leaks with known flow rates. Methods for using these two types of sources are described in the following paragraphs. All of the methods are applicable to single-component gas introduction, but some of the methods can be influenced by transition flow behavior in the leak element, and consequently may not deliver the various components of a gas mixture with the simple predictability obtained under molecular or viscous flow operation. Care must be given to assure that the gas at the ionizer represents the gas in the process or standard mixture.[8,9,27]

1. Gas supply with variable leak

A flow diagram for gas inletting with a variable leak is shown in Fig. 7. The supply gases are connected to a common manifold. The manifold is evacuated, the gas of choice is expanded into the manifold, and the variable leak is adjusted to allow the gas to flow into the chamber to produce the pressure desired. A given chamber pressure can be produced from combinations of manifold pressure and variable valve settings. In general, the gas flow is more stable if a valve is set and the manifold pressure is adjusted to produce the calibration chamber pressures desired. The flow control device should be designed to maintain a constant flow over times longer than are required for measurement, typically on the order of an hour. Table I gives a description of some variable leaks and their flow rate and driving pressure ranges. The devices listed mechanically change the dimensions of a flow channel to control the flow rate. The elements are usually operated in the transition flow regime where the admixture of molecular and viscous flow character changes with the dimensions of most of these leaks. The pulsed gas injection valve controls flow

TABLE I. Gas supply methods to introduce gases for PPA calibration.

Method	Flow control element	Supply pressure range	Flow rate Torr ℓ/s	Flow type
Pure gas supply with variable leak	Needle valve	< 30 psia	10^{-5}–300	Transition
	Bent flat channel	< 400 psia	10^{-9}–600	Transition
	Metal/sapphire	10^{-11}–1 atm	10^{-10}–100	Transition
	Piston/tapered groove	0–10 Torr		Transition
Injector[a]	Pulsed valve	0–10 Torr	10^{-6} 10^{-4}	Transition
gas supply with fixed leak	Porous plug	< 10 Torr	10^{-6}–10^{-4}	Molecular
	Capillary	Atmosphere	10^{-3}–10^{-1}	Viscous
	Crimped capillary	30–400 psia	10^{-7}–10^{-4}	Viscous
	Orifice	< 10 Torr	$> 10^{-5}$	Molecular
	Drawn glass	30–400 psia	10^{-6}–10^{-4}	Viscous
Flow standards with gas supply	Glass	[b]	He	Permeation
	Crimped capillary	[b]		Viscous
	Drawn glass	[b]		Viscous

[a]Reference 23.
[b]A flow standard has a calibrated flow rate so pressure generated at the PPA depends on the pumping speed of the vacuum system.

rate by varying the duration of the open pulse and the repetition rate of pulses.[23] The flow regime is characterized primarily by the open dimensions of the valve.

2. Gas supply with fixed-geometry leak

An alternate flow control method is to use a leak with fixed geometry. The flow rate is varied by adjusting the manifold pressure. See Table I. The porous plug and crimped-capillary leaks are usually operated in the transition flow region much like the variable leaks discussed above. A smooth-bore capillary exhibits viscous flow and may have a flow rate that is too high for direct entry into a calibration chamber. Usually the flow from a capillary is pumped with an intermediate stage pump that reduces the gas pressure presented to the orifice or sintered leak used as the flow restriction at the chamber.[25] For example, the flow through a typical small orifice of 0.05 mm diam is molecular if the gas pressure is < 100 Pa of air.[26] A method for introducing small quantities of gas is to use a pressure reservoir of up to a few liters in volume with a small orifice of 0.05 mm, with single or multiple holes. The pressure in the reservoir is measured by a capacitance manometer. Such a system is referred to as a batch inlet system.[9,27] It uses a small sample, of about 1 atm cm^3, but because the partial pressure of components deplete from the reservoir at rates inversely proportional to the square root of their mass, the individual partial pressures of gas components may need to be calculated at the times when PPA data are acquired if depletion exceeds an acceptible percentage.

3. Calibrated flow rates

For systems which require known flow rates, there are three alternatives: (1) calibrated leaks with attached gas supplies, (2) calibrated leak elements with variable gas pressure to supply them, or (3) a metering valve with flow measurement instruments. See AVS Pump Speed Measurement Recommended Practice. A schematic showing the use of connected flow standards is shown in Fig. 9. If an unknown gas flow is to be determined from calibration with a known gas flow, it is recommended that only one gas inlet port be used for introduction of both gases to eliminate directed flow errors. The calibration and use of flow elements is the subject of another AVS Recommended Practice.

4. Adsorbing and reactive gases

The methods described in this document relate to the handling and analysis of nonreactive and weakly adsorbing gases. Strongly adsorbing gases, such as water vapor, have variable interactions with the surfaces of the vacuum system and the PPA. Equilibration between the gas and adsorbed phases is necessary before stable operation can be achieved. Steady-state water partial pressures are reached only after significant time lag following a change in water partial pressure in the process. Raising the temperature of the gas handling and PPA vacuum system accelerates desorption, allowing steady state to be approached more rapidly. Reactive gases like O_2, NO_2, and H_2O interact with vacuum surfaces and can also be involved in catalytic reactions at the filament of the PPA. Some well-known reactions of these gases with the residual carbon on surface of the filament (especially tungsten) or hot surfaces nearby include

$$C_{\text{hot surface}} + O_2 \rightarrow CO + O \rightarrow CO_2$$

and

$$2H_2O \xrightarrow{\text{hot surface}} 2H_2 + O_2,$$

$$C_{\text{hot surface}} + H_2O \rightarrow CO + H_2.$$

These lead to ions in the mass spectra that are artifacts of the filament reaction and not initially present in the gas. Large shifts in sensitivity to all gases upon exposure to O_2 are also observed followed by long recovery times after the oxidizing gas is removed.[11] Preconditioning the system to the reactive gas before measurement can lead to faster attainment of meaningful PPA output. Use of less reactive filaments may be desirable, such as rhenium for use in an oxygen atmosphere.[28] However rhenium filaments do not

TABLE II. Pressure measuring devices for use in PPA calibration.

Gauge type	Pressure range (Pa)	Accuracy (%)	Comments
Ionization			
Glass BA	10^{-2}–10^{-8}	20	a
Nude BA	10^{-2}–10^{-8}	30	a
Inverted magnetron	10^{-2}–10^{-8}	20	a
Molecular drag	10^{-1}–10^{-4}	1	b
Capacitance manometer	100–10^{-2}	2–10	c

[a]Reading depends on relative ionization cross section of gas species present. Most easily used with pure gases.
[b]Reading depends on accommodation coefficient of gas species present. Most easily used with pure gases.
[c]Reading independent of gas composition. Used with orifice to generate predictable flow rates for pure gases and mixtures.

give the stability or sensitivity exhibited by tungsten.[29] Thoria-coated iridium[30] is partially protected from accidental air exposures but will exhibit a change in emission characteristics if the coating cracks and pulls away from the iridium base.

E. Pressure measurement

All of the calibration methods presented in this recommended practice require either the measurement of partial pressure of a gas component near the ion source of the PPA or else an inferred pressure from flow rate and system conductance. Where direct or indirect pressure measurement is employed, there are three types of gauges that can be considered: Ion gauge (hot and cold cathode), molecular drag gauge and capacitance manometer. A brief description of the features of each type is presented in the following text and the performance is summarized in Table II. Whichever gauge is employed as the pressure transfer standard, the gauge must be calibrated with its gauge controller and readout as a complete system before use. Changes in calibration factors when the gauges are transferred from the calibration to the operating systems can occur and are difficult to detect.

1. Ion gauge

The hot-cathode Bayard–Alpert type of ionization gauge has a usable pressure range of 10^{-8}–10^{-2} Pa (10^{-10}–10^{-4} Torr). An ion gauge used as a pressure reference for PPA calibration must be calibrated for the gases and pressure ranges to be used to determine the gauge constant for these gases. With careful calibration, an accuracy of better than 20% and a linearity of a few percent over the stated pressure range can be attained.[31,32] The advantages of ion gauges as pressure transfer standards are that they are inexpensive, easy to use, and operate in the same pressure ranges as do PPAs. The disadvantages include gas species-dependent ion currents, gas pumping from gettering or sorption, and desorption of previously gettered gases. Ion gauge controllers which change electron emission ranges as the pressure changes may have less accuracy and linearity.

The cold-cathode ion gauge is an alternative to the hot cathode ion gauge. Its advantages over the hot-filament ion gauge include use over a wider pressure range and no filament to burn out or catalyze reactions. The disadvantages include gas dependent gauge sensitivity, difficulty establishing a discharge at low pressures, leakage currents when contaminated for some designs, different sensitivities in the high and low pressure regions[2] and less accuracy than the hot cathode ion gauge.

2. Molecular drag gauge

The molecular drag gauge (MDG) provides an accurate method for measuring pressures in the 10^{-4}–10^{-1} Pa (10^{-6}–10^{-3} Torr) range with measurement times of 30 s or less. The disadvantages of the MDG are sensitivity to vibration, gas-dependent sensitivity, long measurement times, high cost, and changing null point.[33–39] When used with pure gases and the appropriate accommodation factor is used, high accuracy can be attained.[40]

3. Capacitance manometer

The capacitance manometer provides pressure measurement independent of gas composition. A 133 Pa (1 Torr) unit reading as low as 10^{-2} Pa (10^{-4} Torr) can have less than a 10% error in the reading. The disadvantage is that this is not low enough to be directly useful for measuring the range of ion source pressures normally desired, requiring a pressure divider method (see Sec. V C) to take advantage of the 1% accuracy achievable at 10^{-1} Pa and higher pressures. Zero drift, temperature dependence of readings, and thermal transpiration are problems at the lowest end of the range.[41]

IV. MASS SCALE, RESOLVING POWER, AND BACKGROUND

Procedures described in this section presume that the initial setup of the partial pressure measurement system described in Sec. III has been accomplished.

A. *M/Q* scale calibration

The M/Q scale of mass spectrometers must be established for each instrument. Quadrupole mass spectrometers have a linear relationship between the rf voltage applied to the quadrupole rods and the mass-to-charge ratio of ions that are transmitted. Magnetic sector and time-of-flight instruments have a nonlinear mass scale, with $(M/Q)^{1/2}$ dependence. The M/Q scale for any instrument can be calibrated by examining the mass spectrum of a known gas mixture that produces ions over the mass range of the instrument. Table III gives gases and the associated M/Q's of ions produced that are useful in calibrating the mass scale of the instrument. For example, a mixture of hydrogen, helium, nitrogen, and argon will give positive ions from $M/Q = 1$ to 40. Inclusion of krypton extends the scale to $M/Q = 86$. If the mass range of the instrument includes $M/Q = 136$, the addition of Xe (with its nine isotopes) to a mixture will provide peaks with M/Q's in the ranges 41.3–45.3, 62–68, and 124–136 amu/e associ-

TABLE III. Mass peaks for determining mass scale and resolving power.

Mass range	Gases	Mass peaks M/Q
2–4	H_2(BKg), He	2, 4
16–18	Air (H_2O)	18, 17, 16
28–29	N_2	28, 29
28–32	Air (N_2, O_2)	28, 32
40–45	Air (Ar, CO_2)	40, 44, 45
39–43	Kr^{2+}	39, 40, 41, 41.5, 42, 43
62–68	Xe^{2+}	62, 63, 64, 64.5, 65, 66, 67, 68
78–86	Kr^{+}	78, 80, 82, 83, 84, 86
124–136	Xe^{+}	124, 126, 128, 129, 130, 131, 132, 134, 136

ated with the various charge states Xe^{3+}, Xe^{2+}, Xe^{1+}, of Xe ions. It is useful to keep a gas supply of a pertinent mixture for checking the mass calibration.

The scan parameter, X, identified with a particular M/Q, has the value X_M that produces the maximum peak for the M/Q under study. Data pairs of M/Q and X_M can be fitted to a polynomial curve

$$M/Q = a_{-1}X_M^{-1} + a_0 + a_1X_M + a_2X_M^2 + \cdots,$$

where the a_i are fitting coefficients. Use of a_0 and a_1 is normally sufficient to describe the relation for the entire mass range of quadrupole mass spectrometers. For sector mass spectrometers, coefficient a_2 dominates for magnetic scanning and coefficient a_{-1} dominates when the accelerating voltage is scanned.

In many modern instruments, the fitting of the M/Q scale is done by instrument software after the operator identifies the correct M/Q of the peaks in the scan. It is important to perform this M/Q scale calibration in the analog display mode to identify peaks from the real display of ion current versus M/Q rather than a bar graph display. For example, if the $M/Q = 28$ peak from N_2 calibrant gas falls at 27.5 amu on the displayed M/Q scale, a bar graph display of that peak may give two peaks at $m/e = 27$ and 28 each with reduced intensity and neither representing the calibration gas. The eventual calibration of sensitivity for such PPAs will use the ion currents measured by the software, it is vital that the M/Q scale be accurate so that the peak amplitude be correctly measured.

B. Measurement of resolving power

Resolving power R_{10} is the ratio of the mass-to-charge ratio to the peak width at 10% peak height [definition (19)]

$$R_{10} = (M/Q)/\Delta(M/Q)_{10},$$

where $\Delta(M/Q)_{10}$ designates the peak width at 10% of the height of an isolated peak. The procedure can be broken down into a sequence of simple steps as follows.

(1) Select a mass peak with an M/Q value the same as, or close to the value at which the resolving power is to be determined. The peak chosen should be free from tailing contributions from adjacent peaks.

(2) For the isolated peak of interest, determine the scan parameter values X_{+10} and X_{-10} corresponding to 10% peak height on either side of the peak, as well as the value X_m corresponding to the maximum peak height.

(3) Using the mass scale calibration (Sec. IV A), compute the peak width as

$$\Delta(M/Q)_{10} = a_1[X_{+10} - X_{-10}] + a_2[(X_{+10})^2 - (X_{-10})^2] + \cdots.$$

(4) If the mass-to-charge ratio of the selected peak is not known, this value can also be calculated from the mass scale calibration as

$$M/Q = a_0 + a_1X_M + a_2X_M^2 + \cdots.$$

(5) From the values for M/Q and $\Delta(M/Q)_{10}$ determined, the resolving power can be calculated.

The peak width can also be calculated graphically from a mass spectrum as shown in Fig. 3. Peaks M_1 and M_2 in Fig. 3 are appropriate to the establishment of the mass scale and M_2, but not M_1, can be used to determine $\Delta(M/Q)_{10}$. Note that the 10% positions of the low mass and high mass sides of the peak must each be measured to account for asymmetry.

Using a screen display, graphical printout, or chart trace, the peak width can be measured geometrically from the distance between known, nearby peaks and the peak width measured at 10% of peak height. Referring to the dimensions in Fig. 3,

$$\Delta(M_2/Q_2)_{10} = X_2(M_2/Q_2 - M_1/Q_1)/\Delta X.$$

The resolving power at the mass M_2 is then calculated from M_2/Q_2 and the graphically determined $\Delta(M_2/Q_2)_{10}$.

Although the peak width can be set over a continous range of values, most commercial quadrupole PPAs are designed so that the peak width shows little variation from the set value as the instrument is scanned over its useful M/Q range. This leads to a resolving power R which is proportional to the M/Q value at which the instrument is operating. By contrast, in a magnetic sector mass analyzer, the resolving power is constant because it is defined by the radius of the ion path and the source and detector slit widths, W_{source} and $W_{\text{collector}}$.

$$R \propto \text{radius}/(W_{\text{source}} + W_{\text{collector}}).$$

Table III lists some known mass pairs or clusters which are useful for determining mass scale calibration and resolving power in the 1–150 M/Q range.

C. Background scan

The background scan with a PPA records the ion intensity as a function of M/Q with no inletting of gases. This record can be the point by point ion current record as the mass range is scanned or it can be the ion intensity of selected ions. The residual peaks that appear are due to the

outgassing from surfaces within the vacuum system. The normal presumption is that the background spectrum is constant over the short term and can be subtracted from a scan taken with a test gas present to give the spectrum of the test gas only. Usually this has sufficient accuracy but two other situations can occur: The background can increase due to the active desorption of wall contaminants (e.g., H_2O and hydrocarbons) by some active gases (e.g., H_2, O_2, NO)[13,14] or the background can decrease by blanketing of the surface by test gas, thus lowering the outgassing rate.

V. SENSITIVITY AND LINEARITY MEASUREMENT

To relate quantitatively the ion signals of a PPA to partial pressures or partial flow rates, it is necessary to perform a calibration. To establish this relation, the basic calibration data required are: change ΔH in PPA ion signal of the gas species versus the corresponding change ΔP in partial pressure or change ΔF in flow rate. The basic calibration data emphasized in this document, are the partial pressure sensitivity or partial flow sensitivity plotted or tabulated as a function of the change in partial pressure, ΔP. The partial pressure sensitivity $S = \Delta H/\Delta P$ or the partial flow sensitivity $S_F = \Delta H/\Delta F$ must be determined for each gas of interest. Once this relation is established, the partial pressure change of a species i at the ionizer corresponding to some measured ion signal change can be calculated using

$$\Delta P_i = \Delta H_i / S_i$$

or the flow rate change of a gas species i into a specific pumping system using

$$\Delta F_i = \Delta H_i / S_{F_i}.$$

To perform the calibration (i.e., determining the requisite S_i), it is necessary to produce a known pressure change at the ionizer of the PPA or introduce a known flow rate either in a controlled test chamber for evaluation and calibration of the PPA or in the process apparatus itself, *in situ*. The relationships between flow rate, pumping speed and pressure at the ion source of a PPA used for calibration have been previously reported.[8,9]

The apparatus and operating principles pertaining to three test stand calibration procedures are described in Sec. III C. The calibration procedures to be used with these test stands are described in Secs. V A–V C below. *In situ* calibration procedures are described in Sec. V D.

A. Direct pressure comparison method

1. Preparation

The calibration system for this method is shown in Fig. 7 as described in Sec. III. Evacuate the calibration chamber. Ensure that there is no flow from the flow device. Turn on the PPA and the transfer standard pressure gauge when within their respective operating ranges and allow them to warm up. Because the background level determines the lowest pressure at which calibration can be performed, care should be exercised in evacuation procedures, performing a vacuum bakeout if necessary. Continue evacuation to a stable background level at least ten times lower than the lowest pressure to be used for PPA calibration. For high accuracy, gas of high purity must be introduced, starting with a source $>99.9\%$ pure and performing the necessary purging or purge/evacuation of gas supply lines to assure that purity is maintained in the connecting lines.

2. Pressure calibration of PPA

After the preceding criteria have been met, perform a background scan using the PPA over the mass range to be used for process gas analysis. [The peak chosen to represent the partial pressure of a gas component is usually the molecular ion of the gas (e.g., N_2^+ at $M/Q = 28$ for N_2). There are times when the parent peak cannot be used due to interferences. Thus, CH_3^+ is used instead of CH_4^+ in the presence of water or oxygen.] The PPA response in whatever units given (voltage, current, "pressure" value) is a representation of the background ion current that will be used for calibration [e.g., $H_0(28)$ for $M/Q = 28$ for N_2^+].

Measure the background pressure using the transfer standard gauge. This background pressure P_0 reading represents the pressure of all gas components before the calibrating gas is introduced, even though the response of the gauge is species dependent. It is presumed that this background pressure remains constant when calibration gas is introduced.

Close the inlet manifold evacuation valve and set up a flow into the calibration chamber to produce the desired calibration pressure or flow rate. Allow the flow to stabilize in the calibration chamber. If desired, a full mass scan can be performed using the PPA to determine if the purity of the inlet gas is sufficient to provide the required measurement accuracy.

Using the PPA, scan the peaks of interest. Record the PPA response in the same units as H_0 (voltage, current, "pressure" value) to representation of the total ion current H that will be used for the sensitivity calculation. Using the pressure transfer standard, measure the chamber pressure with calibration gas present and call it P. The PPA sensitivity S as defined in definition (24) (Sec. II) is then

$$S = (H - H_0)/(P - P_0).$$

Repeat the sensitivity measurements at a sufficient number of different pressures to determine if the PPA is linear (i.e., constant S) over the range of interest. Typically, at least a two-decade pressure range is needed.

The PPA sensitivity must be determined for each gas of interest.

B. Pressure divider method

1. Preparation

The calibration system for this method, shown in Fig. 8, is prepared as follows. Begin evacuation of the calibration chamber with valves V_1, V_2, and V_3 open. Also to insure that no gas is flowing to the chamber from the gas supply system, close the leak valve V_0 and begin evacuation of the gas manifold to a pressure at least 1000 times lower than

the lowest fill pressure at which it will be used. The PPA and gauge (if present) may then be turned on when the chamber pressure has fallen to less than 10^{-4} Torr. Continue evacuation until a stable base pressure, at least 10 times lower than the lowest calibration pressure step, is attained. It may be necessary to bake the chamber to achieve the desired base pressure.

2. Pressure calibration of PPA

Assuming that the preparations described above have been completed and the system pressures are all at acceptibly low base values, the calibration procedures to be followed next depend on the range of pressures over which one wishes to calibrate the PPA.

C. Normal direct comparison method

If the calibration pressure range of interest lies within the pressure directly measureable with the calibration transfer gauge G (e.g., 10^{-6}–10^{-1} Torr for the molecular drag gauge) then close valves V_1 and V_3 but leave V_2 open. The system is then basically the same as the direct comparison system shown in Fig. 7 and the procedures are the same.

D. Indirect method using pressure ratio R_p

(1) With the chamber and gas inlet each at their respective base pressures, close V_1 and V_2 but leave V_3 open. Record the base pressure (zero) reading P_{i0} on gauge G while it is connected to the inlet side of C.

(2) Close V_3 and open V_2, and record the base pressure (zero) reading P_{c0} on the gauge G while it is connected to the calibration chamber. Also record the corresponding peak height H_{c0} from a background scan with the PPA for the M/Q of interest.

(3) Start a flow of gas through C to the chamber and adjust the flow rate until the pressure in the calibration chamber becomes large enough to produce a reading on the most sensitive range of gauge G.

(4) Record the pressure reading P_c on gauge G while it is connected to the calibration chamber. Also record the corresponding peak height H_c yielded by the PPA at the M/Q of interest.

(5) Leaving the flow to the chamber undisturbed, close V_2 and open V_3. Record the pressure reading P_i on gauge G while it is connected to the inlet side of C.

(6) Using the data obtained in steps (1)–(5), calculate a value for pressure ratio as follows:

$$R_p = (P_i - P_{i0})/(P_c - P_{c0}).$$

(7) Continue incrementing the flow to the chamber and repeating steps (1)–(6) until sufficient data are obtained to show the range of $(P_i - P_{i0})$ over which the pressure ratio is constant and to yield a reliable average value for this ratio.

Once the value of the pressure ratio R_p has been established for the system with a particular calibration gas, then this value, together with measurement of the calibration gas pressure change $(P_i - P_{i0})$ on the high pressure (inlet) side of the conductance C, can be used to calculate the corresponding pressure change in the calibration chamber for those cases in which $(P_c - P_{c0})$ is too small to be measured directly by the calibration transfer gauge G:

$$(P_c - P_{c0}) = (P_i - P_{i0})/\langle R_p \rangle,$$

where $\langle R_p \rangle$ is the average value determined for the pressure ratio. The pressure ratio will be slightly gas species-dependent because its value depends on the ratio of pump speed to conductance of the flow restricting element.

To determine the sensitivity of a PPA using the pressure divider method, scan the peak of interest and record the peak height H_c. The PPA sensitivity S, adapted from definition (24), is

$$S = (H_c - H_{c0})/(P_c - P_{c0}),$$

where the pressure change in the calibration chamber $(P_c - P_{c0})$ is read directly or calculated using the pressure ratio R_p. Repeat sensitivity measurements at a sufficient number of pressures to determine if the PPA is linear (i.e., constant S) over the range of interest.

E. Orifice-flow method

1. Preparation

The orifice flow system is shown in Fig. 9. The preparation of the vacuum system, gas supply and PPA is described in Sec. III.

Evacuate the calibration chamber ensuring that there is no flow from the flow control/measurement device. Turn on the PPA when within its specified operating ranges and allow it to warm up. Continue evacuation to a stable background level at least ten times lower than the lowest calibration pressure to be used for the PPA. Perform a vacuum bakeout, if necessary. Evacuate the inlet manifold to a pressure one thousand times lower than its normal operating pressure. Ensure that the chamber ion gauge has been thoroughly degassed and is acting as neither a significant gas source nor a gas sink.

2. Pressure calibration of PPA

After the previous criteria have been met, perform a background scan using the PPA at the peak of interest. Call the peak height H_0.

Set up a known flow F into the calibration chamber using flow standards or a flow measurement device. Allow the flow to stabilize in the calibration chamber. If desired, a full mass scan can be performed using the PPA to determine if the purity of the inlet gas is sufficient for the required level of accuracy.

Using the PPA, scan the peak of interest. Call the peak height H. The pressure of the pure gas in the calibration chamber is found using chamber orifice conductance C,

$$P = F/C.$$

The PPA sensitivity for the ith peak S_i, in units of ion current per unit pressure, is

$$S_i = (H - H_0)/P,$$

where H and H_0 were determined as above and P is determined by the known or measured flow rates and the conductance of the orifice. Similarly, a flow sensitivity can be calculated

$$S_{F_i} = (H_i - H_{i0})/F_i .$$

where F_i is the value of flow rate introduced into the vacuum system. This calibration of ion current related to flow rate can be useful in the measurement of permeation or outgassing rates.

Close the leak and allow the chamber to reach its background. Repeat this sensitivity measurement process at different pressures (from different flow rates) until the number of points are gathered to characterize the linearity of the PPA over the pressure range of interest.

F. *In situ* calibration of a PPA in a process application

1. Adaption of a PPA to process vacuum systems

A PPA used to monitor conditions in a process vacuum system or test apparatus can be calibrated *in situ* by the introduction of known gas pressures or flow rates using one or more of the test stand calibration methods in the previous sections. Adaptation of these calibration methods to process vacuum systems is discussed in Sec. III.

2. Partial-pressure sensitivity calibration

A common application of a PPA is to measure the partial pressures of gas components in the process. To do this, the sensitivity of the mass spectrometer for each component near the pressure of interest must be determined. If the sensitivities were previously determined on the test stand, a remeasurement of at least a few sensitivity values should be made to check the effects of moving the PPA to the process system, such as air exposure during transit.

The sensitivity is determined by using the test stand procedure that is appropriate to the method chosen for producing known pressures at the PPA. Refer to the appropriate procedure to gather the data needed for determining sensitivity over the range of pressures needed for the application. Repeat this sensitivity measurement process at different pressures (from different flow rates) until the number of points are gathered to characterize the linearity of the PPA over the pressure range of interest.

3. Partial flow-rate sensitivity determination

If the process quantity of interest is the flow rate of a gas component, a flow-rate sensitivity can be determined using flow rates generated by methods described in Sec. III. Gather the data of ion current versus flow rate needed to cover the range of flow rates to be measured in the process. Repeat this flow-rate sensitivity measurement process at different flow rates until a number of points are gathered to characterize the linearity of the PPA over the flow-rate range of interest.

VI. DISCUSSION

A. Gas interactions

There are instances in which the major peak of one constituent has the same M/Q as a peak of another. For example, with a mixture of N_2 and CO_2 there is at $M/Q = 28$, the parent peak of nitrogen, N_2^+, and also CO^+, a fragment ion from ionization carbon dioxide. In this case, the quantities of nitrogen and carbon dioxide would have to be determined using the peaks N^+, CO_2^+, and N_2/CO^+ at $M/Q = 14$, 44, and 28, respectively. Many other such interferences can be present in complex mixtures requiring matrix reduction techniques.

In this recommended practice, it has been assumed until now that the gas species in the ion source are independent of each other so that calibrating with a pure gas predicts the correct sensitivity for the species when other components are present. This is not always true. At higher pressures, space charge in the ion source can alter ion extraction efficiencies and ion–molecule collisions can alter ion species ratios and quantities. If the application involves measuring a minor impurity in the presence of major components, the ion source pressure is necessarily high to provide sufficient ions to measure the impurity. This high ion source pressure can lead to inaccurate measurement of the minor constituent. One way to test for such gas interference is to introduce a flow of one species and then add a separate flow of another gas of interest. If the ion intensity of the original gas component changes, either up or down, then some form of gas interference is occurring. If it is severe, it may negate the pure gas calibration. Some adjustments can be made to minimize the effect (e.g., reduce the electron emission current) or a calibration using a standard mixture with major and minor components present can be made, provided that the mole fraction of the minor components are near those expected in the process gas. If the standard mixture matches the process gas, this type of *in situ* calibration may be the only technique providing accurate results.

The peaks due to the background gases are not, in general, constant. Temperature fluctuations will cause the water peaks to change by large amounts. The hydrogen signal, due to wall outgassing, not only changes with temperature but also with pumping speed fluctuations. The background can increase due to the desorption of wall contaminants by some active gases (e.g., H_2O and hydrocarbons by H_2, O_2, NO) or by electron or ion stimulated desorption. The background could decrease by blanketing of the surface by test gas, thus lowering the outgassing rate, or it could increase by the occupation of surface adsorption sites by the test gas.

B. Linearity

The linearity [definition (27) in Sec. II] of the PPA is measured as the largest ($\pm$) percent deviation of the sensitivity from its average value over a specified pressure range. The average sensitivity will be approximated by the arithmetic average $\langle S \rangle$ of a discrete set of sensitivities mea-

sured over the pressure range of interest. The largest deviation from the average is calculated from the sensitivity values in this discrete set of measurements

$$D_{\max}(\%) = 100|S_i - \langle S\rangle|_{\max}/\langle S\rangle.$$

The value of $D_{\max}(\%)$ describes the systematic error of sensitivity due to nonlinear processes in the ion source like those indicated in Fig. 5. For this PPA, a 30% increase in sensitivity is seen for the low ion energy data and a 15% decrease for higher ion energy at pressures less than 2×10^{-4} Torr. This is contrasted by the 4% random error in sensitivity measurements indicated in Fig. 6 for a different PPA at pressures less than 2×10^{-5} Torr. Deviations from linearity[11,42–46] are due to effects in the ionization of the sample gas and in the detection of the ions.

In the ionizer, at pressures higher than about 10^{-5} Torr, two types of events can occur. First, space charge due to large numbers of electrons and ions in an ionizer distort the field lines, leading to different distributions of ion velocities and ion fractions drawn out of the ionizer. Thus, higher emission currents of electron impact ionizers and higher gas pressures will not necessarily yield proportionately higher PPA signals. Indeed, as pressures or electron emissions are increased, sensitivities can actually increase or decrease (Fig. 5). Reduction of emission current at high pressures reduces space charge and generally improves linearity. A secondary source of nonlinearity can occur at higher pressures where the probabilities of ion–molecule collisions in mixtures, and ion–electron recombination increase proportional to pressure. An example of an ion–molecule reaction that is probable is charge exchange for He^+ and Xe:

$$He^+ + Xe \rightarrow He + Xe^+.$$

Here, the sensitivity of He in the PPA would be reduced and that of Xe increased compared to sensitivities measured at much lower pressures. The efficiency of this charge exchange reaction depends on the partial pressures of the components and the difference in ionization potential of the colliding species.

The nonlinearities due to effects of detection are generally not as severe as those encountered in the ionizer. Most electrometers use high-value feedback resistors to change the gain range. Deviations of feedback resistors from the nominal values lead to apparent disagreement (up to several percent) between sensitivity values determined on adjacent electrometer range settings. In addition, an offset between ranges can be introduced if the detector amplifier circuit has not been properly zeroed. At high gain, electrometers experience much larger drifts and noise levels so that background and peak level changes can become large. Ion counting electronics have a deadtime correction that can be significant with high ion currents which gives lower than expected sensitivities as the ion current is increased.

C. Sensitivity

The sensitivity of a PPA is the change in output signal per unit change in pressure of the species in the ionizer. It is thus the end product of many processes, including ionization, transmission through the mass filter, detection efficiency, and signal amplification. To compare instruments, it would seem helpful to establish a standard set of conditions under which the sensitivity would be measured. The sensitivity measured at a pressure of 10^{-4} Pa with an electron energy of 70 V, and a resolution of 1 would seem to be useful. However, there are several other adjustable parameters, different for different PPA models, whose values can have significant effect on sensitivity. If all these parameters are adjusted to values that the manufacturer recommends for routine process gas analysis, then, and only then, can a basic sensitivity value be useful for comparison. It has been found, however, that instruments with the highest sensitivities do not necessarily have the lowest minimum detectable partial pressure..

As shown in Figs. 5 and 6, the sensitivity is a function of pressure of the gas, and is in some cases affected by the total pressure of all gas components. The linear response range [see definition (28) in Sec. II] can be very clearly shown over a wide pressure range by displaying the sensitivity for a gas species as a function of pressure of the species.

However, to be most useful as an alternative representation of the basic calibration data [see (24) in Sec. II], the sensitivity determinations should be tabulated or graphed as a function of the corresponding change in ion signal, rather than in pressure. Under this procedure (and using linear interpolation where necessary in the table or graph of S versus ΔH), measured ion signal changes can be accurately related to the corresponding, but unknown, pressure changes, even in regions of nonlinear response. A statement of sensitivity should always be accompanied by the values of the parameters which significantly influence the sensitivity. These include resolution, electron emission current, electron energy, ion energy, peak width, scan speed, damping, and, if employed, the gain of a secondary electron multiplier. When stated without reference to the pressure, a sensitivity value will be understood to mean the value corresponding to the region of linear response to pressure.

D. Stability

Stability refers to the constancy of sensitivity over a period of time. Two periods can be considered as important to analysis. The change in sensitivity over the shortest interval which is required to perform both a calibration and a determination of an unknown defines short term stability of a PPA. It limits the repeatability, and thus the accuracy, of any analysis. Thus, an instrument with a short-term stability of 2% could not be used to measure samples with 1% accuracy regardless of the care taken to ensure high accuracy of calibration. Long term stability would be determined over the interval between which calibrations are routinely performed. If, for example, the 24-h stability of a PPA was found to be 10% but the analysis accuracy required was 5%, the calibrations would have to be performed at least twice a day.

There are some things that the operator can do to obtain higher stability of a PPA. The operating temperature of an

instrument is only slowly reached in a vacuum system, so that leaving the PPA on for extended periods is required. Exposure to some kinds of gases, such as water, oxygen, and fluorine, can change the characteristics of the ionizer. In some cases, pretreatment with process gases can diminish these problems. Electron multipliers are, by their nature, unstable since the gain depends on the composition of the active surface. The gain, changes with time as a result of changes in the surfaces caused by surface reactions and annealing. For highest accuracy, therefore, high-level signals should be detected with a Faraday cup and low-level signals should be measured by ion-counting techniques.

E. Operator controls and software

It has been stressed that the PPA parameters must be adjusted to give the optimum peak shape, peak position, sensitivity, scan speed, and damping. An inexperienced operator would do best to follow the recommendations of the manufacturer. The parameters, once adjusted, *must not* be changed *between* the calibration and use of the PPA for process monitoring. Likewise, data must be acquired and reduced in identical manners for calibration and use. Because of shifting sensitivities and because changes in the process may require different analytical approaches, *in situ* calibration is recommended where possible.

To understand the limitation of the software, in the case of software-controlled instruments, one must understand the algorithms that are used to acquire and analyze the ion currents and scan parameter data. Begin evaluation of the software with descriptions in the manufacturer's literature. The mass scale calibration is usually straightforward but the peak measurement may be inaccurate for some peak shape conditions due to limitations of the software. Some peak measurement algorithms choose the maximum ion current in a narrow mass range which could be a noise spike. More sophisticated programs do some averaging of ion intensities at a precise peak location or curve fit the peak data near the maxima. Some other problems encountered include inappropriate scan speed/damping/electrometer range combinations, start of data acquisition before the electrometer or mass selection has settled, use of incorrect library cracking patterns, and use of cracking patterns and sensitivities which were not obtained for that specific instrument. There are even some instruments for which the updating of library data is not possible, leading to large errors. The user of computer controlled PPAs is strongly urged to perform more complete calibrations in order to be assured that the data are acquired and reduced correctly.

F. Quality assurance of calibration and analysis

Partial pressure analyzers can be very useful for monitoring, and even controlling, processes based on levels of partial pressures of selected components. The reliability of the control is only as good as the accuracy of the measurements. To validate the accuracy of the measurement, some calibration check should be routinely performed. The frequency of calibration must be determined by the user, based on variability of the calibration results, and the accuracy requirements of the process being controlled. Inclusion of one of the calibration gas introduction methods into the process hardware provides a convenient way to check calibration stability. Usually, if the sensitivity changes for one gas species, it changes for others in a correlated fashion.[9,11] Thus, analyzing a representative gas (e.g., a selected single-component gas or a mixture that simulates the process composition) can check absolute and relative sensitivities. A control chart plotting the ratio QA versus time can indicate calibration stability or drift:

$$QA = [H_i/S_i]/P_{TSG}$$

where H and S are the net ion current and sensitivity, respectively, for the check gas and P_{TSG} is the corresponding reading of the transfer standard gauge. An ion gauge may not have sufficient stability to assure that important trends are due only to the PPA. Another, more stable, measurement related to the flow rate of a check gas can be substituted for the ion gauge value to produce a QA indicator. Drift of the QA indicator can be used to determine when recalibration is needed. If a mixture of gases is analyzed, the composition calculated from the partial pressures of the components measured can be plotted versus time and compared with the standard to monitor drifts in relative sensitivities.

ACKNOWLEDGMENTS

The authors thank many AVS members for their comments and input to the committee during the evolution of this document. We especially thank J. H. Batey, W. R. Blanchard, R. A. Grant, J. F. Loan, C. R. Tilford, M. A. Wilson, N. J. Wilson, and S. J. Wyrick for their contributions.

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Index of Main Subjects and Terms